

# VAMP 259

## Line Manager

Publication version: V259/en M/A012

## User Manual



Trace back information:  
Workspace VAMP Range version a4  
Checked in 2018-02-13  
Skribenta version 5.2.027

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# 1 General

## 1.1 Legal notice

### Copyright

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### Disclaimer

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

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## 1.2 Safety information

### Important Information

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



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



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

**⚠ DANGER**

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

**⚠ WARNING**

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

**⚠ CAUTION**

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

**NOTICE**

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

**User qualification**

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

**Password protection**

Use the IED's password protection feature to protect untrained persons from interacting with this device.

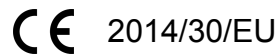
**⚠ WARNING****WORKING ON ENERGIZED EQUIPMENT**

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

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

## 1.3 EU directive compliance

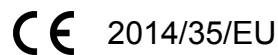
### EMC compliance



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

- EN 60255-26: 2013

### Product safety



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

- EN60255-27:2014

## 1.4 Periodical testing

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

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

## 1.5 Purpose

This document contains instructions on the installation, commissioning and operation of VAMP 259.

This document is intended for persons who are experts on electrical power engineering, and it covers the device models as described by the ordering code in Chapter 14 Order information.

### Related documents

Document	Identification <sup>*)</sup>
VAMP Relay Mounting and Commissioning Instructions	VRELAY_MC_XXXX
VAMPSET Setting and Configuration Tool User Manual	VVAMPSET_EN_M_XXXX

<sup>\*)</sup> XXXX = revision number

Download the latest software and manual at [www.schneider-electric.com/vamp-protection](http://www.schneider-electric.com/vamp-protection) or [m.vamp.fi](http://m.vamp.fi).

## 1.6 Relay features

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

**Table 1.1: List of protection functions**

IEEE/ANSI code	IEC symbol	Function name
21	Z<	Short circuit distance protection
21N	Ze<	Earth-Fault distance protection
25	$\Delta f, \Delta U, \Delta \varphi$	Synchrocheck
27	U<, U<<, U<<<	Undervoltage protection
32	P<, P<<	Reverse power protection
37	I<	Undercurrent protection
46R	$I_2/I_1 >$	Broken line protection
49	T>	Thermal overload protection
50/51	I>, I>>, I>>>	Overcurrent protection
50ARC/ 50NARC	ArcI>, ArcI <sub>0</sub> >	Optional arc fault protection
50BF	CBFP	Circuit-breaker failure protection
50N/51N	I <sub>0</sub> >, I <sub>0</sub> >>, I <sub>0</sub> >>>, I <sub>0</sub> >>>>	Earth fault protection
59	U>, U>>, U>>>	Overvoltage protection
59N	U <sub>0</sub> >, U <sub>0</sub> >>	Zero sequence voltage protection
67	I <sub>φ</sub> >, I <sub>φ</sub> >>, I <sub>φ</sub> >>>, I <sub>φ</sub> >>>>	Directional overcurrent protection
67N	I <sub>0φ</sub> >, I <sub>0φ</sub> >>	Directional earth-fault, low-set stage, sensitive, definite or inverse time (can be used as non directional)
67NI	I <sub>0INT</sub> >	Intermittent transient earth fault protection
68F2	I <sub>r2</sub> >	Magnetising inrush



IEEE/ANSI code	IEC symbol	Function name
68F5	$I_{f5}>$	Transformer overexcitation
79	AR	Auto-reclosing
81H/81L	$f><, f>><<$	Overfrequency and underfrequency protection
81L	$f<, f<<$	Underfrequency protection
81R	$df/dt$	Rate of change of frequency (ROCOF) protection
85		ANSI 85 communication
87L	$Ldl>, Ldl>>, Ldl>>>$	Line differential protection
99	Prg1 – 8	Programmable stages

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

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

### 1.6.1 User interface

The relay can be controlled in three ways:

- Locally with the push-buttons on the relay front panel
- Locally using a PC connected to the serial port on the front panel or on the rear panel of the relay (both cannot be used simultaneously)
- Via remote control over the optional remote control port on the relay rear panel.

# 1.7 Abbreviations

ANSI	American National Standards Institute. A standardization organisation.
CB	Circuit breaker
CBFP	Circuit breaker failure protection
$\cos\phi$	Active power divided by apparent power = P/S. (See power factor PF). Negative sign indicates reverse power.
CT	Current transformer
$CT_{PRI}$	Nominal primary value of current transformer
$CT_{SEC}$	Nominal secondary value of current transformer
Dead band	See hysteresis.
DI	Digital input
DO	Digital output, output relay
Document file	Stores information about the IED settings, events and fault logs.
DSR	Data set ready. An RS232 signal. Input in front panel port of VAMP relays to disable rear panel local port.
DST	Daylight saving time. Adjusting the official local time forward by one hour for summer time.
DTR	Data terminal ready. An RS232 signal. Output and always true (+8 Vdc) in front panel port of VAMP relays.
FFT	Fast Fourier transform. Algorithm to convert time domain signals to frequency domain or to phasors.
HMI	Human-machine interface
Hysteresis	I.e. dead band. Used to avoid oscillation when comparing two near by values.
$I_{L1}$	Current input for $I_{L1}$
$I_{L2}$	Current input for $I_{L2}$
$I_{L3}$	Current input for $I_{L3}$
$I_N$	Nominal current. Rating of CT primary or secondary.
$I_{SET}$	Another name for pick up setting value $I>$
$I_{0N}$	Nominal current of $I_0$ input in general
$I_{0SET}$	Another name for pick up setting value $I_{0>}$
IEC	International Electrotechnical Commission. An international standardization organisation.
IEC-101	Abbreviation for communication protocol defined in standard IEC 60870-5-101
IEC-103	Abbreviation for communication protocol defined in standard IEC 60870-5-103
IED	Intelligent electronic device, refers to VAMP 259 in this document
IEEE	Institute of Electrical and Electronics Engineers
LAN	Local area network. Ethernet based network for computers and IEDs.
Latching	Output relays and indication LEDs can be latched, which means that they are not released when the control signal is releasing. Releasing of latched devices is done with a separate action.
LCD	Liquid crystal display
LED	Light-emitting diode
Local HMI	IED front panel with display and push-buttons
NTP	Network Time Protocol for LAN and WWW
P	Active power. Unit = [W]
PF	Power factor. The absolute value is equal to $\cos\phi$ , 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 $1 \text{ pu} = 1 \times I_N$ .
Q	Reactive power. Unit = [var] acc. IEC
RMS	Root mean square
S	Apparent power. Unit = [VA]
SF	IED status inoperative
SNTP	Simple Network Time Protocol for LAN and WWW
TCS	Trip circuit supervision
THD	Total harmonic distortion
$U_{0SEC}$	Voltage at input $U_c$ at zero ohm ground fault.
$U_A$	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
$U_{SYNC}$	Voltage input for synchronizing voltage. Depending on the voltage input mode can be phase to ground or phase to phase voltage
UTC	Coordinated Universal Time (used to be called GMT = Greenwich Mean Time)
VAMPSET	Configuration tool for VAMP protection devices
Webset	http configuration interface
VT	Voltage transformer i.e. potential transformer PT
$VT_{PRI}$	Nominal primary value of voltage transformer
$VT_{SEC}$	Nominal secondary value of voltage transformer

## 2 Local panel user interface

### 2.1 Relay front panel

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



1. Navigation push-buttons
2. LED indicators
3. LCD
4. RS 232 serial communication port for PC

#### Navigation push-button function



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



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



ENTER push-button for activating or confirming a function.



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



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



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










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

## LED indicators

The relay is provided with eight LED indicators:

LED indicator	Meaning	Measure/ Remarks
Power LED lit	The auxiliary power has been switched on	Normal operation state
Error LED lit	Internal fault, operates in parallel with the self supervision output relay	The relay attempts to reboot [REBOOT]. If the error LED remains lit, call for maintenance.
Com LED lit or flashing	The serial bus is in use and transferring information	Normal operation state
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 matrix, please see Chapter 2.4.5 Configuring digital outputs DO).	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 Configuring digital outputs DO).	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- C LED lit	Application-related status indicators.	Configurable





## Adjusting LCD contrast

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

### Resetting latched indicators and output relays

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

There are several ways to reset latched indicators and relays:

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

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

## 2.1.1 Display

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

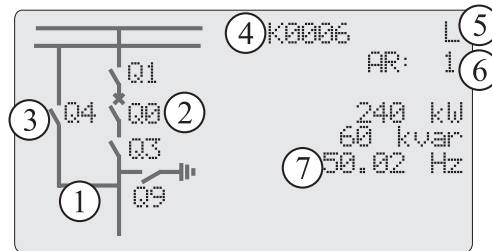


Figure 2.1: Sections of the LCD dot matrix display

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

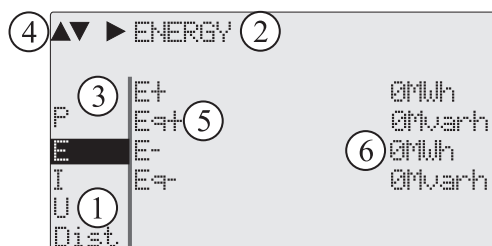


Figure 2.2: Sections of the LCD dot matrix display

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

### **Backlight control**

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

## **2.1.2**

### **Adjusting display contrast**

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



## 2.2 Local panel operations

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

### Moving in the menus

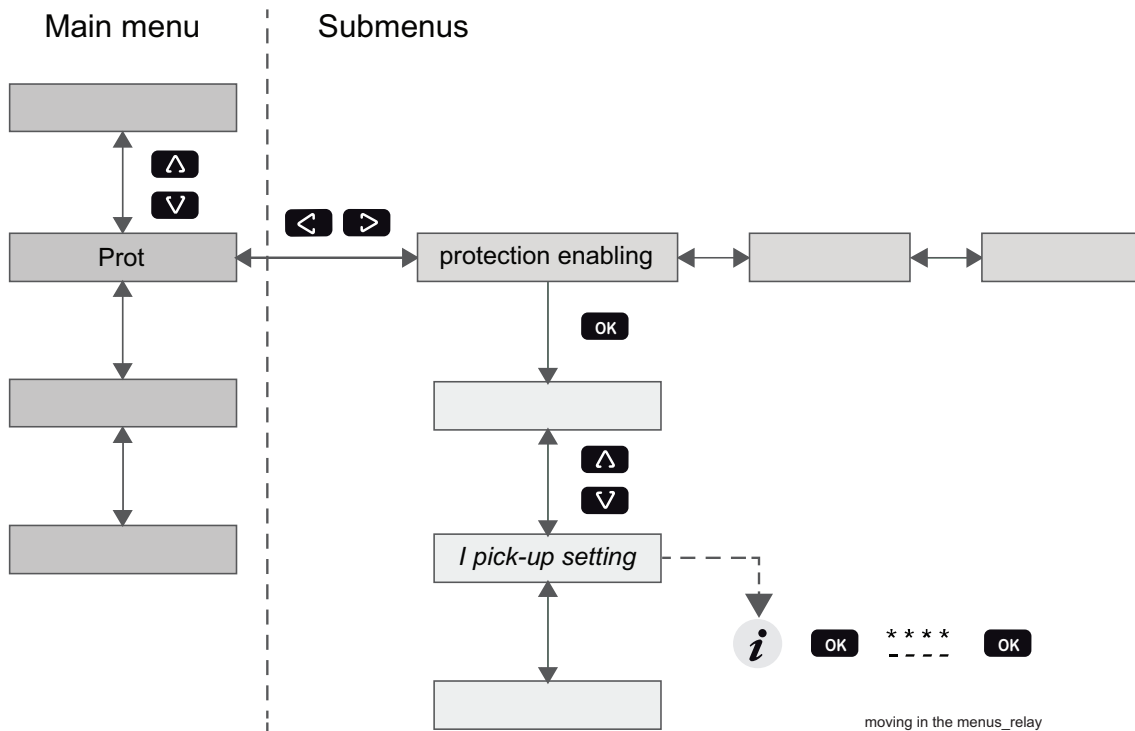


Figure 2.3: Moving in the menus using local HMI

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

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

## Main menu

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

### A list of the local main menu

Main menu	Number of menus	Description	ANSI code	Note
	1	Interactive mimic display		1
	5	Double size measurements defined by the user		1
	1	Title screen with device name, time and firmware version.		
P	14	Power measurements		
E	4	Energy measurements		
I	13	Current measurements		
U	15	Voltage measurements		
Dema	15	Demand values		
Umax	5	Time stamped min & max of voltages		
Imax	9	Time stamped min & max of currents		
Pmax	5	Time stamped min & max of power and frequency		
Month	21	Maximum values of the last 31 days and the last twelve months		
Evnt	2	Events		
DR	2	Disturbance recorder		2
Runh	2	Running hour counter. Active time of a selected digital input and time stamps of the latest start and stop.		
TIMR	6	Day and week timers		
DI	5	Digital inputs including virtual inputs		
DO	4	Digital outputs (relays) and output matrix		
ExtAI	3	External analogue inputs		3
ExtAO	3	External analogue outputs		3
ExDI	3	External digital inputs		3
ExDO	3	External digital outputs		3
Prot	27	Protection counters, combined overcurrent status, protection status, protection enabling, cold load and inrush detection and block matrix		
DIST	1	Common settings for distance zones (Z1 ... Z5)		
Z1<	6	Short circuit distance zone 1	21	4
Z2<	6	Short circuit distance zone 2	21	4
Z3<	6	Short circuit distance zone 3	21	4
Z4<	6	Short circuit distance zone 4	21	4
Z5<	6	Short circuit distance zone 5	21	4
Ze1<	6	Earth fault distance zone	21N	4
Ze2<	6	Earth fault distance zone	21N	4
Ze3<	6	Earth fault distance zone	21N	4

Main menu	Number of menus	Description	ANSI code	Note
Ze4<	6	Earth fault distance zone	21N	4
Ze5<	6	Earth fault distance zone	21N	4
Ldl>	4	Line differential stage	87L	4
Ldl>>	4	Line differential stage	87L	4
Ldl>>>	4	Line differential stage	87L	4
I>	5	1st overcurrent stage	50/51	4
I>>	3	2nd overcurrent stage	50/51	4
I>>>	3	3rd overcurrent stage	50/51	4
I $\phi$ >	6	1st directional overcurrent stage	67	4
I $\phi$ >>	6	2nd directional overcurrent stage	67	4
I $\phi$ >>>	4	3rd directional overcurrent stage	67	4
I $\phi$ >>>>	4	4th directional overcurrent stage	67	4
I<	3	Undercurrent stage	37	4
I2>	3	Current unbalance stage	46	4
T>	3	Thermal overload stage	49	4
Io>	5	1st earth fault stage	50N/51N	4
Io>>	3	2nd earth fault stage	50N/51N	4
Io>>>	3	3rd earth fault stage	50N/51N	4
Io>>>>	3	4th earth fault stage	50N/51N	4
Io $\phi$ >	6	1st directional earth fault stage	67N	4
Io $\phi$ >>	6	2nd directional earth fault stage	67N	4
Ioint>	4	Transient intermittent E/F	67NI	4
U>	4	1st overvoltage stage	59	4
U>>	3	2nd overvoltage stage	59	4
U>>>	3	3rd overvoltage stage	59	4
U<	4	1st undervoltage stage	27	4
U<<	3	2nd undervoltage stage	27	4
U<<<	3	3rd undervoltage stage	27	4
Uo>	3	1st residual overvoltage stage	59N	4
Uo>>	3	2nd residual overvoltage stage	59N	4
P<	3	1st reverse and underpower stage	32	4
P<<	3	2nd reverse and underpower stage	32	4
f><	4	1st over/under-frequency stage	81	4
f>><<	4	2nd over/under-frequency stage	81	4
f<	4	1st underfrequency stage	81L	4
f<<	4	2nd underfrequency stage	81L	4
dfdt	3	Rate of change of frequency (ROCOF) stage	81R	4
Prg1	3	1st programmable stage		4
Prg2	3	2nd programmable stage		4
Prg3	3	3rd programmable stage		4
Prg4	3	4th programmable stage		4
Prg5	3	5th programmable stage		4

Main menu	Number of menus	Description	ANSI code	Note
Prg6	3	6th programmable stage		4
Prg7	3	7th programmable stage		4
Prg8	3	8th programmable stage		4
If2>	3	Second harmonic O/C stage	68F2	4
If5>	3	Fifth harmonic O/C stage	68F5	4
CBFP	3	Circuit breaker failure protection	50BF	4
CBWE	4	Circuit breaker wearing supervision		4
AR	15	Auto-reclose	79	
CTSV	1	CT supervisor		4
VTSV	1	VT supervisor		4
ArcI>	4	Optional arc protection stage for phase-to-phase faults and delayed light signal.	50ARC	4
Arclo>	3	Optional arc protection stage for earth faults. Current input = I0	50NARC	4
OBJ	11	Object definitions		5
Lgic	2	Status and counters of user's logic		1
CONF	10+2	Device setup, scaling etc.		6
Bus	13	Serial port and protocol configuration		7
Diag	6	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. Their position or status can be displayed and controlled in the interactive mimic display.
6. There are two extra menus, which are visible only if the access level "operator" or "configurator" has been opened with the corresponding password.
7. Detailed protocol configuration is done with VAMPSET.

## 2.2.1 Menu structure of protection functions

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

▲▼ ▶ I>> STATUS		50 / 51
ExDO	Status	-
Prot	SCntr	5
I>	TCntr	2
I>>	SetGrp	1
Iv>	SGrpDI	-
Iφ>	Force	OFF

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

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

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

▲▼◀▶	I>> SET	50 / 51
Stage	setting	group 1
ExDI	ILmax	403A
ExDO	Status	-
Prot	I>>	1013A
I>>	I>>	2.50xIn
CBWE	t>>	0.60s
OBJ		

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

This is the main setting menu.

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

▲▼◀	I>> LOG	50/51
FAULT	LOG 1	
ExDI	2006-09-14	
ExDO	12:25:10.288	
Prot	Type 1-2	
I>>	Flt 2.86xIn	
CBWE	Load 0.99xIn	
OBJ	EDly 81%	
	SetGrp 1	

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

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

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

## 2.2.2 Setting groups

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

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

▲▼ ▶ I> STATUS		51
Evnt	Status	-
DR	SCntr	0
DI	TCntr	0
DO	SetGrp	1
Prot	SGrpDI	DI1
I>	Force	OFF

Figure 2.7: Example of protection submenu with setting group parameters

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

SET I>		51
Setting for stage I>		
	ILmax	400 A
	Status	-
	I>	600 A
Set1	I>	1.10xIn
I>	Type	DT
	t>	0.50 s

Figure 2.8: Example of I> setting submenu



### 2.2.3 Fault logs

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

▲▼◀▶	I> log buffer	51
	Log buffer 1	
DR	2003-04-28	
DI	11:11:52;251	
DO	Type 1-2	
Prot	Flt 0.55 xIn	
I>	Load 0.02 xIn	
I>>	EDly 24 %	

Figure 2.9: Example of fault log

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

	I> log buffer	
Date	2003-04-24	
	03:08:21;342	
	Type 1-2	
Log2	Flt 1.69 xIn	
I>	Load 0.95 xIn	
	EDly 13 %	

Figure 2.10: Example of selected fault log


## 2.2.4 Operating levels

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


### USER level

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

### OPERATOR level

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

### Opening access

1. Push  and **OK** on the front panel



Figure 2.11: Opening the access level

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

### Password handling

The passwords can only be changed using VAMPSET software connected to the 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 virtual serial port settings are 38400 bps, 8 data bits, no parity and one stop bit. The bit rate is configurable via the front panel.

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

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

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

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

## 2.3 Operating measures

### 2.3.1 Control functions

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

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

#### toggling Local/Remote control

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

#### Object control

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

#### toggling virtual inputs

1. Push **OK**. The previously activated object starts to blink.
2. Select the virtual input object (empty or black square)
3. The dialog opens
4. Select “Vlon” to activate the virtual input or select “Vloff” to deactivate the virtual input

## 2.3.2 Measured data

The measured values can be read from the P, E, I and U menus and their submenus. Furthermore, any measurement value in the following table can be displayed on the main view next to the single line diagram. Up to six measurements can be shown. Impedance measurements (Z12, Z23, Z31) are located in distance stage displays.

Value	Menu/Submenu	Description
P	P/POWER	Active power [kW]
Q	P/POWER	Reactive power [kvar]
S	P/POWER	Apparent power [kVA]
$\varphi$	P/POWER	Active power angle [°]
P.F.	P/POWER	Power factor [ ]
f	P/POWER	Frequency [Hz]
Pda	P/15 MIN POWER	Active power [kW]
Qda	P/15 MIN POWER	Reactive power [kvar]
Sda	P/15 MIN POWER	Apparent power [kVA]
Pfda	P/15 MIN POWER	Power factor [ ]
fda	P/15 MIN POWER	Frequency [Hz]
PL1	P/POWER/PHASE 1	Active power of phase 1 [kW]
PL2	P/POWER/PHASE 1	Active power of phase 2 [kW]
PL3	P/POWER/PHASE 1	Active power of phase 3 [kW]
QL1	P/POWER/PHASE 1	Reactive power of phase 1 [kvar]
QL2	P/POWER/PHASE 1	Reactive power of phase 2 [kvar]
QL3	P/POWER/PHASE 1	Reactive power of phase 3 [kvar]
SL1	P/POWER/PHASE 2	Apparent power of phase 1 [kVA]
SL2	P/POWER/PHASE 2	Apparent power of phase 2 [kVA]
SL3	P/POWER/PHASE 2	Apparent power of phase 3 [kVA]
PF_L1	P/POWER/PHASE 2	Power factor of phase 1 [ ]
PF_L2	P/POWER/PHASE 2	Power factor of phase 2 [ ]
PF_L3	P/POWER/PHASE 2	Power factor of phase 3 [ ]
cos	P/COS & TAN	Cosine phi [ ]
tan	P/COS & TAN	Tangent phi [ ]
cosL1	P/COS & TAN	Cosine phi of phase L1 [ ]
cosL2	P/COS & TAN	Cosine phi of phase L2 [ ]
cosL3	P/COS & TAN	Cosine phi of phase L3 [ ]
Iseq	P/PHASE SEQUENCIES	Actual current phase sequency [OK; Reverse; ??]
Useq	P/PHASE SEQUENCIES	Actual voltage phase sequency [OK; Reverse; ??]
Io $\varphi$	P/PHASE SEQUENCIES	Io/Uo angle [°]
fAdop	P/PHASE SEQUENCIES	Adopted frequency [Hz]
E+	E/ENERGY	Exported energy [MWh]
Eq+	E/ENERGY	Exported reactive energy [Mvar]
E-	E/ENERGY	Imported energy [MWh]

Value	Menu/Submenu	Description
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]
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/E-pulse TEST	Test the exported energy pulse [ ]
Eq+	E/E-pulse TEST	Test the exported reactive energy [ ]
E-	E/E-pulse TEST	Test the imported energy [ ]
Eq-	E/E-pulse 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]
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 [%]
Diagram	I/HARMONICS of IL1	Harmonics of phase current IL1 [%] (See Figure 2.12)
Diagram	I/HARMONICS of IL2	Harmonics of phase current IL2 [%] (See Figure 2.12)
Diagram	I/HARMONICS of IL3	Harmonics of phase current IL3 [%] (See Figure 2.12)
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-earth voltage UL1 [V]

Value	Menu/Submenu	Description
UL2	U/PHASE VOLTAGES	Phase-to-earth voltage UL2 [V]
UL3	U/PHASE VOLTAGES	Phase-to-earth voltage UL3 [V]
Uo	U/SYMMETRIC VOLTAGES	Residual voltage Uo [%]
U1	U/SYMMETRIC VOLTAGES	Positive sequence voltage [%]
U2	U/SYMMETRIC VOLTAGES	Negative sequence voltage [%]
U2/U1	U/SYMMETRIC VOLTAGES	Negative sequence voltage related to positive sequence voltage [%]
THDU	U/HARM. DISTORTION	Total harmonic distortion of the mean value of voltages [%]
THDUa	U/HARM. DISTORTION	Total harmonic distortion of the voltage input a [%]
THDUb	U/HARM. DISTORTION	Total harmonic distortion of the voltage input b [%]
THDUc	U/HARM. DISTORTION	Total harmonic distortion of the voltage input c [%]
Diagram	U/HARMONICS of Ua	Harmonics of voltage input Ua [%] (See Figure 2.12)
Diagram	U/HARMONICS of Ub	Harmonics of voltage input Ub [%] (See Figure 2.12)
Diagram	U/HARMONICS of Uc	Harmonics of voltage input Uc [%] (See Figure 2.12)
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]
Z12, Z23, Z31	Z1<, Z2<, Z3<, Z4<, Z5<	Line to line impedance (primary/sec)
Z12angle, Z23angle, Z31angle	Z1<, Z2<, Z3<, Z4<, Z5<	Impedance angle

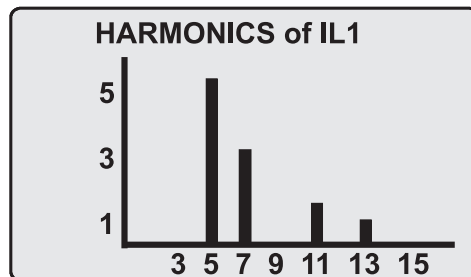



Figure 2.12: Example of harmonics bar display

### 2.3.3 Reading event register

The event register can be read from the Evnt submenu:

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

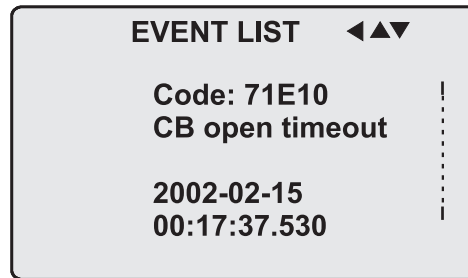





Figure 2.13: Example of an event register

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

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



## 2.3.4 Forced control (Force)

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

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

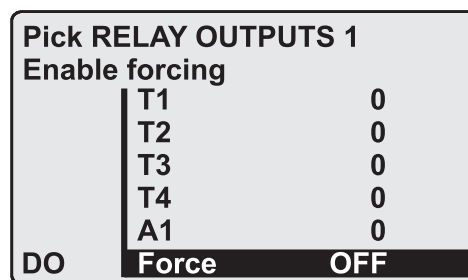


Figure 2.14: Selecting Force function

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

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

## 2.4 Configuration and parameter setting

The minimum procedure to configure a device is

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

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

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

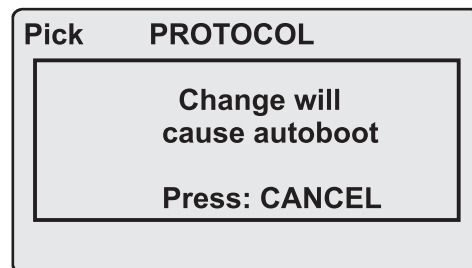





Figure 2.15: Example of auto-reset display

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

## 2.4.1 Parameter setting

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

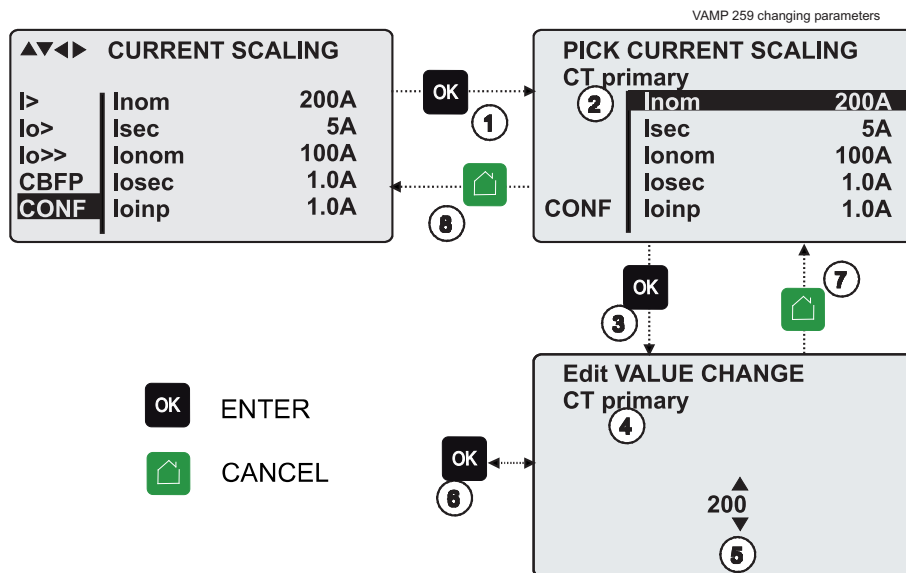


Figure 2.16: Changing parameters

## 2.4.2 Setting range limits

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

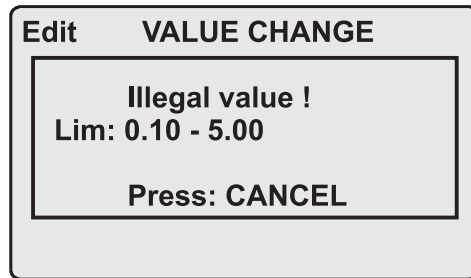


Figure 2.17: Example of a fault message

The allowed setting range is shown in the display in the setting mode.

To view the range, push . Push  to return to the setting mode.

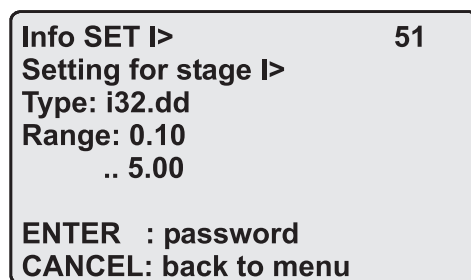


Figure 2.18: Allowed setting ranges show in the display

### 2.4.3

## Disturbance recorder menu DR

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

### Disturbance settings

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

### Recorder settings

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

### Rec. coupling

- Add a link to the recorder (AddLink)
- Clear all links (ClrLnks)

### Available links

- DO, DI
- IL
- I2/In, I2/I1, I2, I1, IoCalc
- f
- Io
- IL3, IL2, IL1
- IL1Rem, IL2Rem, IL3Rem
- THDIL1, THDIL2, THDIL3
- IL1RMS, IL2RMS, IL3RMS
- Uo
- Uline, Uphase
- U2/U1, U2, U1
- UL3, UL2, UL1
- U31, U23, U12
- CosFii
- PF, S, Q, P
- Prms, Qrms, Srms
- Tanfii
- THDUa, THDUb, THDUc
- ILmin, ILmax, ULLmin, ULLmax, ULNmin, ULNmax
- fy, fz, U12y, U12z

## 2.4.4 Configuring digital inputs DI

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

1. The status of digital inputs (DIGITAL INPUTS 1 – 20 / 24 / 32)
2. Operation counters (DI COUNTERS)
3. Operation delay (DELAYS for DigIn)
4. The polarity of the input signal (INPUT POLARITY). Either normally open (NO) or normally closed (NC) circuit.
5. Event enabling EVENT MASK1

## 2.4.5 Configuring digital outputs DO

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

- The status of the output relays (RELAY OUTPUTS 1, 2, 3 and 4)
- The forcing of the output relays (RELAY OUTPUTS 1, 2, 3 and 4) (only if Force = ON):
  - Forced control (0 or 1) of the Trip relays
  - Forced control (0 or 1) of the Alarm relays
  - Forced control (0 or 1) of the SF relay
- The configuration of the output signals to the output relays. The configuration of the operation indicators (LED) Alarm and Trip and application specific alarm leds A, B and C (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:

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

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

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

## 2.4.7 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]
- PC access level [PCAcc]

### Language

- List of available languages in the relay

### Current scaling

- Rated phase CT primary current ( $I_{nom}$ )
- Rated phase CT secondary current ( $I_{sec}$ )
- Rated input of the relay [ $I_{input}$ ]. 5 A or 1 A. This is specified in the order code of the device.
- Rated input of the relay [ $I_{input}$ ]. 5 A or 1 A. This is specified in the order code of the device.
- Rated value of  $I_0$  CT primary current ( $I_{onm}$ )

- Rated value of  $I_0$  CT secondary current ( $I_{0sec}$ )
- Rated  $I_0$  input of the relay [ $I_{0inp}$ ]. 5 A, 1 A or 0.2 A. This is specified in the order code of the device.

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

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

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

### Voltage scaling

- Rated VT primary voltage ( $U_{prim}$ )
- Rated VT secondary voltage ( $U_{sec}$ )
- Rated  $U_0$  VT secondary voltage ( $U_{0sec}$ )
- Voltage measuring mode ( $U_{mode}$ )

### Motor setting

- Rated current of the motor ( $I_{mot}$ ).

### Units for mimic display

- Unit for voltages (V). The choices are V (volt) or kV (kilovolt).
- Scaling for active, reactive and apparent power [Power]. The choices are k for kW, kvar and kVA or M for MW, Mvar and MVA.

### Device info

- Relay type (Type VAMP 259)
- Serial number (SerN)
- Software version (PrgVer)
- Bootcode version (BootVer)

### Date/time setup

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



### Clock synchronisation

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

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

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

### SW options

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

## 2.4.8

### Protocol menu Bus

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

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

#### Remote port

- Communication protocol for remote port X5 [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 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.

The counters are useful when testing the communication.

### PC (Local/SPA-bus)

This is a second menu for local port X4. The VAMPSET communication status is showed.

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

### Extension port

- Communication protocol for extension port 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.

### Ethernet port

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

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

### Modbus

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

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

### External I/O protocol

This is a Modbus master protocol to communicate with the extension I/O modules connected to the extension port. Only one instance of this protocol is possible.

- Bit rate [bit/s]. Default is "9600".
- Parity [Parity]. Default is "Even".

For details, see Chapter 9.2.8 External I/O (Modbus RTU master).

### SPA-bus

Several instances of this protocol are possible.

- SPA-bus address 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 Chapter 9.2.4 SPA-bus.

### 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 Chapter 9.2.5 IEC 60870-5-103.

### IEC 103 Disturbance recordings

For details, see Table 9.12.

### 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 Chapter 9.2.3 Profibus DP.

**DNP3**

Only one instance of this protocol is possible.

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

For details, see Chapter 9.2.6 DNP 3.0.

**IEC 60870-5-101**

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

For details, see Chapter 9.2.7 IEC 60870-5-101.

**DeviceNet**

- Bit rate [bit/s]. Default is "125kbps".
- Slave address [SlvAddr]

For details, see Chapter 9.2.12 DeviceNet.

**2.4.9****Single line diagram editing**

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

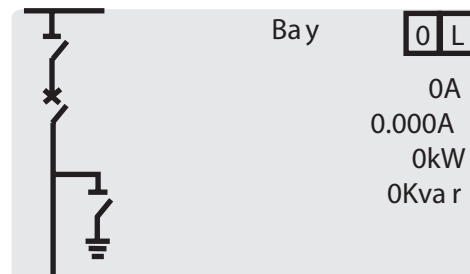


Figure 2.19: Single line diagram

## 2.4.10 **Blocking and Interlocking configuration**

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

## 3 VAMPSET PC software

The PC user interface can be used for:

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

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. For more information about the VAMPSET software, please refer to the user's manual with the code VVAMPSET/EN M/xxxx. Also the VAMPSET user's manual is available at our web site.

### 3.1 Folder view

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

The idea of folder view is to make it easier for the user to work with relay functions inside VAMPSET. When folder view is enabled, VAMPSET gathers similar functions together and places them appropriately under seven different folders (GENERAL, MEASUREMENTS, INPUTS/OUTPUTS, MATRIX, LOGS and COMMUNICATION). The contents (functions) of the folders depend on the relay type and currently selected application mode.

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

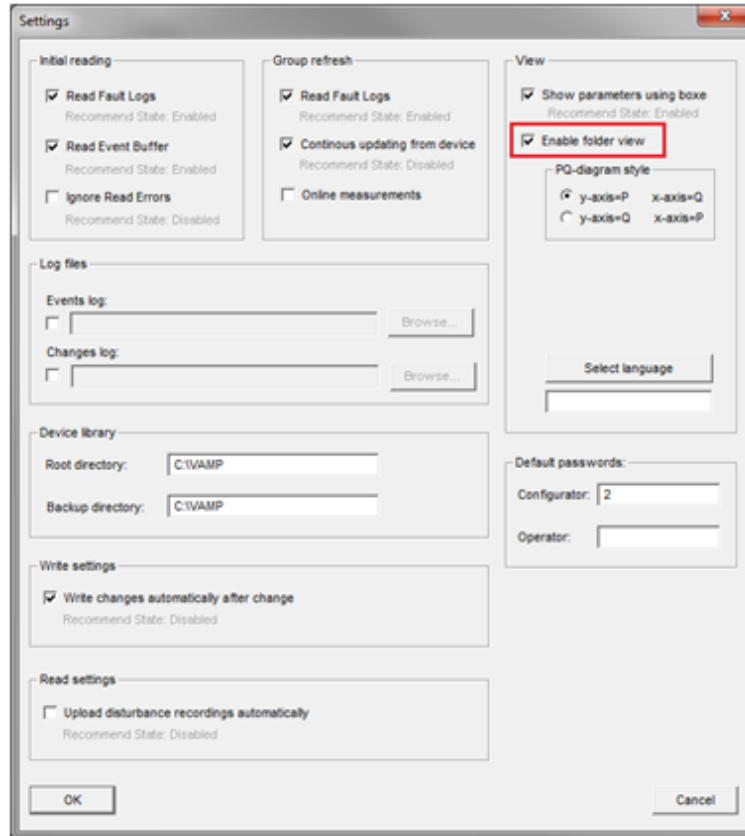


Figure 3.1: Enable folder view setting in Program Settings dialog

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

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



Figure 3.2: Folder view buttons



# 4 Introduction

The numerical line protection device includes as main protection full scheme distance and line differential protection functions backed up with several standard protection functions needed in protection schemes of medium voltage and sub-transmission overhead lines and cables in utilities, industry, power plants and offshore applications.

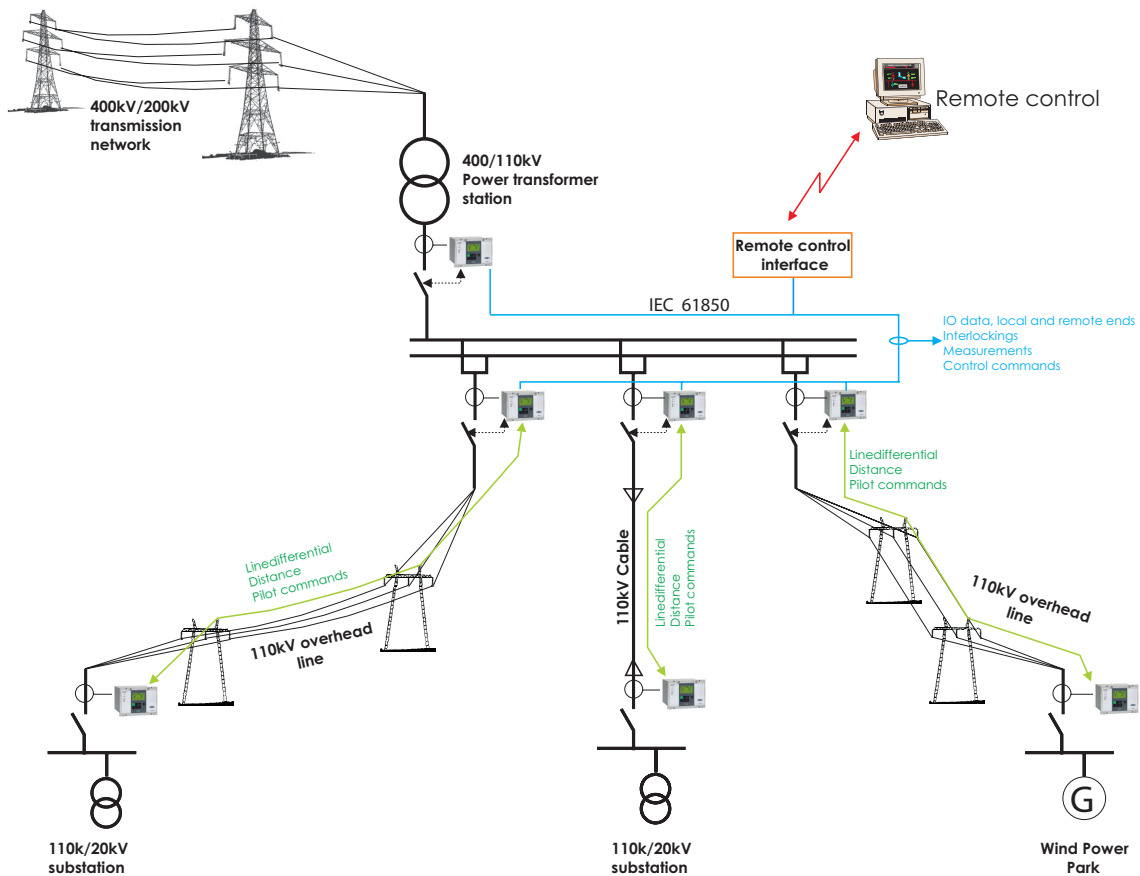


Figure 4.1: Applications of the line protection device

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## 4.1 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%.
- Integrated fault location for short-circuit faults.
- The device can be matched to the requirements of the application by disabling the functions that are not needed.
- Flexible control and blocking possibilities due to digital signal control inputs (DI) and outputs (DO).
- Easy adaptability of the device to various substations and alarm systems due to flexible signal-grouping matrix in the device.
- Possibility to control six objects (e.g. circuit-breakers, disconnectors).
- Status of eight objects (e.g. circuit-breakers, disconnectors, switches).
- Freely configurable display with six measurement values.
- Freely configurable interlocking schemes with basic logic functions.
- Recording of events and fault values into an event register from which the data can be read via a keypad and a local HMI or by means of a PC based VAMPSET user interface.
- Latest events and indications 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 auxiliary power supply from any source within the range from 40 to 265 Vdc or Vac. The alternative power supply is for 18 to 36 Vdc.
- Built-in disturbance recorder for evaluating all the analogue and digital signals.
- Eight (8) programmable stages for alarming or protection purposes

## 4.2 Principles of numerical protection techniques

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

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

By using synchronized sampling of the measured 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 secondary testing of a brand new device should be started with voltage protection functions and voltage injection to let the relay learn the local frequency. 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 4.2 shows a principle block diagram of a numerical device. The main components are the energizing inputs, digital input elements, output relays, A/D converters and the micro controller including memory circuits. Further, a device contains a power supply unit and a human-machine interface (HMI).

Figure 4.3 shows the heart of the numerical technology. That is the main block diagram for calculated functions.

Figure 4.4 shows a principle diagram of a single-phase overvoltage function.

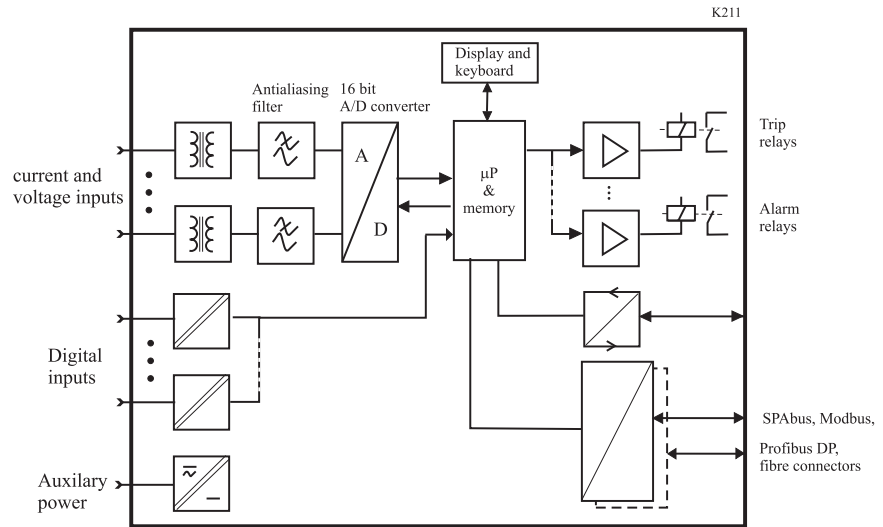


Figure 4.2: Principle block diagram of the VAMP hardware

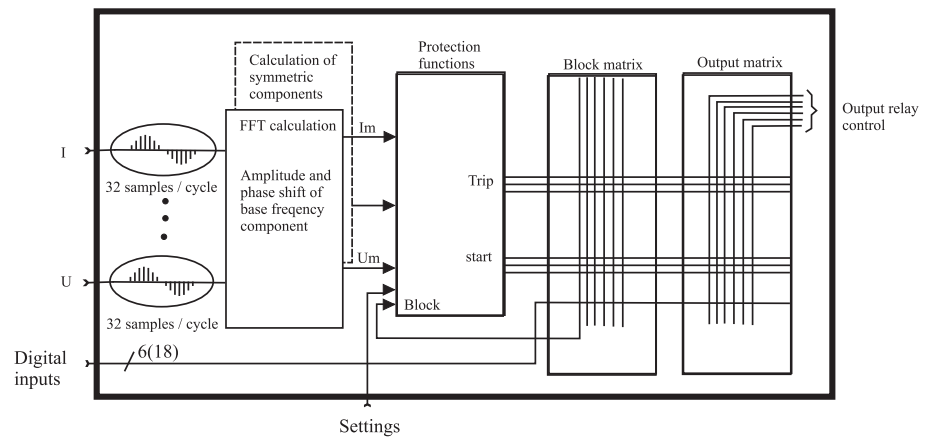


Figure 4.3: Block diagram of signal processing and protection software

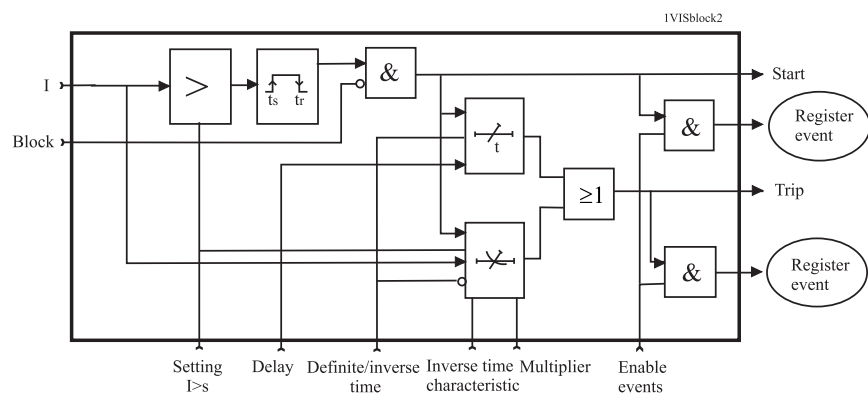


Figure 4.4: Block diagram of a basic protection function

# 5 Protection functions

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

## 5.1 Maximum number of protection stages in one application

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

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

## 5.2 General features of protection stages

### Setting groups

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

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

### Example

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

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

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

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

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

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

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

### Forcing start or trip condition for testing

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

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

The blocking reason may be an active signal via the block matrix from other stages, the programmable logic or any digital input. Some stages also have inbuilt blocking logic. For more details about block matrix, see Chapter 8.5 Blocking matrix.

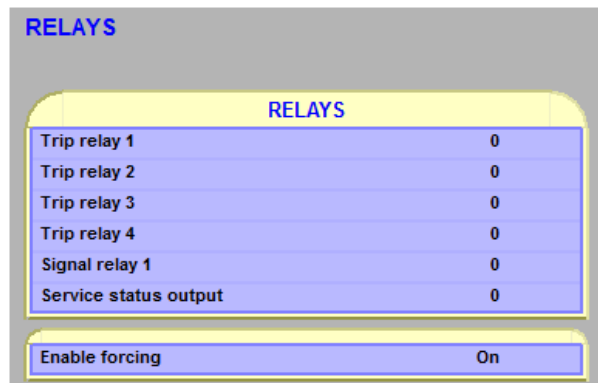
### Forcing start or trip condition for testing purposes

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

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

The force flag also enables forcing of the output relays and forcing the optional mA outputs.

Force flag can be found in relays menu.



### Start and trip signals

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

### Output matrix

Using the output matrix the user connects the internal start and trip signals to the output relays and indicators. For more details, see Chapter 8.4 Output matrix.

### Blocking

Any protection function, except arc protection, can be blocked with internal and external signals using the block matrix (Chapter 8.5 Blocking matrix). Internal signals are for example logic outputs and start and trip signals from other stages and external signals are for example digital and virtual inputs.

Some protection stages have also inbuilt blocking functions. For example under-frequency protection has inbuilt under-voltage blocking to avoid tripping when the voltage is off.

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 operate time delay. This parameter is important when grading the operate time delay settings between relays.

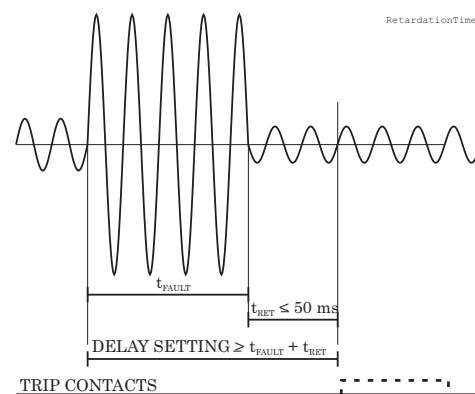


Figure 5.3: Definition for retardation time. If the delay setting would be slightly shorter, an unselective trip might occur (the dash line pulse).

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

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

### Reset time (release time)

Figure 5.4 shows an example of reset time i.e. release delay, when the relay is clearing an overcurrent fault. When the relay's trip contacts are closed the circuit breaker (CB) starts to open. After the CB contacts are open the fault current will still flow through an arc between the opened contacts. The current is finally cut off when the



arc extinguishes at the next zero crossing of the current. This is the start moment of the reset delay. After the reset delay the trip contacts and start contact are opened unless latching is configured. The precise reset time depends on the fault size; after a big fault the reset time is longer. The reset time also depends on the specific protection stage.

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

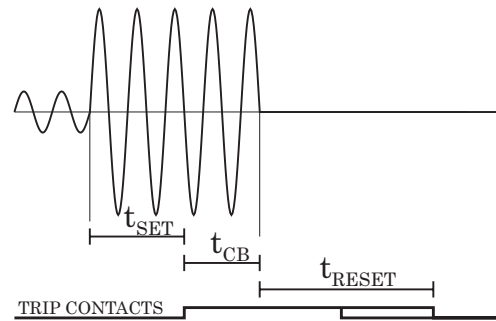


Figure 5.4: Reset time is the time it takes the trip or start relay contacts to open after the fault has been cleared.

### Hysteresis or dead band

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

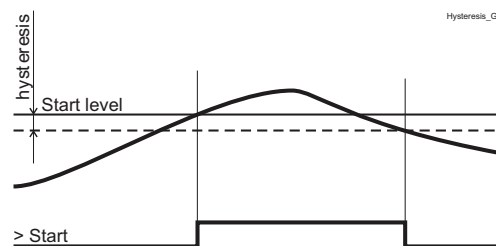


Figure 5.5: Behaviour of a greater than comparator. For example in overvoltage stages the hysteresis (dead band) acts according this figure.

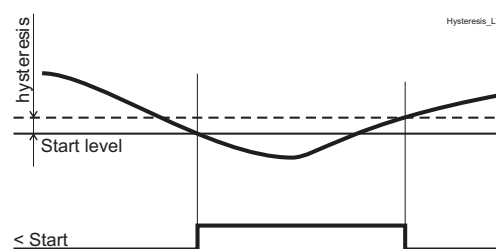


Figure 5.6: Behaviour of a less than comparator. For example in under-voltage and under frequency stages the hysteresis (dead band) acts according this figure.

## 5.3 Distance protection Z< (21)

### 5.3.1 Short circuit distance Z< (21)

The distance protection function calculates the impedance  $Z = U/I$  of the short circuit fault loops.

If impedance is inside the tripping zone (normally presented in R-X plane), the distance function operates. In short circuit faults there are 3 possible fault loops. The VAMP distance protection function calculates the impedances of the fault loops continuously and thus separate pick-up conditions are not needed.

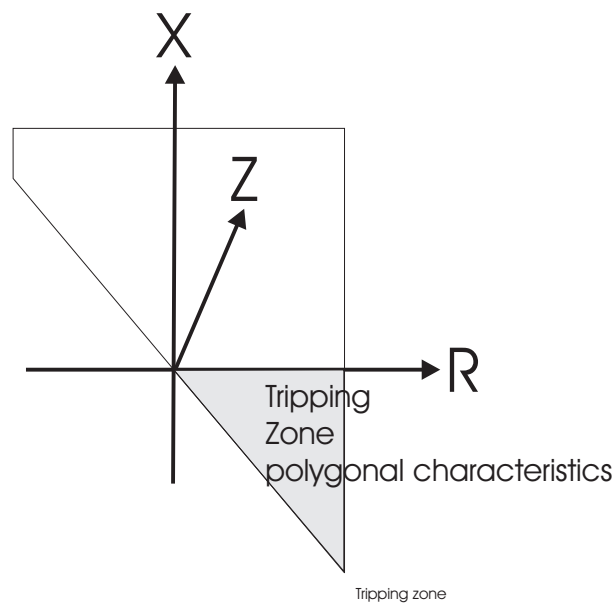


Figure 5.7: An example of tripping zone. Gray area is the tripping zone, polygonal characteristics.

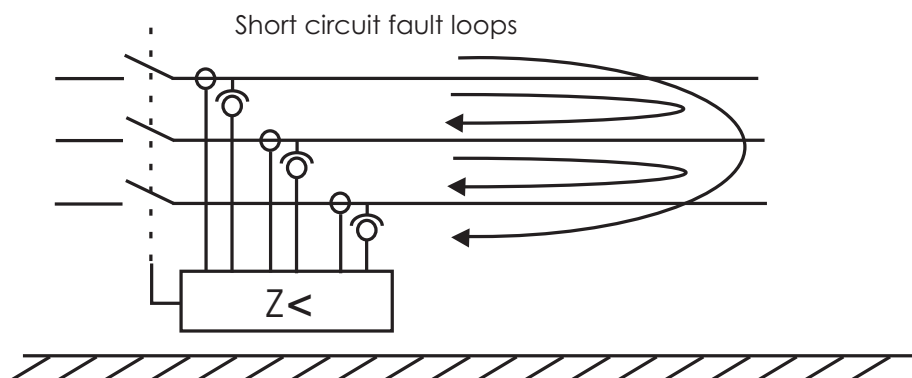


Figure 5.8: Short circuit fault loops and formulas to calculate the fault impedances.

### Zones and characteristics

There are 5 zones (Z1, Z2, Z3, Z4 and Z5) for short circuit protection. These are implemented as protection stages Z1<, Z2<, Z3<, Z4< and Z5<. Z1 extension can be implemented by applying second setting group to cover the extension zone in auto-reclosing.

The distance protection's zones implement a polygonal characteristic as shown in Figure 5.9.

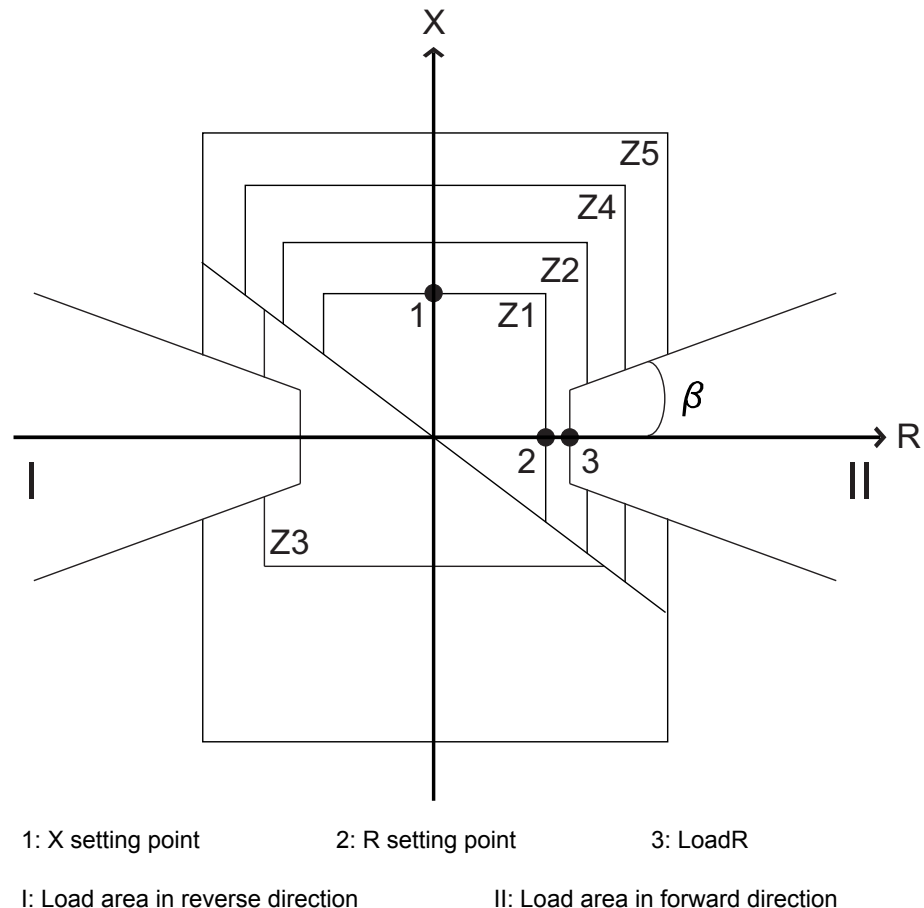


Figure 5.9: The distance protection polygonal characteristics. In this example zone 3 is in reverse direction and zone 5 is non-directional.

Parameter	Value	Unit	Default	Description
X	0.05 – 250.00	ohm	0.80	X-setting
R	0.05 – 250.00	ohm	0.80	R-setting
MODE	Reverse/Forward/ Undirectional		Forward	Direction mode
t<	0.04 – 300.00	S		Operation delay
LOAD BLOCK	No/Yes		Yes	Load block in use
<b>Common parameters for all zones</b>				
LoadAngle	10 – 40	°	40	Load angle $\beta$
LoadR	0.05 – 250.00	ohm	1.00	Load resistance

X-, R- and Load resistance settings are secondary impedances. Primary values of settings are displayed in VAMPSET and display.

### Voltage memory

A 0.5 second cyclic buffer storing the phase-to-earth voltages is used as voltage memory. The stored phase angle information is used as direction reference if all the phase voltages drop below 1% during a fault.

### Teleprotection signals

Signalling between two distance protection relays (teleprotection) can be implemented using the normal DI and DO signals of the relay. An external signal transfer system is needed to transfer signals from one relay to another. The signal transfer system has to have internal signal supervision and fault indication.

The DO output signals can be activated by protection zone's start or trip signals or by the programmable logic functions.

The DI input can be used to block protection zone(s) or it can be used as input into the programmable logic of the device. Different type of permissive tripping conditions such as, permissive under reach (PUTT), permissive over reach (POTT), acceleration or blocking conditions can thus be implemented. The relay's object control can be used to trip the breaker via the "DI for remote open ctr" or "DI for local open ctr" input of the object. Outputs of the relay programmable logic can be connected to "DI for remote open crt" or "DI for local open ctr" inputs via the internal "Virtual output" signals.

## 5.3.2

### Earth-fault distance Ze< (21N)

The earth-fault distance protection function calculates the impedance

$$Z_G = \frac{U}{(I + k_0 \times 3 \times I_0)}$$

of the earth-fault fault loops.

$$K_0 = (Z_{0L} - Z_{1L}) / (3 \times Z_{1L})$$

$Z_{0L}$  = Zero sequence line impedance

$Z_{1L}$  = Positive sequence line impedance

If impedance is inside the tripping zone (normally presented in R-X plane) and set  $I_0$  current is exceeded, the distance function operates. In earth-fault faults there are 3 possible fault loops. The VAMP distance protection function calculates the impedances of the fault loops continuously and thus separate pick-up conditions are not needed.

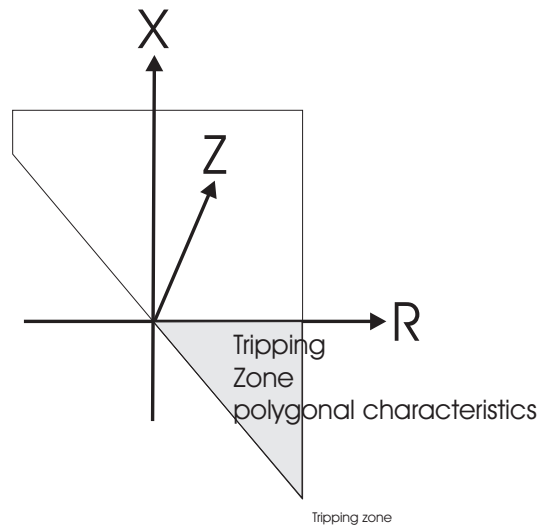


Figure 5.10: An example of tripping zone. Grey area is the tripping zone, polygonal characteristics.

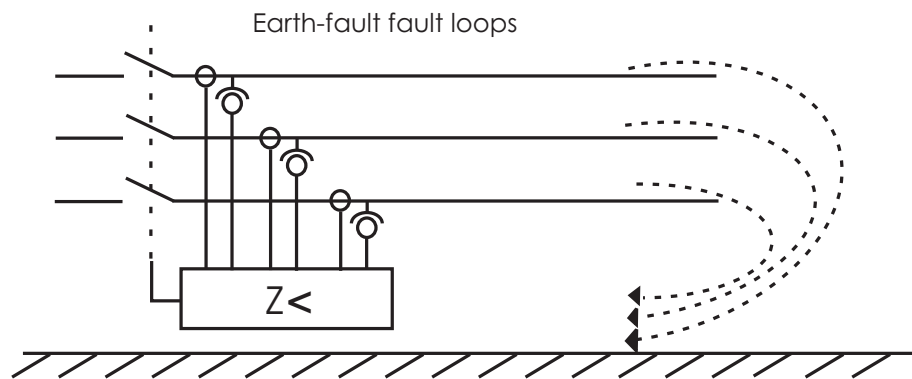


Figure 5.11: Earth-fault fault loops

### Zones and characteristics

There are 5 zones ( $Z1e$ ,  $Z2e$ ,  $Z3e$ ,  $Z4e$  and  $Z5e$ ) for earth-fault protection. These are implemented as protection stages  $Z1e<$ ,  $Z2e<$ ,  $Z3e<$ ,  $Z4e<$  and  $Z5e<$ .  $Z1e$  extension can be implemented by applying second setting group to cover the extension zone in auto-reclosing.

The distance protection's zones implement a polygonal characteristics as shown in Figure 5.12.

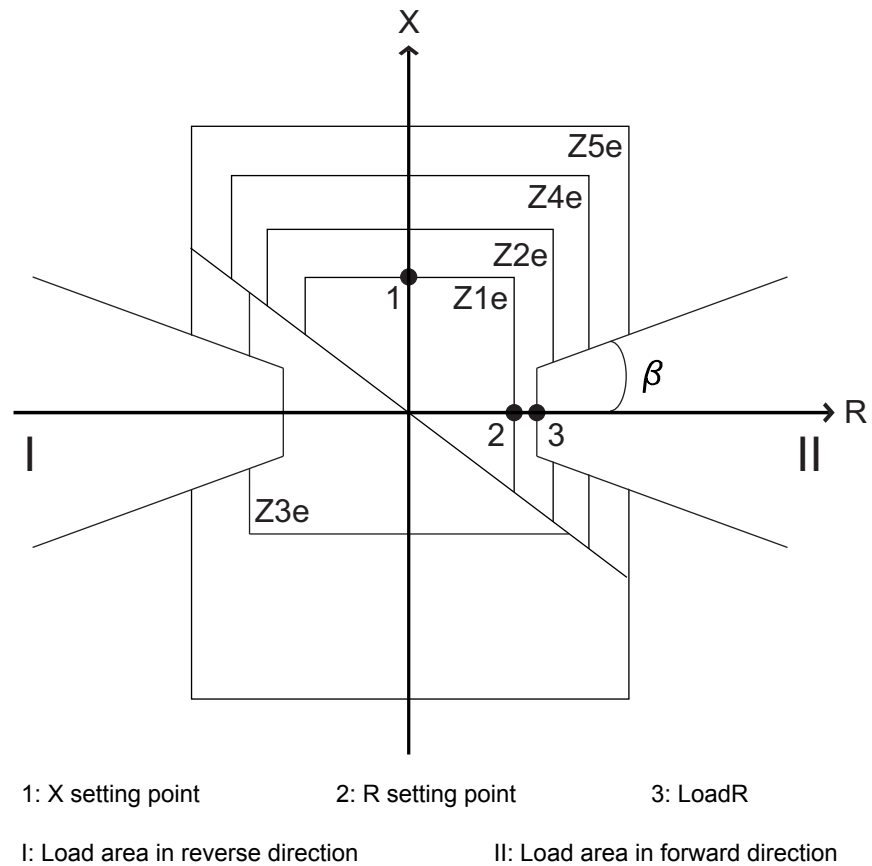


Figure 5.12: The distance protection polygonal characteristics. In this example zone 3 is in reverse direction and zone 5 is non-directional.

Table 5.1: Parameters of the distance protection stage (21N)

Parameter	Value	Unit	Default	Description
X	0.05 – 250.00	ohm	0.80	X-setting
R	0.05 – 250.00	ohm	0.80	R-setting
MODE	Reverse/Forward/ Undirectional		Forward	Direction mode
$t_c$	0.04 – 300.00	s		Operation delay
LOAD BLOCK	No/Yes		Yes	Load block in use
$I_0$ min input	$I_0$ ; $I_0$ Calc	-	$I_0$	$I_0$ input in use for minimum $I_0$ current
$I_0$ min	0.005 – 8.000 (20.000 for $I_0$ Calc)	pu	0.050	Minimum $I_0$ current for trip
<b>Common parameters for all zones</b>				
LoadAngle	10 – 40	°	40	Load angle $\beta$
LoadR	0.05 – 250.00	ohm	1.00	Load resistance
<b>Common parameters for all earth fault zones</b>				
$k_0$	0.00 – 10.00		0.00	Earth factor
$\varphi(k_0)$	-60 – 60	°	10	Earth factor angle

X-, R- and Load resistance settings are secondary impedances. Primary values of settings are displayed in VAMPSET and display.

### Teleprotection signals

Signalling between two distance protection relays (teleprotection) can be implemented using the normal DI and DO signals of the relay. An external signal transfer system is needed to transfer signals from one relay to another. The signal transfer system has to have an internal signal supervision and fault indication.

The DO output signals can be activated by protection zone's start or trip signals or by the programmable logic functions.

The DI input can be used to block protection zone(s) or it can be used as input into the programmable logic of the device. Different type of permissive tripping conditions such as, permissive under reach (PUTT), permissive over reach (POTT), acceleration or blocking conditions can thus be implemented. The relay's object control can be used to trip the breaker via the "DI for remote open ctr" or "DI for local open ctr" input of the object. Outputs of the relay programmable logic can be connected to "DI for remote open crt" or "DI for local open ctr" inputs via the internal "Virtual output" signals.

### 5.3.3

### Double earth fault (21DEF)

VAMP 259 is equipped with DEF (Cross country fault) functionality which operates together with distance protection (21). DEF is planned to operate in compensated and isolated meshed network. The single phase to earth -fault in this case does not correspond to a short-circuit cause only a small capacitive or compensated earth-current flows. In mentioned network types system can be operated with the fixed earth-fault for several hours, until the earth fault is located and removed by the isolation of the faulted feeder. The distance protection must not operate during such single-phase earth fault. This can be ensured by using DEF –algorithm.

When small impedance earth fault occur the voltage of the faulty phase will drop and the voltage of the two other phases will increase almost to the amplitude of line to line voltage. Due the raise of phase-earth voltage, on the healthy phases in the entire system, double earth faults may result. The result is similar to two phase short-circuit, however, the short circuit is here from one earth fault location to the other via earth. The second fault may be at any other position in the galvanic connected system, depending on where the weakest point in the insulation is.

The protection strategy usually applied for double-earth faults is aimed at isolating one of the fault locations with the expectation that the second fault location will then extinguish on its own, similar to a single-phase earth-fault, or will be tripped by a hand after successful earth fault searching.

DISTANCE COMMON SETTINGS	
Line angle	90 °
Load setting R	6.00 ohm
LoadAngle	30 °
Primary scaled load resistance	4.09 ohm
Earth factor	0.00
Earth factor angle	10 °
Network grounding	Comp

EARTH FAULT PHASE PRIORITIZATION	
Phase priority	1.>2.>3.>4
Phase undervoltage limit	E 90 %Un
Phase overvoltage limit	F 110 %Un
Residual overvoltage limit	30 %
Residual overcurrent limit	0.500 pu
Comparison conditions	U <sub>0</sub>

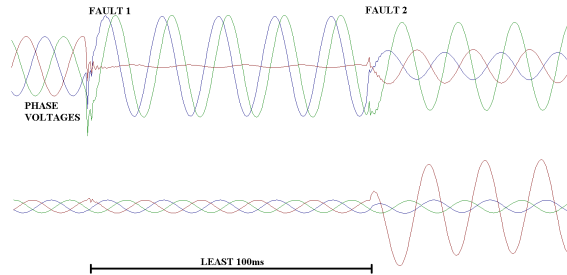
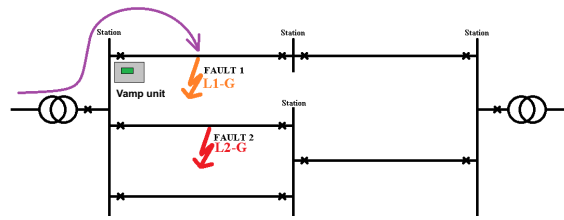
DEF –algorithm is enabled together with distance protection Z1e<. Enabling is done by selecting network grounding as “Comp” compensated. When DEF -function is enabled earth fault loop Z1e< is blocked during faults as long as DEF -sequence is fulfilled.

During first earth-fault the fault is recognized due to several terms. One of the phase voltages has to drop below “Phase under-voltage limit”. Two of the phase voltages need to increase above “Phase over-voltage limit”. Now the relay memorises that in which phase the first earth-fault in the network appeared. In case impedance measurement goes inside the zone Z1e< during voltage drop caused by the first earth-fault the trip will be blocked.

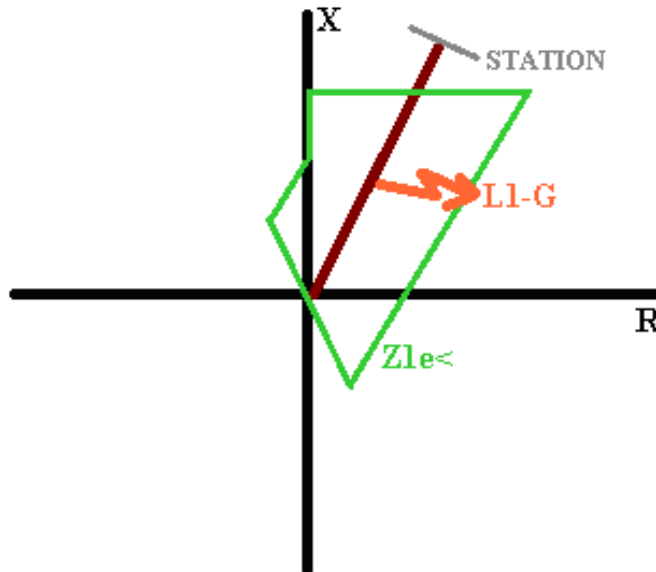
When earth fault turns into double earth fault the fault is recognized as follows. Second faulty phase has to decrease 10% below the healthy phase. Healthy phase still has to stay above the “Phase over-voltage limit”. Also certain amount of zero sequence voltage ( $U_0$ ) is required in the final phase. Additionally if comparison condition is selected as  $U_0-I_0$  also residual current has to exceed the set limit.



**Fault L1-G inside zone  $Z_{1e<}$**



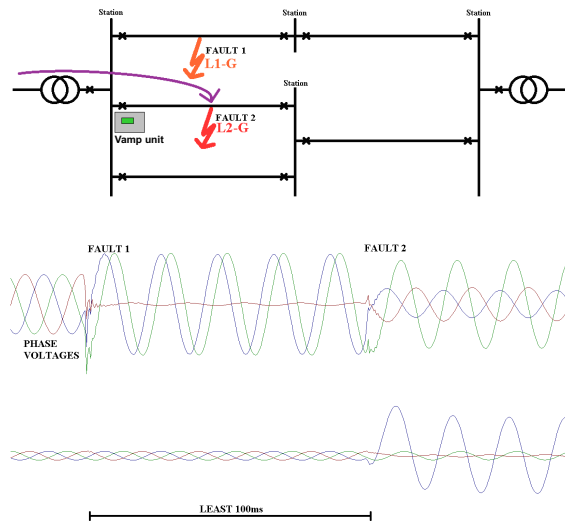
Fault is noticed since one of the voltages in the network area is dropped below the set “Phase under-voltage limit” limit and two other voltages are increasing above the set “Phase over-voltage limit” limit. This phase has to last least 100ms.



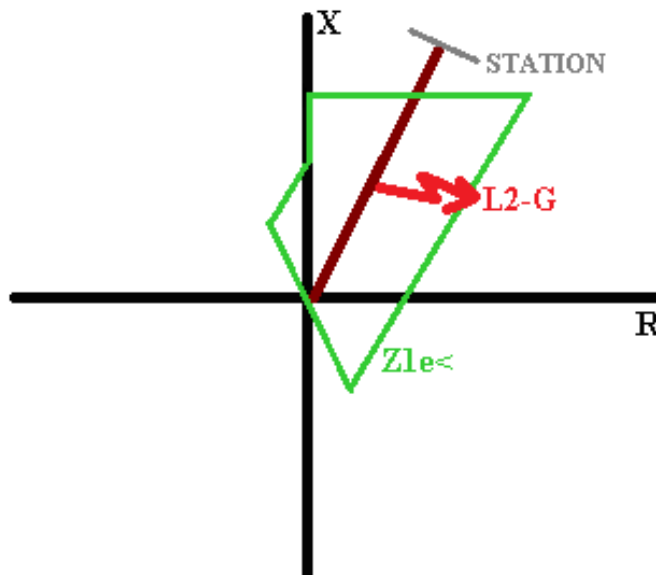
When second fault appears another voltage has to drop at least 10% below the healthy phase”. Also set amount of zero sequence voltage has to be exceeded (same applies to residual current if triggering condition  $U_0-I_0$  is selected).

Selected relay sees the fault 1 (L1-G) inside the zone  $Z_{1e<}$ . If phase priority is selected as “1-> 2-> 3” this relay would trip and the same would do to the relay opposite the protected line.

**Fault L2-G inside zone  $Z1e<$**



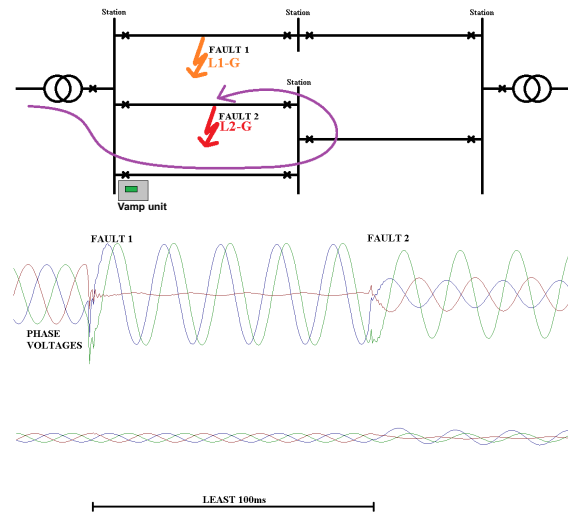
Fault is noticed since one of the voltages in the network area is dropped below the set “Phase under-voltage limit” limit and two other voltages are increasing above the set “Phase over-voltage limit” limit. This phase has to last at least 100ms.



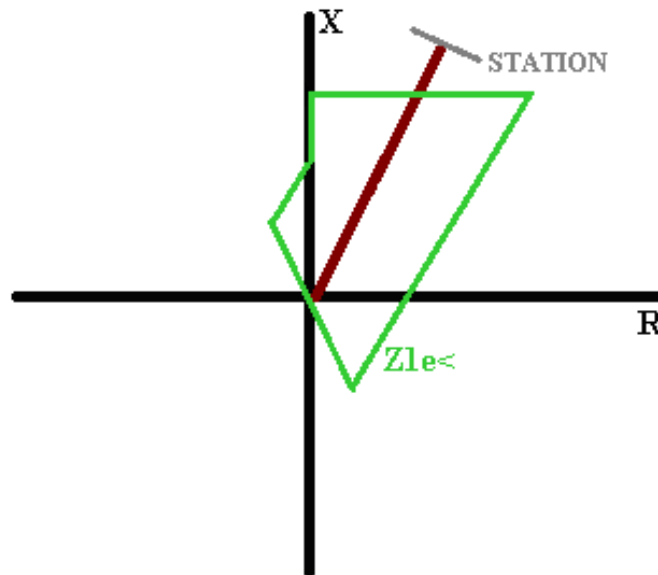
When second fault appears another voltage has to drop at least 10% below the healthy phase”. Also set amount of zero sequence voltage has to be exceeded (same applies to residual current if triggering condition  $U_0_I_0$  is selected).

Selected relay sees the fault 2 (L2-G) inside the zone  $Z1e<$ . If phase priority is selected as “1-> 2-> 3” this relay would NOT trip because fault L2-G inside the zone does not have the highest priority at the moment when the double earth-fault occurs.

No fault inside the protected zone  $Z1e <$



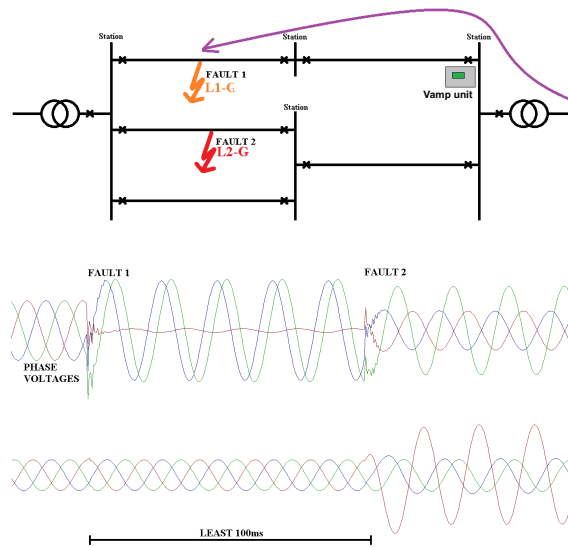
Fault is noticed since one of the voltages in the network area is dropped below the set “Phase under-voltage limit” limit and two other voltages are increasing above the set “Phase over-voltage limit” limit. This phase has to last least 100ms.



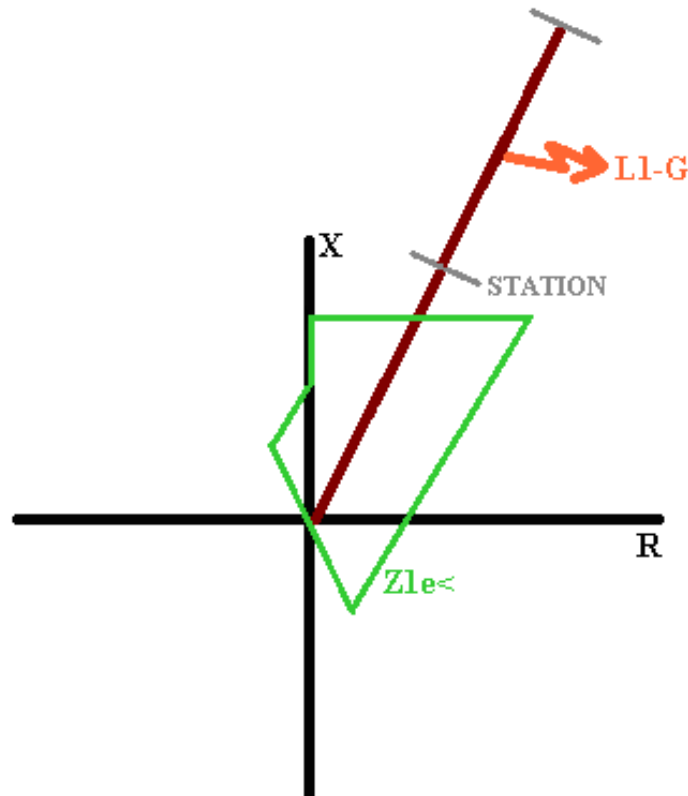
When second fault appears another voltage has to drop at least 10% below the healthy phase”. Also set amount of zero sequence voltage has to be exceeded (same applies to residual current if triggering condition  $U_0-I_0$  is selected).

Selected relay does not see any fault inside the zone  $Z1e <$ . There is no reason to trip.

**Fault too far away from the protected zone Z1e<**



Fault is noticed since one of the voltages in the network area is dropped below the set “Phase under-voltage limit” limit and two other voltages are increasing above the set “Phase over-voltage limit” limit. This phase has to last least 100ms.



When second fault appears another voltage has to drop at least 10% below the healthy phase”. Also set amount of zero sequence voltage has to be exceeded (same applies to residual current if triggering condition  $U_0_I_0$  is selected).

Selected relay sees the fault but outside the zone Z1e< so there is no reason to trip.

### Problem situations

Sometimes in certain type of network when fault 1 and 2 both appear in very short distance from the incomer the short circuit distance  $Z1 >$  protection might disconnect the whole ring. Same would happen even if the DEF –algorithm is not used since short circuit distance protection happens to see the fault inside the zone.

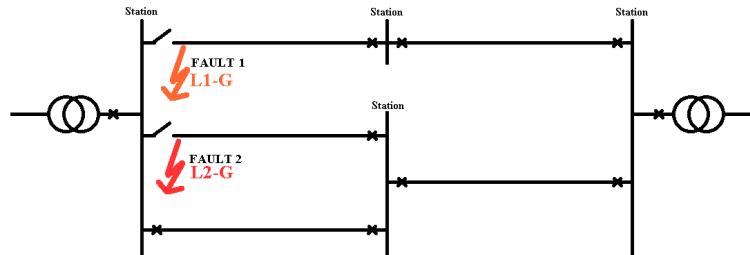


Figure 5.13: Two earth faults very close to the incomer. SC distance protection  $Z1 >$  operated.

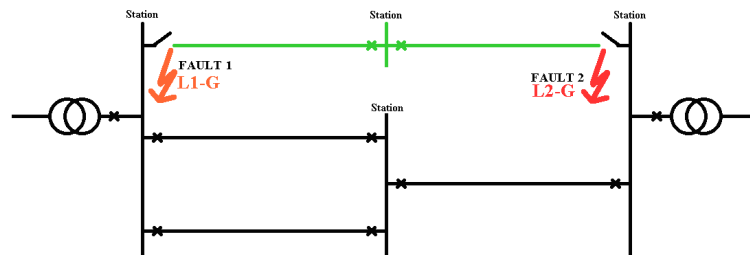


Figure 5.14: Two earth faults very close to the incomers at different ends of “same” line. Both lines will be separated from the network due the activation of SC-distance stage.

**NOTE:** Simple over-current and earth-fault protection is preferred to have as a back-up for “DEF algorithm”.

### The behavior of power swing blocking and out of step tripping functions

Power swing is using the setting value “Power swing setting  $dZ$ ”. Power swing function is enabled when the “Enable for power swing” is active. Depending of the setting “ $dZ$ ” there is a certain sized area outside the biggest used distance zone. If the  $dZ$  is set to  $1.0 \Omega$  the “swing area” starts one ohm away from the edge of the biggest zone. The idea of this area is to notice the power swing before it reaches the zone to have enough time to activate the internal blocking. Power swing blocking is used to block desired distance zones by connecting the “power swing” line to the distance zones at the block matrix (see Figure 5.15).

Power swing blocking is active when the speed of the swing is less than the set value for example  $1.0 \Omega / 40 \text{ ms}$  (40 ms is fixed value).

If the speed of the swing exceeds the  $1.0 \Omega / 40 \text{ ms}$  limit there won't be block and the distance stage trips normally.

**NOTE:** Out of step activates at the edge of the power swing area, NOT at the edge of the distance zone. Out of step function can be connected to a tripping signal at the output matrix.

1. Power swing may reach the zone from any direction but only as long as it leaves the zone at the first quadrant it will remain as a power swing. In case that the swing stops in the middle of zone and none of the terms of fault are active the block will remain until the zone is left or fault occurs.
2. Situation starts as a power swing but the swing comes out from the second quadrant. Therefore out of step is activated. When out of step is activated the activation lasts for 0.5 seconds.
3. Fault during the power swing.
4. Basically power swing function is always unidirectional. This means quadrants I and III are working similar way regardless the direction mode of distance stage (passing quadrant III with certain speed always activates power swing block). This makes the power swing to function when using reverse or unidirectional mode.

**NOTE:** The conditions for the power swing blocking to be activated require in addition of the previously mentioned rate of change of impedance ( $dZ/dt$ ) condition that sequences unbalance ( $I_2/I_1$ ) is less than 25% and calculated residual current ( $I_{0Calc}$ ) is less than 10%. These mentioned parameters  $I_2/I_1$  and  $I_{0Calc}$  are fixed in the relay and can not be set by users.

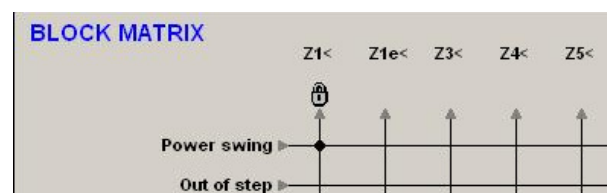
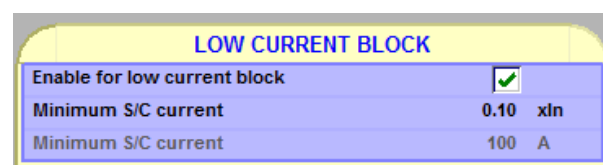


Figure 5.15: How to use power swing blocking with certain zones.

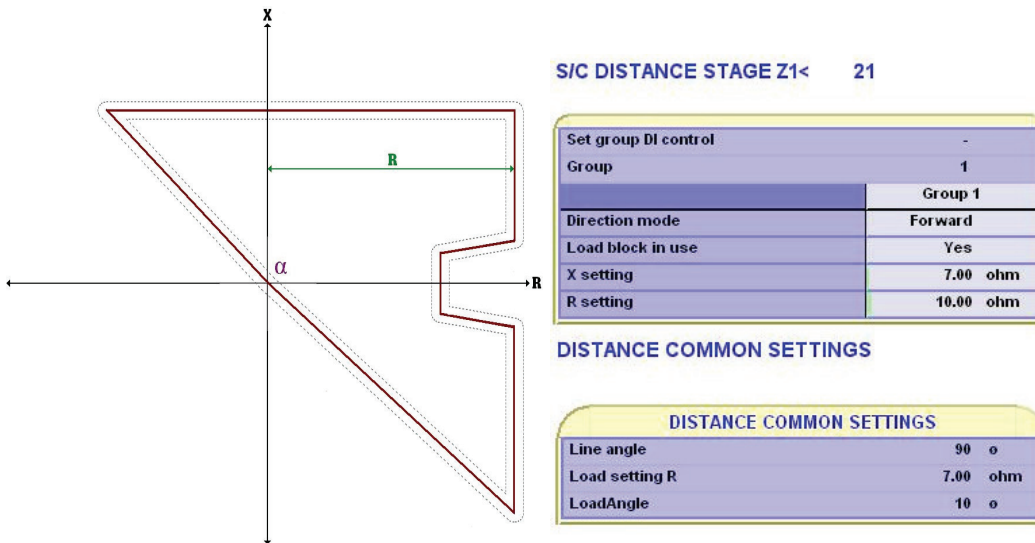
Low current blocking can be used to avoid Distance Protection nuisance tripping in case of low voltage.

Low current blocking is active when Short Circuit current is lower than the set value.



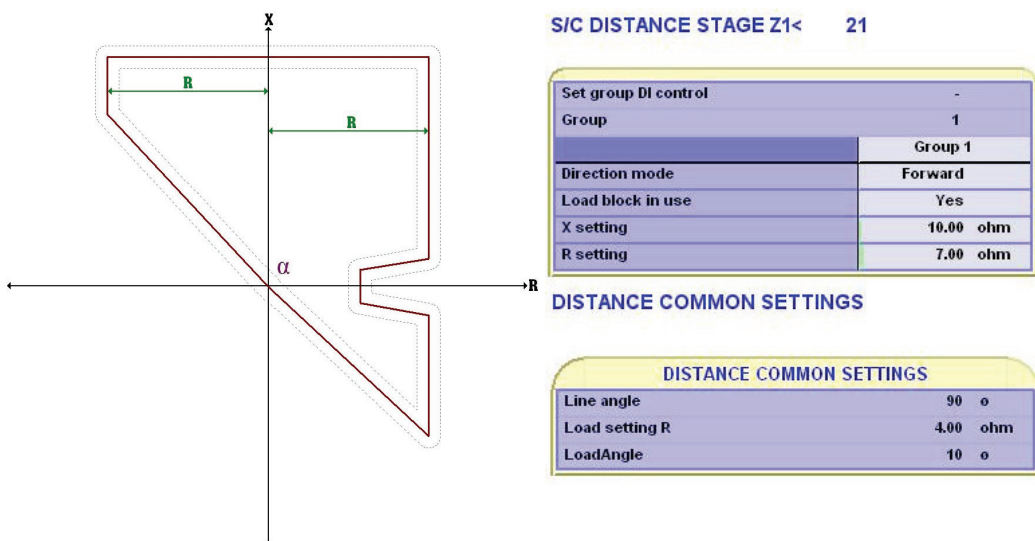
### 5.3.4 Distance protection applications

#### The behavior of distance zones



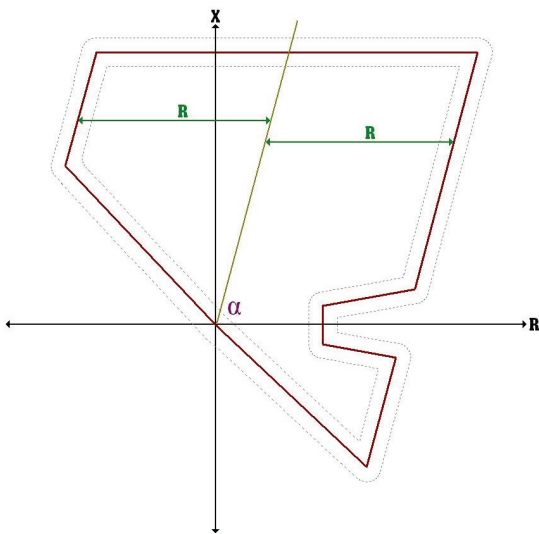
- Characteristic type 1**

In the characteristic type 1 the line angle is set to 90 degrees. The resistive setting R is set above the reactive setting X. Therefore the resistive reach does not reach as far on the second quadrant as on the first quadrant. The load setting R and the angle setting of load block can be found from “distance common settings” menu. These values are being used only if the “Load block in use” is selected as “Yes”. The tolerance of inaccuracy is now taken from the R setting. This is because the R value is greater than the X value. If the allowed inaccuracy is for example 5 % and R setting is 10 Ω the allowed tolerance would be 0.5 Ω.



• **Characteristic type 2**

In the characteristic type 2 the line angle is set to 90 degrees. The reactive setting X is set above the resistive setting R. The resistive reach is equal at the both sides of the line setting. The load setting R and the angle setting of load block can be found from “distance common settings” menu. These values are being used only if the “Load block in use” is selected as “Yes”. The tolerance of inaccuracy is now taken from the X setting. This is because the X value is greater than the R value. If the allowed inaccuracy is for example 5 % and X setting is 10 Ω the allowed tolerance would be 0.5 Ω.



S/C DISTANCE STAGE Z1< 21

Set group DI control	-
Group	1
	Group 1
Direction mode	Forward
Load block in use	Yes
X setting	10.00 ohm
R setting	7.00 ohm

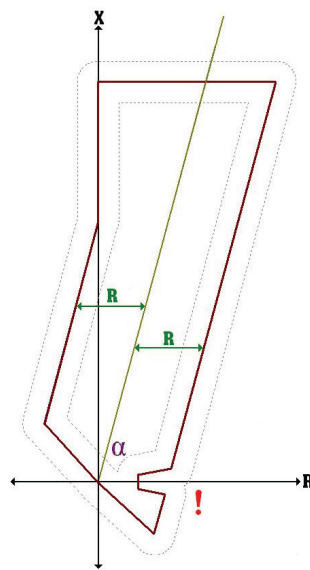
DISTANCE COMMON SETTINGS

DISTANCE COMMON SETTINGS	
Line angle	75 °
Load setting R	4.00 ohm
LoadAngle	10 °



- **Characteristic type 3**

In the characteristic type 3 the line angle is set to 75 degrees. The reactive setting X is set above the resistive setting R. The resistive reach is equal at the both sides of the line setting. The load setting R and the angle setting of load block can be found from “distance common settings” menu. These values are being used only if the “Load block in use” is selected as “Yes”. The tolerance of inaccuracy is now taken from the X setting. This is because the X value is greater than the R value. If the allowed inaccuracy is for example 5 % and X setting is 10  $\Omega$  the allowed tolerance would be 0.5  $\Omega$ .



S/C DISTANCE STAGE Z1&lt; 21

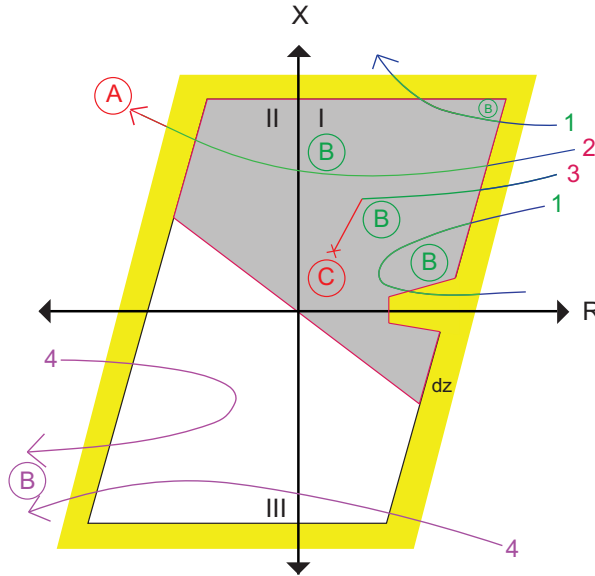
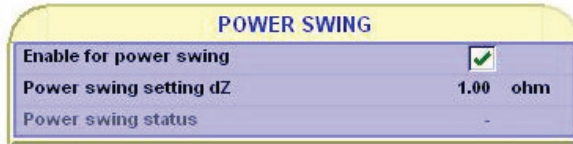
Set group DI control	-
Group	1
Group 1	
Direction mode	Forward
Load block in use	Yes
X setting	40.00 ohm
R setting	7.00 ohm

DISTANCE COMMON SETTINGS

DISTANCE COMMON SETTINGS	
Line angle	75 °
Load setting R	4.00 ohm
LoadAngle	10 °

- **Characteristic type 4**

In the characteristic type 4 the line angle is set to 75 degrees. The reactive setting X is set significantly above the resistive setting R. The resistive reach is equal at the both sides of the line setting until the resistive reach of quadrant II hits the line X. The load setting R and the angle setting of load block can be found from “distance common settings” menu. These values are being used only if the “Load block in use” is selected as “Yes”. The tolerance of inaccuracy is now taken from the X setting. This is because the X value is greater than the R value. If the allowed inaccuracy is for example 5 % and X setting is 40  $\Omega$  the allowed tolerance would be 2.0  $\Omega$ . Notice that with these settings the load block area is fully covered with the tolerance so all settings are not reasonable.



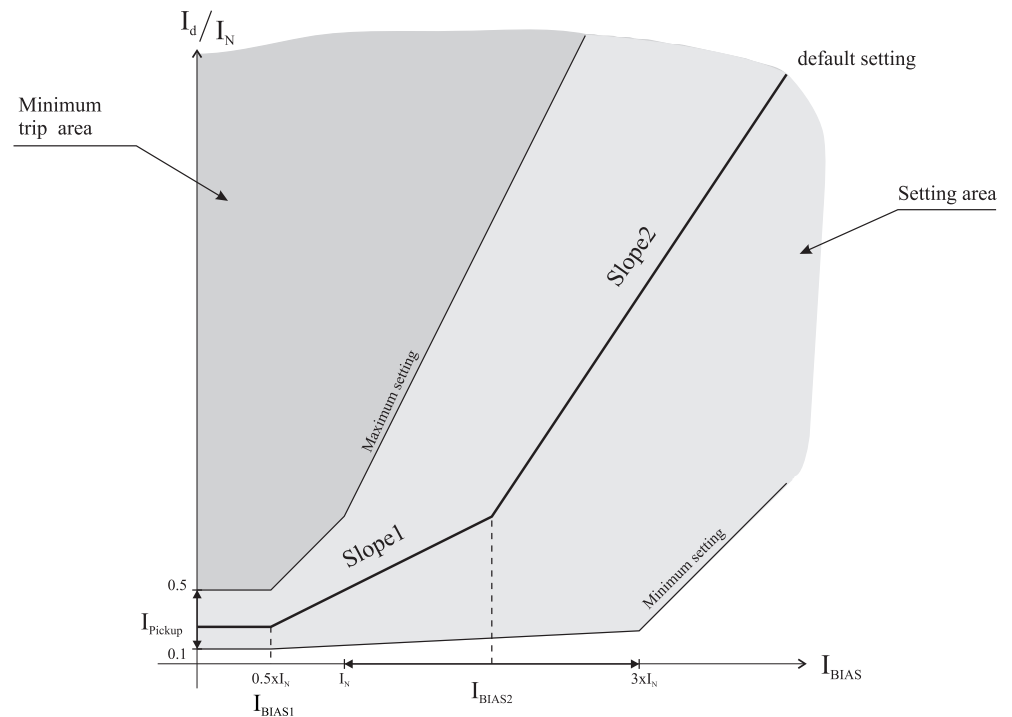
A. Out of step                      B. Block                      C. Trip

1. Power swing may reach the zone from any direction but only as long as it leaves the zone at the first quadrant it will remain as a power swing. In case that the swing stops in the middle of zone and none of the terms of fault are active the block will remain until the zone is left or fault occurs.
2. Situation starts as a power swing but the swing comes out from the second quadrant. Therefore out of step is activated. When out of step is activated the activation lasts for 0.5 seconds.
3. Fault during the power swing.
4. Basically power swing function is always undirectional. This means quadrants I and III are working similar way regardless the direction mode of distance stage (passing quadrant III with certain speed always activates power swing block). This makes the power swing to function when using reverse or undirectional mode.

## 5.4 Line differential protection Ldl> (87L)

VAMP 259 is a differential protection device mainly designed for sub-transmission overhead lines, medium voltage cables and transformers. Two line ends may lie within the protection zone.

Phase segregated protection is based on current (vector) differential. Combination of both phase and magnitude differential is used to determine operation. The differential element takes a sampled version of the instantaneous current waveform as its local input and compares it with a corresponding current from the remote end. The signal is converted to magnitude and angle information for comparison. The threshold characteristics is biased for CT saturation as presented in Figure 5.16.



Settings:

$$I_{\text{Pick-Up}} = 20 - 50\%$$

$$\text{Start of slope1} = 0.5 - 1.0 \times I_N$$

$$\text{Slope1} = 0 - 100\%$$

$$\text{Start of slope2} = 1.0 - 3.0 \times I_N$$

$$\text{Slope2} = 50 - 200\%$$

Figure 5.16: Tripping threshold characteristics

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

Equation 5.1: Bias current

$$I_b = \frac{|\bar{I}_{RELAY1}| + |\bar{I}_{RELAY2}|}{2}$$

Equation 5.2: Differential current

$$I_d = |\bar{I}_{RELAY1} - \bar{I}_{RELAY2}|$$

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

Figure 5.17: Setting example

**Example 1: Normal situation from relay 1 point of view**

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

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

Relay1: measured phase current  $I_{L1} = 1000A / 0^\circ$

Relay2: measured phase current  $I_{L1} = 300A / -180^\circ$

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

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

Relay2 sends primary current measurement information to relay1.

Relay1 swaps the angle of received current by 180 degrees (relay2 phase current  $I_{L1} = 300A / -180^\circ \Rightarrow 300A / 0^\circ$ ).

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

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

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

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

$$I_d = |1\angle 0^\circ - 1\angle 0^\circ| = 0 \times I_N$$

**Example 2: Fault situation from relay 1 point of view**

Relay1: measured phase current  $I_{L1} = 2400A / -30^\circ$

Relay2: measured phase current  $I_{L1} = 2100A / -45^\circ$

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

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

Relay2 sends primary current measurement information to relay1.

Relay1 swaps the angle of received current by 180 degrees (relay2 phase current  $I_{L1} = 2100A / -45^\circ \Rightarrow 2100A / 135^\circ$ ).

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

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

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

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

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

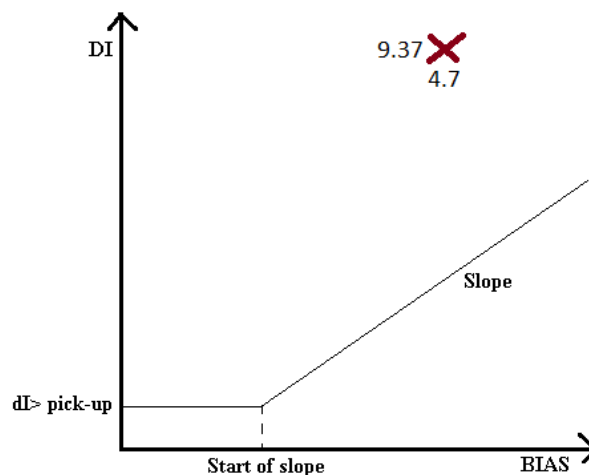


Figure 5.18: Example BIAS and differential calculation

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

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

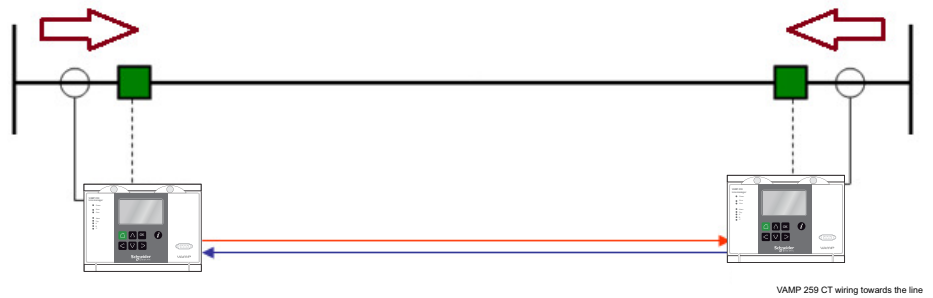


Figure 5.19: CT wiring towards the line

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

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

PROTOCOL CONFIGURATION	
COM 1 PORT	
COM 1 port protocol	ANSI85
-	64000/8N1
Message counter	16706092
Error counter	0
Timeout counter	0

Figure 5.20: Enabling line differential communication

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

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

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



Figure 5.21: Communication failure

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

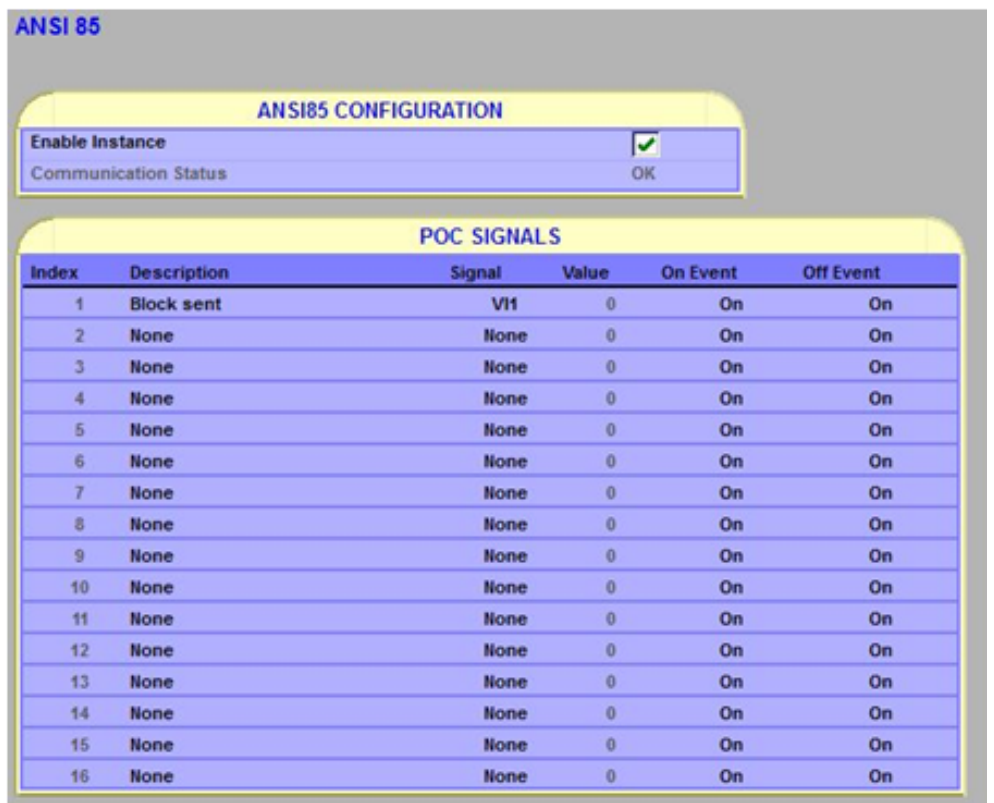


Figure 5.22: Up to 16 event stamped binary signals

In VAMP 259 current comparison is based to nominal primary currents of both ends in this unit. In line or cable differential protection “nominal primary” value should be the same the “CT primary” value.

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

When there is transformer on the line or the VAMP 259 is used mainly to transformer differential protection, it is possible to select correct connection group and whether the relay is on high voltage (HV) or low voltage side (LV).

SCALING	
Nominal primary	1000 A
CT primary	1000 A
CT secondary	5 A
Nominal input	5 A
Nominal primary (remote end)	1000 A
VT primary	20000 V
VT secondary	100 V
Io1 CT primary	10 A
Io1 CT secondary	1.0 A
Nominal Io1 input	1.0 A
VTo secondary	100.000 V
Voltage meas. mode	3LN+Uo
Frequency adaptation mode	Auto
Adapted frequency	50.0 Hz
Angle memory duration	0.50 s
Transformer settings	
Transformer	Dy11
Transformer side	HV
This end	D
Remote end	y

Figure 5.23: CT – and transformer settings

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



**LINE DIFF STAGE Ldl> 87L**

Enable for Ldl>

Status	-
CTS Status	Inactive
Line distance	0 km
Communication Status	OK
Synchronized	Yes
Start counter	7
Trip counter	7

IO compensation enable

**Table 5.2: Zero current compensation in transformer applications**

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

For details of setting ranges, see Table 12.18, Table 12.19, Table 12.20.

### Testing mode

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

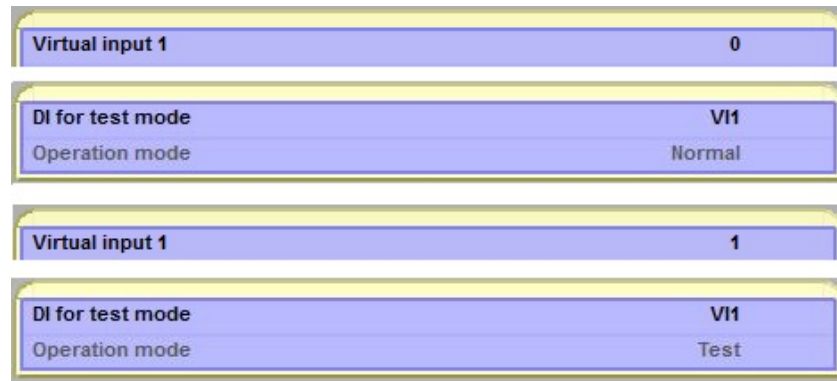


Figure 5.24: When V11 was activated, “Operation mode” changed from normal to test.

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

POC SIGNALS					
Index	Description	Signal	Value	On Event	Off Event
1	Block sent	V11	1	On	On

Figure 5.25: Sending the Block signal

POC SIGNALS					
Index	Description	Signal	Value	On Event	Off Event
1	Block receive	None	1	On	On

Figure 5.26: Receiving the Block signal in other relay

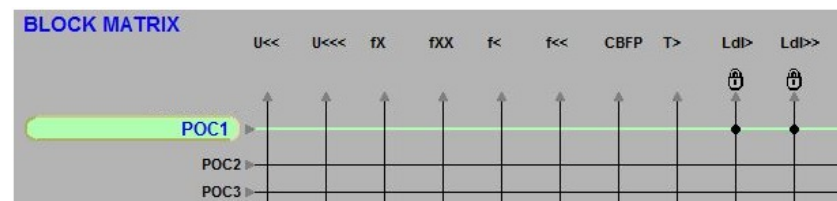


Figure 5.27: Using the block signal for differential protection blocking

### Current transformer supervision

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

Differential CTS	<input checked="" type="checkbox"/>
Operation mode	Restrained
I1 limit	0.05 xIn
I1 limit	50 A
I2/I1 limit	30 %

Figure 5.28: Current transformer supervision settings

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

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

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

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

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

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

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

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

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

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

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

### 5.4.1 Capacitive charging current

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

*Equation 5.3: Capacitive charging current*

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

l = Cable length (km)

$I_C$  = Charging current (amperes)

f = Frequency

C = Cable capacitance (  $\mu\text{F}$  / km)

U = Voltage to neutral (kV)

**Example: 32km of certain 15kV cable:**

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

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

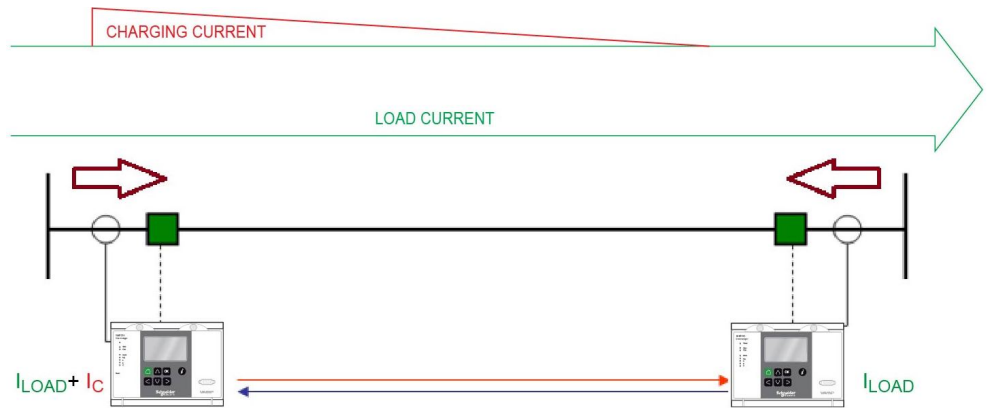


Figure 5.29: Behaviour of constant charging current

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

### 5.4.2 ANSI 85 communication (POC –signals)

Total of 16 signals can be sent between two VAMP 259 line differential relays via ANSI 85 communication. Basically it means when relay is using 8 of the signals there is still 8 more signals left for the other end. Signal status is updated every 10 ms.

Table 5.3: List of POC –signals between the relays (ANSI 85 communication)

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

ANSI 85

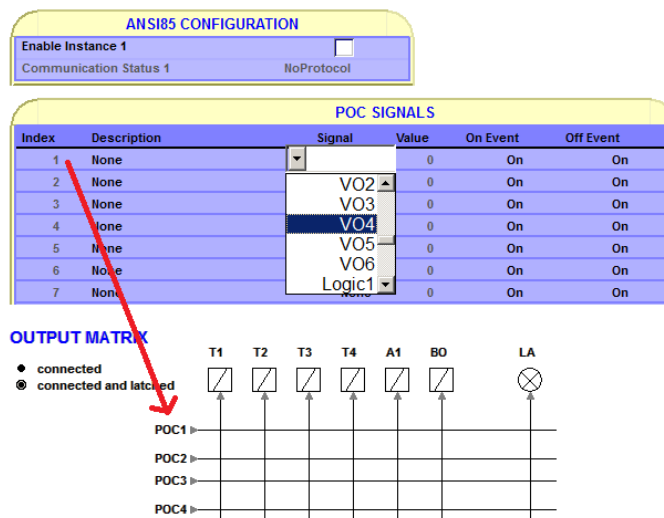


Figure 5.30: Selecting POC – signals

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

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

### 5.4.3 Frequency adaptation

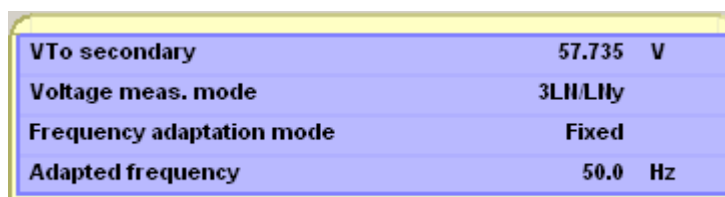


Figure 5.31: Frequency adaptation mode has to be set as “Fixed” when line differential protection is used

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

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

## 5.4.4 Second harmonic blocking

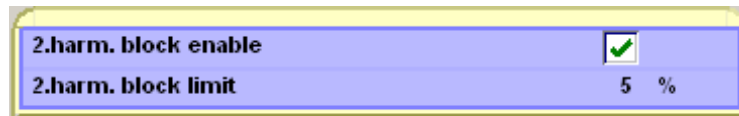


Figure 5.32: Second harmonic blocking can be enabled in the Ldl menus

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

## 5.4.5 Fifth harmonic blocking

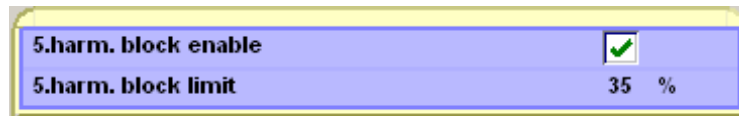


Figure 5.33: Fifth harmonic blocking can be enabled in the Ldl> and Ldl>> menus.

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

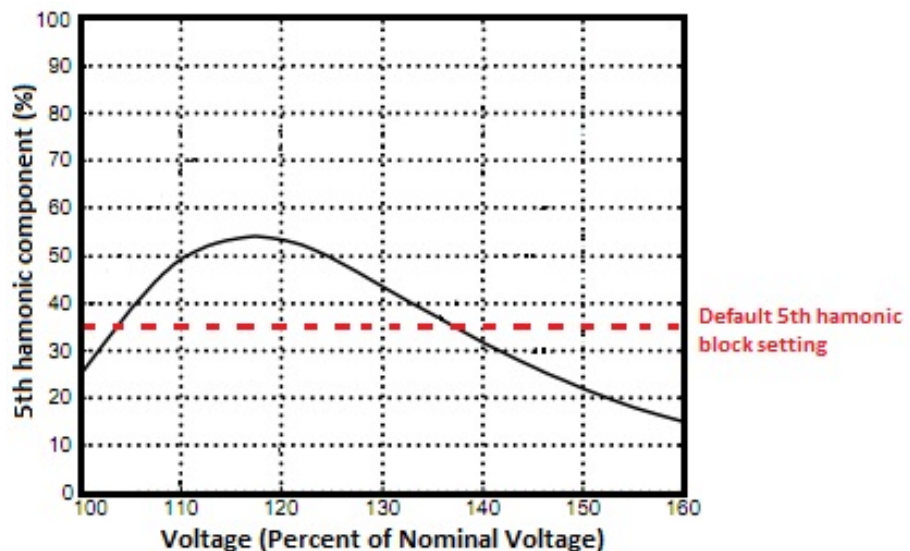


Figure 5.34: Harmonic content of transformer exciting current as a function of the applied voltage

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



## 5.5 Line differential protection Ldl>>> (87L)

Line differential protection (LDP) provides high speed clearing for faults occurring at any point on a transmission line.

The line differential protection unit uses voltage measurements to calculate the resistive part of each of the three phase currents. The dedicated communication channel, called pilot channel, is used between two relays to exchange information on resistive phase currents and to determine whether the fault is internal or external to the protected line. In each piloting relay the difference between the corresponding resistive phase currents from this unit and from the remote unit is computed and compared against the configured threshold. In case any of the phases shows the difference in resistive currents greater than the threshold, the relay trips after the configurable operation time.

The measurement and transmission operations in the two piloting relays are not synchronized. Therefore, the communication speed on the pilot channel should be high enough to minimize the impact of fault detection delay asymmetry. The default communication speed is 38400 bps. Using the lower speed may result in longer minimum operation time of the relay.

Serial remote port of the relay is used by line differential protection.

The recommended solution for the pilot channel is the supervised fibre optic wiring. With multimode fibre cables and VSExxx-GG fibre optic modems the communication distance can be up to 1 km. When using single mode fibre cables and third party modems the distance can be up to tens of kilometres.

Using resistive currents for comparison assures good insensitivity to line capacitive charge currents.

The threshold characteristics is biased for CT saturation as presented in Figure 5.35.

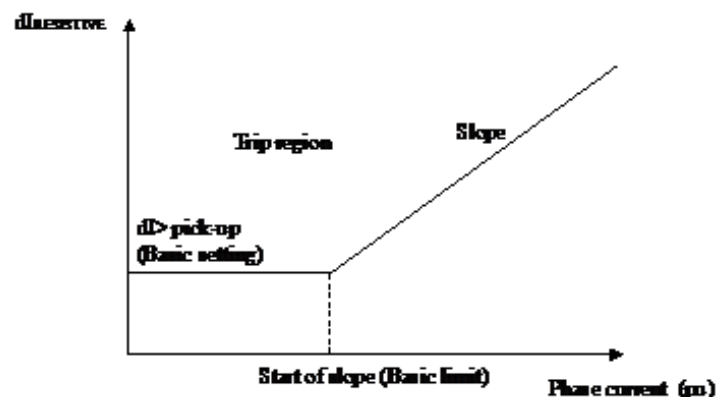


Figure 5.35: LDP tripping threshold characteristics

Definite operation time of the Ldl>>> stage can be configured, starting with 60 ms as the minimum value.

When the difference between resistive currents current has been greater than the threshold for at least 60 ms the line differential stage starts to count the operation time according to the configured parameter. If the difference between resistive currents drops below the threshold while counting, the counting to trip is stopped. If the difference between resistive currents remains like this for at least the time defined as the release delay (default 5 ms), the counting is cleared and the relay start is also cleared.

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

LDP Start and Trip signals as well as pilot channel failure status are available as inputs in the output matrix and blocking matrix of the relay.

The pilot channel between two line differential protection relays carries also binary signals in both directions: the status of LDP Start and Trip signals, and the Remote Trip command signal which is an output from the output logic matrix of the sending relay. Remote Trip signal can be processed as an input in the output matrix and blocking matrix of the receiving relay.

**Table 5.4: Parameters of the line differential protection stage Ldl>>> (87L)**

	Parameter	Value/unit	Description
Setting values	dl>>> pick-up	In	Basic setting for lower phase currents
	Start of slope	In	Phase current limit for applying linear threshold characteristics
	Slope	%	Linear characteristics slope
	Operation delay	[0.050 - 3.000] / s	Operation time Default 0.050
	CT primary other	[10 - 20000]	CT ratio of the other unit Default 500
Recorded values	SCntr		Start counter (Start) reading
	TCntr		Trip counter (Trip) reading
	dl> status		Protection state

## 5.6 Overcurrent protection I> (50/51)

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

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

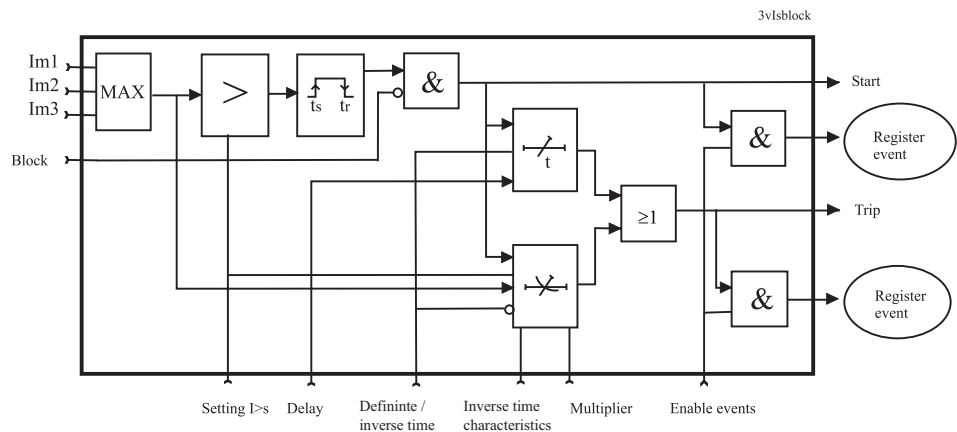


Figure 5.36: Block diagram of the three-phase overcurrent stage I>

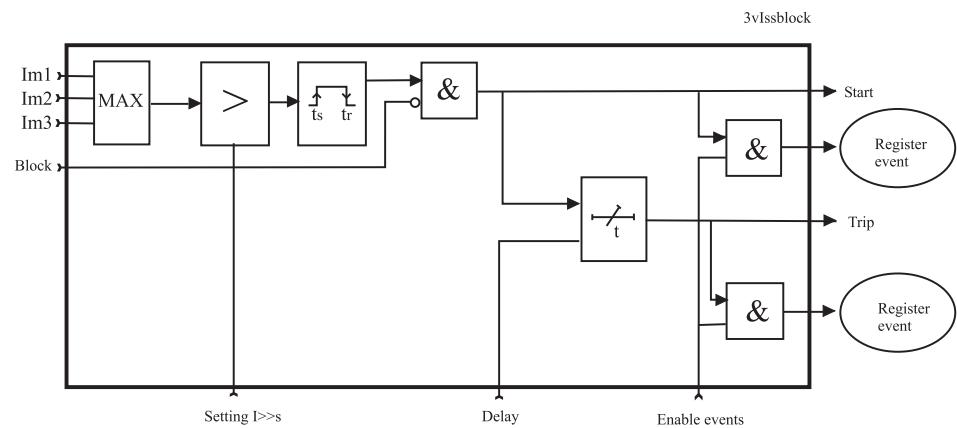


Figure 5.37: Block diagram of the three-phase overcurrent stage I>> and I>>>

### Three independent stages

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

Figure 5.36 shows a functional block diagram of the I> overcurrent stage with definite time and inverse time operate time. Figure 5.37 shows a functional block diagram of the I>> and I>>> overcurrent stages with definite time operation delay.

### Inverse operate time

Inverse delay means that the operate time depends on the amount the measured current exceeds the pick-up setting. The bigger the fault current is, the faster is the operation. Accomplished inverse delays are available for the I> stage. The inverse delay types are described in Chapter 5.26 Inverse time operation. The device shows the currently used inverse delay curve graph on the local panel display.

### Inverse time limitation

The maximum measured secondary current is  $50 \times I_N$ . This limits the scope of inverse curves with high pick-up settings. See Chapter 5.26 Inverse time operation for more information.

### Cold load and inrush current handling

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

### Setting groups

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

**Table 5.5: Parameters of the overcurrent stage I> (50/51)**

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	  F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	Dlx		Digital input	
	Vlx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	

Parameter	Value	Unit	Description	Note
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. This flag is automatically reset 5 minutes after the last front panel push button pressing.	Set
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
Status			Current status of the stage	
I>		A	Pick-up value scaled to primary value	
I>		$xI_N$	Pick-up setting	Set
Curve	DT IEC, IEEE, IEEE2, RI, PrgN		Delay curve family: Definite time Inverse time. See Chapter 5.26 Inverse time operation.	Set
Type	DT NI, VI, EI, LTI, Parameters		Delay type Definite time Inverse time. See Chapter 5.26 Inverse time operation.	Set
t>		s	Definite operate 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	
IncHarm		On/off	Include Harmonics	
Delay curves			Graphic delay curve picture (only local display)	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. Chapter 5.26 Inverse time operation.	Set
Recorded values	LOG1		Date and time of trip	
	Type		Fault type	
	Flt	$xI_N$	Fault current	
	Load	$xI_N$	Pre-fault current	
	Edly	%	Elapsed delay time	
	SetGrp		Active set group during fault	

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

For details of setting ranges, see Table 12.21

**Table 5.6: Parameters of the overcurrent stages I>, I>>> (50/51)**

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Blocked			
	Start			F
	Trip			F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C

Parameter	Value	Unit	Description	Note
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	DIx		Digital input	
	VIx		Virtual input	
	LEDx		LED indicator signal	
Force	Off		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
	On			
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
I>>, I>>>		A	Pick-up value scaled to primary value	
I>>, I>>>		$xI_N$	Pick-up setting	Set
t>>, t>>>		s	Definite operate time	Set
IncHarm		On/off	Include Harmonics	Set

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

For details of setting ranges, see Table 12.22, Table 12.23.

### Recorded values of the latest eight faults

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

**Table 5.7: Recorded values of the overcurrent stages (8 latest faults) I>, I>>, I>>> (50/51)**

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

## 5.6.1 Remote controlled overcurrent scaling

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

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

The screenshot shows the 'Group 2 o/c remote scaling' menu with 'Enable' checked and 'Grp. 2 remote scaling' set to 150%. Below it is a table comparing Group 1 and Group 2 settings.

Set group DI control	-	
Group	2	
	Group 1	Group 2
Pick-up setting	1000 A	1500 A
Pick-up setting	1.00 xIn	1.50 xIn
Delay curve family	IEC	IEC
Delay type	III	III
Inv. time coefficient k	0.20	0.20
Inverse delay (20x)	0.45 s	0.45 s
Inverse delay (4x)	0.99 s	0.99 s
Inverse delay (1x)	141.83 s	141.15 s
<b>Common settings</b>		
Include harmonics	Off	

Figure 5.38: Remote scaling example.

In the Figure 5.38 can be seen the affect of remote scaling. After enabling group is changed from group one to group two and all settings from group one are copied to group two. The difference is that group two uses scaled pick-up settings.

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

## 5.7 Directional phase overcurrent $I_{\phi>}$ (67)

Directional overcurrent protection can be used for directional short circuit protection. Typical applications are:

- Short circuit protection of two parallel cables or overhead lines in a radial network.
- Short circuit protection of a looped network with single feeding point.
- Short circuit protection of a two-way feeder, which usually supplies loads but is used in special cases as an incoming feeder.
- Directional overcurrent protection in low impedance earthed networks. Please note that in this case the device has to be connected to line-to-neutral voltages instead of line-to-line voltages. In other words the voltage measurement mode has to be "3LN" (See chapter Chapter 7.7 Voltage measurement modes).

The stages are sensitive to the amplitude of the highest fundamental frequency current of the three measured phase currents.

In phase to phase and in three phase faults, the fault angle is determined by using angles between positive sequence of currents and voltages. In phase to ground faults, the fault angle is determined by using fault phase current and the healthy line to line voltage. For details of power direction, see Chapter 7.9 Direction of power and current.

A typical characteristic is shown in Figure 5.39. The base angle setting is  $-30^\circ$ . The stage will pick up, if the tip of the three phase current phasor gets into the grey area.

**NOTE:** If the maximum possible earth fault current is greater than the used most sensitive directional over current setting, the device has to be connected to the line-to-neutral voltages instead of line-to-line voltages in order to get the right direction for earth faults, too. (For networks having the maximum possible earth fault current less than the over current setting, use 67N, the directional earth fault stages.)



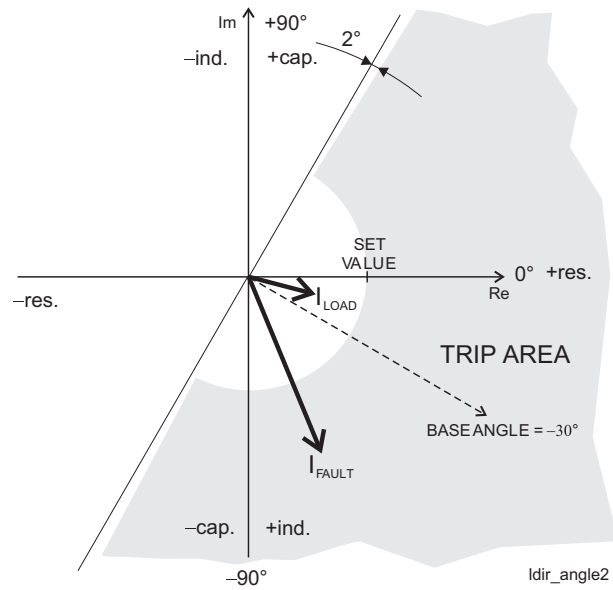


Figure 5.39: Example of protection area of the directional overcurrent function.

Three modes are available: dirctional, non-direct, and directional+back-up (Figure 5.40). In the non-directional mode the stage is acting just like an ordinary overcurrent 50/51 stage.

Directional+back-up mode works the same way as directional mode but it has undirectional back-up protection in case a close-up fault will force all voltages to about zero. After the angle memory hold time, the direction would be lost. Basically the directional+backup mode is required when operate time is set longer than voltage memory setting and no other undirectional back-up protection is in use.

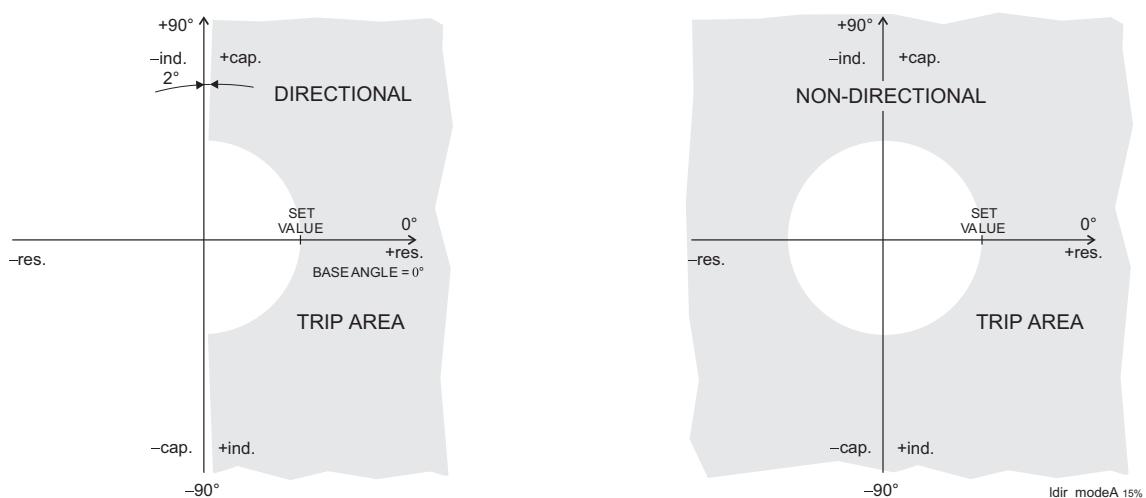


Figure 5.40: Difference between directional mode and non-directional mode. The grey area is the trip region.

An example of bi-directional operation characteristic is shown in Figure 5.41. The right side stage in this example is the stage  $I_{\phi >}$  and

the left side is  $I_{\phi>>}$ . The base angle setting of the  $I_{\phi>}$  is  $0^\circ$  and the base angle of  $I_{\phi>>}$  is set to  $-180^\circ$ .

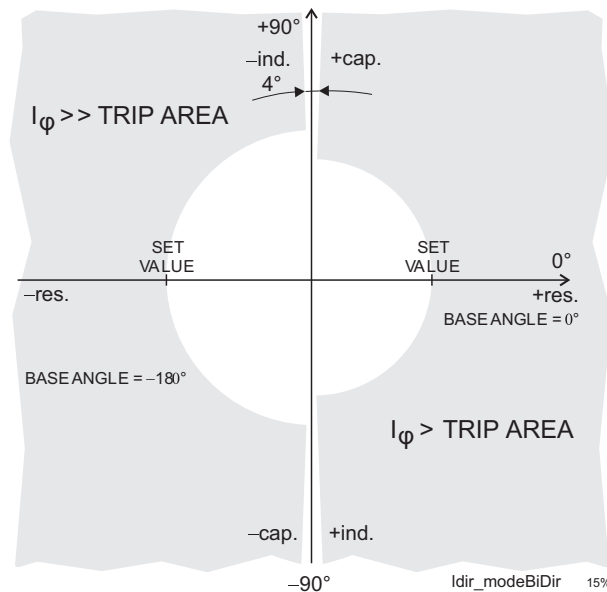


Figure 5.41: Bi-directional application with two stages  $I_{\phi>}$  and  $I_{\phi>>}$ .

When any of the three phase currents exceeds the setting value and – in directional mode – the phase angle including the base angle is within the active  $\pm 88^\circ$  wide sector, the stage picks up and issues a start signal. If this fault situation remains on longer than the delay setting, a trip signal is issued.

### Four independent stages

There are four separately adjustable stages available:  $I_{\phi>}$ ,  $I_{\phi>>}$ ,  $I_{\phi>>>}$  and  $I_{\phi>>>>}$ .

### Inverse operate time

Stages  $I_{\phi>}$  and  $I_{\phi>>}$  can be configured for definite time or inverse time characteristic. See Chapter 5.26 Inverse time operation for details of the available inverse delays. Stages  $I_{\phi>>>}$  and  $I_{\phi>>>>}$  have definite time (DT) operation delay. The device will show a scaleable graph of the configured delay on the local panel display.

### Inverse time limitation

The maximum measured secondary current is  $50 \times I_N$ . This limits the scope of inverse curves with high pick-up settings. See Chapter 5.26 Inverse time operation for more information.

### Cold load and inrush current handling

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

### Setting groups

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

**Table 5.8: Parameters of the directional overcurrent stages  $I_{\phi>}$ ,  $I_{\phi>>}$  (67)**

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	  F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI	- 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	
$I_{\phi>}$ , $I_{\phi>>}$		A	Pick-up value scaled to primary value	
$I_{\phi>}$ , $I_{\phi>>}$		$xI_N$	Pick-up setting	Set
Curve	DT IEC, IEEE, IEEE2, RI, PrgN		Delay curve family: Definite time Inverse time. See Chapter 5.26 Inverse time operation.	Set
Type	DT NI, VI, EI, LTI, Parameters		Delay type Definite time Inverse time. See Chapter 5.26 Inverse time operation.	Set
$t_{>}$		s	Definite operate 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	

Parameter	Value	Unit	Description	Note
Mode	Dir		Directional mode (67)	Set
	Undir		Undirectional (50/51)	
	Dir+back-up		Directional and undirectional back-up	
Offset		°	Angle offset in degrees	Set
U/I angle		°	Measured $U_1/I_1$ angle	
U1		% $U_N$	Measured positive sequence voltage	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See Chapter 5.26 Inverse time operation.	Set

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

For details of setting ranges, see Table 12.32

**Table 5.9: Parameters of the directional overcurrent stages  $I_{\phi>>>}$ ,  $I_{\phi>>>>}$  (67)**

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Blocked			
	Start			F
	Trip			F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	Dix		Digital input	
	Vix		Virtual input	
	LEDx		LED indicator signal	
	Vox		Virtual output	
Force	Off		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
	On			
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
$I_{\phi>>>}$ , $I_{\phi>>>>}$		A	Pick-up value scaled to primary value	
$I_{\phi>>>}$ , $I_{\phi>>>>}$		$xI_N$	Pick-up setting	Set
$t>>>$		s	Definite operate time (for definite time only)	Set
$t>>>>$				
Mode	Dir		Directional (67)	Set
	Undir		Undirectional (50/51)	
	Dir+back-up		Directional and undirectional back-up	
Offset		°	Angle offset in degrees	Set
U/I angle		°	Measured $U_1/I_1$ angle	
U1		% $U_N$	Measured positive sequence voltage	

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

For details of setting ranges, see Table 12.33

### 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.

**Table 5.10: Recorded values of the directional overcurrent stages (8 latest faults)  $I_{\phi>}$ ,  $I_{\phi>>}$ ,  $I_{\phi>>>}$ ,  $I_{\phi>>>>}$  (67)**

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
	1-2-N		Two phase fault with earth contact
	2-3-N		Two phase fault with earth contact
	3-1-N		Two phase fault with earth contact
	1-2-3-N		Three phase fault with earth contact
Flt		$xI_N$	Maximum fault current
Load		$xI_N$	1 s average phase currents before the fault
EDly		%	Elapsed time of the operate time setting. 100% = trip
Angle		°	Fault angle in degrees
U1		$xU_N$	Positive sequence voltage during fault
SetGrp	1, 2, 3, 4		Active setting group during fault
Direction mode			Dir, undir, dir+back-up

## 5.8 Current unbalance stage $I_2/I_1 >$ (46)

The purpose of the unbalance stage is to detect unbalanced load conditions, for example a broken conductor of a heavily loaded overhead line in case there is no earth fault. The operation of the unbalanced load function is based on the negative phase sequence component  $I_2$  related to the positive phase sequence component  $I_1$ . This is calculated from the phase currents using the method of symmetrical components. The function requires that the measuring inputs are connected correctly so that the rotation direction of the phase currents are as in Chapter 11.9 Connection examples. The unbalance protection has definite time operation characteristic.

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

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

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

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

**Table 5.11: Setting parameters of the current unbalanced stage  $I_2/I_1 >$  (46)**

Parameter	Value	Unit	Default	Description
$I_2/I_1 >$	2 – 70	%	20	Setting value, $I_2/I_1$
$t >$	1.0 – 600.0	s	10.0	Definite operate time
Type	DT INV	-	DT	The selection of time characteristics
S_On	Enabled; Disabled	-	Enabled	Start on event
S_Off	Enabled; Disabled	-	Enabled	Start off event
T_On	Enabled; Disabled	-	Enabled	Trip on event
T_Off	Enabled; Disabled	-	Enabled	Trip off event

For details of setting ranges, see Table 12.26

**Table 5.12: Measured and recorded values of the current unbalanced stage  $I_2/I_1 >$  (46)**

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

## 5.9 Undercurrent protection $I <$ (37)

The undercurrent unit measures the fundamental 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.

**Table 5.13: Parameters of the undercurrent stage I< (37)**

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Blocked			
	Start			F
	Trip			F
SCntr			Start counter (Start) reading	C
TCntr			Trip counter (Trip) reading	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	Dlx		Digital input	
	Vlx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
Force	Off		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
	On			
ILmin		A	Min. value of phase currents IL1, IL2, IL3 in primary value	
Status			Status of protection stage	
I<		A	Start detection current scaled to primary value, calculated by relay	
I<		% In	Setting value in percentage of In	
t<		s	Operate time delay [s]	
NoCmp		% In	Block limit	
NoCmp		60 A	Block limit scaled to primary value, calculated by relay	
Log			Start and trip time	
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		x In	Min. value of fault current as per times Imot	
Load		x In	1s mean value of pre-fault currents IL1—IL3	
Edly		%	Elapsed time as compared to the set operate time, 100% = tripping	

For details of setting ranges, see Table 12.25

## 5.10 Directional earth fault protection $I_{0\phi} >$ (67N)

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

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

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

### Polarization

The negative zero sequence voltage  $-U_0$  is used for polarization i.e. the angle reference for  $I_0$ . The  $-U_0$  voltage is measured via energizing input  $U_0$  or it is calculated from the phase voltages internally depending on the selected voltage measurement mode (see Chapter 7.7 Voltage measurement modes):

- 3LN/LL $\gamma$  and 3LN/LN $\gamma$ : the zero sequence voltage is calculated from the phase voltages and therefore any separate zero sequence voltage transformers are not needed. The setting values are relative to the configured voltage transformer (VT) voltage/ $\sqrt{3}$ .
- 3LN+ $U_0$ : the zero sequence voltage is measured with voltage transformer(s) for example using a broken delta connection. The setting values are relative to the VT $_0$  secondary voltage defined in configuration.

### Modes for different network types

The available modes are:



- ResCap
 

This mode consists of two sub modes, Res and Cap. A digital signal can be used to dynamically switch between these two sub modes. This feature can be used with compensated networks, when the Petersen coil is temporarily switched off.

  - Res
 

The stage is sensitive to the resistive component of the selected  $I_0$  signal. This mode is used with compensated **networks** (resonant grounding) and **networks earthed with a high resistance**. Compensation is usually done with a Petersen coil between the neutral point of the main transformer and earth. In this context "high resistance" means, that the fault current is limited to be less than the rated phase current. The trip area is a half plane as drawn in Figure 5.43. The base angle is usually set to zero degrees.
  - Cap
 

The stage is sensitive to the capacitive component of the selected  $I_0$  signal. This mode is used with **unearthed networks**. The trip area is a half plane as drawn in Figure 5.43. The base angle is usually set to zero degrees.
- Sector
 

This mode is used with **networks earthed with a small resistance**. In this context "small" means, that a fault current may be more than the rated phase currents. The trip area has a shape of a sector as drawn in Figure 5.44. The base angle is usually set to zero degrees or slightly on the lagging inductive side (i.e. negative angle).
- Udir
 

This mode makes the stage equal to the unidirectional stage  $I_{0>}$ . The phase angle and  $U_0$  amplitude setting are discarded. Only the amplitude of the selected  $I_0$  input is supervised.

### Input signal selection

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

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

### Intermittent earth fault detection

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

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

### Two independent stages

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

### Inverse operate time

Inverse delay means that the operate 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  $I_{0\phi}>$  and  $I_{0\phi}>>$ . The inverse delay types are described in Chapter 5.26 Inverse time operation. The device will show a scaleable graph of the configured delay on the local panel display.

### Inverse time limitation

The maximum measured secondary residual current is  $10 \times I_{0N}$  and maximum measured phase current is  $50 \times I_N$ . This limits the scope of inverse curves with high pick-up settings. See Chapter 5.26 Inverse time operation for more information.

### Setting groups

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

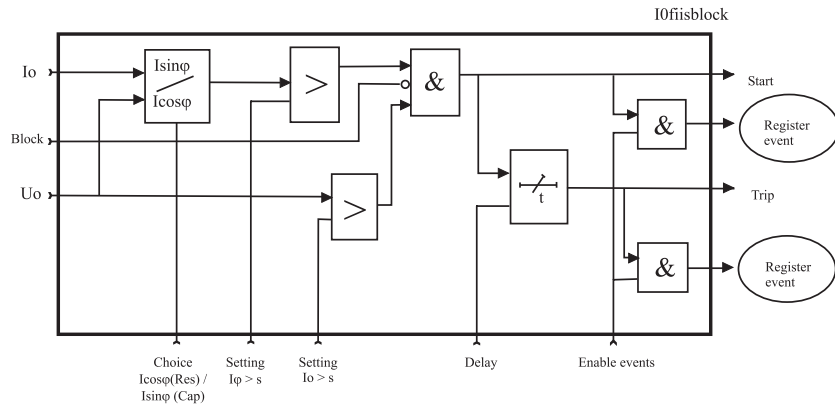


Figure 5.42: Block diagram of the directional earth fault stages  $I_{0\phi} >$ ,  $I_{0\phi} >>$

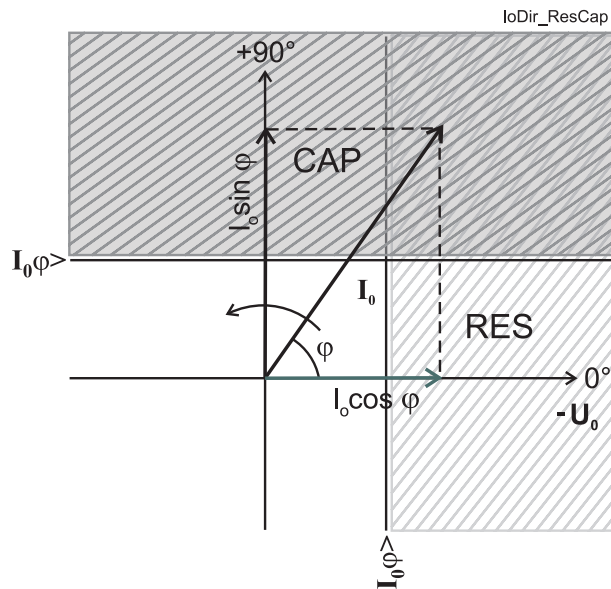


Figure 5.43: Operation characteristic of the directional earth fault protection in Res or Cap mode. Res mode can be used with compensated networks and Cap mode is used with ungrounded networks.

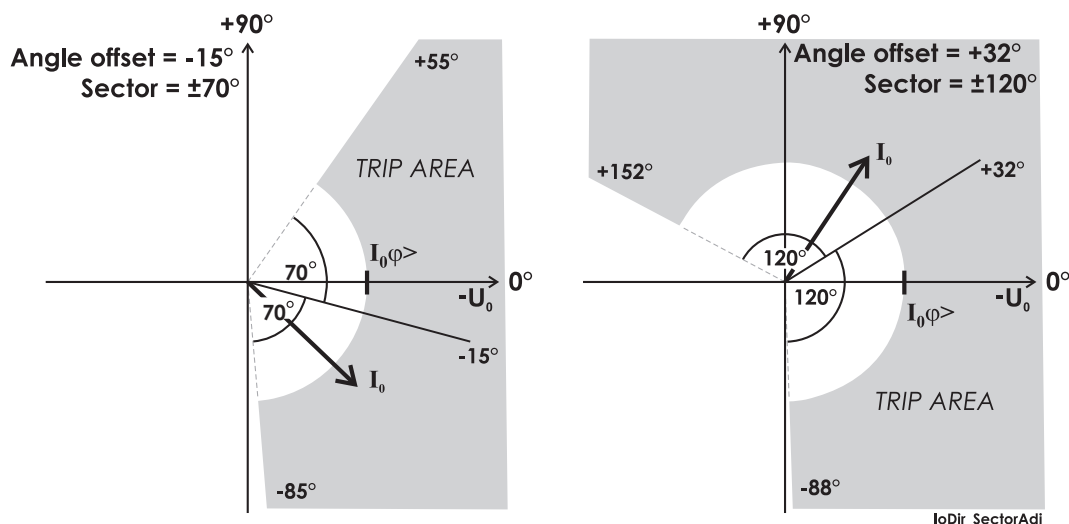


Figure 5.44: Two example of operation characteristics of the directional earth fault stages in sector mode. The drawn  $I_0$  phasor in both figures is inside the trip area. The angle offset and half sector size are user's parameters.

Table 5.14: Parameters of the directional earth fault stages  $I_{0\varphi>}$ ,  $I_{0\varphi>>}$  (67N)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	  F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI	- 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 IoCalc IoPeak		pu	The supervised value according the parameter "Input" below. ( $I_{0\varphi>}$ only)	
IoRes		pu	Resistive part of $I_0$ (only when "InUse"=Res)	
IoCap		pu	Capacitive part of $I_0$ (only when "InUse"=Cap)	
Io $\varphi>$		A	Pick-up value scaled to primary value	
Io $\varphi>$		pu	Pick-up setting relative to the parameter "Input" and the corresponding CT value	Set

Parameter	Value	Unit	Description	Note
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. Chapter 5.26 Inverse time operation.	Set
Type	DT NI, VI, EI, LTI, Parameters		Delay type. Definite time Inverse time. Chapter 5.26 Inverse time operation.	Set
t>		s	Definite operate time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Mode	ResCap Sector Undir		High impedance earthed nets Low impedance earthed nets Undirectional mode	Set
Offset		°	Angle offset (MTA) for ResCap and Sector modes	Set
Sector	Default = 88	±°	Half sector size of the trip area on both sides of the offset angle	Set
ChCtrl			Res/Cap control in mode ResCap	Set
	Res		Fixed to Resistive characteristic	
	Cap		Fixed to Capacitive characteristic	
	Dlx		Controlled by digital input	
	Vlx		Controlled by virtual input	
InUse			Selected submode in mode ResCap.	
	-		Mode is not ResCap	
	Res		Submode = resistive	
	Cap		Submode = capacitive	
Input	Io IoCalc IoPeak		X1:7 – 8. See Chapter 11 Connections. IL1 + IL2 + IL3 X1:7 – 8 peak mode ( $I_{0\phi}>$ only)	Set
Intrmt		s	Intermittent time	Set
Dly20x		s	Delay at $20xI_{0N}$	
Dly4x		s	Delay at $4xI_{0N}$	
Dly2x		s	Delay at $2xI_{0N}$	
Dly1x		s	Delay at $1xI_{0N}$	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See Chapter 5.26 Inverse time operation.	Set

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

For details of setting ranges, see Table 12.34

### Recorded values of the latest eight faults

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

**Table 5.15: Recorded values of the directional earth fault stages (8 latest faults)  $I_{0\phi} >$ ,  $I_{0\phi} >>$  (67N)**

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

# 5.11 Earth fault protection $I_0 >$ (50N/51N)

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

The unidirectional 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 operate time delay setting, a trip signal is issued.

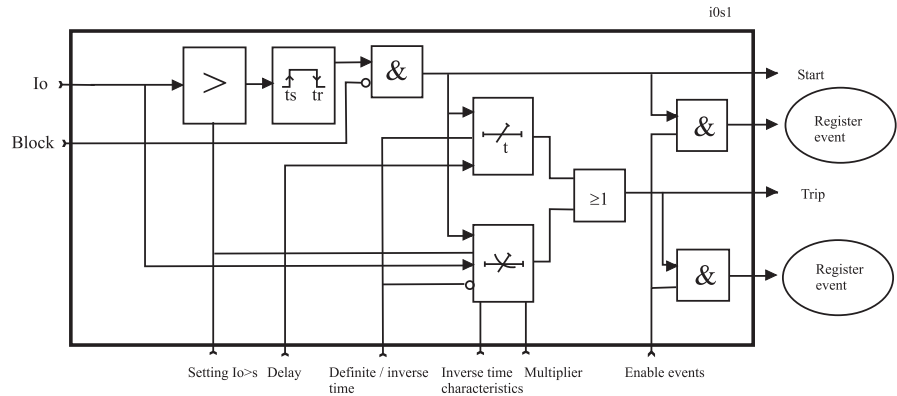


Figure 5.45: Block diagram of the earth fault stage  $I_0 >$

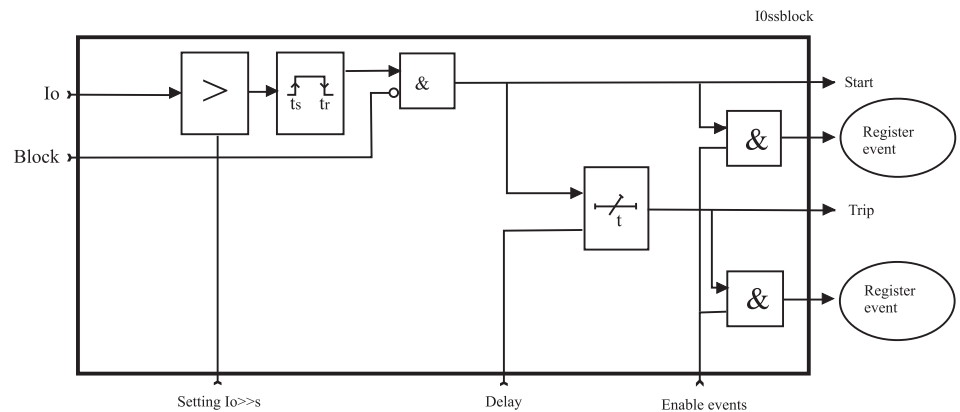


Figure 5.46: Block diagram of the earth fault stages  $I_0 >>$ ,  $I_0 >>>$ ,  $I_0 >>>>$

Figure 5.45 shows a functional block diagram of the  $I_0 >$  earth overcurrent stage with definite time and inverse time operate time. Figure 5.46 shows a functional block diagram of the  $I_0 >>$ ,  $I_0 >>>$  and  $I_0 >>>>$  earth fault stages with definite time operation delay.

### Input signal selection

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

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

### Intermittent earth fault detection

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

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

### Four or six independent unidirectional earth fault overcurrent stages

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

Using the directional earth fault stages (Chapter 5.10 Directional earth fault protection  $I_{0\phi} >$  (67N)) in unidirectional mode, two more stages with inverse operate time delay are available for unidirectional earth fault protection.

### Inverse operate time ( $I_0 >$ stage only)

Inverse delay means that the operate time depends on the amount the measured current exceeds the pick-up setting. The bigger the fault current is the faster will be the operation. Accomplished inverse delays are available for the  $I_0 >$  stage. The inverse delay types are described in Chapter 5.26 Inverse time operation. The device will show a scaleable graph of the configured delay on the local panel display.

### Inverse time limitation

The maximum measured secondary residual current is  $10 \times I_{0N}$  and maximum measured phase current is  $50 \times I_N$ . This limits the scope of inverse curves with high pick-up settings. See Chapter 5.26 Inverse time operation for more information.



### Setting groups

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

**Table 5.16: Parameters of the unidirectional 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, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	Dlx		Digital input	
	Vlx		Virtual input	
	LEDx		LED indicator signal	
Force	Off		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
	On			
Io, IoCalc, IoPeak		pu	The supervised value according the parameter "Input" below.	
Io>		A	Pick-up value scaled to primary value	
Io>		pu	Pick-up setting relative to the parameter "Input" and the corresponding CT value	Set
Curve	DT		Delay curve family: Definite time	Set
	IEC, IEEE, IEEE2, RI, PrgN		Inverse time. Chapter 5.26 Inverse time operation.	
Type	DT		Delay type. Definite time	Set
	NI, VI, EI, LTI, Parameters		Inverse time. Chapter 5.26 Inverse time operation.	
t>		s	Definite operate time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Input	Io		X1:7 – 8. See Chapter 11 Connections.	Set
	IoCalc		IL1 + IL2 + IL3	
	IoPeak		X1:7 – 8 peak mode ( $I_{0\phi>}$ only)	
Intrmt		s	Intermittent time	Set
Dly20x		s	Delay at 20 x $I_{0N}$	

Parameter	Value	Unit	Description	Note
Dly4x		s	Delay at $4 \times I_{0N}$	
Dly2x		s	Delay at $2 \times I_{0N}$	
Dly1x			Delay at $1 \times I_{0N}$	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See Chapter 5.26 Inverse time operation.	Set

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

For details of setting ranges, see Table 12.27

**Table 5.17: Parameters of the unidirectional earth fault stage  $I_0 >>$ ,  $I_0 >>>$ ,  $I_0 >>>>$  (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, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	Dix		Digital input	
	Vix		Virtual input	
	LEDx		LED indicator signal	
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
		pu	The supervised value according the parameter "Input" below.	
$I_0 >>$ , $I_0 >>>$ , $I_0 >>>>$		A	Pick-up value scaled to primary value	
$I_0 >>$ , $I_0 >>>$ , $I_0 >>>>$		pu	Pick-up setting relative to the parameter "Input" and the corresponding CT value	Set
$t >$		s	Definite operate time (for definite time only)	Set
Input	$I_0$		X1:7 – 8. See Chapter 11 Connections.	Set
	$I_0 \text{Calc}$		IL1 + IL2 + IL3	

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

For details of setting ranges, see Table 12.28

### Recorded values of the latest eight faults

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

**Table 5.18: Recorded values of the unidirectional earth fault stages (8 latest faults)  $I_0>>$ ,  $I_0>>>$ ,  $I_0>>>>$  (50N/51N)**

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

## 5.11.1 Earth fault faulty phase detection algorithm

### Phase recognition:

A zero sequence overcurrent has been detected.

Faulted phase/ phases are detected in 2 stage system.

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

### Ideal grounded network:

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

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

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

### Implementation:

When faulty phase is recognized, it will be recorded in 50N protection fault log (also in event list and alarm screen). This faulted phase and direction recording function has a tick box for enabling/disabling in protection stage settings. For compensated network, this is not a 100% reliable algorithm because it depends on the network compensation degree. So for compensated networks this feature can be turned off so it will not cause confusion. For high impedance

earthed networks, there will be drop down menu in both setting groups to choose between RES/CAP. RES is default and it is for earthed networks. When CAP is chosen, the  $I_0$  angle will be corrected to inductive direction 90 degrees and after that faulty phase detection is made.

Possible outcomes and conditions for those detections:

- FWD L1  
Phase L1 increases above the set limit and two other phases remain inside the set (delta) limit.  $I_0$  current angle is +/- 60 degrees from L1 phase angle.
- FWD L2  
Phase L2 increases above the set limit and two other phases remain inside the set (delta) limit.  $I_0$  current angle is +/- 60 degrees from L2 phase angle.
- FWD L3  
Phase L3 increases above the set limit and two other phases remain inside the set (delta) limit.  $I_0$  current angle is +/- 60 degrees from L3 phase angle.
- FWD L1-L2  
Phase L1 and L2 increase above the set limit and phase L3 remains inside the set (delta) limit.  $I_0$  current angle is between L1 and L2 phase angles.
- FWD L2-L3  
Phase L2 and L3 increase above the set limit and phase L1 remains inside the set (delta) limit.  $I_0$  current angle is between L2 and L3 phase angles.
- FWD L3-L1  
Phase L3 and L1 increase above the set limit and phase L2 remains inside the set (delta) limit.  $I_0$  current angle is between L3 and L3 phase angles.
- FWD L1-L2-L3  
All three phase currents increase above the set delta limit.
- REV 1 (any one phase)  
One phase decreases below the set delta limit and other two phases remain inside the delta limit.
- REV 2 (any two phase)  
Two phases decrease below the set delta limit and third phase remains inside the delta limit.
- REV 3 (all three phases)  
All three phase currents decrease below the set delta limit.

Below are simulated different fault scenarios:

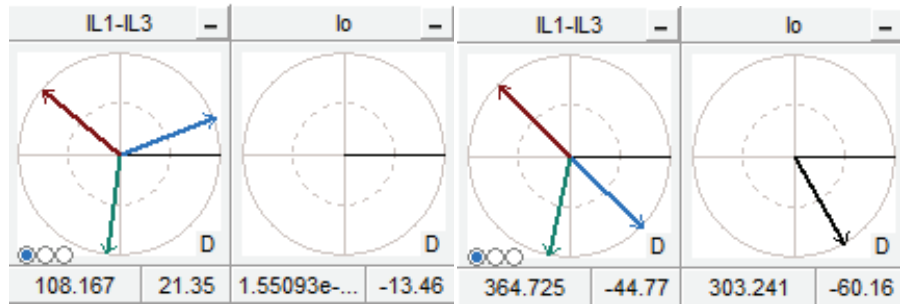


Figure 5.47: Phase L1 forward

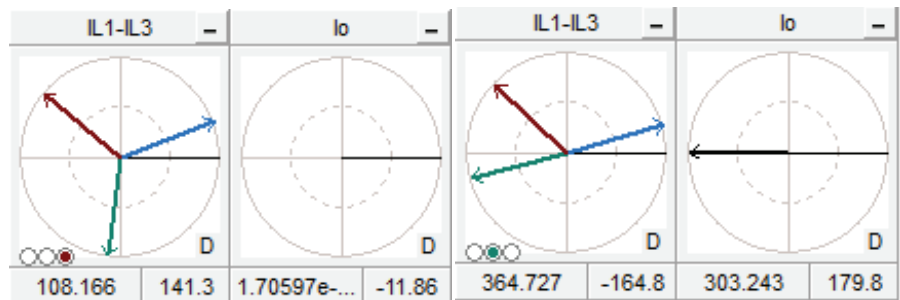


Figure 5.48: Phase L2 forward

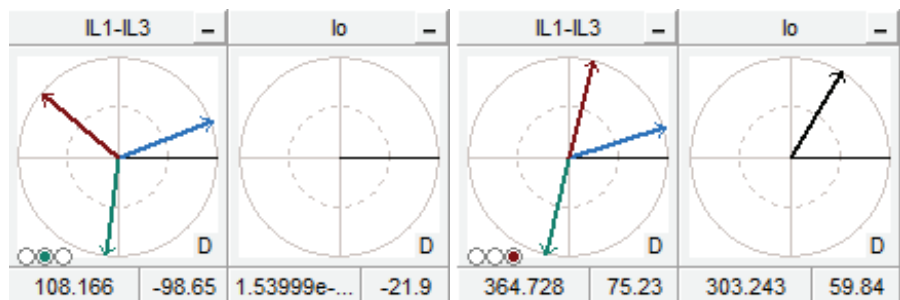


Figure 5.49: Phase L3 forward

## 5.12 Zero sequence voltage protection $U_0 >$ (59N)

The zero sequence voltage protection is used as unselective backup for earth faults.

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

Whenever the measured value exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued.

If the fault situation remains on longer than the user's operate time delay setting, a trip signal is issued.

### Measuring the zero sequence voltage

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

- When the voltage measurement mode is 3LN: the zero sequence voltage is calculated from the phase voltages and therefore a separate zero sequence voltage transformer is not needed. The setting values are relative to the configured voltage transformer (VT) voltage/ $\sqrt{3}$ .
- When the voltage measurement mode contains "+ $U_0$ ": 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.

### Two independent stages

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

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

### Setting groups

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

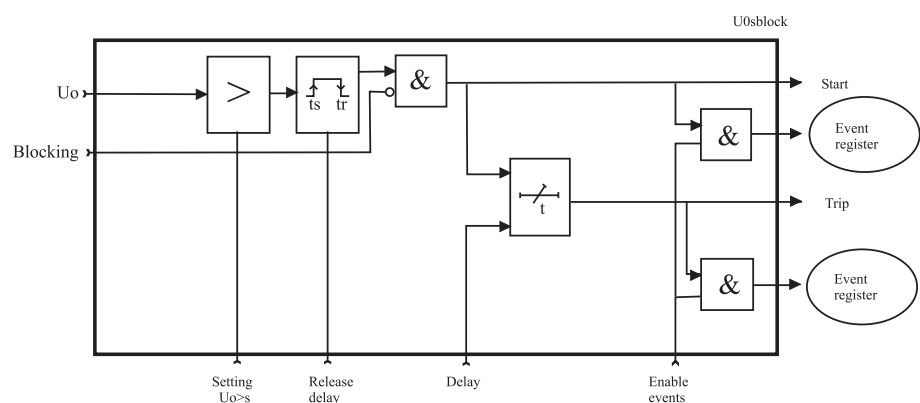


Figure 5.50: Block diagram of the zero sequence voltage stages  $U_0>$ ,  $U_0>>$

**Table 5.19: Parameters of the residual overvoltage stages  $U_0>$ ,  $U_0>>$** 

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	  F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	Dlx		Digital input	
	Vlx		Virtual input	
	LEDx		LED indicator signal	
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
$U_0$		%	The supervised value relative to $U_n / \sqrt{3}$	
$U_0>$ , $U_0>>$		%	Pick-up value relative to $U_n / \sqrt{3}$	Set
$t>$ , $t>>$		s	Definite operate time	Set

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

For details of setting ranges, see Table 12.42, Table 12.43.

### Recorded values of the latest eight faults

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

**Table 5.20: Recorded values of the residual overvoltage stages  $U_0>$ ,  $U_0>>$** 

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

## 5.13 Thermal overload protection T> (49)

The thermal overload function protects cables against excessive heating.

### Thermal model

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

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

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

$$\text{Trip: } a = k \cdot k_{\Theta} \cdot I_N$$

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

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

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

T = operate time

$\tau$  = Thermal time constant tau (Setting value)

ln = Natural logarithm function

I = Measured rms phase current (the max. value of three phase currents)

I<sub>p</sub> = 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 $\Theta$  = Ambient temperature factor (Permitted current due to t<sub>amb</sub>).

I<sub>N</sub> = The rated current

C <sub>$\tau$</sub>  = Relay cooling time constant (Setting value)



### 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  $\Theta_{TRIP}$  i.e. the heat capacitance of the cable.  $I_{MAX}$  depends of the given service factor  $k$  and ambient temperature  $\Theta_{AMB}$  and settings  $I_{MAX40}$  and  $I_{MAX70}$  according the following equation.

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

The value of ambient temperature compensation factor  $k_{\Theta}$  depends on the ambient temperature  $\Theta_{AMB}$  and settings  $I_{MAX40}$  and  $I_{MAX70}$ . See Figure 5.51. Ambient temperature is not in use when  $k_{\Theta} = 1$ . This is true when

- $I_{MAX40}$  is 1.0
- $S_{amb}$  is "n/a" (no ambient temperature sensor)
- $T_{AMB}$  is +40 °C.

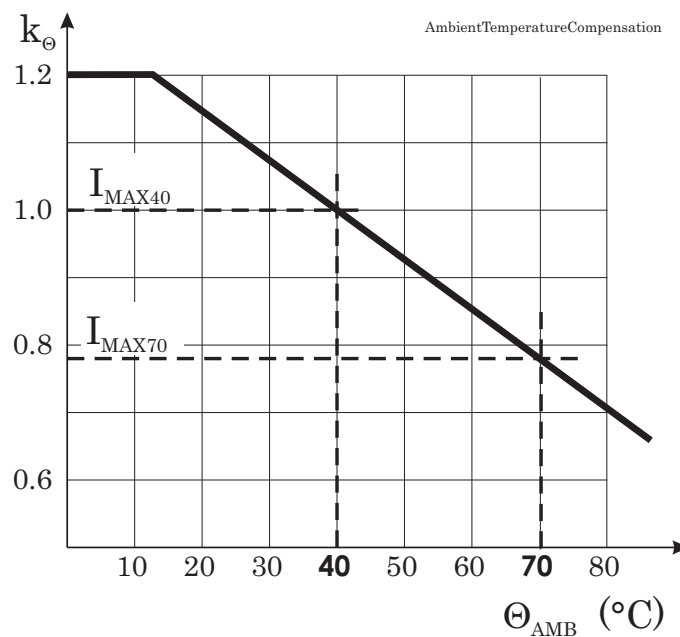


Figure 5.51: Ambient temperature correction of the overload stage T>.

### Example of a behaviour of the thermal model

Figure 5.51 shows an example of the thermal model behaviour. In this example  $\tau = 30$  minutes,  $k = 1.06$  and  $k\Theta = 1$  and the current has been zero for a long time and thus the initial temperature rise is 0 %. At time = 50 minutes the current changes to  $0.85 \times xI_N$  and the temperature rise starts to approach value  $(0.85/1.06)^2 = 64$  % according the time constant. At time = 300 min, the temperature is about stable, and the current increases to 5 % over the maximum defined by the rated current and the service factor  $k$ . The temperature rise starts to approach value 110 %. At about 340 minutes the temperature rise is 100 % and a trip follows.

### Initial temperature rise after restart

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

### Alarm function

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

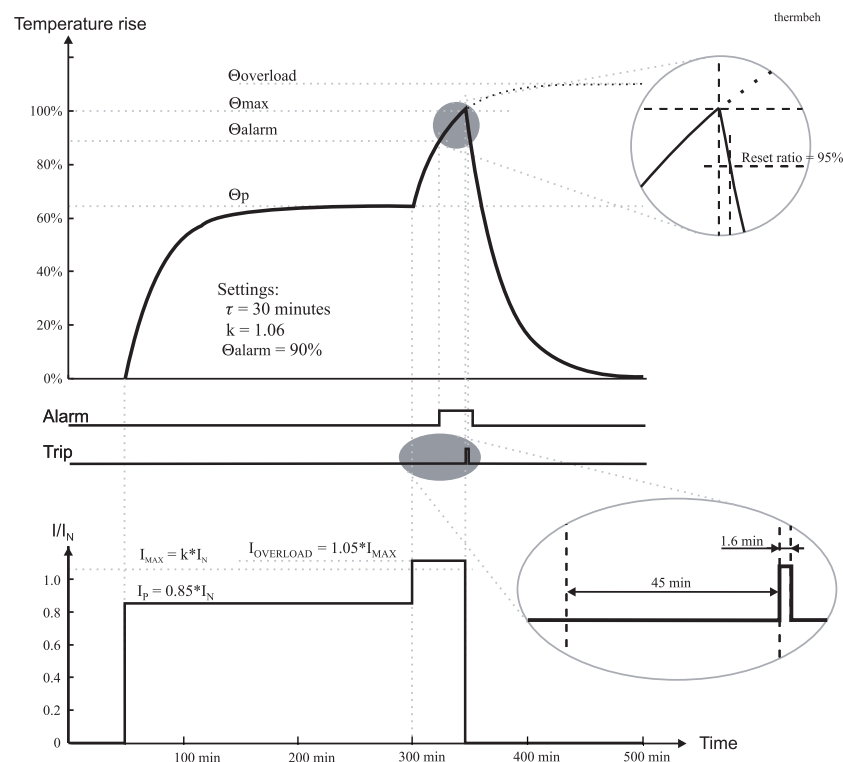


Figure 5.52: Example of the thermal model behaviour.

Table 5.21: Parameters of the thermal overload stage T&gt; (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.	
I <sub>max</sub>		A	$k \cdot I_N$ . Current corresponding to the 100 % temperature rise.	
k>		$xI_N$	Allowed overload (service factor)	Set
Alarm		%	Alarm level	Set
tau		min	Thermal time constant	Set
ctau		xtau	Coefficient for cooling time constant. Default = 1.0	Set
kTamb		$xI_N$	Ambient temperature corrected max. allowed continuous current	
I <sub>max40</sub>		$\%I_N$	Allowed load at Tamb +40 °C. Default = 100 %.	Set
I <sub>max70</sub>		$\%I_N$	Allowed load at Tamb +70 °C.	Set
Tamb		°C	Ambient temperature. Editable Samb=n/a. Default = +40 °C	Set
Samb			Sensor for ambient temperature	Set
	n/a		No sensor in use for Tamb	
	ExtAI1 – 16		External Analogue input 1 – 16	

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

For details of setting ranges, see Table 12.24

## 5.14 Intermittent transient earth fault protection $I_{0INT} > (67NI)$

**NOTE:** This function is available only in 3LN +  $U_0$  mode (see Chapter 7.7 Voltage measurement modes).

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 5.53).

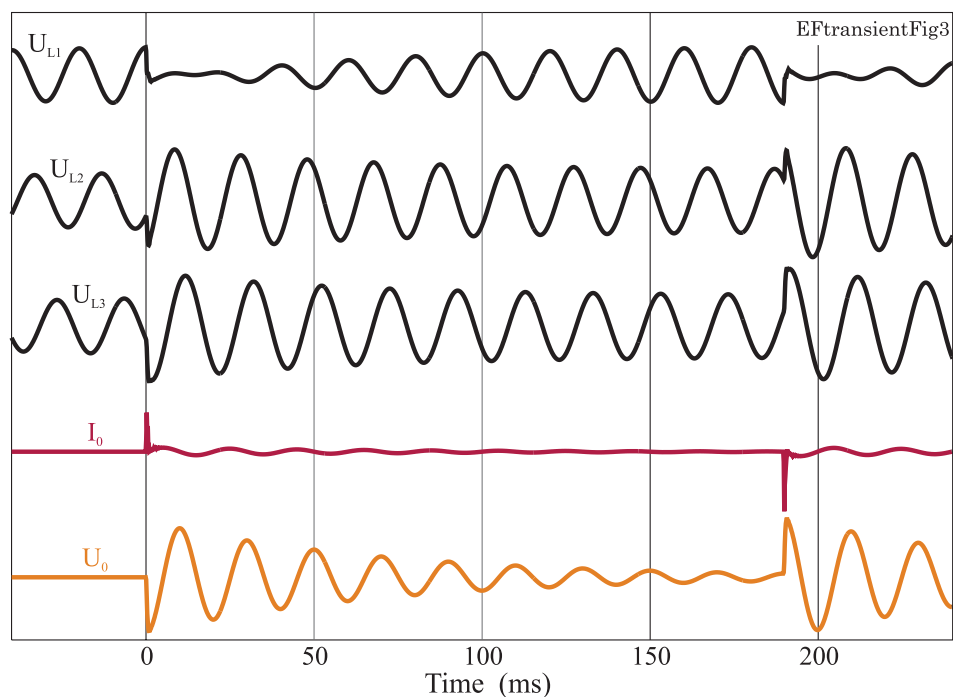


Figure 5.53: Typical phase to earth voltages, residual current of the faulty feeder and the zero sequence voltage  $U_0$  during two transient earth faults in phase L1. In this case the network is compensated.

### 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  $\mu$ s 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  $I_{0INT}>$  doesn't operate fast enough. The actual operate time of the  $I_{0INT}>$  stage is very dependent on the behaviour of the fault and the intermittent time setting. To make the co-ordination between  $U_0>$  and  $I_{0INT}>$  more simple, the start signal of the transient stage  $I_{0INT}>$  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  $I_{0INT}>$  should always be used together with the normal directional earth fault protection stages  $I_{0\phi}>$ ,  $I_{0\phi}>>$ . The transient stage  $I_{0INT}>$  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  $I_{0INT}>$  to trip.

The operate time of the transient stage  $I_{0INT}>$  should be lower than the settings of any directional earth fault stage to avoid any unnecessary trip from the  $I_{0\phi}>$ ,  $I_{0\phi}>>$  stages. The start signal of the  $I_{0INT}>$  stage can be also used to block  $I_{0\phi}>$ ,  $I_{0\phi}>>$  stages of all parallel feeders.

### Auto reclosing

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

Usually the  $I_{0INT}>$  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.

### Operate time, peak amount counter and intermittent time co-ordination

Algorithm has three independently settable parameters: operation delay, required amount of peaks and intermittent time. All requirements need to be satisfied before stage issues trip signal. There is also a settable reset delay: to ensure that stage does not release before circuit breaker has operated. The setting range for the required amount of peaks is 1–20 and the setting range for the operational delay is 0.02–300 s. The reset delay setting range is 0.06–300 s. The intermittent time setting is 0.01–300 s. If in example setting for peaks is set to 2 and setting for operation delay is set to 160ms and intermittent time is set to 200ms then function starts calculating operation delay from first peak and after second peak in 80ms peak amount criteria is satisfied and when 160ms comes full operate time criteria is satisfied and the stage issues trip (Figure 5.54). If second peak does not come before operational delay comes full the stage is released after intermittent time has come full. But if the second peak comes after operate time has come full but still inside intermittent time then trip is issued instantly (Figure 5.55). If intermittent time comes full before operation delay comes full the stage is released (Figure 5.56). There is a of couple limitations to avoid completely incorrect settings. Algorithm assumes that peaks can't come more often than 10ms so if peak amount is set to 10 then operation delay will not accept smaller value than 100ms and also if operational delay is set to 40ms then it's not possible to set higher peak amount setting than 4. This is not fail proof but prohibits usage of that kind of settings that can never be satisfied.

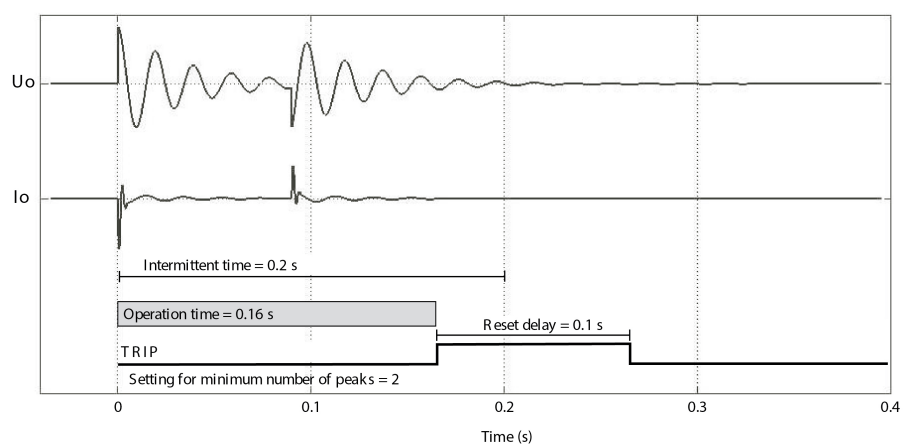


Figure 5.54: Set peak amount is satisfied and operate time comes full inside intermittent time setting. Stage issues a trip.

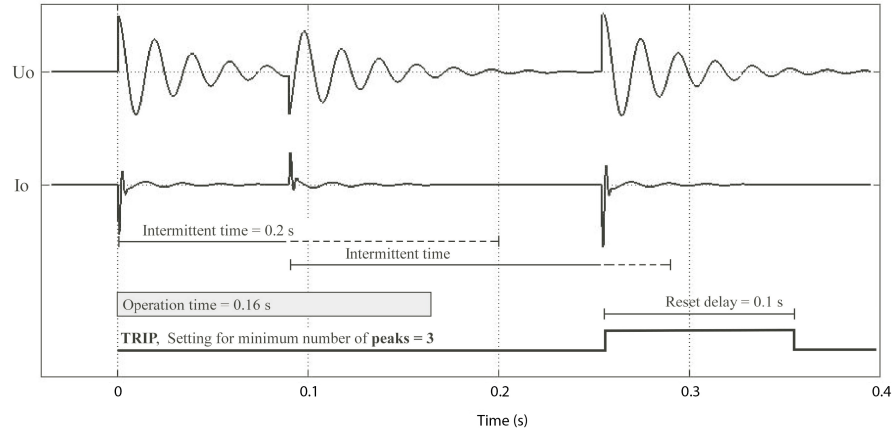


Figure 5.55: Peak amount is not satisfied when operation delay comes full but last required peak comes during intermittent time. Stage issues instant trip when peak amount comes satisfied.

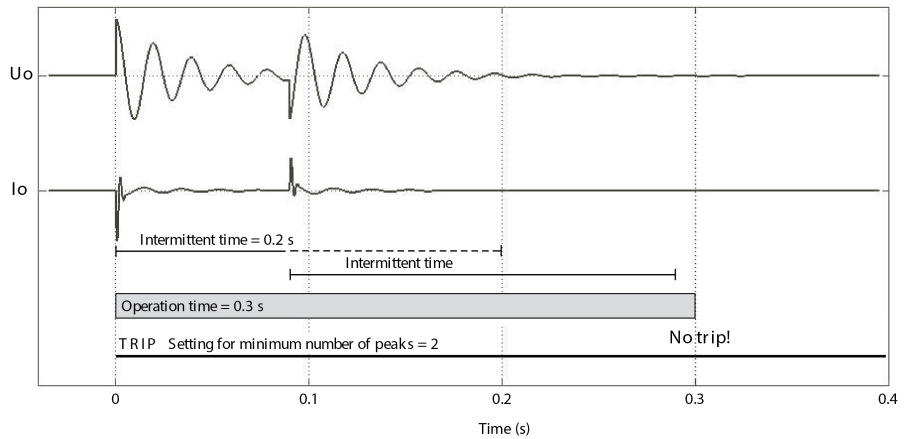


Figure 5.56: Peak amount is satisfied but intermittent time comes full before operate time comes full. Stage is released.

### Setting groups

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

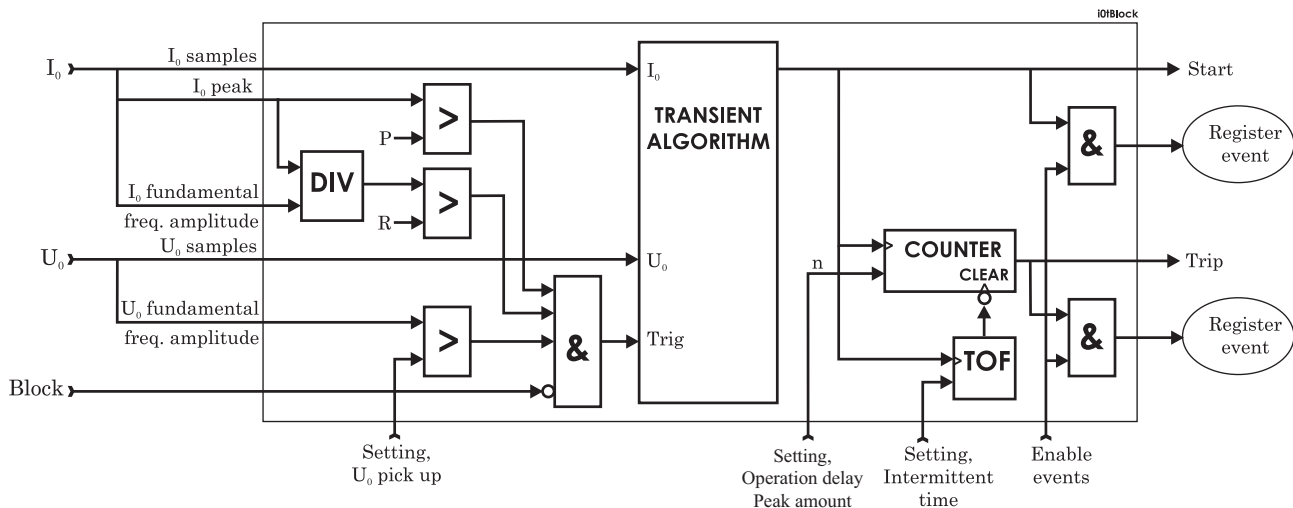


Figure 5.57: Block diagram of the directional intermittent transient earth fault stage  $I_{0INT}>$ .

Table 5.22: Parameters of the directional intermittent transient earth fault stage  $I_{0INT}>$  (67NI)

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, 2, 3, 4		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
Io input	IoPeak		$I_0$ Connectors X:1-7, 8, 9	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
Io peak		pu	The detected $I_0$ value according the parameter "Input" below.	
Uo		%	The measured $U_0$ value. $U_{0N} = 100\%$	
Direction mode	Forward Reverse		Setting between direction towards line or bus	Set
Uo>		%	$U_0$ pick up level. $U_{0N} = 100\%$	Set
t>	0.04 – 300	s	Operation delay setting	Set



Parameter	Value	Unit	Description	Note
Min. peaks	1 – 20		Minimum number of peaks required	Set
Reset	0.06 – 300	s	Reset delay setting	Set
Intrmt		s	Intermittent time. When the next fault occurs within this time, the delay counting continues from the previous value.	Set

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

For details of setting ranges, see Table 12.35

### 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.

**Table 5.23: Recorded values of the directional intermittent transient earth fault stage (8 latest faults)  $I_{OINT>}$  (67NI)**

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 operate time setting. 100% = trip
Uo		%	Max. $U_0$ voltage during the fault
SetGrp	1, 2, 3, 4		Active setting group during fault
FWD peaks		pcs	Amount of detected peaks to forward direction
REV peaks		pcs	Amount of detected peaks to reverse direction

## 5.15 Overvoltage protection U> (59)

The overvoltage function measures the fundamental frequency component of the line-to-line voltages regardless of the voltage measurement mode (Chapter 7.7 Voltage measurement modes). By using line-to-line voltages any phase-to-ground over-voltages during earth faults have no effect. (The earth fault protection functions will take care of earth faults.) Whenever any of these three line-to-line voltages 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 operate time delay setting, a trip signal is issued.

In rigidly earthed 4-wire networks with loads between phase and neutral overvoltage protection may be needed for phase-to-ground voltages, too. In such applications the programmable stages can be used. Chapter 5.24 Programmable stages (99)

### Three independent stages

There are three separately adjustable stages: U>, U>> and U>>>. All the stages can be configured for definite time (DT) operation characteristic.

### Configurable release delay

The U> stage has a settable release delay, which enables detecting intermittent faults. This means that the time counter of the protection function does not reset immediately after the fault is cleared, but resets after the release delay has elapsed. If the fault appears again before the release delay time has elapsed, the delay counter continues from the previous value. This means that the function will eventually trip if faults are occurring often enough.

### Configurable hysteresis

The dead band is 3 % by default. It means that an overvoltage fault is regarded as a fault until the voltage drops below 97 % of the pick up setting. In a sensitive alarm application a smaller hysteresis is needed. For example if the pick up setting is about only 2 % above the normal voltage level, hysteresis must be less than 2 %. Otherwise the stage will not release after fault.

### Setting groups

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

Figure 5.58 shows the functional block diagram of the overvoltage function stages U>, U>> and U>>>.

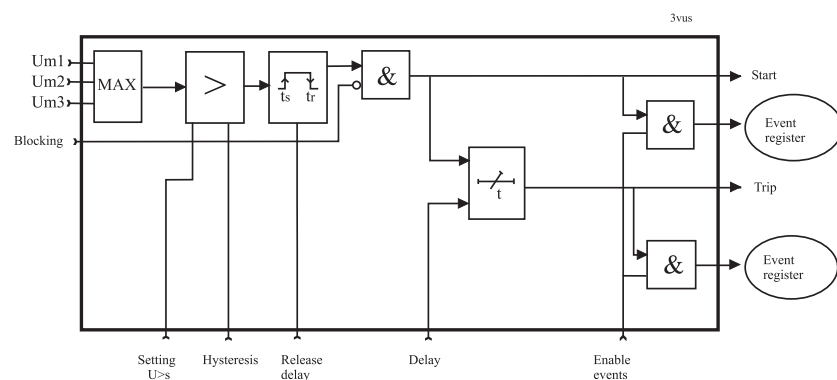


Figure 5.58: Block diagram of the three-phase overvoltage stages U>, U>> and U>>>

**Table 5.24: Parameters of the overvoltage stages U>, U>>, U>>>**

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	  F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	Dlx		Digital input	
	Vlx		Virtual input	
	LEDx		LED indicator signal	
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
		V	The supervised value. Max. of U12, U23 and U31	
U>, U>>, U>>>		V	Pick-up value scaled to primary value	
U>, U>>, U>>>		% Un	Pick-up setting relative to U <sub>N</sub>	Set
t>, t>>, t>>>		s	Definite operate time	Set
RlsDly		s	Release delay (U> stage only)	Set
Hyster	3 (default)	%	Dead band size i.e. hysteresis	Set

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

For details of setting ranges, see Table 12.36, Table 12.37, Table 12.38.

### Recorded values of the latest eight faults

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

**Table 5.25: Recorded values of the overvoltage stages (8 latest faults) U>, U>>, U>>>**

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

## 5.16 Undervoltage protection U< (27)

This is a basic undervoltage protection. The function measures the three line-to-line voltages and whenever the smallest of them drops below 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 operate time delay setting, a trip signal is issued.

### Blocking during VT fuse failure

As all the protection stages the undervoltage function can be blocked with any internal or external signal using the block matrix. For example if the secondary voltage of one of the measuring transformers disappears because of a fuse failure (See VT supervision function in Chapter 6.7 Voltage transformer supervision). The blocking signal can also be a signal from the user's logic (see Chapter 8.8 Logic functions).

### Self blocking at very low voltage

The stages can be blocked with a separate low limit setting. With this setting, the particular stage will be blocked, when the biggest of the three line-to-line voltages drops below the given limit. The idea is to avoid purposeless tripping, when voltage is switched off. If the operate time is less than 0.08 s, the blocking level setting should not be less than 15 % to the blocking action to be enough fast. The self blocking can be disabled by setting the low voltage block limit equal to zero.

Figure 5.59 shows an example of low voltage self blocking.

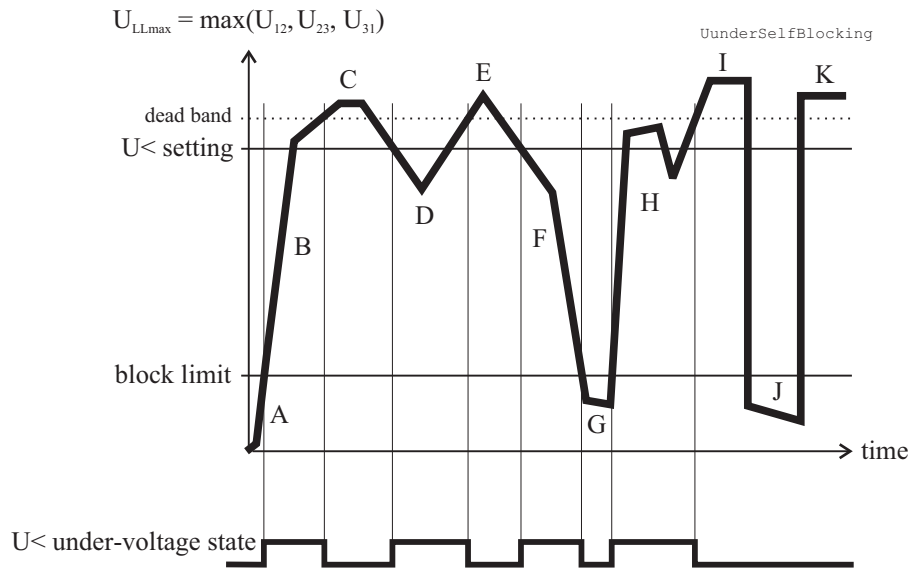


Figure 5.59: Under voltage state and block limit.

- |   |   |
|---|---|
| <p>A The maximum of the three line-to-line voltages <math>U_{LLmax}</math> is below the block limit. This is not regarded as an under voltage situation.</p> <p>B The voltage <math>U_{LLmin}</math> is above the block limit but below the pick-up level. This is an undervoltage situation.</p> <p>C Voltage is OK, because it is above the pick-up limit.</p> <p>D This is an under voltage situation.</p> <p>E Voltage is OK.</p> | <p>F This is an under voltage situation.</p> <p>G The voltage <math>U_{LLmin}</math> is under block limit and this is not regarded as an under voltage situation.</p> <p>H This is an under voltage situation.</p> <p>I Voltage is OK.</p> <p>J Same as G</p> <p>K Voltage is OK.</p> |
|---|---|

### Three independent stages

There are three separately adjustable stages: U<, U<< and U<<<. All these stages can be configured for definite time (DT) operation characteristic.

### Setting groups

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

**Table 5.26: Parameters of the under voltage stages U<, U<<, U<<<**

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Blocked			
	Start			F
	Trip			F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	DIx		Digital input	
	VIx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
Force	Off		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
	On			
MinU		V	The supervised minimum of line-to-line voltages in primary volts	
U<, U<<, U<<<		V	Pick-up value scaled to primary value	
U<, U<<, U<<<		% Un	Pick-up setting	Set
t<, t<<, t<<<		S	Definite operate time	Set
LVBik		% Un	Low limit for self blocking	Set
RIsDly		S	Release delay (U< stage only)	Set
Hyster	Default 3.0 %	%	Dead band setting	Set

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

For details of setting ranges, see Table 12.39, Table 12.40, Table 12.41.

### Recorded values of the latest eight faults

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

**Table 5.27: Recorded values of the undervoltage stages (8 latest faults) U<, U<<, U<<<**

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		% Un	Minimum fault voltage
EDly		%	Elapsed time of the operate time setting. 100% = trip
PreFlt		% Un	Supervised value before fault, 1 s average value.
SetGrp	1, 2, 3, 4		Active setting group during fault

## 5.17 Directional power protection P< (32)

Directional 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. It can also be used to detect loss of load of a motor.

Directional power function is sensitive to active power. For reverse power function the pick-up value is negative. For underpower 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  $S_N$ . The nominal apparent power is determined by the configured voltage and current transformer values.

Equation 5.4:

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

There are two identical stages available with independent setting parameters.

**Table 5.28: Setting parameters of P< and P<< stages**

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

For details of setting ranges, see Table 12.47

**Table 5.29: Measured and recorded values of P< and P<< stages**

	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 operate time, 100% = tripping

## 5.18 Frequency Protection f><, f>><< (81)

Frequency protection is used for load sharing, loss of mains detection and as a backup protection for over-speeding.

The frequency function measures the frequency from the two first voltage inputs. At least one of these two inputs must have a voltage connected to be able to measure the frequency. Whenever the frequency crosses the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault remains on longer than the operate delay setting, a trip signal is issued. For situations, where no voltage is present an adapted frequency is used.

### Protection mode for f>< and f>><< stages

These two stages can be configured either for overfrequency or for underfrequency.

### Under voltage self blocking of underfrequency stages

The underfrequency stages are blocked when biggest of the three line-to-line voltages is below the low voltage block limit setting. With this common setting, LVBlk, all stages in underfrequency mode are blocked, when the voltage drops below the given limit. The idea is to avoid purposeless alarms, when the voltage is off.

### Initial self blocking of underfrequency stages

When the biggest of the three line-to-line voltages has been below the block limit, the under frequency stages will be blocked until the pick-up setting has been reached.

### Four independent frequency stages

There are four separately adjustable frequency stages: f><, f>><<, f<, f<<. The two first stages can be configured for either overfrequency or underfrequency usage. So totally four underfrequency stages can be in use simultaneously. Using the programmable stages even more can be implemented (chapter Chapter 5.24 Programmable stages (99)). All the stages have definite operate time delay (DT).

### Setting groups

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



**Table 5.30: Parameters of the over & underfrequency stages**

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	DIx		Digital input	
	VIx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
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
f		Hz	The supervised value.	
fX		Hz	Pick-up value	Set
fXX			Over/under stage f><. See row "Mode".	
f<			Over/under stage f>><<.	
f<<			Under stage f<	
f<<<			Under stage f<<	
tX		s	Definite operate time	Set
tXX			f>< stage	
t<			f>><< stage	
t<<			f< stage	
t<<<			f<< stage	
Mode	> <		Operation mode. (only for f>< and f>><<) Overfrequency mode Underfrequency mode	Set
LVbck		% Un	Low limit for self blocking. This is a common setting for all four stages.	Set

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

For details of setting ranges, see Table 12.44, Table 12.45.

### Recorded values of the latest eight faults

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

**Table 5.31: Recorded values of the over & under frequency stages (8 latest faults)  $f > <$ ,  $f >> <<$ ,  $f <$ ,  $f <<$**

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

## 5.19 Rate of change of frequency (ROCOF) (81R)

Rate of change of frequency (ROCOF or  $df/dt$ ) function is used for fast load shedding, to speed up operate time in over- and under-frequency situations and to detect loss of grid. For example a centralized dedicated load shedding relay can be omitted and replaced with distributed load shedding, if all outgoing feeders are equipped with VAMP devices.

A special application for ROCOF is to detect loss of grid (loss of mains, islanding). The more the remaining load differs from the load before the loss of grid, the better the ROCOF function detects the situation.

### Frequency behaviour during load switching

Load switching and fault situations may generate change in frequency. A load drop may increase the frequency and increasing load may decrease the frequency, at least for a while. The frequency may also oscillate after the initial change. After a while the control system of any local generator may drive the frequency back to the original value. However, in case of a heavy short circuit fault or in case the new load exceeds the generating capacity, the average frequency keeps on decreasing.

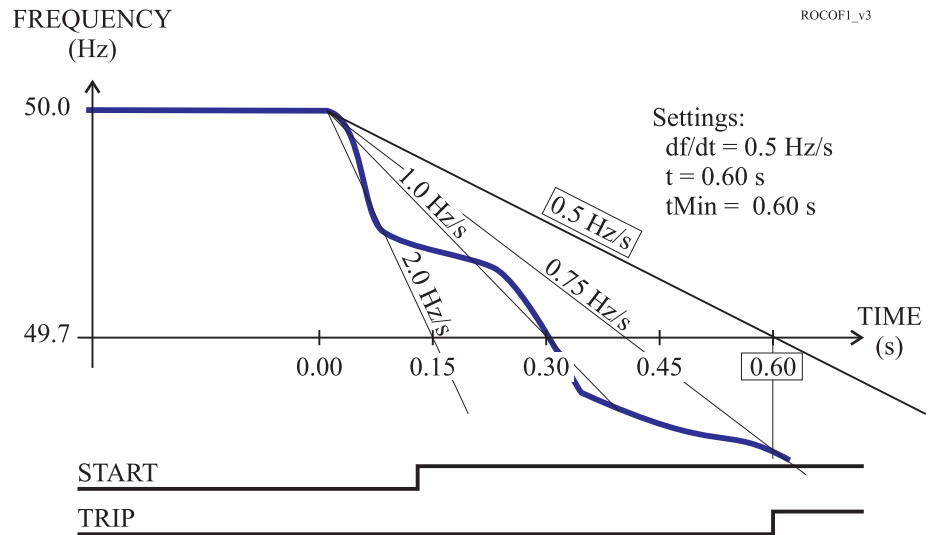


Figure 5.60: An example of definite time  $df/dt$  operate time. At 0.6 s, which is the delay setting, the average slope exceeds the setting 0.5 Hz/s and a trip signal is generated.

### Setting groups

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

### Description of ROCOF implementation

The ROCOF function is sensitive to the absolute average value of the time derivate of the measured frequency  $|df/dt|$ . Whenever the measured frequency slope  $|df/dt|$  exceeds the setting value for 80 ms time, the ROCOF stage picks up and issues a start signal after an additional 60 ms delay. If the average  $|df/dt|$ , since the pick-up moment, still exceeds the setting, when the operation delay time has elapsed, a trip signal is issued. In this definite time mode the second delay parameter "minimum delay,  $t_{MIN}$ " must be equal to the operation delay parameter "t".

If the frequency is stable for about 80 ms and the time t has already elapsed without a trip, the stage will release.

### ROCOF and frequency over and under stages

One difference between over-/under-frequency and  $df/dt$  function is the speed. In many cases a  $df/dt$  function can predict an overfrequency or underfrequency situation and is thus faster than a simple overfrequency or underfrequency function. However, in most cases a standard overfrequency and underfrequency stages must be used together with ROCOF to ensure tripping also in case the frequency drift is slower than the slope setting of ROCOF.

### Definite operate time characteristics

Figure 5.60 shows an example where the  $df/dt$  pick-up value is 0.5 Hz/s and the delay settings are  $t = 0.60$  s and  $t_{MIN} = 0.60$  s. Equal times  $t = t_{MIN}$  will give a definite time delay characteristics. Although the frequency slope fluctuates the stage will not release but continues to calculate the average slope since the initial pick-up. At the defined operate time,  $t = 0.6$  s, the average slope is 0.75 Hz/s. This exceeds the setting, and the stage will trip.

At slope settings less than 0.7 Hz/s the fastest possible operate time is limited according the Figure 5.61

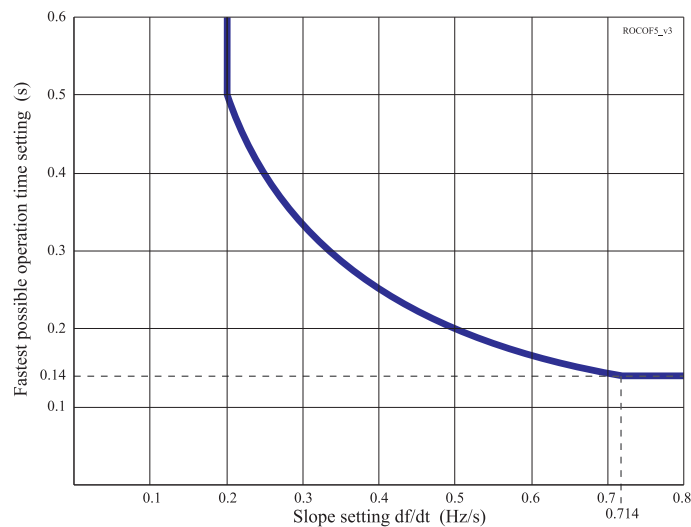


Figure 5.61: At very sensitive slope settings the fastest possible operate time is limited according the figure.

### Inverse operate time characteristics

By setting the second delay parameter  $t_{MIN}$  smaller than the operational delay  $t$ , an inverse type of operate time characteristics is achieved.

Figure 5.63 shows one example, where the frequency behaviour is the same as in the first figure, but the  $t_{MIN}$  setting is 0.15 s instead of being equal with  $t$ . The operate time depends of the measured average slope according the following equation.

$t_{TRIP}$  = Resulting operate time (seconds).

$s_{SET}$  =  $df/dt$  i.e. slope setting (hertz/seconds).

$t_{SET}$  = operate time setting  $t$  (seconds).

$s$  = Measured average frequency slope (hertz/seconds).

Equation 5.5:

$$t_{TRIP} = \frac{s_{SET} \cdot t_{SET}}{|s|}$$

The minimum operate time is always limited by the setting parameter  $t_{MIN}$ . In the example of the fastest operate time, 0.15 s, is achieved when the slope is 2 Hz/s or more. The leftmost curve in Figure 5.62

shows the inverse characteristics with the same settings as in Figure 5.63.

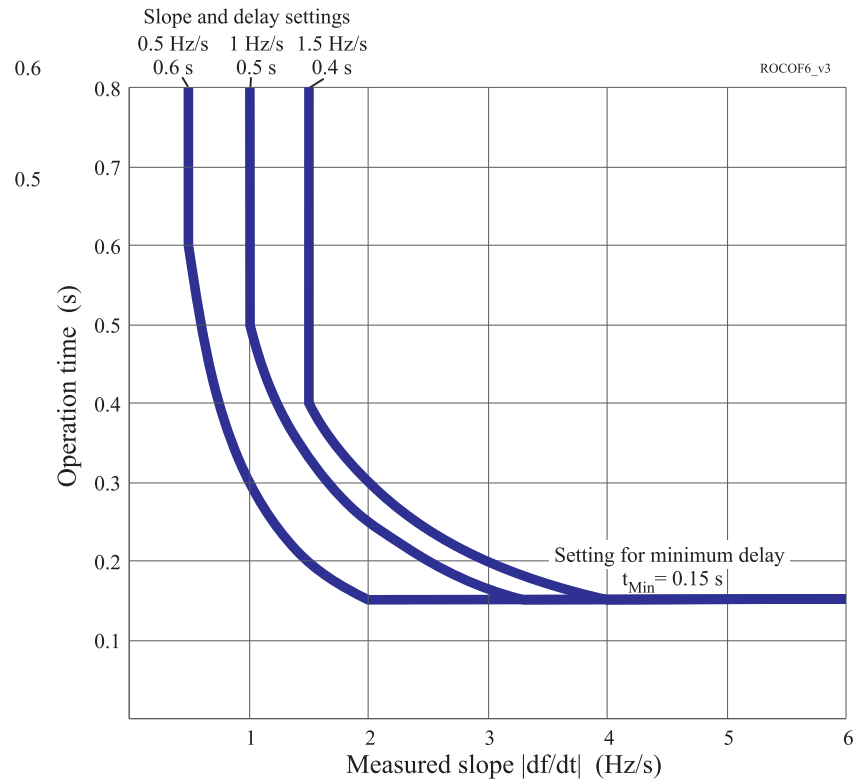


Figure 5.62: Three examples of possible inverse  $df/dt$  operate time characteristics. The slope and operation delay settings define the knee points on the left. A common setting for  $t_{Min}$  has been used in these three examples. This minimum delay parameter defines the knee point positions on the right.

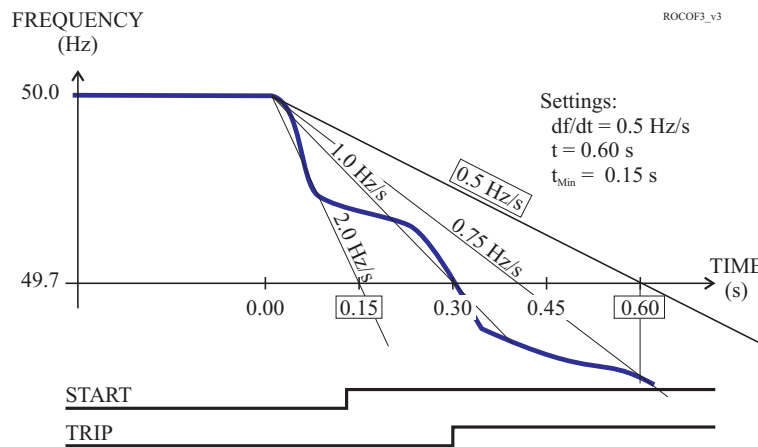


Figure 5.63: An example of inverse  $df/dt$  operate time. The time to trip will be 0.3 s, although the setting is 0.6 s, because the average slope 1 Hz/s is steeper than the setting value 0.5 Hz/s.

**Table 5.32: Setting parameters of df/dt stage**

Parameter	Value	Unit	Default	Description
df/dt	0.2 – 10.0	Hz/s	5.0	df/dt pick-up setting
t>	0.14 – 10.0	s	0.50	df/dt operational delay
tMin>	0.14 – 10.0	s	0.50	df/dt minimum 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

For details of setting ranges, see Table 12.46

**Table 5.33: Measured and recorded values of df/dt stage**

	Parameter	Value	Unit	Description
Measured value	f		Hz	Frequency
	df/dt		Hz/s	Frequency rate of change
Recorded values	SCntr		-	Start counter (Start) reading
	TCntr		-	Trip counter (Trip) reading
	Flt		%Hz/s	Max rate of change fault value
	EDly		%	Elapsed time as compared to the set operate time, 100% = tripping

## 5.20 Synchrocheck (25)

The device includes a function that will check synchronism when the circuit-breaker is closed. The function will monitor voltage amplitude, frequency and phase angle difference between two voltages, feeding side and reference. The reference voltage used for sychrochecking is either phase-to-phase voltage  $U_{12}$  or phase-to-ground voltage  $U_{L1}$ .

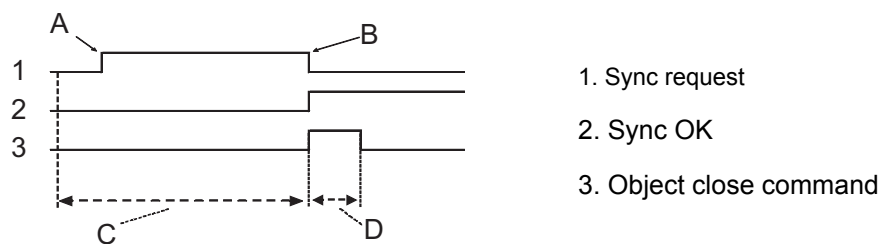
**Table 5.34: Setting parameters of synchrocheck stage SyC1 (25)**

Parameter	Values	Unit	Default	Description
Side	UL1/ULLy UL1/ULNy	-	U12/ULLy	Voltage selection. The used voltage reference is selected with voltage measurement mode from the Scaling menu.
CBObj	Obj1 – Obj6	-	Obj1	<b>NOTE!</b> The stage can be configured by using OBJ1-OBJ6. Two objects can be defined simultaneously.
SMode	Async; Sync; Off	-	Sync	Synchrocheck mode. <b>Off</b> = only voltage check <b>Async</b> = the function checks dU, df and dangle. Furthermore, the frequency slip, df, determines the remaining time for closing. This time must be longer than “CB time”. <b>Sync mode</b> = Synchronization is tried to make <b>exactly</b> when angle difference is zero. In this mode df-setting should be very small (<0.3Hz).
UMode	-, DD, DL, LD, DD/DL, DD/LD, DL/LD, DD/DL/LD	-	-	Voltage check mode: The first letter refers to the reference voltage and the second letter refers to the comparison voltage. <b>D</b> means that the side must be “dead” when closing (dead = The voltage below the dead voltage limit setting) <b>L</b> means that the side must be “live” when closing (live = The voltage higher than the live voltage limit setting) Example: DL mode for stage 1: The U12 side must be “dead” and the U12y side must be “live”.
CBtime	0.04 – 0.6	s	0.1	Typical closing time of the circuit-breaker.
Dibypass	Digital inputs	-	-	Bypass input. If the input is active, the function is bypassed.
Bypass	0; 1	-	0	The bypass status. “1” means that the function is bypassed. This parameter can also be used for manual bypass.
CBCtrl	Open;Close	-	-	Circuit-breaker control
ShowInfo	Off; On	-	On	Additional information display about the sychrocheck status to the mimic display.
SGrpDI	Digital inputs	-	-	The input for changing the setting group.
SetGrp	1, 2, 3, 4	-	1	The active setting group.

1) Please note that the labels (parameter names) change according to the voltage selection.

For details of setting ranges, see Table 12.48

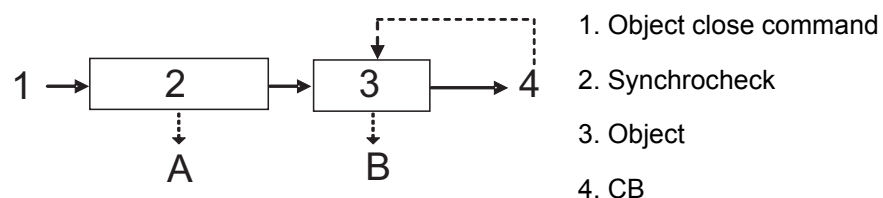
The following signals of the stage are available in the output matrix and the logic: “Request”, “OK” and “Fail”. The “request”-signal is active, when a request has received but the breaker is not yet closed. The “OK”-signal is active, when the synchronising conditions are met, or the voltage check criterion is met. The “fail”-signal is activated, if the function fails to close the breaker within the request timeout setting. See below the figure.



- A. Object close command given (minic or bus) actually make only sync request  
B. Request going down when "real" object close being requested  
C. Synchronizing time if timeout happens, Sync\_Fail signal activates Timeout defined in synchrocheck  
D. Normal object close operation

Figure 5.64: The principle of the synchrocheck function

Please note that the control pulse of the selected object should be long enough. For example, if the voltages are in opposite direction, the synchronising conditions are met after several seconds.



- A. Sync\_Fail signal if sync timeout happen  
B. Object\_Fail signal if "real" object control fail.

Time settings:

- Synchrocheck: Max synchronize time (~seconds)
- Object: Max object control pulse len (~200 ms)

Figure 5.65: The block diagram of the synchrocheck and the controlling object

Please note that the wiring of the secondary circuits of voltage transformers to the device terminal depends on the selected voltage measuring mode.



**Table 5.35: Voltage measurement modes for synchrocheck function**

Voltage input	Terminals	Signals in mode "3LN/1LLy"	Signals in mode "3LN/1LNy"
$U_{L1}$	X1:11-12	$U_{L1}$	$U_{L1}$
$U_{L2}$	X1:13-14	$U_{L2}$	$U_{L2}$
$U_{L3}$	X1:15-16	$U_{L3}$	$U_{L3}$
$U_{SYNC}$	X1:17-18	$U_{L12}$ (phase to phase sync voltage)	$U_{L1}$ (phase to ground sync voltage)
<b>Number of synchrocheck stages</b>		2	2
<b>Availability of <math>U_0</math> and directional <math>I_0</math> stages</b>		Yes	Yes
<b>Power measurement</b>		3-phase power, un-symmetrical loads	3-phase power, un-symmetrical loads

## 5.21 Magnetishing inrush $I_{f2} > (68F2)$

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

The start and trip signals can be used for blocking the other stages. The trip delay is irrelevant if only the start signal is used for blocking. The trip delay of the stages to be blocked must be more than 60 ms to ensure a proper blocking.

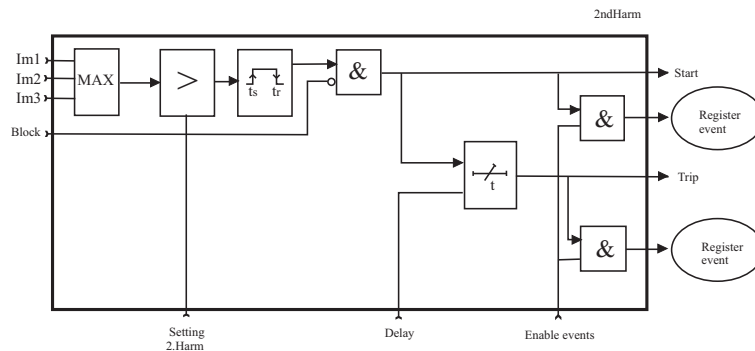


Figure 5.66: Block diagram of the magnetishing inrush stage.

**Table 5.36: Setting parameters of magnetising inrush blocking (68F2)**

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

For details of setting ranges, see Table 12.49

**Table 5.37: Measured and recorded values of magnetising inrush blocking (68F2)**

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

## 5.22 Transformer over excitation $I_{f5}>$ (68F5)

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

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

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

**Table 5.38: Setting parameters of over excitation blocking (68F5)**

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

For details of setting ranges, see Table 12.50

**Table 5.39: Measured and recorded values of over excitation blocking (68F5)**

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

## 5.23 Circuit breaker failure protection CBFP (50BF)

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

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

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

The CBFP stage is supervising all the protection stages using the same selected trip relay, since it supervises the control signal of this device. See Chapter 8.4 Output matrix.

**Table 5.40: Parameters of the circuit breaker failure stage CBFP (50BF)**

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	  F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Cbrelay			The supervised output relay.	Set
	1 – 14		Relay T1 – T14 (depending on the orderinf code)	
t>		s	Definite operate time.	Set

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

For details of setting ranges, see Table 12.51

### Recorded values of the latest eight faults

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

**Table 5.41: 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 operate time setting. 100% = trip

## 5.24 Programmable stages (99)

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

The following parameters are available:

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

**Table 5.42: Available signals to be supervised by the programmable stages**

IL1, IL2, IL3	Phase currents
Io	Residual current input
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 $\varphi$
IoCalc	Phasor sum $I_{L1} + I_{L2} + I_{L3}$

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 $(I_{L1} + I_{L2} + I_{L3}) / 3$
TanFii	Tangent $\varphi$ [= $\tan(\arccos\varphi)$ ]
Prms	Active power rms value
Qrms	Reactive power rms value
Srms	Apparent powre rms value
Uphase	Average of UL1, UL2, UL3
Uline	Average of U12, U23, U32
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 $U_A$
THDUb	Total harmonic distortion of input $U_B$
THDUc	Total harmonic distortion of input $U_C$
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
ILmin, ILmax	Minimum and maximum of phase currents
ULLmin, ULLmax	Minimum and maximum of line voltages
ULNmin, ULNmax	Minimum and maximum of phase voltages
VAI1, VAI2, VAI3, VAI4, VAI5	Virtual analog inputs 1, 2, 3, 4, 5 (GOOSE)

### Eight independent stages

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

### Setting groups

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

There are four identical stages available with independent setting parameters.

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

**Table 5.43: Parameters of the programmable stages PrgN (99)**

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Blocked			
	Start			F
	Trip			F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	DIx		Digital input	
	VIx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
Force	Off		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
	On			
Link	See Table 5.42		Name for the supervised signal	Set
See Table 5.42			Value of the supervised signal	
Cmp			Mode of comparison	Set
	>		Over protection	
	<		Under protection	
	Diff		Difference	
	AbsDiff		Absolut difference	
Pickup			Pick up value scaled to primary level	
Pickup		pu	Pick up setting in pu	Set
t		s	Definite operate time	Set
Hyster		%	Dead band setting	Set
NoCmp		pu	Minimum value to start under comparison. (Mode='<')	Set

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

### Recorded values of the latest eight faults

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

**Table 5.44: 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 operate time setting. 100% = trip
SetGrp	1, 2, 3, 4		Active setting group during fault



## 5.25 Arc fault protection (50ARC/50NARC) optional

**NOTE:** This protection function needs optional hardware in slot X6. More details of the hardware can be found in Chapter 11.4 Optional two channel arc protection card and Table 12.11).

Arc protection is used for fast arc protection. The function is based on simultaneous light and current measurement. Special arc sensors are used to measure the light of an arc.

### Stages for arc faults

There are three separate stages for the various current inputs:

Arcl>: for phase-to-phase arc faults. Current inputs  $I_{L1}$ ,  $I_{L2}$ ,  $I_{L3}$  are used.

Arcl<sub>0</sub>>: for phase-to-earth arc faults. Current input  $I_0$  is used.

### Light channel selection

The light information source to the stages can be selected from the following list.

- - : No sensor selected. The stage will not work.
- S1: Light sensor S1.
- S2: Light sensor S2.
- S1/S2: Either one of the light sensors S1 or S2.
- BI: Binary input of the arc card. 48 Vdc.
- S1/BI: Light sensor S1 or the binary input.
- S2/BI: Light sensor S2 or the binary input.
- S1/S2/BI: Light sensor S1 or S2 or the binary input.

### Binary input

The binary input (BI) on the arc option card (see Chapter 11.4 Optional two channel arc protection card) 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 8.4 Output matrix). BI is a dry input for 48 Vdc signal from binary outputs of other VAMP devices or dedicated arc protection devices by VAMP.

### Binary output

The binary output (BO) on the arc option card (see Chapter 11.4 Optional two channel arc protection card) 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 8.4 Output matrix). 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

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

### Pick up scaling

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

Arcl>:  $1 \text{ pu} = 1 \times I_N = \text{rated phase current CT value}$

Arcl<sub>0</sub>>:  $1 \text{ pu} = 1 \times I_{0N} = \text{rated residual current CT value for input } I_0$ .

**Table 5.45: Parameters of arc protection stages Arcl>, Arcl<sub>0</sub>> (50ARC/50NARC)**

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Start		Light detected according Arcl <sub>N</sub>	F
	Trip		Light and overcurrent detected	F
LCntr			Cumulative light indication counter. S1, S2 or BI.	C
SCntr			Cumulative light indication counter for the selected inputs according parameter Arcl <sub>N</sub>	C
TCntr			Cumulative trip counter	C
Force	Off		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
	On			
ILmax			Value of the supervised signal	
	lo>		Stage Arcl <sub>0</sub> >	
Arcl>		pu	Pick up setting $\times I_N$	Set
Arcl <sub>0</sub> >		pu	Pick up setting $\times I_{0N}$	

Parameter	Value	Unit	Description	Note
ArcIn			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		Sensor in terminals 1 and 2	
	S1/BI		Sensor 1 and BI in use	
	S2/BI		Sensor 2 and BI in use	
	S1/S2/BI		Sensor 1, 2 and BI in use	
<b>Delayed light signal output</b>				
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		Sensor in terminals 1 and 2	
	BI		Terminals X6:1 – 3	
	S1/BI		Sensor 1 and BI in use	
	S2/BI		Sensor 2 and BI in use	
S1/S2/BI		Sensor 1, 2 and BI in use		

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

For details of setting ranges, see Table 12.52

### Recorded values of the latest eight faults

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

**Table 5.46: Recorded values of the arc protection stages**

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

## 5.26 Inverse time operation

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

Inverse delay means that the operate 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 operate time does not depend on the size of a fault.

### Stage specific inverse delay

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

### Operation modes

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

- **Standard delays**  
Using standard delay characteristics by selecting a curve family (IEC, IEEE, IEEE2, RI) and a delay type (Normal inverse, Very inverse etc). See Chapter 5.26.1 Standard inverse delays IEC, IEEE, IEEE2, RI.
- **Standard delay formulae with free parameters**  
selecting a curve family (IEC, IEEE, IEEE2) and defining one's own parameters for the selected delay formula. This mode is activated by setting delay type to 'Parameters', and then editing the delay function parameters A – E. See Chapter 5.26.2 Free parameterization using IEC, IEEE and IEEE2 equations.
- **Fully programmable inverse delay characteristics**  
Building the characteristics by setting 16 [current, time] points. The relay interpolates the values between given points with 2nd degree polynomials. This mode is activated by setting curve family to 'PrgN'. There are maximum three different programmable curves available at the same time. Each programmed curve can be used by any number of protection stages. See Chapter 5.26.3 Programmable inverse time curves.

### Local panel graph

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

### Inverse time setting error signal

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

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

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

### Limitations

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

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

\*) The available  $I_{0N}$  values depend on the order code. VAMP 259 has 5 A, 1 A or 0.2 A residual current inputs available. Desired input needs to be specified when ordering the relay.

### 1. Example of limitation

$$CT = 750 / 5$$

Application mode is Feeder

$$CT_0 = 100 / 1 \text{ (cable CT is used for residual current)}$$

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

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

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  $0.5 \text{ A} / 1 \text{ A} = 0.5 \times I_{0N} = 50 \text{ A}_{\text{Primary}}$ .

## 5.26.1

### Standard inverse delays IEC, IEEE, IEEE2, RI

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

#### Inverse time setting error signal

The inverse time setting error signal will be activated, if the delay category is changed and the old delay type doesn't exist in the new category. See Chapter 5.26 Inverse time operation for more details.

#### Limitations

The minimum definite time delay start latest, when the measured value is twenty times the setting. However, there are limitations at high setting values due to the measurement range. Chapter 5.26 Inverse time operation for more details.

**Table 5.47: Available standard delay families and the available delay types within each family.**

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

### IEC inverse time operation

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

$t$  = Operation delay in seconds

$k$  = User's multiplier

$I$  = Measured value

$I_{PICKUP}$  = User's pick up setting

$A, B$  = Constants parameters according Table 5.48.

Equation 5.6:

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

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

**Table 5.48: 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)":**

$k = 0.50$

$I = 4 \text{ pu}$  (constant current)

$I_{\text{PICKUP}} = 2 \text{ pu}$

$A = 0.14$

$B = 0.02$

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

The operate time in this example will be 5 seconds. The same result can be read from Figure 5.67.

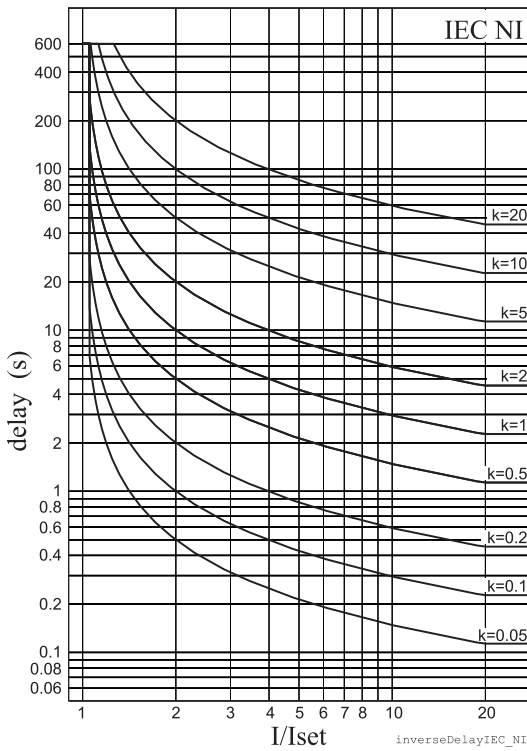


Figure 5.67: IEC normal inverse delay.

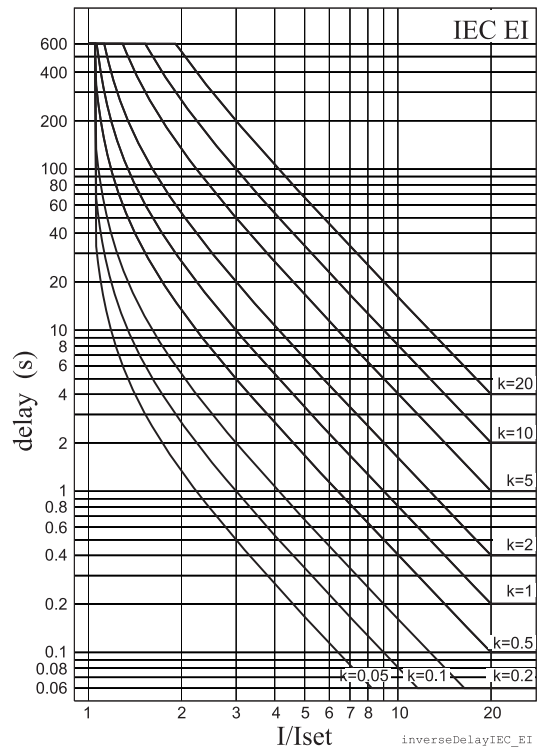


Figure 5.68: IEC extremely inverse delay.



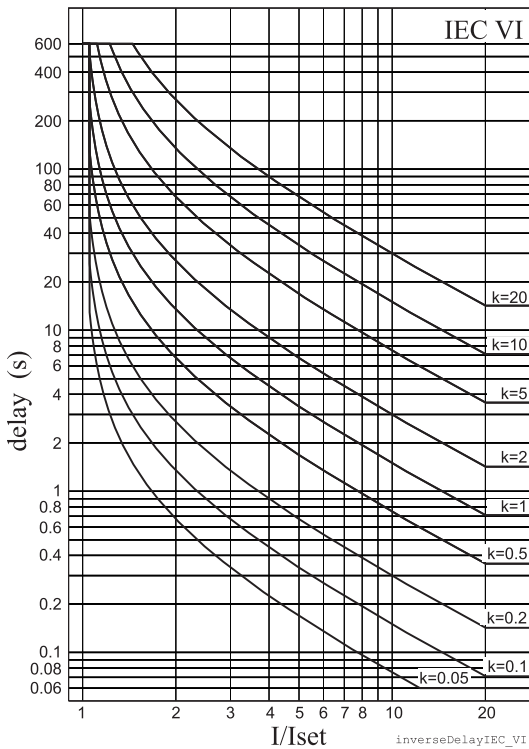


Figure 5.69: IEC very inverse delay.

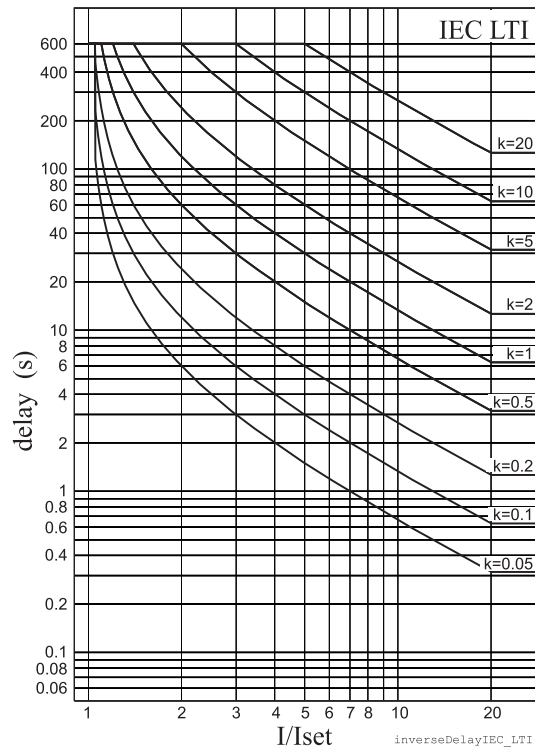


Figure 5.70: IEC long time inverse delay.

### IEEE/ANSI inverse time operation

There are three different delay types according IEEE Std C37.112-1996 (MI, VI, EI) and many de facto versions according Table 5.49. The IEEE standard defines inverse delay for both trip and release operations. However, in the VAMP relay only the trip time is inverse according the standard but the release time is constant.

The operation delay depends on the measured value and other parameters according Equation 5.7. Actually this equation can only be used to draw graphs or when the measured value I is constant during the fault. A modified version is implemented in the relay for real time usage.

Equation 5.7:

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

t = Operation delay in seconds

k = User's multiplier

I = Measured value

I<sub>PICKUP</sub> = User's pick up setting

A,B,C = Constant parameter according Table 5.49.

**Table 5.49: 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)":**

$$k = 0.50$$

$$I = 4 \text{ pu}$$

$$I_{\text{PICKUP}} = 2 \text{ pu}$$

$$A = 0.0515$$

$$B = 0.114$$

$$C = 0.02$$

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

The operate time in this example will be 1.9 seconds. The same result can be read from Figure 5.74.

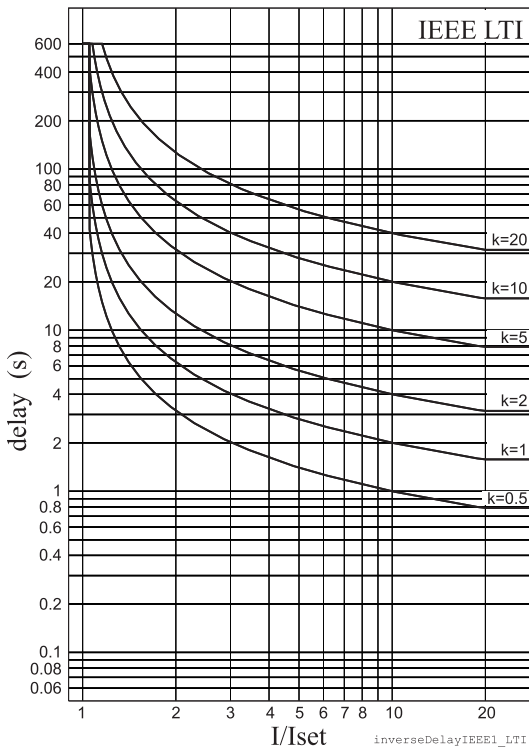


Figure 5.71: ANSI/IEEE long time inverse delay

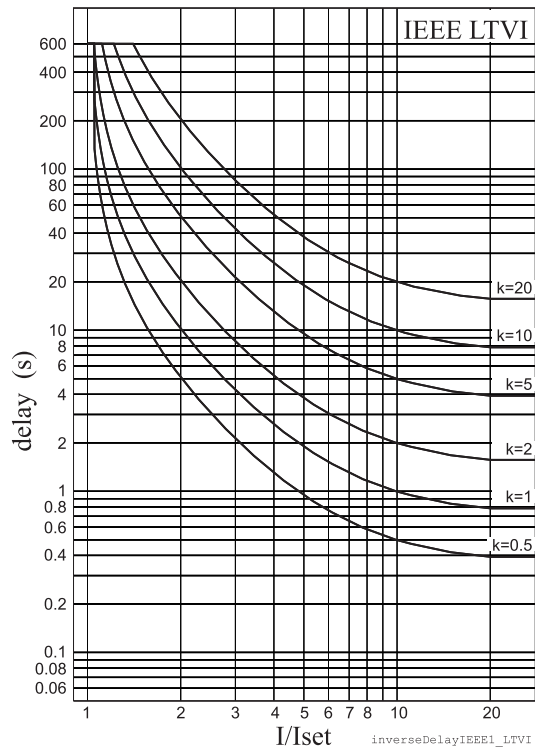


Figure 5.72: ANSI/IEEE long time very inverse delay

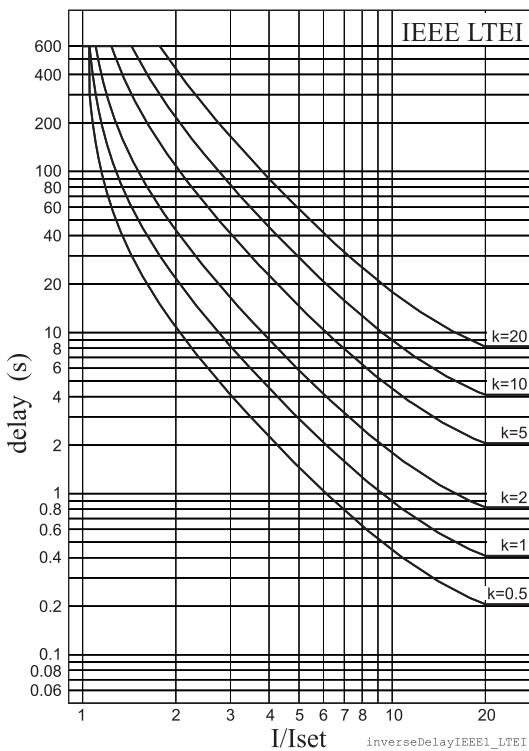


Figure 5.73: ANSI/IEEE long time extremely inverse delay

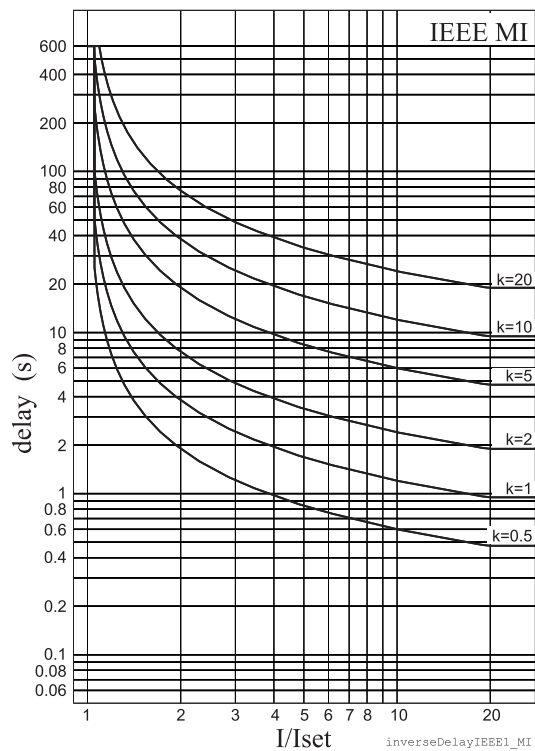


Figure 5.74: ANSI/IEEE moderately inverse delay

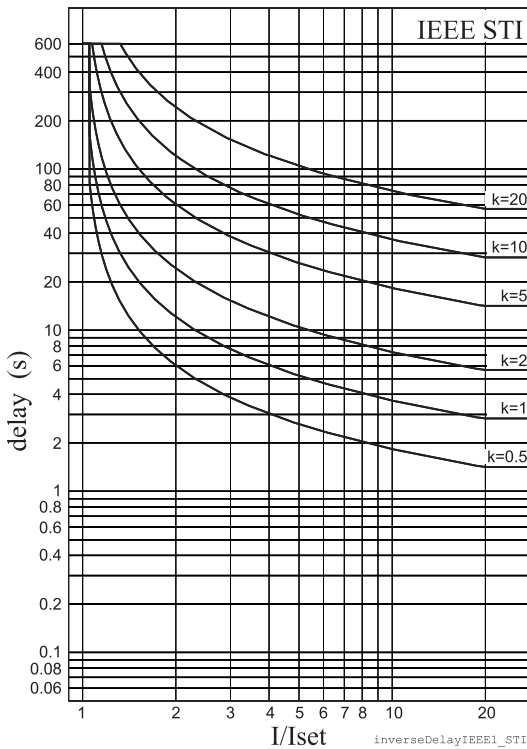


Figure 5.75: ANSI/IEEE short time inverse delay

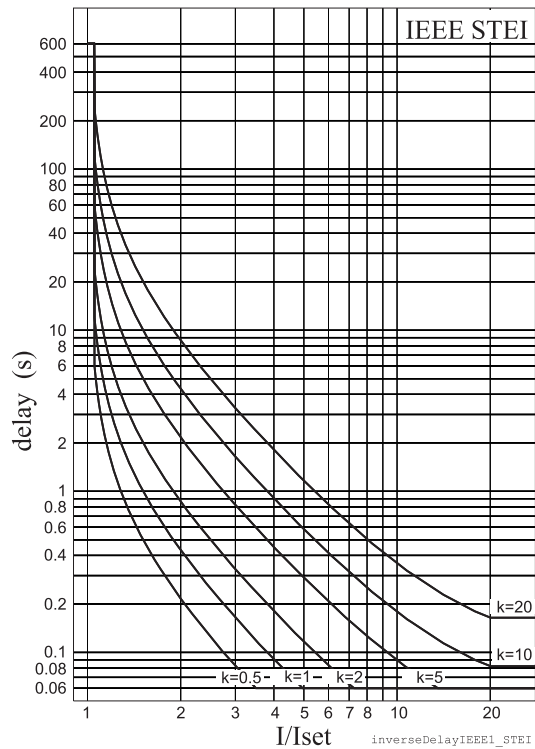


Figure 5.76: ANSI/IEEE short time extremely inverse delay

### IEEE2 inverse time operation

Before the year 1996 and ANSI standard C37.112 microprocessor relays were using equations approximating the behaviour of various induction disc type relays. A quite popular approximation is Equation 5.8, which in VAMP relays is called IEEE2. Another name could be IAC, because the old General Electric IAC relays have been modeled using the same equation.

There are four different delay types according Table 5.50. The old electromechanical induction disc relays have inverse delay for both trip and release operations. However, in VAMP relays only the trip time is inverse the release time being constant.

The operation delay depends on the measured value and other parameters according Equation 5.8. Actually this equation can only be used to draw graphs or when the measured value I is constant during the fault. A modified version is implemented in the relay for real time usage.

Equation 5.8:

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

t = Operation delay in seconds

k = User's multiplier

I = Measured value

I<sub>PICKUP</sub> = User's pick up setting

A, B, C, D = Constant parameter according Table 5.50.

**Table 5.50: Constants for IEEE2 inverse delay equation**

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

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

k = 0.50

I = 4 pu

I<sub>PICKUP</sub> = 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 operate time in this example will be 0.38 seconds. The same result can be read from Figure 5.77.

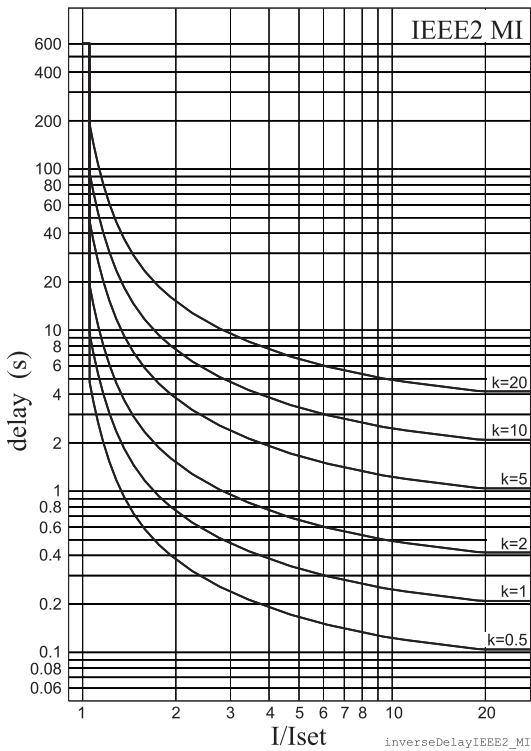


Figure 5.77: IEEE2 moderately inverse delay

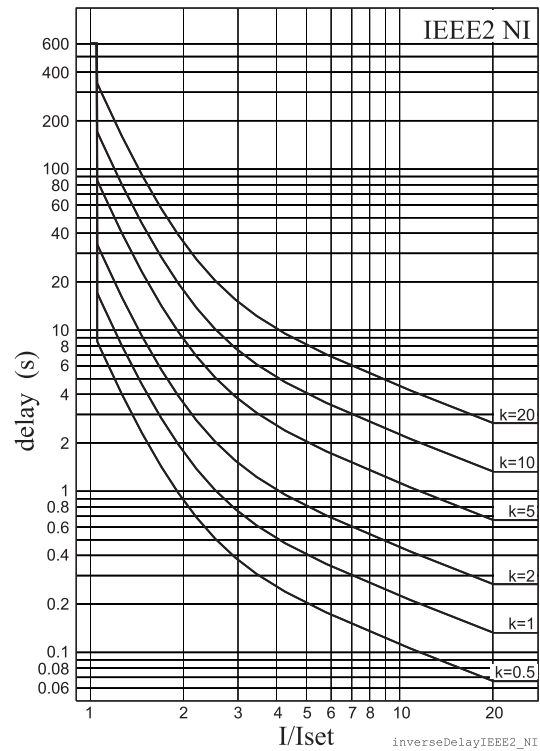


Figure 5.78: IEEE2 normal inverse delay

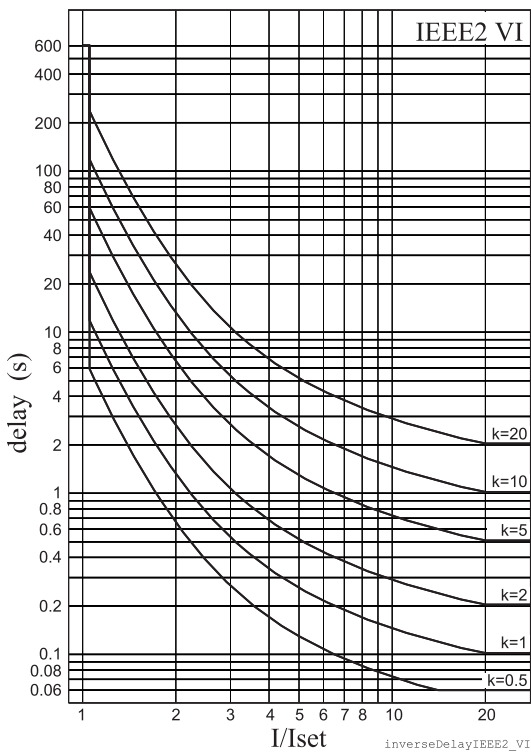


Figure 5.79: IEEE2 very inverse delay

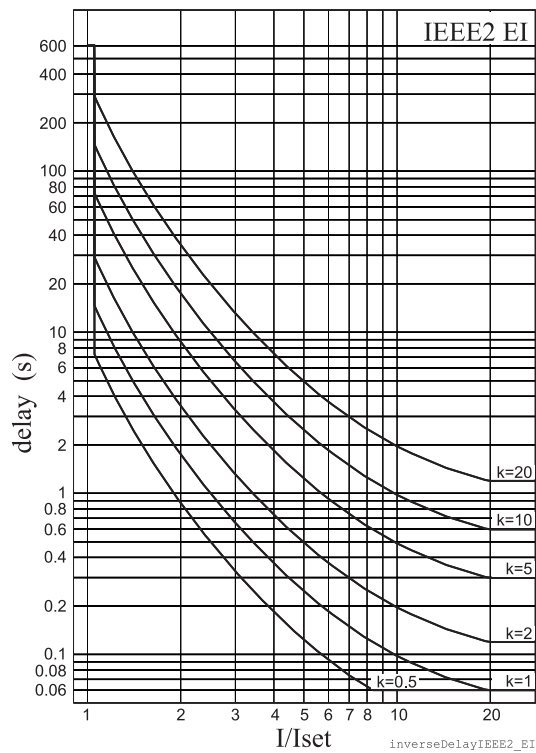


Figure 5.80: IEEE2 extremely inverse delay

### RI and RXIDG type inverse time operation

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

The operation delay of types RI and RXIDG depends on the measured value and other parameters according Equation 5.9 and Equation 5.10. Actually these equations can only be used to draw graphs or when the measured value  $I$  is constant during the fault. Modified versions are implemented in the relay for real time usage.

Equation 5.9: RI

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

Equation 5.10: RXIDG

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

$t$  = 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 operate time in this example will be 2.3 seconds. The same result can be read from Figure 5.81.

#### 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 operate time in this example will be 3.9 seconds. The same result can be read from Figure 5.82.

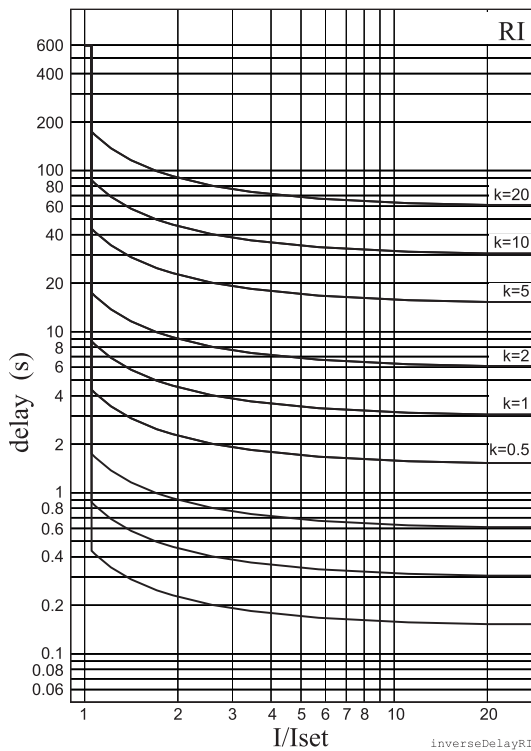


Figure 5.81: Inverse delay of type RI.

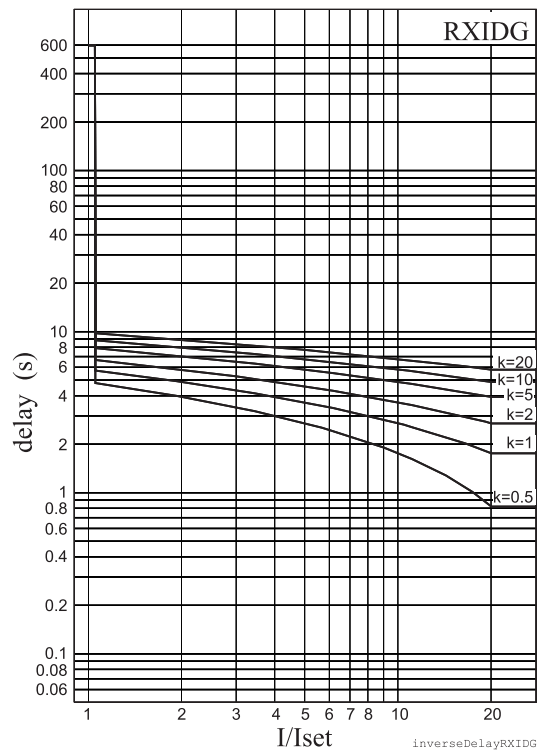


Figure 5.82: Inverse delay of type RXIDG.

### 5.26.2 Free parameterization using IEC, IEEE and IEEE2 equations

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

#### Example for GE-IAC51 delay type inverse:

$$k = 0.50$$

$$I = 4 \text{ pu}$$

$$I_{\text{PICKUP}} = 2 \text{ pu}$$

$$A = 0.2078$$

$$B = 0.8630$$

$$C = 0.8000$$

$$D = -0.4180$$

$$E = 0.1947$$



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

The operate time in this example will be 0.37 seconds.

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

### Inverse time setting error signal

The inverse time setting error signal will become active, if interpolation with the given parameters is not possible. See Chapter 5.26 Inverse time operation for more details.

### Limitations

The minimum definite time delay start latest, when the measured value is twenty times the setting. However, there are limitations at high setting values due to the measurement range. See Chapter 5.26 Inverse time operation for more details.

## 5.26.3

### 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 operate time) on the top and the largest current (shortest operate 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 <sub>PICKUP</sub>	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

---

Point	Current $I/I_{PICKUP}$	Operation delay
10	1.00	0.00 s
11	1.00	0.00 s
12	1.00	0.00 s
13	1.00	0.00 s
14	1.00	0.00 s
15	1.00	0.00 s
16	1.00	0.00 s

### Inverse time setting error signal

The inverse time setting error signal will be activated, if interpolation with the given points fails. See Chapter 5.26 Inverse time operation for more details.

### Limitations

The minimum definite time delay start latest, when the measured value is twenty times the setting. However, there are limitations at high setting values due to the measurement range. See Chapter 5.26 Inverse time operation for more details.

# 6 Supporting functions

## 6.1 Event log

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

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

EVENT	Description	Local panel	Communication protocols
Code: 01E02	Channel 1, event 2	Yes	Yes
I> trip on	Event text	Yes	No
2.7 x In	Fault value	Yes	No
2007-01-31	Date	Yes	Yes
08:35:13.413	Time	Yes	Yes
Type: U12, U23, U31	Fault type	Yes	No

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

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

### Event enabling/masking

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

Modification can be done in “Local panel conf” –menu.

Indication screen (popup screen) can also be enabled in this same menu when VAMPSET setting tool is used. The oldest one will be overwritten, when a new event does occur. The shown resolution of a time stamp is one millisecond, but the actual resolution depends of the particular function creating the event. For example most protection stages create events with 5ms, 10 ms or 20 ms resolution.

The absolute accuracy of all time stamps depends on the time synchronizing of the relay. See Chapter 6.10 System clock and synchronization for system clock synchronizing.

### Event buffer overflow

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

**Table 6.1: Setting parameters for events**

Parameter	Value	Description	Note
Count		Number of events	
ClrEn	- Clear	Clear event buffer	Set
Order	Old-New New-Old	Order of the event buffer for local display	Set
FVSca		Scaling of event fault value	Set
	PU	Per unit scaling	
	Pri	Primary scaling	
Display	On	Indication display is enabled	Set
Alarms	Off	No indication display	
<b>FORMAT OF EVENTS ON THE LOCAL DISPLAY</b>			
Code: CHENN		CH = event channel, NN=event code	
Event description		Event channel and code in plain text	
yyyy-mm-dd		Date (for available date formats, see Chapter 6.10 System clock and synchronization)	
hh:mm:ss.nnn		Time	

## 6.2 Disturbance recorder

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

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.

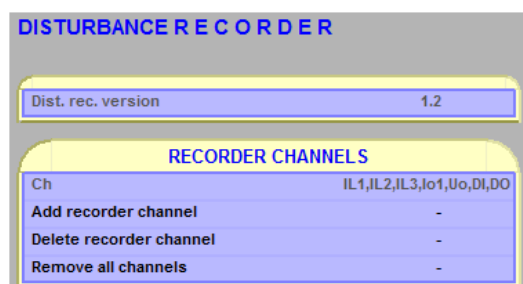
### Reading recordings

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

For more details, please see a separate VAMPSET manual.

### Number of channels

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



**Table 6.2: VAMP 259 Disturbance recorder waveform**

Channel	Description	Available for waveform	
		Voltage measurement mode	
		3LN/LNy	3LN/LLy
IL1, IL2, IL3	Phase current	Yes	Yes
Io1, Io2	Measured residual current	Yes	Yes
U12	Line-to-line voltage	-	-
U23	Line-to-line voltage	-	-
U31	Line-to-line voltage	-	-

Channel	Description	Available for waveform	
		Voltage measurement mode	
		3LN/LNy	3LN/LLy
UL1, UL2, UL3	Phase-to-neutral voltage	Yes	Yes
Uo	Zero sequence voltage	-	-
f	Frequency	-	-
P, Q, S	Active, reactive, apparent power	-	-
P.F.	Power factor	-	-
CosFii	cosφ	-	-
IoCalc	Phasor sum $I_o = (I_{L1} + I_{L2} + I_{L3})/3$	-	-
I1	Positive sequence current	-	-
I2	Negative sequence current	-	-
I2/I1	Relative current unbalance	-	-
I2/In	Current unbalance to nominal ratio	-	-
U1	Positive sequence voltage	-	-
U2	Negative sequence voltage	-	-
U2/U1	Relative voltage unbalance	-	-
IL	Average $(I_{L1} + I_{L2} + I_{L3})/3$	-	-
Uphase	Average $(U_{L1} + U_{L2} + U_{L3})/3$	-	-
Uline	Average $(U_{12} + U_{23} + U_{31})/3$	-	-
DO	Digital outputs	Yes	Yes
DI	Digital inputs	Yes	Yes
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 Ua	-	-
THDUb	Total harmonic distortion of Ub	-	-
THDUc	Total harmonic distortion of Uc	-	-
DI_2	Digital inputs 21 – 32	Yes	Yes
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	-	-
ULNy	Voltage behind circuit breaker, phase to ground	Yes	-
ULLy	Voltage behind 2nd circuit breaker, phase to phase	-	Yes
IL1RMS	IL1 RMS for average sampling	-	-
IL2RMS	IL2 RMS for average sampling	-	-
IL3RMS	IL3 RMS for average sampling	-	-

**Table 6.3: Disturbance recorder parameters**

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

Parameter	Value	Unit	Description	Note
AddCh			Add one channel. Maximum simultaneous number of channels is 12.	Set
	IL1, IL2, IL3		Phase current	
	Io		Measured residual current	
	U12, U23, U31		Line-to-line voltage	
	UL1, UL2, UL3		Phase-to-neutral voltage	
	Uo		Zero sequence voltage	
	f		Frequency	
	P, Q, S		Active, reactive, apparent power	
	P.F.		Power factor	
	CosFii		cos $\phi$	
	I1		Positive sequence current	
	I2		Negative sequence current	
	I2/I1		Relative current unbalance	
	U1		Positive sequence voltage	
	U2		Negative sequence voltage	
	U2/U1		Relative negative sequence voltage	
	IL		Average (IL1 + IL2 + IL3) / 3	
	Uphase		Average phase voltage	
	Uline		Average line-to-lines voltages	
	DI, DO		Digital inputs, Digital outputs	
	TanFii		tan $\phi$	
	THDIL1, THDIL2, THDIL3		Total harmonic distortion of IL1, IL2 or IL3	
	THDUa, THDUb, THDUc		Total harmonic distortion of Ua, Ub or Uc	
	DI_2		Digital inputs 21-32	
	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	
	ULNy		Voltage behind circuit breaker, phase to ground	
	ULLy		Voltage behind circuit breaker, phase to phase	
	IL1RMS, IL2MRS, IL3RMS		IL1, IL2, IL3 RMS for average sampling	
	Starts		Protection stage start signals	
Trips		Protection stage trip signals		
Delete recorder channel			Delete selected channel	
ClrCh	-, Clear		Remove all channels	Set
(Ch)			List of selected channels	



Set = An editable parameter (password needed).

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

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

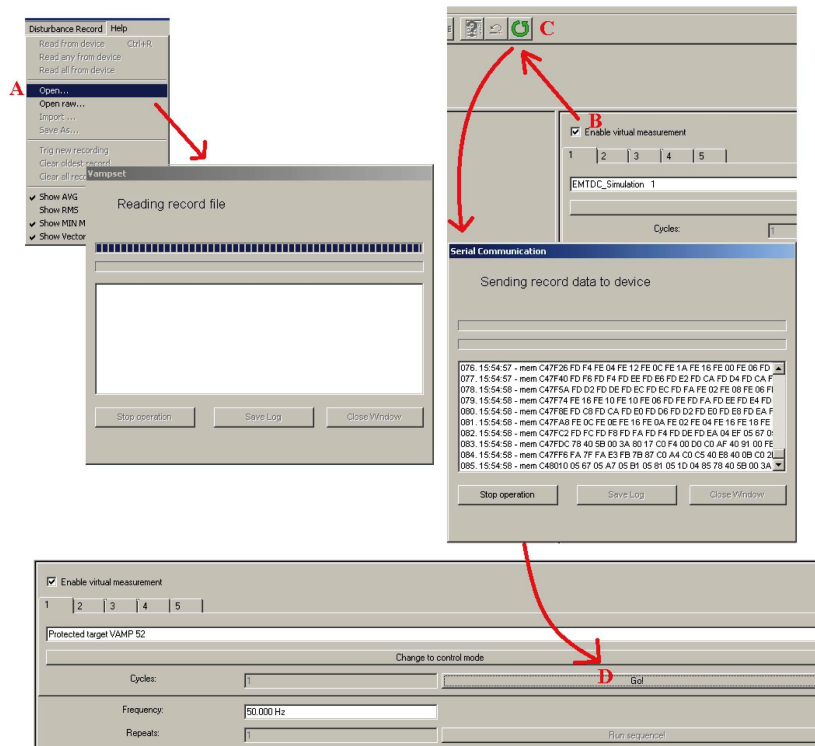
For details of setting ranges, see Table 12.53

## 6.2.1 Running virtual comtrade files

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

Steps of opening the VAMPSET setting tool:

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



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

## 6.3 Cold load pick-up and inrush current detection

### Cold load pick-up

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

### Application for cold load detection

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

### Inrush current detection

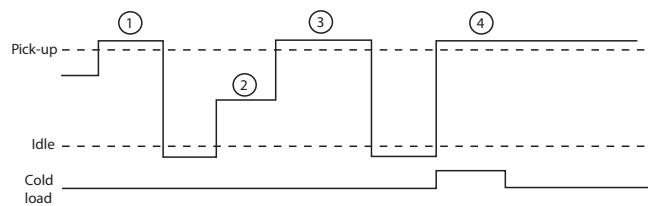
Inrush current detection is quite similar with the cold load detection but it does also include a condition for second harmonic relative content of the currents. When all phase currents have been less than a given idle value and then at least one of them exceeds a given pick-up level within 80 ms and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

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

### Application for inrush current detection

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

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



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

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

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

Parameter	Value	Unit	Description	Note
ColdLd	-		Status of cold load detection:	
	Start		Cold load situation is active	
	Trip		Timeout	
Inrush	-		Status of inrush detection:	
	Start		Inrush is detected	
	Trip		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		$xI_N$	Current limit setting for idle situation	Set
Pickup		$xI_N$	Pick-up setting for minimum start current	Set
	80	ms	Maximum transition time for start recognition	

Parameter	Value	Unit	Description	Note
Pickupf2		%	Pick-up value for relative amount of 2nd harmonic, $I_{f2}/I_{f1}$	Set

Set = An editable parameter (password needed).

For details of setting ranges, see Table 12.54

## 6.4 Voltage sags and swells

The power quality of electrical networks has become increasingly important. The sophisticated loads (e.g. computers etc.) require uninterrupted supply of “clean” electricity. VAMP protection platform provides many power quality functions that can be used to evaluate, monitor and alarm on the basis of the quality. One of the most important power quality functions are voltage sag and swell monitoring.

VAMP provides separate monitoring logs for sags and swells. The voltage log is triggered, if any voltage input either goes under the sag limit (U<) or exceeds the swell limit (U>). There are four registers for both sags and swells in the fault log. Each register will have start time, phase information, duration, minimum, average, maximum voltage values of each sag and swell event. Furthermore, there are total number of sags and swells counters as well as total timers for sags and swells.

The voltage power quality functions are located under the submenu “U”.

**Table 6.5: Setting parameters of sags and swells monitoring**

Parameter	Value	Unit	Default	Description
U>	20 – 150	%	110	Setting value of swell limit
U<	10 – 120	%	90	Setting value of sag limit
Delay	0.04 – 1.00	s	0.06	Delay for sag and swell detection
SagOn	On; Off	-	On	Sag on event
SagOff	On; Off	-	On	Sag off event
SwelOn	On; Off	-	On	Swell on event
SwelOf	On; Off	-	On	Swell off event

**Table 6.6: Recorded values of sags and swells monitoring**

	Parameter	Value	Unit	Description
Recorded values	Count		-	Cumulative sag counter
	Total		-	Cumulative sag time counter
	Count		-	Cumulative swell counter
	Total		-	Cumulative swell time counter
Sag / swell logs 1 – 4	Date		-	Date of the sag/swell
	Time		-	Time stamp of the sag/swell
	Type		-	Voltage inputs that had the sag/swell
	Time		s	Duration of the sag/swell
	Min1		% Un	Minimum voltage value during the sag/swell in the input 1
	Min2		% Un	Minimum voltage value during the sag/swell in the input 2
	Min3		% Un	Minimum voltage value during the sag/swell in the input 3
	Ave1		% Un	Average voltage value during the sag/swell in the input 1
	Ave2		% Un	Average voltage value during the sag/swell in the input 2
	Ave3		% Un	Average voltage value during the sag/swell in the input 3
	Max1		% Un	Maximum voltage value during the sag/swell in the input 1
	Max2		% Un	Maximum voltage value during the sag/swell in the input 2
	Max3		% Un	Maximum voltage value during the sag/swell in the input 3

For details of setting ranges, see Table 12.57

## 6.5 Voltage interruptions

The device includes a simple function to detect voltage interruptions. The function calculates the number of voltage interruptions and the total time of the voltage-off time within a given calendar period. The period is based on the real time clock of the device. The available periods are:

- 8 hours, 00:00 – 08:00, 08:00 – 16:00, 16:00 – 24:00
- one day, 00:00 – 24:00
- one week, Monday 00:00 – Sunday 24:00
- one month, the first day 00:00 – the last day 24:00
- one year, 1st January 00:00 – 31st December 24:00

After each period, the number of interruptions and the total interruption time are stored as previous values. The interruption

counter and the total time are cleared for a new period. The old previous values are overwritten.

The voltage interruption is based on the value of the positive sequence voltage  $U_1$  and a user given limit value. Whenever the measured  $U_1$  goes below the limit, the interruption counter is increased, and the total time counter starts increasing.

Shortest recognized interruption time is 40 ms. If the voltage-off time is shorter it may be recognized depending on the relative depth of the voltage dip.

If the voltage has been significantly over the limit  $U_1 <$  and then there is a small and short under-swing, it will not be recognized (Figure 6.2).

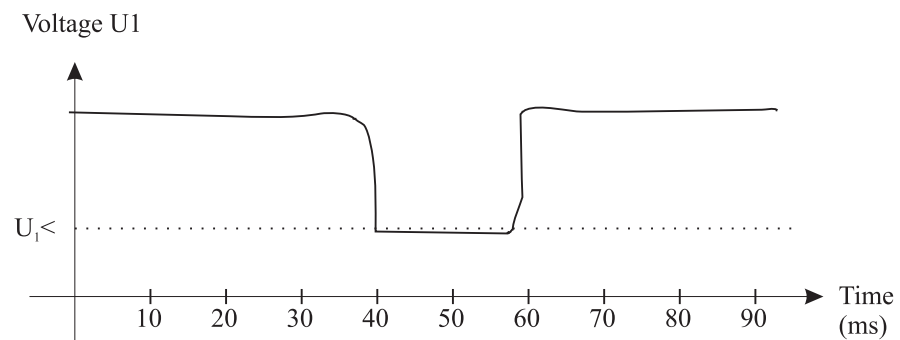


Figure 6.2: A short voltage interruption which is probably not recognized

On the other hand, if the limit  $U_1 <$  is high and the voltage has been near this limit, and then there is a short but very deep dip, it will be recognized (Figure 6.3).

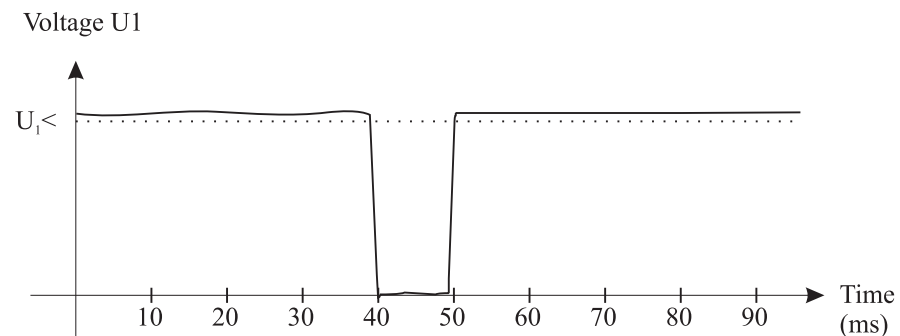


Figure 6.3: A short voltage interrupt that will be recognized

**Table 6.7: Setting parameters of the voltage sag measurement function:**

Parameter	Value	Unit	Default	Description
U1<	10.0 – 120.0	%	64	Setting value
Period	8h Day Week Month	-	Month	Length of the observation period
Date		-	-	Date
Time		-	-	Time

**Table 6.8: Measured and recorded values of voltage sag measurement function:**

	Parameter	Value	Unit	Description
Measured value	Voltage	LOW; OK	-	Current voltage status
	U1		%	Measured positive sequence voltage
Recorded values	Count		-	Number of voltage sags during the current observation period
	Prev		-	Number of voltage sags during the previous observation period
	Total		s	Total (summed) time of voltage sags during the current observation period
	Prev		s	Total (summed) time of voltage sags during the previous observation period

For details of setting ranges, see Table 12.58

## 6.6 Current transformer supervision

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

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

**Table 6.9: Setting parameters of CT supervisor CTSV**

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

**Table 6.10: 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	$I_{max}>$ , $I_{min}<$		A	Setting values as primary values
Recorded values	Date		-	Date of CT supervision alarm
	Time		-	Time of CT supervision alarm
	I <sub>max</sub>		A	Maximum phase current
	I <sub>min</sub>		A	Minimum phase current

For details of setting ranges, see Table 12.55

## 6.7 Voltage transformer supervision

The device supervises the VTs and VT wiring between the device terminals and the VTs. If there is a fuse in the voltage transformer circuitry, the blown fuse prevents or distorts the voltage measurement. Therefore, an alarm should be issued. Furthermore, in some applications, protection functions using voltage signals, should be blocked to avoid false tripping.

The VT supervisor function measures the three phase voltages and currents. The negative sequence voltage  $U_2$  and the negative sequence current  $I_2$  are calculated. If  $U_2$  exceed the  $U_2>$  setting and at the same time,  $I_2$  is less than the  $I_2<$  setting, the function will issue an alarm after the operation delay has elapsed.



**Table 6.11: Setting parameters of VT supervisor VTSV ( )**

Parameter	Value	Unit	Default	Description
U2>	0.0 – 200.0	% Un	34.6	Upper setting for VT supervisor
I2<	0.0 – 200.0	% In	100.0	Lower setting for VT supervisor
t>	0.02 – 600.0	s	0.10	Operation delay
VT on	On; Off	-	On	VT supervisor on event
VT off	On; Off	-	On	VT supervisor off event

**Table 6.12: Measured and recorded values of VT supervisor VTSV ( )**

	Parameter	Value	Unit	Description
Measured value	U2		% Un	Measured negative sequence voltage
	I2		% In	Measured negative sequence current
Recorded Values	Date		-	Date of VT supervision alarm
	Time		-	Time of VT supervision alarm
	U2		% Un	Recorded negative sequence voltage
	I2		% In	Recorded negative sequence current

For details of setting ranges, see Table 12.56

## 6.8 Circuit breaker condition monitoring

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

The CB wear function measures the breaking current of each CB pole separately and then estimates the wearing of the CB accordingly the permissible cycle diagram. The breaking current is registered when the trip relay supervised by the circuit breaker failure protection (CBFP) is activated. (See Chapter 5.23 Circuit breaker failure protection CBFP (50BF) for CBFP and the setting parameter "CBrelay".)

### Breaker curve and its approximation

The permissible cycle diagram is usually available in the documentation of the CB manufacturer (Figure 6.4). The diagram specifies the permissible number of cycles for every level of the breaking current. This diagram is parameterised to the condition monitoring function with maximum eight [current, cycles] points. See Table 6.13. If less than eight points needed, the unused points are set to  $[I_{BIG}, 1]$ , where  $I_{BIG}$  is more than the maximum breaking capacity.

If the CB wearing characteristics or part of it is a straight line on a log/log graph, the two end points are enough to define that part of the characteristics. This is because the relay is using logarithmic

interpolation for any current values falling in between the given current points 2 – 8.

The points 4 – 8 are not needed for the CB in Figure 6.4. Thus they are set to 100 kA and one operation in the table to be discarded by the algorithm.

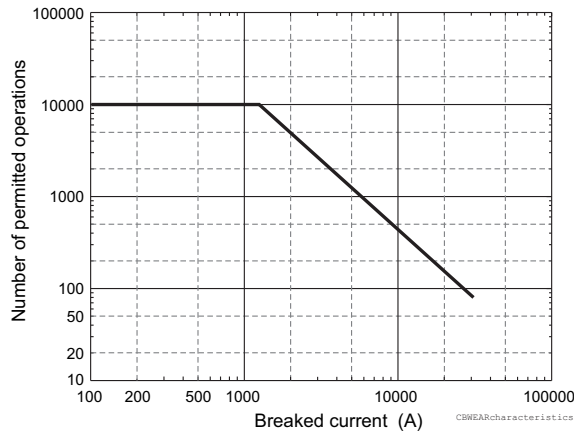


Figure 6.4: An example of a circuit breaker wearing characteristic graph.

**Table 6.13: An example of circuit breaker wearing characteristics in a table format. The values are taken from the figure above. The table is edited with VAMPSET under menu "BREAKER CURVE".**

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

### Setting alarm points

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

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

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

### Clearing "operations left" counters

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

### Operation counters to monitor the wearing

The operations left can be read from the counters "AI1Ln" (Alarm 1) and "AI2Ln" (Alarm2). There are three values for both alarms, one for each phase. The smallest of three is supervised by the two alarm functions.

### Logarithmic interpolation

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

*Equation 6.1:*

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

C = permitted operations

I = interrupted current

a = constant according Equation 6.2

n = constant according Equation 6.3

*Equation 6.2:*

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

ln = natural logarithm function

$C_k, C_{k+1}$  = permitted operations. k = row 2 – 7 in Table 6.13.

$I_k, I_{k+1}$  = corresponding current. k = row 2 – 7 in Table 6.13.

*Equation 6.3:*

$$a = C_k I_k^2$$

### Example of the logarithmic interpolation

Alarm 2 current is set to 6 kA. What is the maximum number of operations according Table 6.13.

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

$$k = 2$$

$$C_k = 10000$$

$$C_{k+1} = 80$$

$$I_{k+1} = 31 \text{ kA}$$

$$I_k = 1.25 \text{ kA}$$

and the Equation 6.2 and Equation 6.3, the relay calculates

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

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

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

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

Thus the maximum number of current breaking at 6 kA is 945. This can be verified with the original breaker curve in Figure 6.4. Indeed, the figure shows that at 6 kA the operation count is between 900 and 1000. A useful alarm level for operation-left, could be in this case for example 50 being about five per cent of the maximum.

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

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

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

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

---

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

*Equation 6.4:*

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

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

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

$$\Delta_{L3} = 1$$

Table 6.14: Local panel parameters of CBWEAR function

Parameter	Value	Unit	Description	Set
<b>CBWEAR STATUS</b>				
AI1L1			Operations left for - Alarm 1, phase L1	
AI1L2			- Alarm 1, phase L2	
AI1L3			- Alarm 1, phase L3	
AI2L1			- Alarm 2, phase L1	
AI2L2			- Alarm 2, phase L2	
AI2L3			- Alarm 2, phase L3	
<b>Latest trip</b>				
Date time			Time stamp of the latest trip operation	
IL1		A	Broken current of phase L1	
IL2		A	Broken current of phase L2	
IL3		A	Broken current of phase L3	
<b>CBWEAR SET</b>				
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
<b>CBWEAR SET2</b>				
AI1On	On ; Off		'Alarm1 on' event enabling	Set
AI1Off	On ; Off		'Alarm1 off' event enabling	Set
AI2On	On ; Off		'Alarm2 on' event enabling	Set
AI2Off	On ; Off		'Alarm2 off' event enabling	Set
Clear	-; Clear		Clearing of cycle counters	Set

Set = An editable parameter (password needed).

The breaker curve table is edited with VAMPSET.

## 6.9 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 6.5. 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.

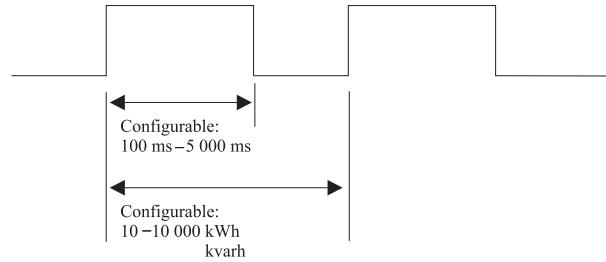


Figure 6.5: Principle of energy pulses

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.

Table 6.15: 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

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.
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.
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.
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.



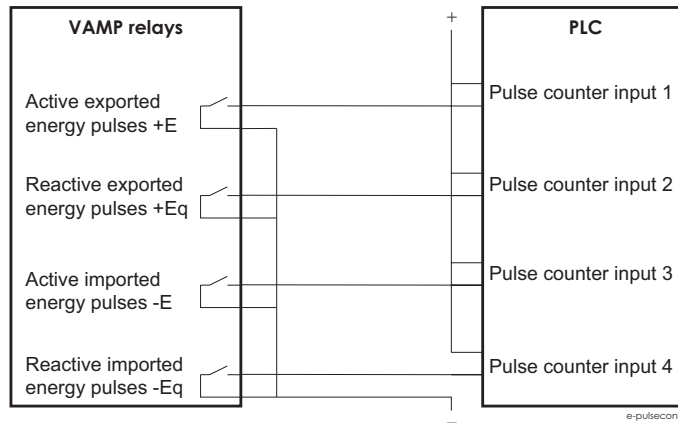


Figure 6.6: Application example of wiring the energy pulse outputs to a PLC having common plus and using an external wetting voltage

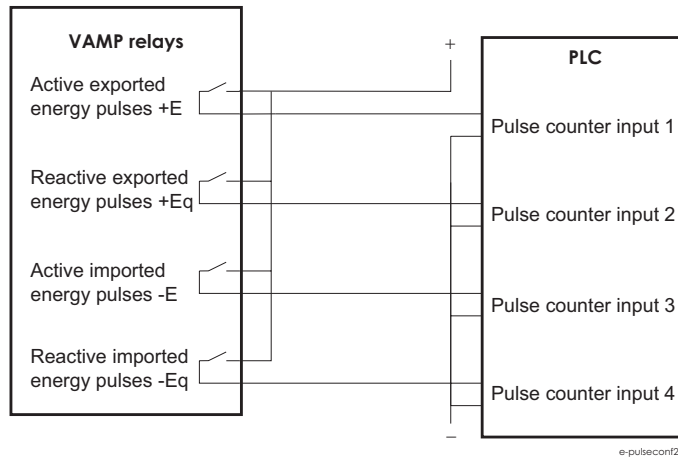


Figure 6.7: Application example of wiring the energy pulse outputs to a PLC having common minus and using an external wetting voltage

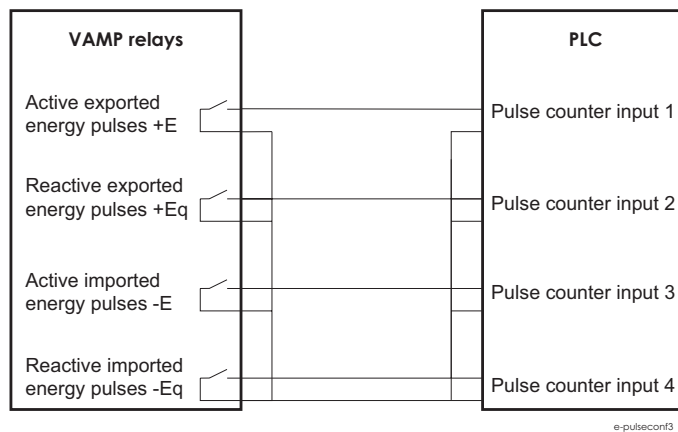


Figure 6.8: Application example of wiring the energy pulse outputs to a PLC having common minus and an internal wetting voltage.

## 6.10 System clock and synchronization

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

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

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

### Time zone offsets

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

### Daylight saving time (DST)

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

SYSTEM CLOCK	
Date	2014-05-12
Day of week	Monday
Time of day	15:24:47
Date style	y-m-d
Time zone	2 h
Enable DST	<input checked="" type="checkbox"/>
Event enabling	<input checked="" type="checkbox"/>
Status of DST	
Status of DST	ACTIVE
Next DST changes	
Next DSTbegin date	2015-03-29
DSTbegin hour	03:00
Next DSTend date	2014-10-26
DSTend hour (DST)	04:00 DST

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

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

- Daylight saving time start: Last Sunday of March at 03.00
- Daylight saving time end: Last Sunday of October at 04.00

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

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

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

### Adapting auto adjust

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

### Time drift correction without external sync

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

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

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

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

The term  $DriftInOneWeek/604.8$  may be replaced with the relative drift multiplied by 1000, if some other period than one week has been

used. For example if the drift has been 37 seconds in 14 days, the relative drift is  $37 \cdot 1000 / (14 \cdot 24 \cdot 3600) = 0.0306$  ms/s.

### Example 1

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

$$AvDrft = Lead$$

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

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

### Example 2

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

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

$$AvDrft = Lead$$

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

**Table 6.16: System clock parameters**

Parameter	Value	Unit	Description	Note
Date			Current date	Set
Time			Current time	Set
Style			Date format	Set
	y-d-m		Year-Month-Day	
	d.m.y		Day.Month.Year	
	m/d/y		Month/Day/Year	
SyncDI	-		DI not used for synchronizing	***)
	DI1 – DI6		Minute pulse input	
TZone	-15.00 – +15.00 *)		UTC time zone for SNTP synchronization.  Note: This is a decimal number. For example for state of Nepal the time zone 5:45 is given as 5.75	Set
DST	No; Yes		Daylight saving time for SNTP	Set

Parameter	Value	Unit	Description	Note
SySrc			Clock synchronisation source	
	Internal		No sync recognized since 200s	
	DI		Digital input	
	SNTP		Protocol sync	
	SpaBus		Protocol sync	
	ModBus		Protocol sync	
	ModBus TCP		Protocol sync	
	ProfibusDP		Protocol sync	
	IEC101		Protocol sync	
	IEC103		Protocol sync	
	DNP3		Protocol sync	
	IRIG-B003		IRIG timecode B003 ****)	
MsgCnt	0 – 65535, 0 – etc.		The number of received synchronisation messages or pulses	
Dev	±32767	ms	Latest time deviation between the system clock and the received synchronization	
SyOS	±10000.000	s	Synchronisation correction for any constant deviation in the synchronizing source	Set
AAIntv	±1000	s	Adapted auto adjust interval for 1 ms correction	Set**)
AvDrft	Lead; Lag		Adapted average clock drift sign	Set**)
FilDev	±125	ms	Filtered synchronisation deviation	

Set = An editable parameter (password needed).

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

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

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

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

### Synchronisation with DI

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

## Synchronisation correction

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

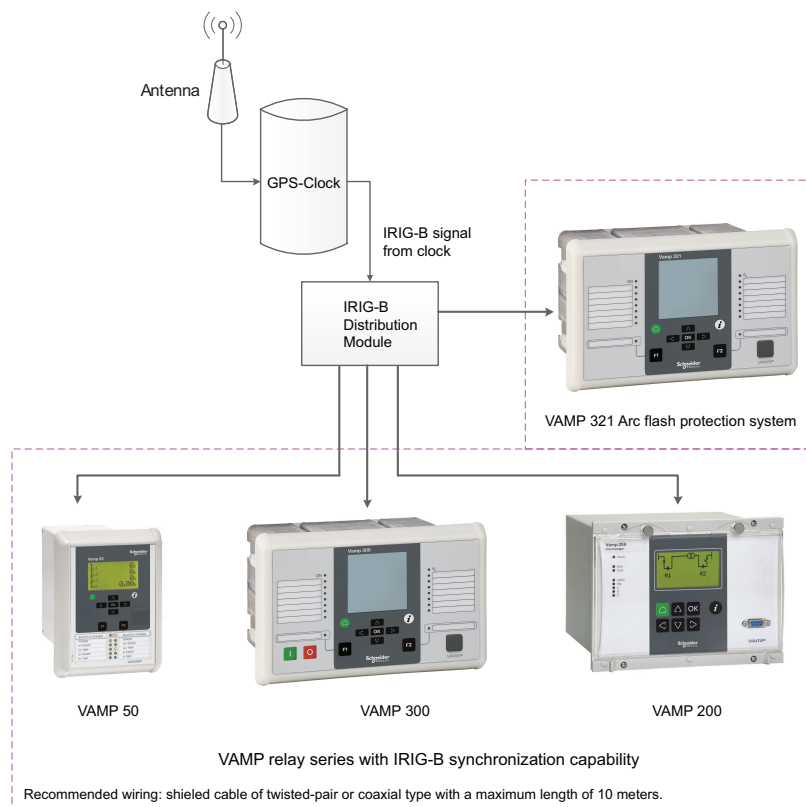
## Sync source

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

## Sync source: IRIG-B

IRIG standard time formats B003 and B004 are supported with a dedicated communication option with either a two-pole or two pins in a D9 rear connector (See Chapter 14 Order information).

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



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

### Deviation

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

### Auto-lag/lead

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

## 6.11 Running hour counter

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

**Table 6.17: Running hour counter parameters**

Parameter	Value	Unit	Description	Note
Runh	0 – 876000	h	Total active time, hours  Note: The label text "Runh" can be edited with VAMPSET.	(Set)
Runs	0 – 3599	s	Total active time, seconds	(Set)
Starts	0 – 65535		Activation counter	(Set)
Status	Stop Run		Current status of the selected digital signal	
DI	- DI1 – DI <sub>n</sub> , VI1 – VI <sub>n</sub> , LedAI, LedTr, LedA, LedB, LedC, LedDR, VO1 – VO6		Select the supervised signal  None Physical inputs Virtual inputs Output matrix out signal AI 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
Started at			Date and time of the last activation	
Stopped at			Date and time of the last inactivation	

Set = An editable parameter (password needed).

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

## 6.12 Timers

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

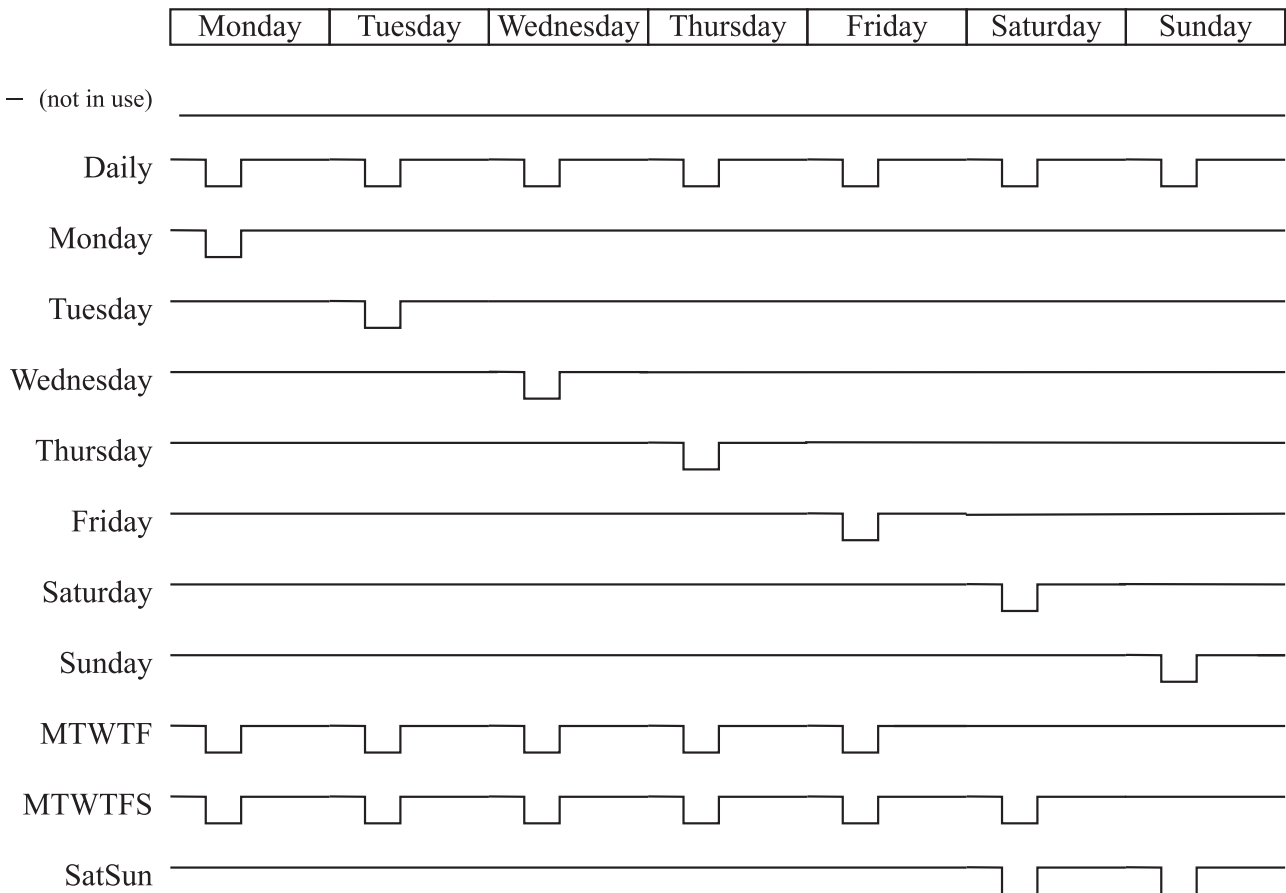


Figure 6.9: Timer output sequence in different modes.

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

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

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



**Table 6.18: Setting parameters of timers**

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

## 6.13 Combined overcurrent status

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

**Table 6.19: Line fault parameters**

Parameter	Value	Unit	Description	Note
IFitLas		$xI_N$	Current of the latest overcurrent fault	(Set)
<b>LINE ALARM</b>				
AlrL1			Start (=alarm) status for each phase.	
AlrL2	0		0 = No start since alarm ClrDly	
AlrL3	1		1 = Start is on	
OCs	0 1		Combined overcurrent start status. AlrL1 = AlrL2 = AlrL3 = 0 AlrL1 = 1 or AlrL2 = 1 or AlrL3 = 1	
LxAlarm	On / Off		'On' Event enabling for AlrL1 – 3 Events are enabled / Events are disabled	Set
LxAlarmOff	On / Off		'Off' Event enabling for AlrL1...3 Events are enabled / Events are disabled	Set
OCAAlarm	On / Off		'On' Event enabling for combined o/c starts Events are enabled / Events are disabled	Set
OCAAlarmOff	On / Off		'Off' Event enabling for combined o/c starts Events are enabled / Events are disabled	Set
IncFitEvtnt	On Off		Disabling several start <u>and</u> 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
<b>LINE FAULT</b>				
FitL1			Fault (=trip) status for each phase.	
FitL2	0		0 = No fault since fault ClrDly	
FitL3	1		1 = Fault is on	
OCT	0 1		Combined overcurrent trip status. FitL1 = FitL2 = FitL3 = 0 FitL1 = 1 or FitL2 = 1 or FitL3 = 1	
LxTrip	On / Off		'On' Event enabling for FitL1 – 3 Events are enabled / Events are disabled	Set
LxTripOff	On / Off		'Off' Event enabling for FitL1...3 Events are enabled / Events are disabled	Set
OCTrip	On / Off		'On' Event enabling for combined o/c trips Events are enabled / Events are disabled	Set

Parameter	Value	Unit	Description	Note
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.

## 6.14 Self-supervision

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

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

### 6.14.1 Diagnostics

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

#### **Permanent inoperative state**

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

#### **Temporal inoperative state**

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

#### **Diagnostic registers**

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

Register	Bit	Code	Description
SelfDiag1	0 (LSB)	T1	Potential output relay problem
	1	T2	
	2	T3	
	3	T4	
	4	A1	
	5	A2	
	6	A3	
	7	A4	
	8	A5	
	10	T5	
	11	T6	
	12	T7	
	13	T8	
SelfDiag3	0 (LSB)	DAC	Potential mA-output problem
	1	STACK	Potential stack problem
	2	MemChk	Potential memory problem
	3	BGTask	Potential background task timeout
	4	DI	Potential input problem (Remove DI1, DI2)
	5		
	6	Arc	Potential arc card problem
	7	SecPulse	Potential hardware problem
	8	RangeChk	DB: Setting outside range
	9	CPULoad	Overload
	10	+24V	Potential internal voltage problem
	11	-15V	
	12	ITemp	Internal temperature too high
	13	ADChk1	Potential A/D converter problem
	14	ADChk2	Potential A/D converter problem
15 (MSB)	E2prom	Potential E2prom problem	
SelfDiag4	1	ComBuff	Potential BUS: buffer problem

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

## 6.15 Incomer short circuit fault locator

The device includes a stand-alone fault locator algorithm. The algorithm can locate a short circuit in radial operated networks provided that the relay located in the incoming feeder is connected CT & VT polarity wise for forward (positive) power direction. In case the incoming feeder's power flow direction is configured negative the short circuit fault locator function does not work. The fault location is given as in reactance (ohms) and kilometres. Fault value can then be exported, for example, with event to a DMS (Distribution Management System). The system can then localize the fault. If a DMS is not available, the distance to the fault is displayed as kilometres, as well as a reactance value. However, the distance value is valid only if the line reactance is set correctly. Furthermore, the line should be homogenous, that is, the wire type of the line should be the same for the whole length. If there are several wire types on the same line, an average line reactance value can be used to get an approximate distance value to the fault (examples of line reactance values: Overhead wire Sparrow: 0.408 ohms/km and Raven: 0.378 ohms/km).

The fault locator is normally used in the incoming bay of the substation. Therefore, the fault location is obtained for the whole network with just one device. This is very cost-effective upgrade of an existing system.

### **The algorithm functions in the following order:**

1. The needed measurements (phase currents and voltages) are continuously available.
2. The fault distance calculation can be triggered in two ways: by opening a feeder circuit-breaker due to a fault and sudden increase in phase currents (Enable Xfault calc1 + Triggering digital input). Other option is to use only the sudden increase in the phase currents (Enable Xfault calc1).
3. Phase currents and voltages are registered in three stages: before the fault, during the fault and after the faulty feeder circuit-breaker was opened.
4. The fault distance quantities are calculated.
5. Two phases with the biggest fault current are selected.
6. The load currents are compensated.
7. The faulty line length reactance is calculated.

**Table 6.20: Setting parameters of incomer short circuit fault locator**

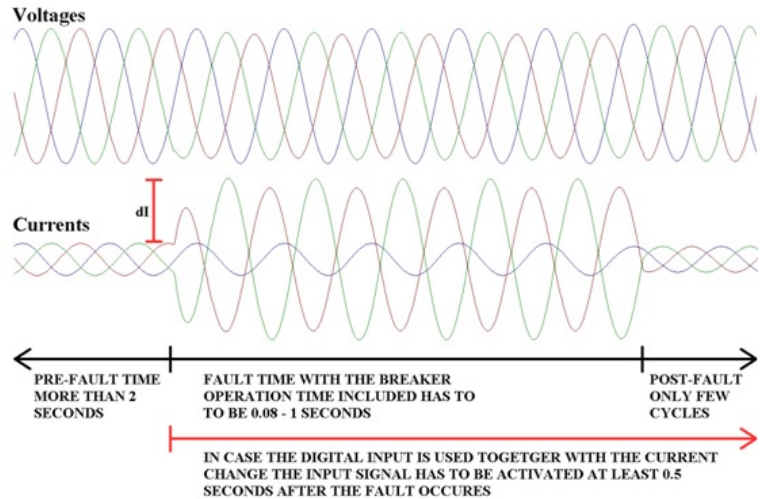
Parameter	Value	Unit	Default	Description
Triggering digital input	-; DI1 – DI18 VI1 – VI4 VO1 – VO6 NI1 – NI64 POC1 – POC16	-	-	Trigger mode (-= triggering based on sudden increase of phase current, otherwise sudden increase of phase current + $Dix/VIx$ )
Line reactance	0.010 – 10.000	Ohms/km	0.389	Line reactance of the line. This is used only to convert the fault reactance to kilometers.
dltrig	10 – 800	% In	50	Trig current (sudden increase of phase current)
Blocked before next trig	10 – 600	s	70	Blocks function for this et time after trigger. This is used for blocking calculation in autoreclose.
Xmax limit	0.5 – 500.0	Ohm	11.0	Limit for maximum reactance. If reactance value is above set limit calculation result will not be shown.
Event	Disabled; Enabled	-	Enabled	Event mask

**Table 6.21: Measured and recorded values of incomer short circuit fault locator**

	Parameter	Value	Unit	Description
Measured values/ recorded values	Distance		km	Distance to the fault
	Xfault		ohm	Fault reactance
	Date		-	Fault date
	Time		-	Fault time
	Time		ms	Fault time
	Cntr		-	Number of faults
	Pre		A	Pre-fault current (=load current)
	Fault		A	Current during the fault
	Post		A	Post-fault current
	Udrop		% Un	Voltage dip during the fault
	Durati		s	Fault duration
	Type		-	Fault type (1-2,2-3,1-3,1-2-3)

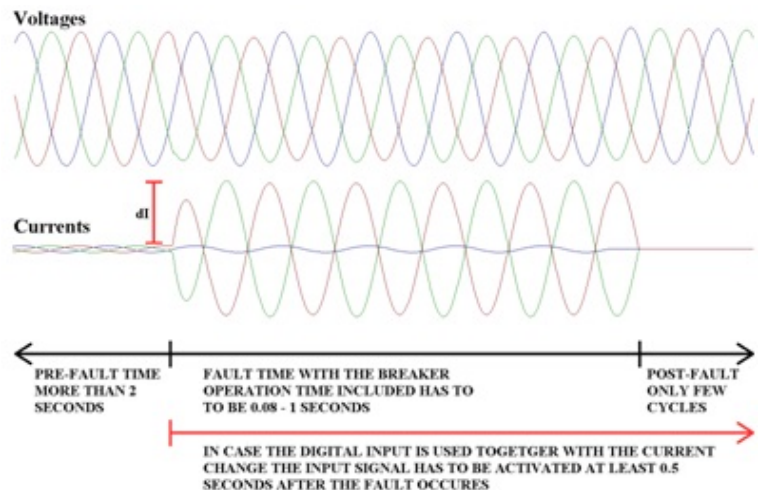
Below is presented an application example where the fault location algorithm is used at the incomer side. Notice following things while commissioning the relay:

INCOMER SC FAULT LOCATOR	
Enable Xfault calc 1	<input checked="" type="checkbox"/>
Fault reactance	22.03 ohm
Distance to fault	44.8 km
Voltage drop	74 %
Fault duration	1.10 s
Fault type	12
<b>Number of faults</b>	<b>1</b>
Fault date	2013-11-21
Fault time hh:mm:ss.mss	17:26:14.449
Current before fault	67 A
Fault current	1337 A
Current after fault	0 A
Algorithm condition OK	
Reference current	67 A
Trig limit current	300 A
Current change to trig	20 %
Triggering digital input	-
Line reactance/unit	0.492 ohm
Blocked before next trig	10 s
Xmax limit	50.0 ohm
Unit(km)	km
Event enabling	<input checked="" type="checkbox"/>



Below is presented an application example where the fault location algorithm is used at the feeder side. Notice following things while commissioning the relay:

INCOMER SC FAULT LOCATOR	
Enable Xfault calc 1	<input checked="" type="checkbox"/>
Fault reactance	22.03 ohm
Distance to fault	44.8 km
Voltage drop	74 %
Fault duration	1.10 s
Fault type	12
<b>Number of faults</b>	<b>1</b>
Fault date	2013-11-21
Fault time hh:mm:ss.mss	17:26:14.449
Current before fault	67 A
Fault current	1337 A
Current after fault	0 A
Algorithm condition OK	
Reference current	67 A
Trig limit current	300 A
Current change to trig	20 %
Triggering digital input	-
Line reactance/unit	0.492 ohm
Blocked before next trig	10 s
Xmax limit	50.0 ohm
Unit(km)	km
Event enabling	<input checked="" type="checkbox"/>





## 6.16 Feeder fault locator

The device includes a stand-alone fault locator algorithm. The algorithm can locate a short circuit and earth fault in radial operated networks. The fault location is given as in reactance (ohms) and kilometres. Fault value can then be exported, for example, with event to a DMS (Distribution Management System). The system can then localize the fault. If a DMS is not available, the distance to the fault is displayed as kilometres, as well as a reactance value.

However, the distance value is valid only if the line reactance is set correctly.

Furthermore, the line should be homogenous, that is, the wire type of the line should be the same for the whole length. If there are several wire types on the same line, an average line reactance value can be used to get an approximate distance value to the fault (examples of line reactance values: Overhead wire Sparrow: 0.408 ohms/km and Raven: 0.378 ohms/km).

This fault locator cannot be used in incomer because this locator has not ability to compensate healthy feeders away.

When feeder fault locator is calculating short circuit impedance following formula is used:

$$Z_{AB} = \frac{\overline{U_A} - \overline{U_B}}{\overline{I_A} - \overline{I_B}}$$

$\overline{U_A}$  = Vector between the voltage and the ground

$\overline{U_B}$  = Vector between the voltage and the ground

$\overline{I_A}$  = Vector between the current and the ground

$\overline{I_B}$  = Vector between the current and the ground

When feeder fault locator is calculating ground fault impedance following formula is used:

$$Z_A = \frac{\overline{U_A}}{\overline{I_A} + k \times 3\overline{I_0}}$$

$\overline{U_A}$  = Vector between the voltage and the ground

$\overline{I_A}$  = Vector between the current and the ground

k = Earth factor k, needs to be set by user

$3\overline{I_0}$  = Residual current, calculated from phase currents ( $I_{0Calc}$ )

Earth factor k is calculated with following formula:

$$K_0 = (Z_{0L} - Z_{1L}) / (3 \times Z_{1L})$$

$Z_{0L}$  = Zero sequence line impedance

$Z_{1L}$  = Positive sequence line impedance

Triggering of the fault reactance calculation happens when "Pick-up setting" -value is exceeded OR if user wants, both "Pick-up setting"

and “Triggering digital input” terms are fulfilled. When used, “Triggering digital input” can be either digital or virtual input.

**Table 6.22: Setting parameters of feeder fault locator**

Parameter	Value	Unit	Default	Description
Pick-up setting	0.10 – 5.00	xIn	1.2	Current limit for triggering.
Triggering digital input	-; DI1 – DI18 VI1 – VI4 VO1 – VO6 NI1 – NI64 POC1 – POC16	-	-	Trigger mode (= triggering based on sudden increase of phase current, otherwise sudden increase of phase current + DIx/VIx/VOx/NIx/POCx)
Line reactance	0.010 – 10.000	Ohms/km	0.491	Line reactance of the line. This is used only to convert the fault reactance to kilometers.
Earth factor	0.000 – 10.000	-	0.678	Calculated earth factor from line specifications.
Earth factor angle	-60 – +60	°	10	Angle of calculated earth factor from line specifications.
Event enabling	Off; On	-	On	Event mask

**Table 6.23: Measured and recorded values of feeder fault locator**

	Parameter	Value	Unit	Description
Measured values/ recorded values	Distance		km	Distance to the fault
	Xfault		ohm	Fault reactance
	Date		-	Fault date
	Time		-	Fault time
	Cntr		-	Number of faults
	Fault		A	Current during the fault
	Udrop		% Un	Voltage dip during the fault
	Type		-	Fault type (1-2, 2-3, 1-3, 1-2-3, 1-N, 2-N, 3-N, 1-N-2-N, 2-N-3-N, 3-N-1-N, 1-N-2-N-3-N)

**FEEDER FAULT LOCATOR**

Enable Xfault calc 2

Fault reactance 22.10 ohm  
Distance to fault 44.9 km  
Fault type 1-N\_3-N

Number of faults 5  
Algorithm condition OK

Pick-up setting 800 A  
Pick-up setting 0.80 xIn  
Triggering digital input -  
Line reactance/unit 0.492 ohm  
Earth factor 0.961  
Earth factor angle -34 °  
Unit(km) km  
Event enabling

**FAULT LOG**

	Date	hh:mm:ss.ms	Fault reactance	Distance to fault	Fault type	Voltage drop	Fault current
[1]	2013-11-21	17:23:38.070	22.10 ohm	44.9 km	1-N_3-N	57.9 %	1.71 xIn
[2]	2013-11-21	17:22:59.653	22.08 ohm	44.9 km	2-N	49.6 %	1.55 xIn
[3]	2013-11-21	17:22:20.074	43.86 ohm	89.1 km	12	37.6 %	1.07 xIn
[4]	2013-11-21	17:21:34.088	22.70 ohm	46.1 km	12	44.8 %	1.31 xIn
[5]	2013-11-21	17:21:12.669	23.39 ohm	47.5 km	12	44.7 %	1.14 xIn
[6]	-	-	0.00 ohm	0.0 km	-	0.0 %	0.00 xIn
[7]	-	-	0.00 ohm	0.0 km	-	0.0 %	0.00 xIn
[8]	-	-	0.00 ohm	0.0 km	-	0.0 %	0.00 xIn

**ADVANCED SETTINGS**

Uavg limit 2.0 %Un  
Io limit 0.50 xIn  
Io limit 500 A  
DI timeout 1.00 s  
Release timeout 0.50 s

## 6.17 Earth-fault location

The device includes a sophisticated stand-alone earth-fault location algorithm. The algorithm can locate an earth-fault accurately in radically operated compensated earthed networks.

The function can locate a fault only if the fault resistance is low, say less than 50 ohms. The fault location is given in reactance value. This value can then be exported, for example, with event to a DMS (Distribution Management System). The system can then localize the fault and display it on a map.

The fault location must be used in the incoming bay of the substation. Therefore, the fault location is obtained for the whole network with just one device. This is very cost-effective upgrade of an existing system.

Please note also that the earth-fault location function requires a change during an earth-fault. This change is done by switching the secondary resistor of the compensation coil on or off. The fault should be allowed to be on at least 200 ms, of which 100 ms without the resistor. The resistor change can be done by using the logic functionality of the device.

The reactance value is converted to distance in the DMS. The following formula is used:

$$S = \frac{3 * X}{X_0 + X_1 + X_2}$$

- S = distance in km  
 X reactance calculated by the device  
 X<sub>0</sub> = zero sequence reactance per kilometre of the line  
 X<sub>1</sub> = positive sequence reactance per kilometre of the line  
 X<sub>2</sub> = negative sequence reactance per kilometre of the line

### The algorithm functions in the following order:

1. The needed measurements (phase currents and voltages) are continuously available.
2. The fault distance calculation can be triggered in two ways: by switching ON or OFF the secondary resistor (that is, by using a digital input) or the calculation can be triggered if there is a change in earth fault or negative sequence current
3. The fault phase is identified by that the voltage of the faulted phase is decreased at least by half.
4. The fault distance is calculated by dividing the change of the voltage by the change of the negative sequence current.
5. Only the imaginary part is used, so then the reactance is solved.

**Table 6.24: Setting parameters of earth-fault location EFDi**

Parameter	Value	Unit	Default	Description
EfMode	Normal; Reverse	-	Normal	Normal: The resistor is switched ON during a fault. Reverse: The resistor is switched OFF during a fault
TrigIn	I <sub>0</sub> ;I <sub>2</sub> ;DI1	-	I <sub>0</sub>	Triggering input: I <sub>0</sub> : earth fault current will trig the function. I <sub>2</sub> : negative phase sequence current will trig the function DI1: the function is triggered by activating the digital input 1
UoTrig	1 – 80	% U <sub>0n</sub>	20	Trig level for U <sub>0</sub>
Itrig	10 – 800	% I <sub>n</sub>	80	Trig level for current
Event	On;Off	-	On	Event mask

**Table 6.25: Measured and recorded values of earth-fault location EFDi**

	Parameter	Value	Unit	Description
Measured values/ recorded values	Fault ph			Fault phase information
	X		ohm	Fault reactance
	Date		-	Fault date
	Time		-	Fault time
	Time		ms	Fault time
	Count		-	Number of faults

# 7 Measurement functions

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

The figure shows a current waveform and the corresponding fundamental frequency component  $f_1$ , second harmonic  $f_2$  and rms value in a special case, when the current deviates significantly from a pure sine wave.

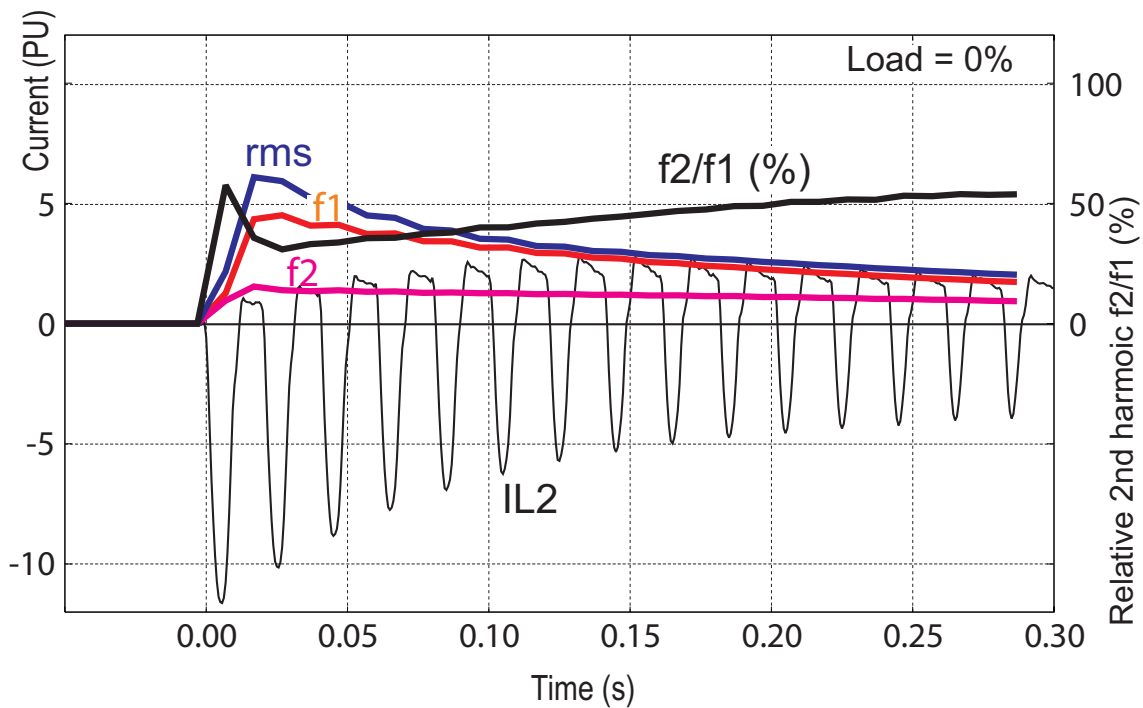


Figure 7.1: Example of various current values of a transformer inrush current

## 7.1 Measurement accuracy

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

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

**Table 7.2: Voltage inputs  $U_A, U_B, U_C, U_D$** 

Measuring range	0.5 – 175 V
Inaccuracy	$\pm 0.5\%$ or $\pm 0.3$ V
The usage of voltage inputs depends on the configuration parameter "voltage measurement mode". For Example $U_D$ is the zero sequence voltage input $U_0$ if the mode 3LN + $U_0$ is selected.	
The specified frequency range is 45 Hz – 65 Hz.	

**Table 7.3: Residual current inputs  $I_0$** 

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

**Table 7.4: Frequency**

Measuring range	16 Hz – 75 Hz
Inaccuracy	$\pm 10$ mHz

**Table 7.5: Power measurements  $P, Q, S$** 

Inaccuracy $ PF  > 0.5$	$\pm 1\%$ of value or $\pm 3$ VA <sub>SEC</sub>
The specified frequency range is 45 Hz – 65 Hz.	

**Table 7.6: Power factor  $\cos\varphi, \tan\varphi$** 

Inaccuracy $ PF  > 0.5$	$\pm 2^\circ$ or $\pm 0.02$
The specified frequency range is 45 Hz – 65 Hz.	

**Table 7.7: Energy counters  $E+, Eq+, E-, Eq-$** 

Inaccuracy $ PF  > 0.5$	$\pm 1\%$ of value or $\pm 3$ Wh <sub>SECONDARY</sub> /1 h
The specified frequency range is 45 Hz – 65 Hz.	

**Table 7.8: THD and harmonics**

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

## 7.2 RMS values

### RMS currents

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

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

### 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 7.5 Minimum and maximum values).

$$U_{RMS} = \sqrt{U_{f1}^2 + U_{f2}^2 + \dots + U_{f15}^2}$$

## 7.3 Harmonics and Total Harmonic Distortion (THD)

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

The harmonic distortion is calculated

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

$h_1 =$  Fundamental value  
 $h_{2-15} =$  Harmonics

### Example

$$h_1 = 100 \text{ A}, \quad h_3 = 10 \text{ A}, \quad h_7 = 3 \text{ A}, \quad h_{11} = 8 \text{ A}$$

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

For reference the RMS value is

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

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

## 7.4 Demand values

The relay calculates average i.e. demand values of phase currents  $I_{L1}$ ,  $I_{L2}$ ,  $I_{L3}$  and power values S, P and Q.

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

**Table 7.9: Demand value parameters**

Parameter	Value	Unit	Description	Set
Time	10 – 30	min	Demand time (averaging time)	Set
<b>Fundamental frequency values</b>				
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	
<b>RMS values</b>				
IL1da		A	Demand of phase current IL1	
IL2da		A	Demand of phase current IL2	
IL3da		A	Demand of phase current IL3	

Set = An editable parameter (password needed).

## 7.5 Minimum and maximum values

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

Min & Max measurement	Description
IL1, IL2, IL3	Phase current (fundamental frequency value)
IL1RMS, IL2RMS, IL3RMS	Phase current, rms value
$I_0$	Residual current
U12, U23, U31	Line-to-line voltage
$U_0$	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.



**Table 7.10: Parameters**

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

Set = An editable parameter (password needed).

## 7.6 Maximum values of the last 31 days and 12 months

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

Measurement	Max	Min	Description	31 days	12 months
IL1, IL2, IL3	X		Phase current (fundamental frequency value)		
Io	X		Residual current		
S	X		Apparent power	X	X
P	X	X	Active power	X	X
Q	X	X	Reactive power	X	X

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

**Table 7.11: Parameters of the day and month registers**

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

Set = An editable parameter (password needed).

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

## 7.7 Voltage measurement modes

Line manager VAMP 259 is always used in the line to ground measurement mode (3LN) and simultaneously to line-to-line (LLy) or line-to-ground (LNy) or residual voltage ( $U_0$ ) measurement mode. Two first alternatives (LLy and LNy) enable synchrocheck stage and third mode ( $U_0$ ) enable intermittent transient e/f stage.

The available modes are:

- “3LN/LLy”  
The synchrocheck voltage transformer is connected to line-to-line voltages  $U_{12}$ .
- “3LN/LNy ”  
The synchrocheck voltage transformer is connected to line-to-ground voltage  $U_{L1}$ .
- “3LN+ $U_0$ ”  
This connection is typically used for feeder protection schemes when intermittent transient earth fault protection is needed.

## 7.8 Power calculations

The equations used for power calculations are described in this chapter. Following equation is used for power calculation.

### The device is connected to line-to-neutral voltage

$$\bar{S} = \bar{U}_{L1} \cdot \bar{I}_{L1}^* + \bar{U}_{L2} \cdot \bar{I}_{L2}^* + \bar{U}_{L3} \cdot \bar{I}_{L3}^*$$

$\bar{S}$  = Three phase power phasor

$\bar{U}_{L1}$  = Measured voltage phasor corresponding the fundamental frequency voltage of phase L1.

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

$\bar{U}_{L2}$  = Measured voltage phasor corresponding the fundamental frequency voltage of phase L2.

$\bar{I}_{L2}^*$  = Complex conjugate of the measured phase L2 fundamental frequency current phasor.

$\bar{U}_{L3}$  = Measured voltage phasor corresponding the fundamental frequency voltage of phase L3.

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

Apparent power, active power and reactive power are calculated similarly as with line-to-line voltages

$$S = |\bar{S}|$$

$$P = \text{real}(\bar{S})$$

$$Q = \text{imag}(\bar{S})$$

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

# 7.9 Direction of power and current

Figure 7.2 shows the concept of three phase current direction and sign of  $\cos\phi$  and power factor PF. Figure 7.3 shows the same concepts, but on a PQ-power plane.

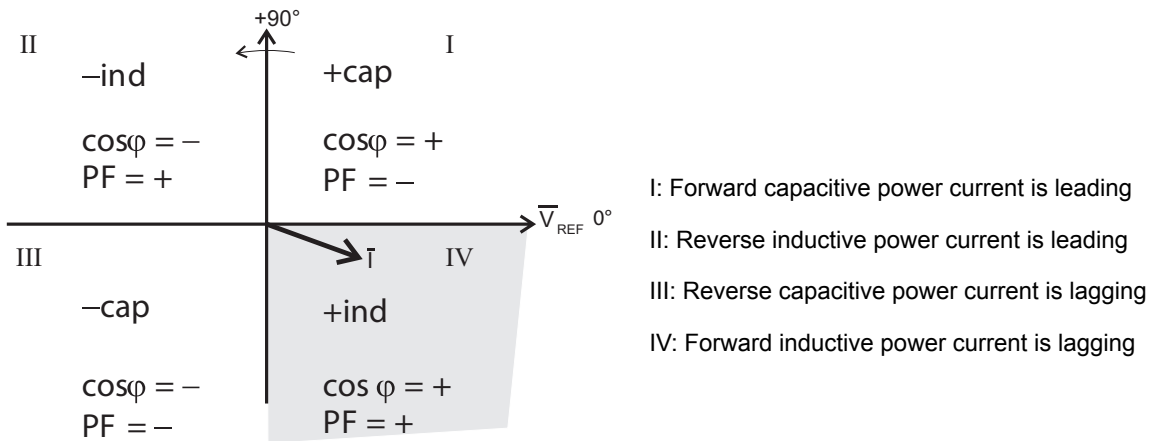


Figure 7.2: Quadrants of voltage/current phasor plane

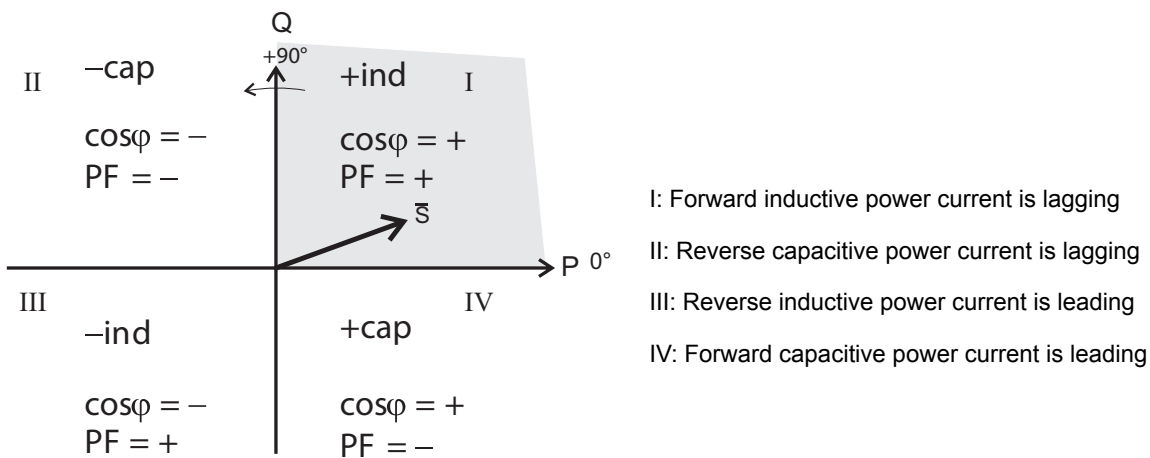


Figure 7.3: Quadrants of power plane

Table 7.12: Power quadrants

Power quadrant	Current related to voltage	Power direction	$\cos\phi$	Power factor PF
+ inductive	Lagging	Forward	+	+
+ capacitive	Leading	Forward	+	-
- inductive	Leading	Reverse	-	+
- capacitive	Lagging	Reverse	-	-

## 7.10 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:

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

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

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

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

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

$\underline{U}$  = phasor of phase L1 (phase current or line-to-neutral voltage)

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

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

**NOTE:** The zero sequence or residual measurement signals connected to the device are  $-U_0$  and  $3I_0$ . However, usually the name “ $I_0$ ” is used instead of the correct name “ $3I_0$ ”.

### 1. Single phase injection

$$U_N = 100 \text{ V}$$

Injection:

$$U_{L1} = U_{12} = 100 \text{ V}$$

$$U_{L2} = U_{23} = 0$$

$$\begin{bmatrix} \underline{U}_1 \\ \underline{U}_2 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & -\underline{a}^2 \\ 1 & -\underline{a} \end{bmatrix} \begin{bmatrix} 100 \angle 0^\circ \\ 0 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 100 \angle 0^\circ \\ 100 \angle 0^\circ \end{bmatrix} = \begin{bmatrix} 33 \\ 33 \end{bmatrix}$$

$$U_1 = 33 \%$$

$$U_2 = 33 \%$$

$$U_2 / U_1 = 100 \%$$

When using a single phase test device, the relative unbalance  $U_2 / U_1$  will always be 100 %.

## 2. Two phase injection with adjustable phase angle

$$U_N = 100 \text{ V}$$

Injection:

$$U_{L1} = U_{L1} = 100/\sqrt{3} \text{ V } \angle 0^\circ = 57.7 \text{ V } \angle 0^\circ$$

$$U_{L2} = U_{L2} = 100/\sqrt{3} \text{ V } \angle -120^\circ = 57.7 \text{ V } \angle -120^\circ$$

$$U_{L3} = U_{L3} = 0 \text{ V}$$

This is actually identical case with example 2 because the resulting line-to-line voltages  $U_{12} = U_{L1} - U_{L2} = 100 \text{ V } \angle 30^\circ$  and  $U_{23} = U_{L2} - U_{L3} = U_{L2} = 100/\sqrt{3} \text{ V } \angle -120^\circ$  are the same as in example 2. The only difference is a  $+30^\circ$  phase angle difference, but without any absolute angle reference this phase angle difference is not seen by the device.

$$\begin{aligned} \begin{bmatrix} \underline{U}_0 \\ \underline{U}_1 \\ \underline{U}_2 \end{bmatrix} &= \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \underline{a} & \underline{a}^2 \\ 1 & \underline{a}^2 & \underline{a} \end{bmatrix} \begin{bmatrix} \frac{100}{\sqrt{3}} \angle 0^\circ \\ \frac{100}{\sqrt{3}} \angle -120^\circ \\ 0 \end{bmatrix} = \frac{1}{3\sqrt{3}} \begin{bmatrix} 100 \angle 0^\circ + 100 \angle -120^\circ \\ 100 \angle 0^\circ + 100 \angle 0^\circ \\ 100 \angle 0^\circ + 100 \angle +120^\circ \end{bmatrix} = \\ &= \frac{1}{3\sqrt{3}} \begin{bmatrix} 100 \angle -60^\circ \\ 200 \angle 0^\circ \\ 100 \angle 60^\circ \end{bmatrix} = \begin{bmatrix} 19.2 \angle -60^\circ \\ 38.5 \angle 0^\circ \\ 19.2 \angle +60^\circ \end{bmatrix} \end{aligned}$$

$$U_0 = 19.2 \%$$

$$U_1 = 38.5 \%$$

$$U_2 = 19.2 \%$$

$$U_2 / U_1 = 50 \%$$

Figure 7.4 shows a graphical solution. The input values have been scaled with  $\sqrt{3}/100$  to make the calculation easier.

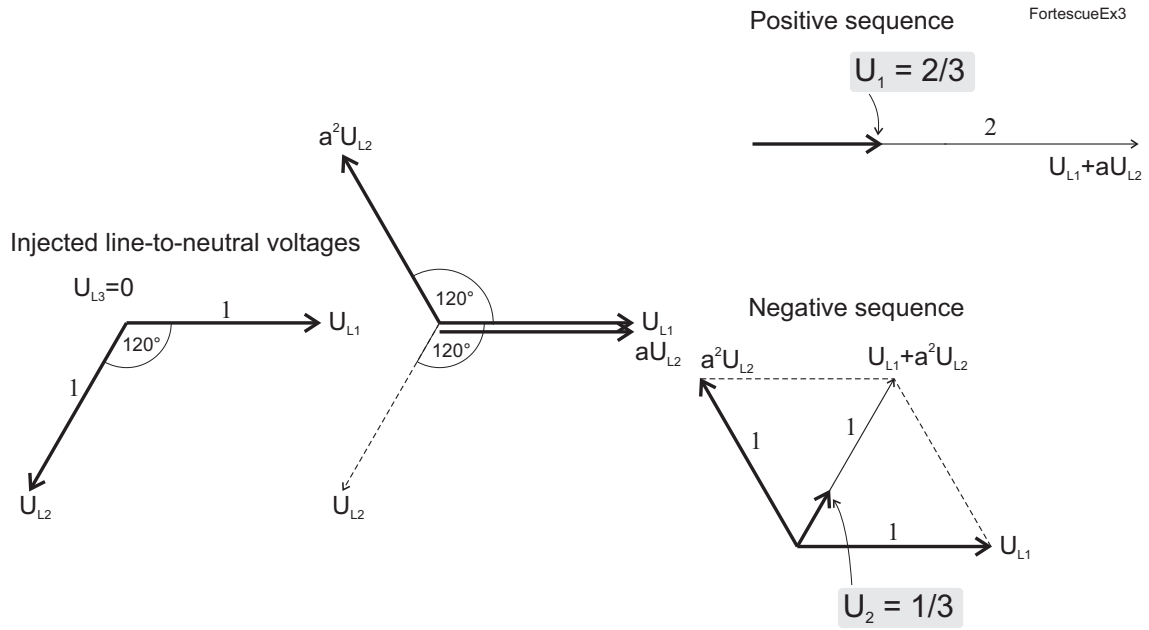


Figure 7.4: Example of symmetric component calculation using line-to-neutral voltages.

Unscaling the geometric results gives

$$U_1 = 100/\sqrt{3} \times 2/3 = 38.5 \%$$

$$U_2 = 100/\sqrt{3} \times 1/3 = 19.2 \%$$

$$U_2 / U_1 = 1/3:2/3 = 50 \%$$

## 7.11 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 ratios in the “Scaling” of the relay.

The following scaling equations are useful when doing secondary testing.

### 7.11.1 Current scaling

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

#### Primary and secondary scaling

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

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

Examples:

#### 1. Secondary to primary

$$CT = 500 / 5$$

Current to the relay's input is 4 A.

$$\Rightarrow \text{Primary current is } I_{PRI} = 4 \times 500 / 5 = 400 \text{ A}$$

#### 2. Primary to secondary

$$CT = 500 / 5$$

The relay displays  $I_{PRI} = 400 \text{ A}$

$$\Rightarrow \text{Injected current is } I_{SEC} = 400 \times 5 / 500 = 4 \text{ A}$$



**Per unit [pu] scaling**

For phase currents excluding Arcl> stage:

1 pu = 1 x  $I_N$  = 100 %, where

$I_N$  is the rated current according to the mode. See Chapter 1.7 Abbreviations

For residual currents and Arcl> stage:

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

	Phase current scaling for phase currents, Arcl> stage and residual current ( $3I_0$ )
secondary → per unit	$I_{PU} = \frac{I_{SEC}}{CT_{SEC}}$
per unit → secondary	$I_{SEC} = I_{PU} \cdot CT_{SEC}$

Examples:

1. **Secondary to per unit for feeder mode and Arcl>**

$$CT = 750 / 5$$

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

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

2. **Per unit to secondary for feeder mode and Arcl>**

$$CT = 750 / 5$$

The device setting is 2 pu = 200 %.

Secondary current is  $I_{SEC} = 2 \times 5 = 10$  A

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

Input is  $I_0$ .

$$CT_0 = 50 / 1$$

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

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

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

Input is  $I_0$ .

$$CT_0 = 50 / 1$$

The relay setting is 0.03 pu = 3 %.

Secondary current is  $I_{SEC} = 0.03 \times 1 = 30$  mA

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

Input is  $I_{0Calc}$ .

$$CT = 750 / 5$$

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

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

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

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

Input is  $I_{0Calc}$ .

$$CT = 750 / 5$$

The relay setting is  $0.1 \text{ pu} = 10 \%$ .

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

## 7.11.2 Voltage scaling

### Primary / secondary scaling of line-to-line voltages

secondary → primary	$U_{PRI} = \sqrt{3} \cdot U_{SEC} \cdot \frac{VT_{PRI}}{VT_{SEC}}$
primary → secondary	$U_{SEC} = \frac{U_{PRI}}{\sqrt{3}} \cdot \frac{VT_{SEC}}{VT_{PRI}}$

Examples:

#### 1. Secondary to primary

$$VT = 12000 / 110$$

Three phase symmetric voltages connected to the device's inputs  $U_A$ ,  $U_B$  and  $U_C$  are 57.7 V.

$$\text{Primary voltage is } U_{PRI} = \sqrt{3} \times 58 \times 12000 / 110 = 10902 \text{ V}$$

#### 2. Primary to secondary

$$VT = 12000 / 110$$

The relay displays  $U_{12} = U_{23} = U_{31} = 10910 \text{ V}$ .

Symmetric secondary voltages at  $U_A$ ,  $U_B$  and  $U_C$  are  $U_{SEC} = 10910 / \sqrt{3} \times 110 / 12000 = 57.7 \text{ V}$ .

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

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

secondary → per unit	$U_{PU} = \sqrt{3} \cdot \frac{U_{SEC}}{VT_{SEC}} \cdot \frac{VT_{PRI}}{U_N}$
per unit → secondary	$U_{SEC} = U_{PU} \cdot \frac{VT_{SEC}}{\sqrt{3}} \cdot \frac{U_N}{VT_{PRI}}$

Examples:

#### 1. Secondary to per unit.

$$VT = 12000 / 110,$$

Three symmetric phase-to-neutral voltages connected to the device's inputs  $U_A$ ,  $U_B$  and  $U_C$  are 63.5 V

$$\text{Per unit voltage is } U_{PU} = \frac{\sqrt{3} \times 63.5}{110 \times 12000 / 11000} = 1.00$$

$$\text{pu} = 1.00 \times U_N = 100\%$$

#### 2. Per unit to secondary.

$$VT = 12000 / 110, U_N = 11000 \text{ V}$$

The relay displays 1.00 pu = 100 %.

Three symmetric phase-to-neutral voltages connected to the device's inputs  $U_A$ ,  $U_B$  and  $U_C$  are

$$U_{SEC} = 1.00 \times 110 / \frac{\sqrt{3}}{12000} \times 11000 = 58.2 \text{ V}$$

### Per unit [pu] scaling of zero sequence voltage

	Zero-sequence voltage ( $U_0$ ) scaling	
	Voltage measurement mode = "3LN+U <sub>0</sub> "	Voltage measurement mode = "3LN"
secondary -> per unit	$U_{PU} = \frac{U_{SEC}}{U_{0SEC}}$	$U_{PU} = \frac{1}{VT_{SEC}} \cdot \frac{ \bar{U}_a + \bar{U}_b + \bar{U}_c _{SEC}}{\sqrt{3}}$
per unit -> secondary	$U_{SEC} = U_{PU} \cdot U_{0SEC}$	$ \bar{U}_a + \bar{U}_b + \bar{U}_c _{SEC} = \sqrt{3} \cdot U_{PU} \cdot VT_{SEC}$

Examples:

1. **Secondary to per unit.**

$$VT = 12000 / 110$$

Voltage connected to the device's input  $U_A$  is 38.1 V, while

$$U_A = U_B = 0.$$

Per unit voltage is  $U_{PU} = (38.1 + 0 + 0) / (\sqrt{3} \times 110) = 0.20 \text{ pu} = 20 \%$

2. **Per unit to secondary.**

$$VT = 12000/110$$

The device displays  $U_0 = 20 \%$ .

If  $U_B = U_C = 0$ , then secondary voltages at  $U_A$  is  $U_{SEC} = \sqrt{3} \times 0.2 \times 110 = 38.1 \text{ V}$

# 8 Control functions

## 8.1 Output relays

The output relays are also called digital outputs. Any internal signal can be connected to the output relays using output matrix. An output relay can be configured as latched or non-latched. See Chapter 8.4 Output matrix for more details.

**NOTE:** If the device has the mA option, it is equipped with only three alarm relays from A1 to A3.

The difference between trip contacts and signal contacts is the DC breaking capacity. See Table 12.5 and Table 12.6 for details. The contacts are SPST normal open type (NO), except alarm relays A1 – A3, which have change over contacts (SPDT). Polarity of all output relays can be changed in VAMPSET or from Local display.

**Table 8.1: Parameters of output relays**

Parameter	Value	Unit	Description	Note
T1 – T14	0		Status of trip output relay	F
	1		(The actual number of relays depends on the ordering code)	
A1 – A5	0		Status of alarm output relay	F
	1			
SF	0		Status of the SF relay	F
	1		In VAMPSET, it is called as "Service status output"	
Force	On		Force flag for output relay forcing for test purposes. This is a common flag for all output relays and detection stage status, too. Any forced relay(s) and this flag are automatically reset by a 5-minute timeout.	Set
	Off			
<b>REMOTE PULSES</b>				
A1 – A5	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
<b>NAMES for OUTPUT RELAYS (editable with VAMPSET only)</b>				
Description	String of max. 32 characters		Names for DO on VAMPSET screens. Default is "Trip relay n", n=1 – 14 or "signal relay n", n=1 – 5	Set

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

## 8.2 Digital inputs

There are 1 – 28 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 contacts connected to digital inputs DI1 – DI6 must be dry (potential free). These inputs use the common internal 48 Vdc wetting voltage from pin X3:1, only.

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

It is possible to use different control voltages for DI7 – 20.

Selection in order code	Nominal voltage
4	24V dc/ac (max 265 V)
5	24V dc/ac (max 265 V) (UL)
6	110V dc/ac (max 265 V)
7	220V dc/ac (max 265 V)

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

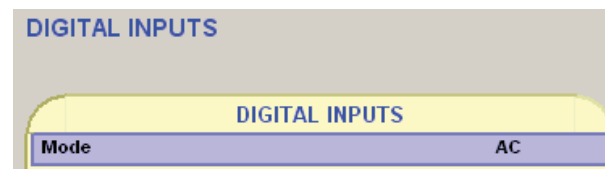


Figure 8.1: AC mode selection in VAMPSET

These inputs are ideal for transferring the status information of switching devices into the device. Please note that it is possible to use two different control voltages for the inputs.

**Table 8.2: Summary of digital inputs:**

DI	Pins	Operating voltage	Note
<-	X3:1	48VDC supply for DI1 – 6	Always available
1	X3:2	Internal 48VDC	
2	X3:3		
3	X3:4		
4	X3:5		
5	X3:6		
6	X3:7		

DI	Pins	Operating voltage	Note
7	X7:1	External 18 – 265 VDC 50 – 250 VAC	Always available
8	X7:2		
9	X7:3		
10	X7:4		
11	X7:5		
12	X7:6		
->	X7:7	Common for DI7 – 12	
13	X7:8	External 18 – 265 VDC 50 – 250 VAC	Always available
14	X7:9		
15	X7:10		
16	X7:11		
17	X7:12		
18	X7:13		
->	X7:14	Common for DI13 – 17	
<b>Optional arc card with 2 DIs</b>			
19	X6:1 – 2	External 18 – 265 VDC	
20	X6:3 – 4	50 – 250 VAC	
<b>Optional additional I/O (X8)</b>			
21	X8:1	External 18 – 265 VDC	
22	X8:2	50 – 250 VAC	
->	X8:3	Common for D21 – 22	
23	X8:4	External 18 – 265 VDC	
24	X8:5	50 – 250 VAC	
->	X8:6	Common for D23 – 24	
25	X8:7	External 18 – 265 VDC	
26	X8:8	50 – 250 VAC	
->	X8:9	Common for D25 – 26	
27	X8:10	External 18 – 265 VDC	
28	X8:11	50 – 250 VAC	
->	X8:12	Common for D27 – 28	

**NOTE:** These digital inputs must not be connected parallel with inputs of an another device.

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



**Table 8.3: Parameters of digital inputs**

Parameter	Value	Unit	Description	Note
DI1 – DI <sub>n</sub>	0; 1		Status of digital input	
<b>DI COUNTERS</b>				
DI1 – DI <sub>n</sub>	0 – 65535		Cumulative active edge counter	(Set)
<b>DELAYS FOR DIGITAL INPUTS</b>				
DI1 – DI <sub>n</sub>	0.00 – 60.00	s	Definite delay for both on and off transitions	Set
<b>CONFIGURATION DI1 – DI32</b>				
Inverted	no		For normal open contacts (NO). Active edge is 0 -> 1	Set
	yes		For normal closed contacts (NC). Active edge is 1 -> 0	
Indication display	no		No pop-up display	Set
	yes		Indication display is activated at active DI edge	
On event	On		Active edge event enabled	Set
	Off		Active edge event disabled	
Off event	On		Inactive edge event enabled	Set
	Off		Inactive edge event disabled	
<b>NAMES for DIGITAL INPUTS (editable with VAMPSET only)</b>				
Label	String of max. 10 characters		Short name for DIs on the local display. Default is "DI <sub>n</sub> ", n = 1 – 32	Set
Description	String of max. 32 characters		Long name for DIs. Default is "Digital input n", n = 1 – 32	Set

Set = An editable parameter (password needed).

## 8.3 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.

**Table 8.4: Parameters of virtual inputs**

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

Set = An editable parameter (password needed).

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

## 8.4 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 three general purpose LED indicators - "A", "B" and "C" - 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 8.2.

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.

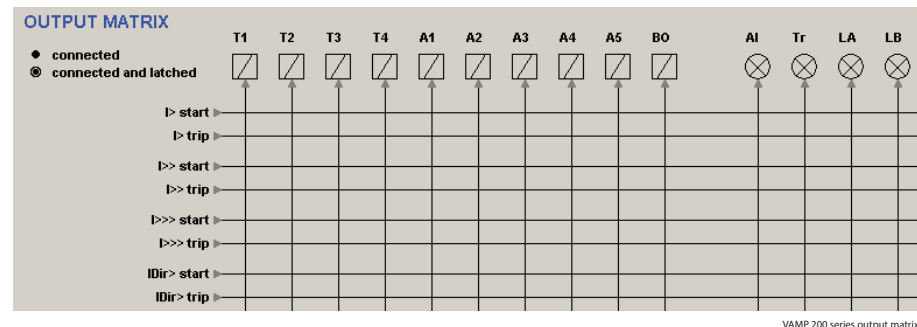


Figure 8.2: Output matrix.

## 8.5 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 DI $n$  (see Chapter 14 Order information), or it can be a start or trip signal from a protection stage or an output signal from the user's programmable logic. In the block matrix Figure 8.3 an active blocking is indicated with a black dot (•) in the crossing point of a blocking signal and the signal to be blocked.

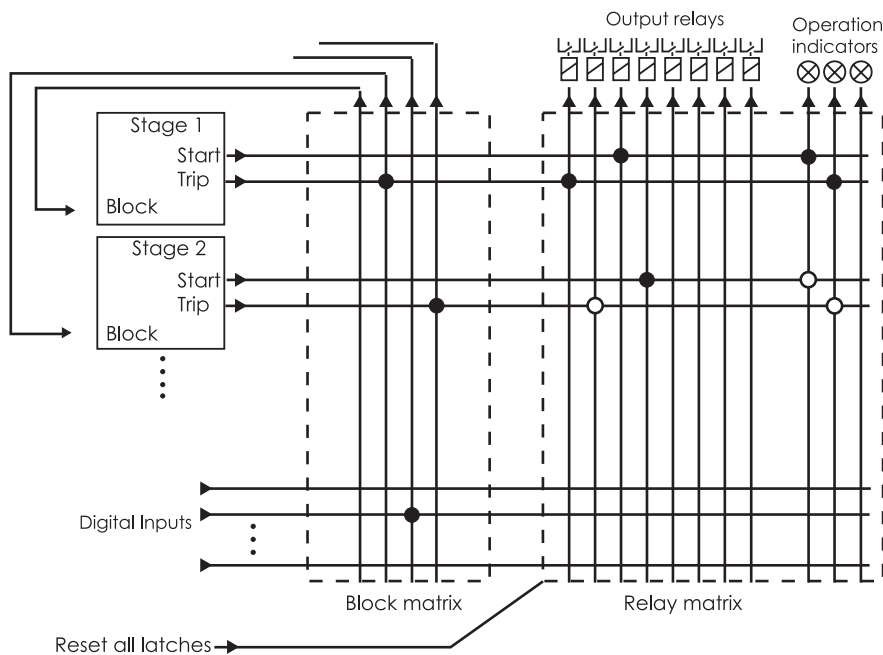


Figure 8.3: Blocking matrix and output matrix

### NOTICE

#### RISK OF NUISANCE TRIPPING

- The blocking matrix is dynamically controlled by selecting and deselecting protection stages.
- Activate the protection stages first, then store the settings in a relay. After that, refresh the blocking matrix before configuring it.

**Failure to follow these instructions can result in unwanted shutdown of the electrical installation.**

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

Controlling is possible by the following ways:

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

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

### Object states

Each object has the following states:

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

### Basic settings for controllable objects

Each controllable object has the following settings:

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

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

**Each controllable object has 2 control signals in matrix:**

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

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

**Settings for read-only objects**

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

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

**8.6.1****Controlling with DI**

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

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

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

**8.6.2****Local/Remote selection**

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

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

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

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

## 8.7 Auto-reclose function (79)

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

### General

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

### Terminology

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

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

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

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

The auto-reclose (AR) matrix in the following Figure 8.4 describes the start and trip signals forwarded to the auto-reclose function.

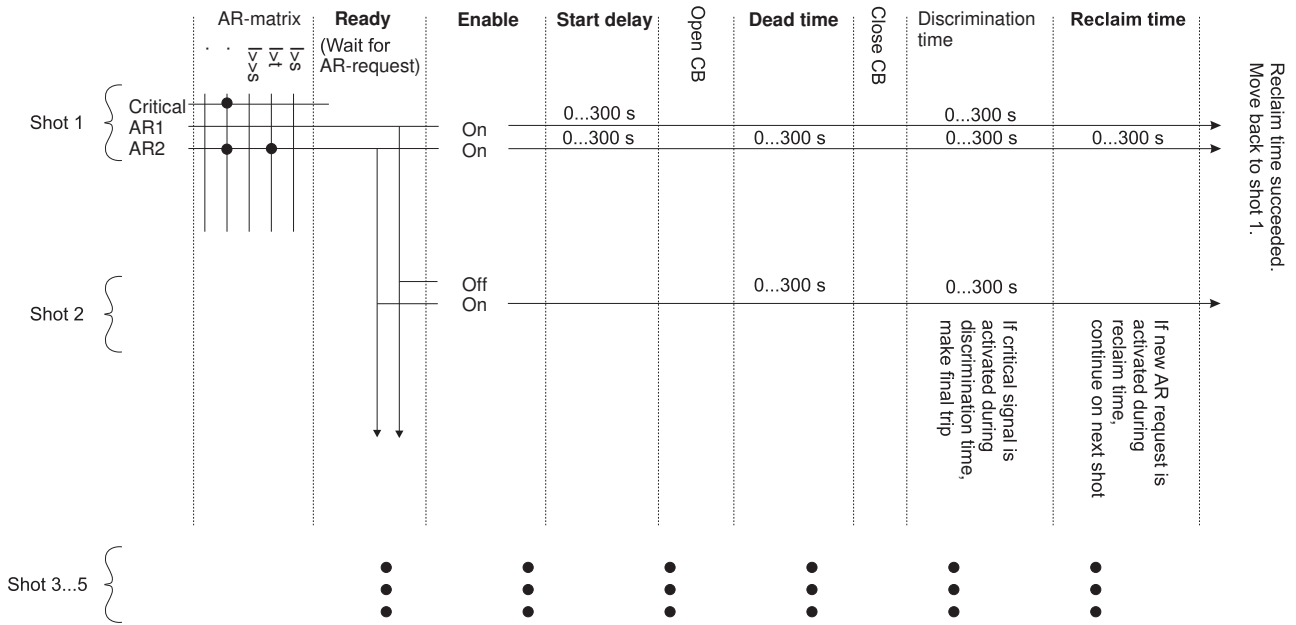


Figure 8.4: Auto-reclose matrix

The AR matrix above defines which signals (the start and trip signals from protection stages or digital input) are forwarded to the auto-reclose function. In the AR function, the AR signals can be configured to initiate the reclose sequence. Each shot from 1 to 5 has its own enabled/disabled flag. If more than one AR signal activates at the same time, AR1 has highest priority and AR2 the lowest. Each AR signal has an independent start delay for the shot 1. If a higher priority AR signal activates during the start delay, the start delay setting will be changed to that of the highest priority AR signal.

After the start delay the circuit-breaker (CB) will be opened if it is closed. When the CB opens, a dead time timer is started. Each shot from 1 to 5 has its own dead time setting.

After the dead time the CB will be closed and a discrimination time timer is started. Each shot from 1 to 5 has its own discrimination time setting. If a critical signal is activated during the discrimination time, the AR function makes a final trip. The CB will then open and the AR sequence is locked. Closing the CB manually clears the “locked” state.

After the discrimination time has elapsed, the reclaim time timer starts. If any AR signal is activated during the reclaim time or the discrimination time, the AR function moves to the next shot. The reclaim time setting is common for every shot.

If the reclaim time runs out, the auto-reclose sequence is successfully executed and the AR function moves to ready -state and waits for a new AR request in shot 1.



A trip signal from the protection stage can be used as a backup. Configure the start signal of the protection stage to initiate the AR function. If something fails in the AR function, the trip signal of the protection stage will open the CB. The delay setting for the protection stage should be longer than the AR start delay and discrimination time.

If a critical signal is used to interrupt an AR sequence, the discrimination time setting should be long enough for the critical stage, usually at least 100 ms.

### Manual closing

When CB is closed manually with the local panel, remote bus, digital inputs etc, the reclaim-state is activated. Within the reclaim time all AR requests are ignored. It is up to protection stages to take care of tripping. Trip signals of protection stages must be connected to a trip relay in the output matrix.

### Manual opening

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

### Reclaim time setting

- Use shot specific reclaim time: No  
Reclaim time setting defines reclaim time between different shots during sequence and also reclaim time after manual closing.
- Use shot specific reclaim time: Yes  
Reclaim time setting defines reclaim time only for manual control. Reclaim time between different shots is defined by shot specific reclaim time settings.

### Support for 2 circuit breakers

AR function can be configured to handle 2 controllable objects. Object 1 – 6 can be configured to CB1 and any other controllable object can be used as CB2. The object selection for CB2 is made with **Breaker 2 object** setting. Switching between the two objects is done with a digital input, virtual input, virtual output or by choosing **Auto CB selection**. AR controls CB2 when the input defined by **Input for selecting CB2** setting is active (except when using auto CB selection when operated CB 1 or 2 is that which was last in close state). Control is changed to another object only if the current object is not close.

### Blocking of AR shots

Each AR shot can be blocked with a digital input, virtual input or virtual output. Blocking input is selected with **Block** setting. When selected input is active the shot is blocked. A blocked shot is treated like it doesn't exist and AR sequence will jump over it. If the last shot in use is blocked, any AR request during reclaiming of the previous shot will cause final tripping.

### Starting AR sequence

Each AR request has own separate starting delay counter. The one which starting delay has elapsed first will be selected. If more than one delay elapses at the same time, an AR request of the highest priority is selected. AR1 has the highest priority and AR4 has the lowest priority. First shot is selected according to the AR request. Next AR opens the CB and starts counting dead time.

### Starting sequence at shot 2 – 5 & skipping of AR shots

Each AR request line can be enabled to any combination of the 5 shots. For example making a sequence of **Shot 2** and **Shot 4** for AR request 1 is done by enabling AR1 only for those two shots.

**NOTE:** If AR sequence is started at shot 2 – 5 the starting delay is taken from the discrimination time setting of the previous shot. For example if Shot 3 is the first shot for AR2, the starting delay for this sequence is defined by Discrimination time of Shot 2 for AR2.

### Critical AR request

Critical AR request stops the AR sequence and cause final tripping. Critical request is ignored when AR sequence is not running and also when AR is reclaiming.

Critical request is accepted during dead time and discrimination time.

### Shot active matrix signals

When starting delay has elapsed, active signal of the first shot is set. If successful reclosing is executed at the end of the shot, the active signal will be reset after reclaim time. If reclosing was not successful or new fault appears during reclaim time, the active of the current shot is reset and active signal of the next shot is set (if there are any shots left before final trip).

### AR running matrix signal

This signal indicates dead time. The signal is set after controlling CB open. When dead time ends, the signal is reset and CB is controlled close.

### Final trip matrix signals

There are 5 final trip signals in the matrix, one for each AR request (1 to 4 and 1 critical). When final trip is generated, one of these signals is set according to the AR request which caused the final tripping. The final trip signal will stay active for 0.5 seconds and then resets automatically.

### DI to block AR setting

This setting is useful with an external synchro-check device. This setting only affects re-closing the CB. Re-closing can be blocked with a digital input, virtual input or virtual output. When the blocking input is active, CB won't be closed until the blocking input becomes inactive again. When blocking becomes inactive the CB will be controlled close immediately.

### AR info for mimic display setting

When AR info is enabled, the local panel mimic display shows small info box during AR sequence.

**Table 8.5: Setting parameters of AR function**

Parameter	Value	Unit	Default	Description
ARena	ARon; ARoff	-	ARon	Enabling/disabling the autoreclose
ExtSync	None, any digital input, virtual input or virtual output	-	-	The digital input for blocking CB close. This can be used for Synchrocheck.
AR_DI	None, any digital input, virtual input or virtual output	-	-	The digital input for toggling the ARena parameter
AR2grp	ARon; ARoff	-	ARon	Enabling/disabling the autoreclose for group 2
RecIT	0.02 – 300.00	s	10.00	Reclaim time setting. This is common for all the shots.
CB	Obj1 – Obj6		Obj1	Breaker object in use
CB1	Obj1 – Obj6		Obj1	Breaker 1 object
CB2	Obj1 – Obj6		-	Breaker 2 object
AutoCBSel	On; Off		off	Enabling/disabling the auto CB selection
CB2Sel	None, any digital input, virtual input or virtual output		-	The digital input for selecting the CB2.
ARreq	On; Off	-	Off	AR request event
ShotS	On; Off	-	Off	AR shot start event
ARlock	On; Off	-	Off	AR locked event
CritAr	On; Off	-	Off	AR critical signal event
ARrun	On; Off	-	Off	AR running event
FinTrp	On; Off	-	Off	AR final trip event
ReqEnd	On; Off	-	Off	AR end of request event
ShtEnd	On; Off	-	Off	AR end of shot event

Parameter	Value	Unit	Default	Description
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
<b>Shot settings</b>				
DeadT	0.02 – 300.00	s	5.00	The dead time setting for this shot. This is a common setting for all the AR lines in this shot
AR1	On; Off	-	Off	Indicates if this AR signal starts this shot
AR2	On; Off	-	Off	Indicates if this AR signal starts this shot
AR3	On; Off	-	Off	Indicates if this AR signal starts this shot
AR4	On; Off	-	Off	Indicates if this AR signal starts this shot
Start1	0.02 – 300.00	s	0.02	AR1 Start delay setting for this shot
Start2	0.02 – 300.00	s	0.02	AR2 Start delay setting for this shot
Start3	0.02 – 300.00	s	0.02	AR3 Start delay setting for this shot
Start4	0.02 – 300.00	s	0.02	AR4 Start delay setting for this shot
Discr1	0.02 – 300.00	s	0.02	AR1 Discrimination time setting for this shot
Discr2	0.02 – 300.00	s	0.02	AR2 Discrimination time setting for this shot
Discr3	0.02 – 300.00	s	0.02	AR3 Discrimination time setting for this shot
Discr4	0.02 – 300.00	s	0.02	AR4 Discrimination time setting for this shot

**Table 8.6: Measured and recorded values of AR function**

	Parameter	Value	Unit	Description
Measured or recorded values	Obj1	UNDEFINED; OPEN; CLOSE; OPEN_REQUEST; CLOSE_REQUEST; READY; NOT_READY; INFO_NOT_AVAILABLE; FAIL	-	Object 1 state
	Status	INIT; RECLAIM_TIME; READY; WAIT_CB_OPEN; WAIT_CB_CLOSE; DISCRIMINATION_TIME; LOCKED; FINAL_TRIP; CB_FAIL; INHIBIT	-	AR-function state
	Shot#	1 – 5	-	The currently running shot
	RecIT	RECLAIMTIME; STARTTIME; DEADTIME; DISCRIMINATIONTIME	-	The currently running time (or last executed)
	SCntr		-	Total start counter
	Fail		-	The counter for failed AR shots
	Shot1*		-	Shot1 start counter
	Shot2*		-	Shot2 start counter
	Shot3*		-	Shot3 start counter
	Shot4*		-	Shot4 start counter
Shot5*		-	Shot5 start counter	

\* There are 5 counters available for each one of the two AR signals.

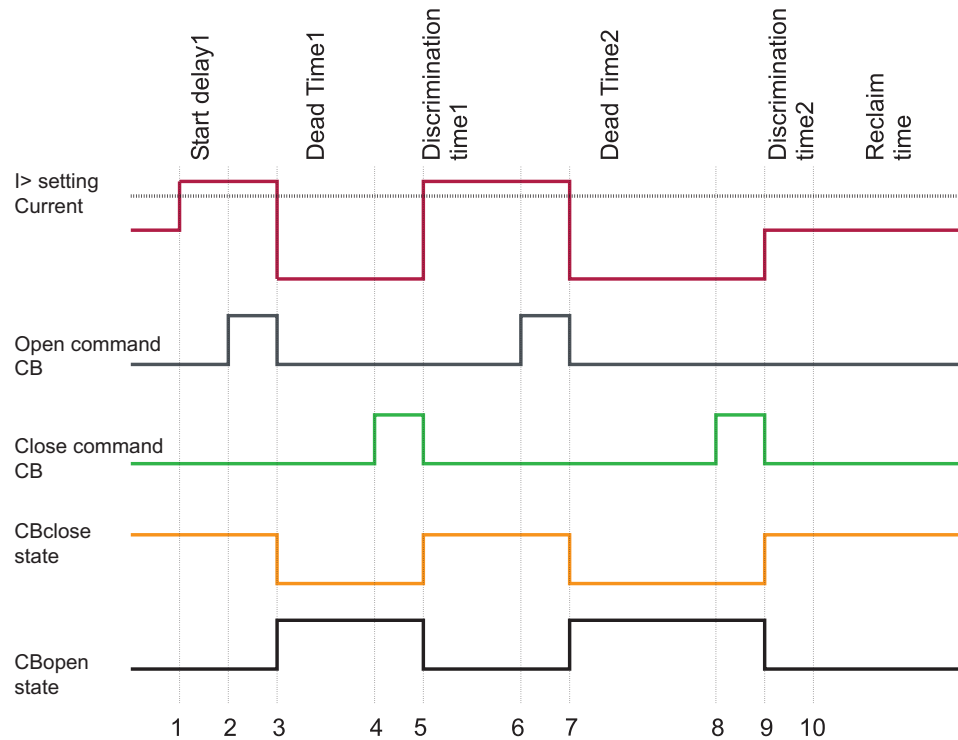


Figure 8.5: Example sequence of two shots. After shot 2 the fault is cleared.

1. Current exceeds the  $I >$  setting; the start delay from shot 1 starts.
2. After the start delay, an OpenCB relay output closes.
3. A CB opens. The dead time from shot 1 starts, and the OpenCB relay output opens.
4. The dead time from shot 1 runs out; a CloseCB output relay closes.
5. The CB closes. The CloseCB output relay opens, and the discrimination time from shot 1 starts. The current is still over the  $I >$  setting.
6. The discrimination time from the shot 1 runs out; the OpenCB relay output closes.
7. The CB opens. The dead time from shot 2 starts, and the OpenCB relay output opens.
8. The dead time from shot 2 runs out; the CloseCB output relay closes.
9. The CB closes. The CloseCB output relay opens, and the discrimination time from shot 2 starts. The current is now under  $I >$  setting.
10. Reclaim time starts. After the reclaim time the AR sequence is successfully executed. The AR function moves to wait for a new AR request in shot 1.

## 8.8 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
- XOR
- COUNTERs
- OR
- NOT
- RS & D flip-flops

Logic is made with VAMPSET setting tool. Consumed memory is dynamically shown on the configuration view in percentage. The first value indicates amount of used inputs, second amount of gates and third values shows amount of outputs consumed.

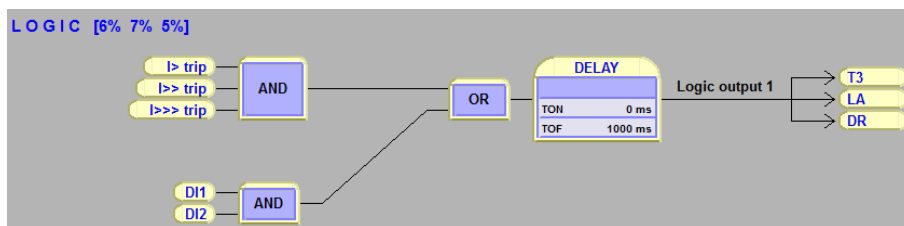


Figure 8.6: Logic can be found and modified in “logic” menu in VAMPSET setting tool

Percentages show used memory amount.

Inputs/Logical functions/Outputs- used. None of these is not allowed to exceed 100%. See guide below to learn basics of logic creation:

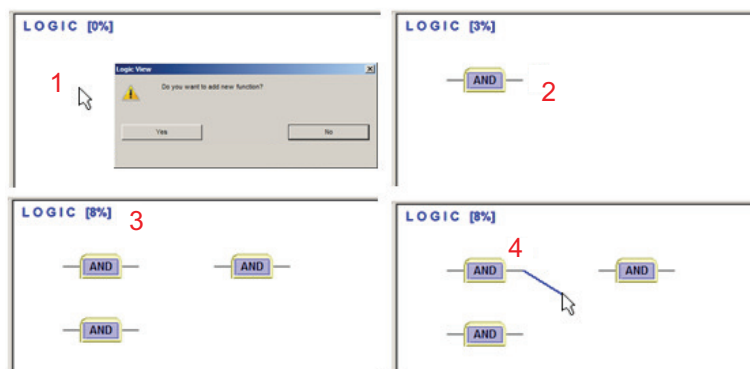


Figure 8.7: How to create logical nodes.

1. Press empty area to add a logic gate, confirm new function by pressing “Yes”.
2. Logic function is always "AND" -gate as a default.
3. While logic increases the capacity is increasing as well.
4. To joint logic functions, go on top of the output line of gate and hold down mouse left -> make the connection to other logic functions input.

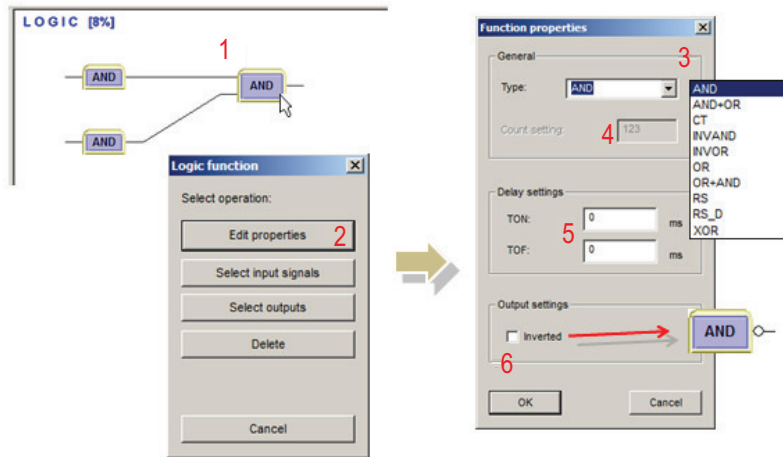


Figure 8.8: Logic creation

1. Left click on top of any logic function to activate the “Select operation” view.
2. Edit properties button opens the “Function properties” window.
3. Generally it is possible to choose the type of logic function between and/or/counter/swing -gate.
4. When counter is selected, count setting may be set here.
5. Separate delay setting for logic activation and dis-activation.
6. Possible to invert the output of logic. Inverted logic output is marked with circle.

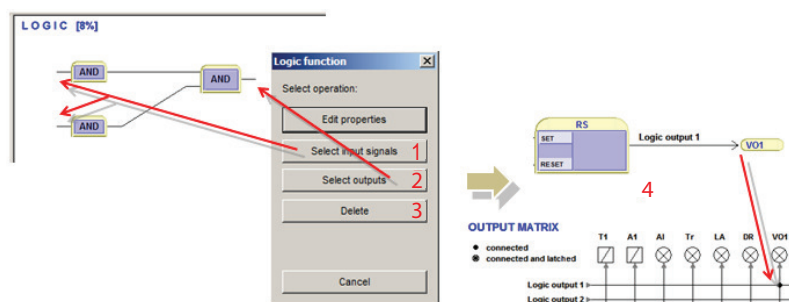


Figure 8.9: Logic creation

1. Select input signals can be done by pressing the following button or by clicking mouse left on top of the logic input line.
2. Select outputs can be done by pressing the following button or by clicking mouse left on top of the logic output line.
3. This deletes the logic function.
4. When logic is created and settings are written to the device the unit requires a restart. After restarting the logic output is automatically assigned in output matrix as well.

**NOTE:** Whenever writing new logic to the device the unit has to be restarted.



# 9 Communication

## 9.1 Communication ports

The device has three communication ports as standard.

A fourth port, Ethernet, is available as an option. When this option is chosen, it will take over communication option 2 slot.

There can be up to three communication ports in the rear panel. The front panel RS-232 port will shut off the local port on the rear panel when a VX003 cable is inserted.

See Figure 9.1 and Chapter 11 Connections.

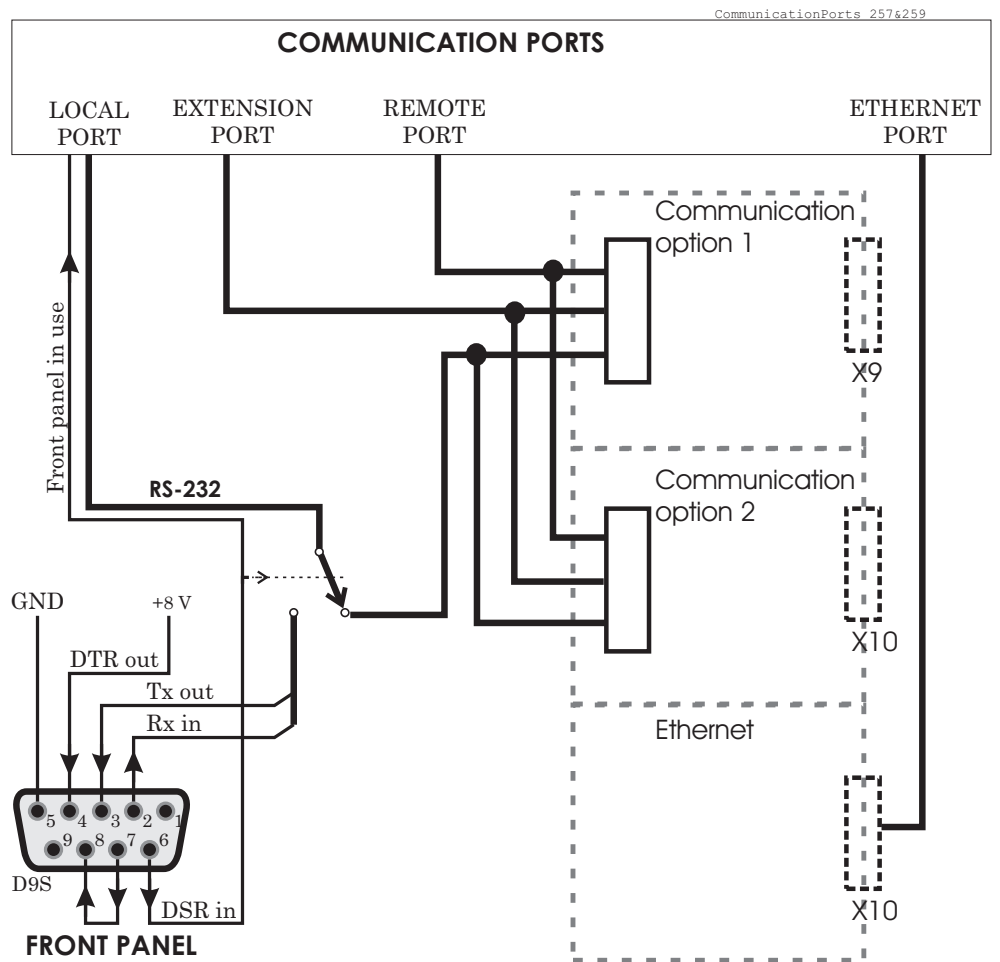


Figure 9.1: Communication ports and connectors. The type of connectors X9 or X10 depends on the type of the communication option.

## 9.1.1 Local port X4

The local port has two connectors:

- On the front panel
- On the rear panel (see Chapter 11 Connections)

Only one can be used at a time.

**NOTE:** The local port functionality may be available via connector X9 or X10 depending on the type of communication modules and DIP switch settings (see Chapter 11 Connections).

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 9.1.

### 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, but the connector type depends on the option module type.

**Table 9.1: Parameters**

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for the rear panel local port.	Set
	None		Command line interface for VAMPSET	
	SpaBus		SPA-bus (slave)	
	ProfibusDP		Profibus DB (slave)	
	ModbusSla		Modbus RTU slave	
	ModbusTCPs		Modbus TCP slave	
	IEC-103		IEC-60870-5-103 (slave)	
	ExternalIO		Modbus RTU master for external I/O-modules	
	DNP3		DNP 3.0	
Msg#	0 – 2 <sup>32</sup> -1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 – 2 <sup>16</sup> -1		Protocol errors since the device has restarted or since last clearing	Clr
Tout	0 – 2 <sup>16</sup> -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)
<b>VAMPSET communication (Direct or SPA-bus embedded command line interface)</b>				
Tx	bytes/size		Unsent bytes in transmitter buffer/size of the buffer	
Msg#	0 – 2 <sup>32</sup> -1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 – 2 <sup>16</sup> -1		Errors since the device has restarted or since last clearing	Clr
Tout	0 – 2 <sup>16</sup> -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.

## 9.1.2 Remote port X9

### Physical interface

The physical interface of this port depends of the communication letter in the order code. See Figure 9.1, Chapter 11 Connections, Chapter 14 Order information and the table below. The TTL interface is for external converters and converter cables only. It is not suitable for direct connection to distances more than one meter.

**Table 9.2: Physical interface and connector types of remote port X5 with various options. TTL (A) is the default**

Order Code	Communication interface	Connector type
A	TTL (for external converters only)	D9S
B	Plastic fibre interface	HFBR-0500
C	Not available	
D	RS-485 (isolated)	screw crimp
E	Glass fibre interface (62.5/125 µm)	SMA
F	Plastic Rx/glass (62.5/125 µm) Tx fibre interface	HFBR-0500/SMA
G	Glass (62.5/125 µm) Rx/plastic fibre interface	SMA/HFBR-0500

**Table 9.3: Parameters**

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for remote port	Set
	None		-	
	SPA-bus		SPA-bus slave	
	ProfibusDP		Profibus DB slave	
	ModbusSla		Modbus RTU slave	
	ModbusTCPs		Modbus TCP slave	
	IEC-103		IEC-60870-5-103 slave	
	ExternalIO		Modbus RTU master for external I/O-modules	
	DNP3		DNP 3.0	
Msg#	0 – 2 <sup>32</sup> -1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 – 2 <sup>16</sup> -1		Protocol errors since the device has restarted or since last clearing	Clr
Tout	0 – 2 <sup>16</sup> -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		Echo to local port No echo	Set
	Binary		For binary protocols	
	ASCII		For SPA-bus protocol	

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.

### 9.1.3 Extension port

This is a RS-485 port for external I/O devices. The physical interface of this port depends on the type of communication modules. The port is located in the rear panel connector X9 or X10. See Figure 9.1 and Chapter 11 Connections.

**Table 9.4: Parameters**

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for extension port	Set
	None		Command line interface for VAMPSET	
	SPA-bus		SPA-bus slave	
	ProfibusDP		Profibus DB slave	
	ModbusSla		Modbus RTU slave	
	ModbusTCPs		Modbus TCP slave	
	IEC-103		IEC-60870-5-103 slave	
	ExternalIO		Modbus RTU master for external I/O-modules	
	DNP3		DNP 3.0	
Msg#	0 – 2 <sup>32</sup> -1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 – 2 <sup>16</sup> -1		Protocol errors since the device has restarted or since last clearing	Clr
Tout	0 – 2 <sup>16</sup> -1		Timeout errors since the device has restarted or since last clearing	Clr
	speed/DPS  Default = 38400/8N1 for VAMPSET		Display of current communication parameters.  Speed = bit/s  D = number of data bits  P = parity: none, even, odd  S = number of stop bits	1)

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.

## 9.1.4 Ethernet port

TCP port 1<sup>st</sup> INST and TCP port 2<sup>nd</sup> INST are ports for ethernet communication protocols. Ethernet communication protocols can be selected to these ports when such hardware option is installed. The parameters for these ports are set via local HMI or with VAMPSET in menus TCP port 1<sup>st</sup> INST and TCP port 2<sup>nd</sup> INST. Two different protocols can be used simultaneously on one physical interface (both protocols use the same IP address and MAC address but different IP port).

Protocol configuration menu contains address and other related information for the ethernet port. TCP port 1st and 2nd instance include selection for the protocol, IP port settings and message/error/timeout counters. More information about the protocol configuration menu on table below.

**Table 9.5: Main configuration parameters (local display), inbuilt Ethernet port**

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for the extension port	Set
	None		Command line interface for VAMPSET	
	ModbusTCPs		Modbus TCP slave	
	IEC-101		IEC-101	
	IEC 61850		IEC-61850 protocol	
	EtherNet/IP		Ethernet/IP protocol	
	DNP3		DNP/TCP	
Port	nnn		Ip port for protocol, default 102	Set
IpAddr	n.n.n.n		Internet protocol address (set with VAMPSET)	Set
NetMsk	n.n.n.n		Net mask (set with VAMPSET)	Set
Gatew	default = 0.0.0.0		Gateway IP address (set with VAMPSET)	Set
NTPSvr	n.n.n.n		Network time protocol server (set with VAMPSET) 0.0.0.0 = no SNTP	Set
KeepAlive	nn		TCP keepalive interval	Set 1)
FTP server	on/off		Enable FTP server	Set
FTP speed	4 Kb/s (default)		Maximum transmission speed for FTP	Set
FTP password	? (user) config (configurator)		FTP password	Set
MAC address	001ADnnnnnnn		MAC address	
VS Port	nn 23 (default)		IP port for VAMPSET	Set
Msg#	nnn		Message counter	
Errors	nnn		Error counter	
Tout	nnn		Timeout counter	

Parameter	Value	Unit	Description	Note
EthSffEn	on/off		Sniffer port enable	Set
SniffPort	Port2		Sniffer port	

Set = An editable parameter (password needed)

1) KeepAlive: The KeepAlive parameter sets in seconds the time between two keepalive packets are sent from the IED. The setting range for this parameter is between zero (0) and 20 seconds; with the exception that zero (0) means actually 120 seconds (2 minutes). A keep alive's packet purpose is for the VAMP IED to send a probe packet to a connected client for checking the status of the TCP-connection when no other packet is being sent e.g. client does not poll data from the IED. If the keepalive packet is not acknowledged, the IED will close the TCP connection. Connection must be resumed on the client side.

**Table 9.6: TCP PORT 1st INST**

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for the extension port.	Set
	None		Command line interface for VAMPSET	
	ModbusTCPs		Modbus TCP slave	
	IEC 61850		IEC-61850 protocol	
	EtherNet/IP		Ethernet/IP protocol	
	DNP3		DNP/TCP	
Port	nnn		Ip port for protocol, default 502	Set
Msg#	nnn		Message counter	
Errors	nnn		Error counter	
Tout	nnn		Timeout counter	

**Table 9.7: CP PORT 2nd INST**

Parameter	Value	Unit	Description	Note
Ethernet port protocol (TCP PORT 2nd INST)			Protocol selection for the extension port.	Set
	None		Command line interface for VAMPSET	
	ModbusTCPs		Modbus TCP slave	
	IEC 61850		IEC-61850 protocol	
	EtherNet/IP		Ethernet/IP protocol	
	DNP3		DNP/TCP	
Port	nnn		Ip port for protocol, default 502	Set
Msg#	nnn		Message counter	
Errors	nnn		Error counter	
Tout	nnn		Timeout counter	

Set = An editable parameter (password needed).

---

## 9.2 Communication protocols

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

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

### 9.2.1 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 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 Ethernet configuration, see Chapter 9.1.4 Ethernet port.



## 9.2.2 Modbus TCP and Modbus RTU

These Modbus protocols are often used in power plants and in industrial applications. The difference between these two protocols is the media. Modbus TCP uses Ethernet and Modbus RTU uses asynchronous communication (RS-485, optic fibre, RS-232).

VAMPSET will show the list of all available data items for Modbus.

The Modbus communication is activated usually for remote port via a menu selection with parameter "Protocol". See Chapter 9.1 Communication ports.

For Ethernet interface configuration, see Chapter 9.1.4 Ethernet port.

**Table 9.8: 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)

### 9.2.3 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 mode, it is not possible to read continuously only one single data item. At least two different data items must be read in turn to get updated data from the device.

There is a separate manual for VPA 3CG (VVPA3CG/EN M/xxxx) for the continuous mode and request mode. The manual is available to download from our website.

#### Available data

VAMPSET will show the list of all available data items for both modes. A separate document "Profibus parameters.pdf" is also available.

The Profibus DP communication is activated usually for remote port via a menu selection with parameter "Protocol". See Chapter 9.1 Communication ports.

**Table 9.9: Parameters**

Parameter	Value	Unit	Description	Note
Mode			Profile selection	Set
	Cont		Continuous mode	
	Reqst		Request mode	
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			Event numbering style.	(Set)
	Channel		Use this for new installations.	
	(Limit60)		(The other modes are for compatibility with old systems.)	
	(NoLimit)			
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			Converter type	4.
	-		No converter recognized	
	VE		Converter type "VE" is recognized	

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 lengths 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.

## 9.2.4 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 “Spabus parameters.pdf” of SPA-bus data items available.

**Table 9.10: 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			Event numbering style.	(Set)
	Channel		Use this for new installations.	
	(Limit60)		(The other modes are for compatibility with old systems.)	
	(NoLimit)			

Set = An editable parameter (password needed)

## 9.2.5 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 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.

For more information on IEC 60870-5-103 in VAMP devices refer to the “IEC103 Interoperability List” document.

**Table 9.11: 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)

**Table 9.12: Parameters for disturbance record reading**

Parameter	Value	Unit	Description	Note
ASDU23	On Off		Enable record info message	Set
SmpIs/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	
<b>Fault numbering</b>				
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)

## 9.2.6 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” and “DNP 3.0 Parameters.pdf”. DNP 3.0 communication is activated via menu selection. RS-485 interface is often used but also RS-232 and fibre optic interfaces are possible.

**Table 9.13: Parameters**

Parameter	Value	Unit	Description	Set
bit/s	4800 9600 (default) 19200 38400	bps	Communication speed	Set
Parity	None (default) Even Odd		Parity	Set
SlvAddr	1 – 65519		An unique address for the device within the system	Set
MstrAddr	1 – 65519 255 = default		Address of master	Set
LLTout	0 – 65535	ms	Link layer confirmation timeout	Set
LLRetry	1 – 255 1 = default		Link layer retry count	Set
APLTout	0 – 65535 5000 = default	ms	Application layer confirmation timeout	Set
CnfMode	EvOnly (default); All		Application layer confirmation mode	Set
DBISup	No (default); Yes		Double-bit input support	Set
SyncMode	0 – 65535	s	Clock synchronization request interval. 0 = only at boot	Set

Set = An editable parameter (password needed)

## 9.2.7 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 device 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 “IEC 101 Profile checklist & datalist.pdf” document.

**Table 9.14: Parameters**

Parameter	Value	Unit	Description	Note
bit/s	1200	bps	Bitrate used for serial communication.	Set
	2400			
	4800			
	9600			
Parity	None		Parity used for serial communication	Set
	Even			
	Odd			
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		The parameter determines time tag format: 3-octet time tag or 7-octet time tag.	Set
	Full			
MeasFormat	Scaled		The parameter determines measurement data format: normalized value or scaled value.	Set
	Normalized			
DbandEna	No		Dead-band calculation enable flag	Set
	Yes			
DbandCy	100 – 10000	ms	Dead-band calculation interval	Set

Set = An editable parameter (password needed)



## 9.2.8 External I/O (Modbus RTU master)

External Modbus I/O devices can be connected to the relay using this protocol. (See Chapter 11.6.2 Third-party external input / output modules module for more information).

## 9.2.9 IEC 61850

The relay supports communication using IEC 61850 protocol with native implementation. IEC 61850 protocol is available with the optional inbuilt Ethernet port. The protocol can be used to read / write static data from the relay or to receive events and to receive / send GOOSE messages to other relays.

IEC 61850 server interface is capable of

- Configurable data model: selection of logical nodes corresponding to active application functions
- Configurable pre-defined data sets
- Supported dynamic data sets created by clients
- Supported reporting function with buffered and unbuffered Report Control Blocks
- Sending analogue values over GOOSE
- Supported control modes:
  - direct with normal security
  - direct with enhanced security
  - select before operation with normal security
  - select before operation with enhanced security
- Supported horizontal communication with GOOSE: configurable GOOSE publisher data sets, configurable filters for GOOSE subscriber inputs, GOOSE inputs available in the application logic matrix

Additional information can be obtained from the separate documents “IEC 61850 conformance statement.pdf”, “IEC 61850 Protocol data.pdf” and “Configuration of IEC 61850 interface.pdf”.

## 9.2.10 EtherNet/IP

The device supports communication using EtherNet/IP protocol which is a part of CIP (Common Industrial Protocol) family. EtherNet/IP protocol is available with the optional inbuilt Ethernet port. The protocol can be used to read / write data from the device using request / response communication or via cyclic messages transporting data assigned to assemblies (sets of data).

For more detailed information and parameter lists for EtherNet/IP, refer to a separate application note “Application Note EtherNet/IP.pdf”.

For the complete data model of EtherNet/IP, refer to the document “Application Note DeviceNet and EtherNetIP Data Model.pdf”.

## 9.2.11 FTP server

The FTP server is available on VAMP IEDs equipped with an inbuilt or optional Ethernet card.

The server enables downloading of the following files from an IED:

- Disturbance recordings.
- The MasterICD and MasterICDEd2 files.

The MasterICD and MasterICDEd2 files are VAMP specific reference files that can be used for offline IEC61850 configuration.

The inbuilt FTP client in Microsoft Windows or any other compatible FTP client may be used to download files from the device.

Parameter	Value	Unit	Description	Note
Enable FTP server	Yes No		Enable or disable the FTP server.	Set
FTP password	Max 33 characters		Required to access the FTP server with an FTP client. Default is “config”. The user name is always “VAMP”.	Set
FTP max speed	1 – 10	KB/s	The maximum speed at which the FTP server will transfer data.	Set

### 9.2.12

## DeviceNet

The device supports communication using DeviceNet protocol which is a part of CIP (Common Industrial Protocol) family. DeviceNet protocol is available with the optional external VSE009 module. The protocol can be used to read / write data from the device using request / response communication or via cyclic messages transporting data assigned to assemblies (sets of data).

For more detailed information about DeviceNet, refer to a separate application note “Application Note DeviceNet.pdf”.

For the complete data model of DeviceNet, refer to the document “Application Note DeviceNet and EtherNet/IP Data Model.pdf”.

# 10 Application

The following examples illustrate the versatile functions in different applications.

## 10.1 Subtransmission line protection

In this application example, VAMP 259 is used in subtransmission application. Protected line is 110 kV and the length of the line is 40 km. In this example the line is protected with line differential and distance functions.

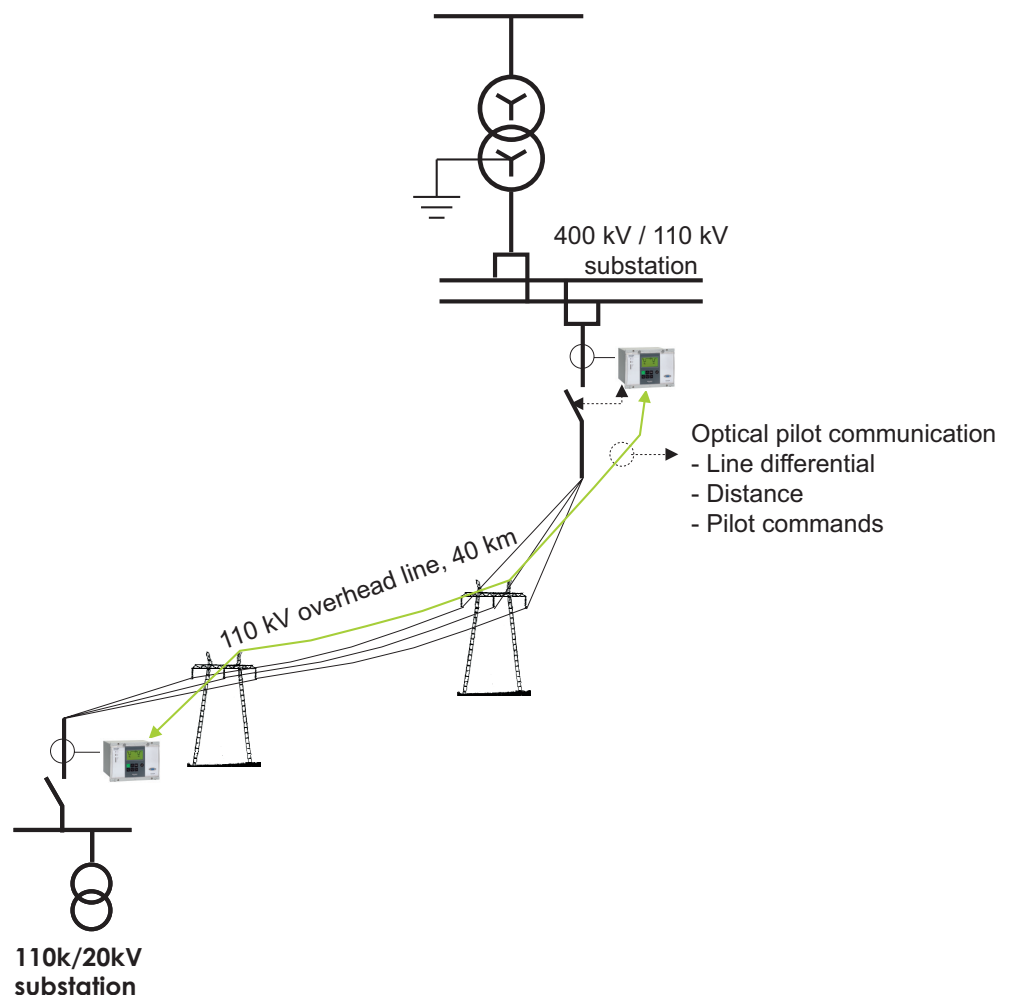


Figure 10.1: VAMP Line protection devices used in subtransmission line protection

In between of the two line managers is used optical communication link which is carried along the power lines in the overhead line towers. Relays communicate with each other in 5 ms cycles in which time the measurement data is transferred and processed in each of the line ends.

## 10.2 Distributed generation application

In this application example, VAMP 259 is used in medium voltage application. Protected line is 20 kV and in the line is connected distributed generation. In this example the line is protected with line differential and distance functions. Transfer trip is used for anti-islanding of the DG power plant.

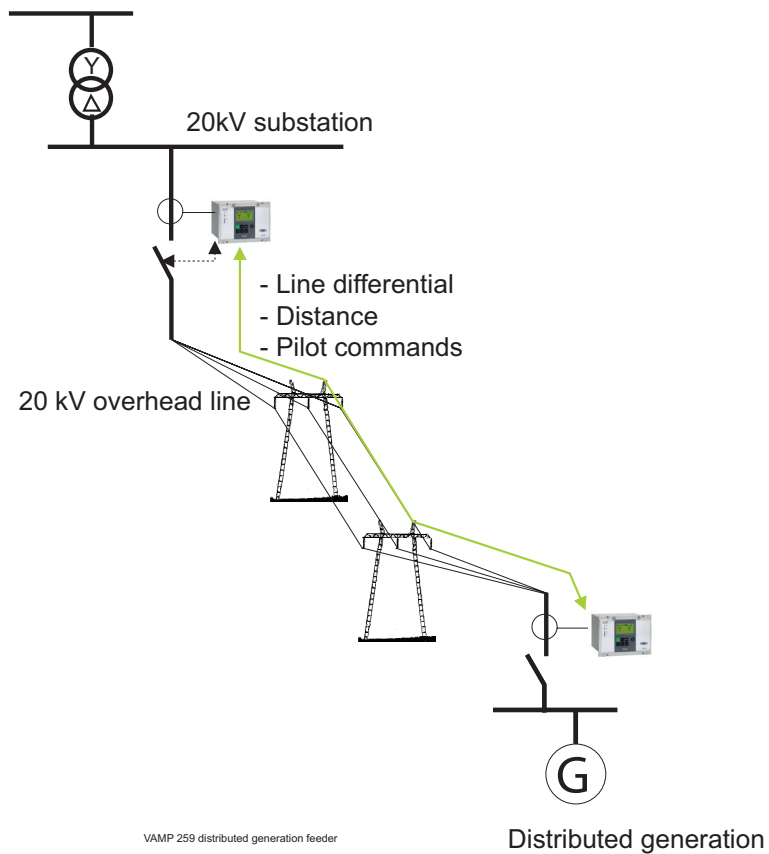


Figure 10.2: VAMP Line protection devices used in distributed generation feeder.

By using the transfer tripping command in the line managers distributed generation can be disconnected simultaneously when the feeder relay is about to initiate autoreclosing.

## 10.3 Medium voltage ring network protection

With distance and linedifferential protection relays the protected area of each relay can be set up specifically thus giving optimal solutions into ring network protection. Also the power generation in the protected areas does not cause troubles in the protection scheme and the operating times of the set zones. All of the fault situations can be cleared with minimum operating time.

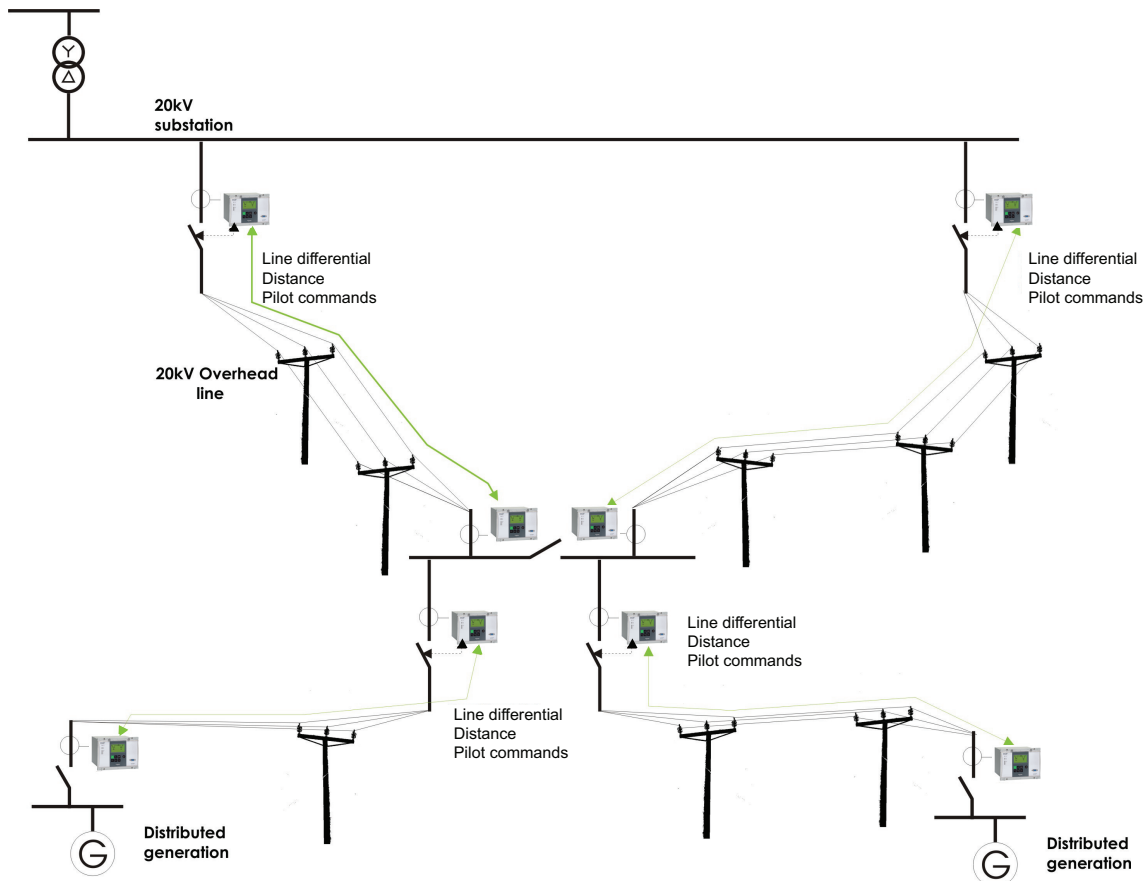


Figure 10.3: VAMP Line protection devices used in ring network feeders with distributed generation.

By using distance and linedifferential relays the back-up protection in the ring network can also be set to very fast and precise operation.

## 10.4 Trip circuit supervision

Trip circuit supervision is used to ensure that the wiring from the protective device to a circuit-breaker is in order. This circuit is unused most of the time, but when a protection device detects a fault in the network, it is too late to notice that the circuit-breaker cannot be tripped because of a broken trip circuitry.

The digital inputs of the device can be used for trip circuit monitoring. The dry digital inputs are most suitable for trip circuit supervision.

The first six digital inputs of VAMP 200 series relays are not dry and an auxiliary miniature relay is needed, if these inputs are used for trip circuit supervision.

Also the closing circuit can be supervised, using the same principle.

The optimum digital inputs for trip circuit supervision are inputs DI29 – DI32, which are internally wired in parallel within trip relays T5 – T8. These inputs are not sharing the common terminal with others inputs.

### 10.4.1 Internal parallel digital inputs

In VAMP 259-4C7 and VAMP 259-4C8, the output relays T5 (DI29), T6(DI30), T7(DI31) and T8(DI32) have internal, parallel digital inputs available for trip circuit supervision.

### 10.4.2 Trip circuit supervision with one digital input

The benefits of this scheme is that only one digital inputs is needed and no extra wiring from the relay to the circuit breaker (CB) is needed. Also supervising a 24 Vdc trip circuit is possible.

The drawback is that an external resistor is needed to supervise the trip circuit on both CB positions. If supervising during the closed position only is enough, the resistor is not needed.

- The digital input is connected parallel with the trip contacts (Figure 10.4).
- The digital input is configured as Normal Closed (NC).
- The digital input delay is configured longer than maximum fault time to inhibit any superfluous trip circuit fault alarm when the trip contact is closed.
- The digital input is connected to a relay in the output matrix giving out any trip circuit alarm.
- The trip relay should be configured as non-latched. Otherwise, a superfluous trip circuit fault alarm will follow after the trip contact operates, and the relay remains closed because of latching.
- By utilizing an auxiliary contact of the CB for the external resistor, also the auxiliary contact in the trip circuit can be supervised.
- When using the dry digital inputs DI7 –, using the other inputs of the same group, sharing a common terminal, is limited.
- When using the wet digital inputs DI1 – DI6, an auxiliary relay is needed.

#### Using any of the dry digital inputs DI7 –

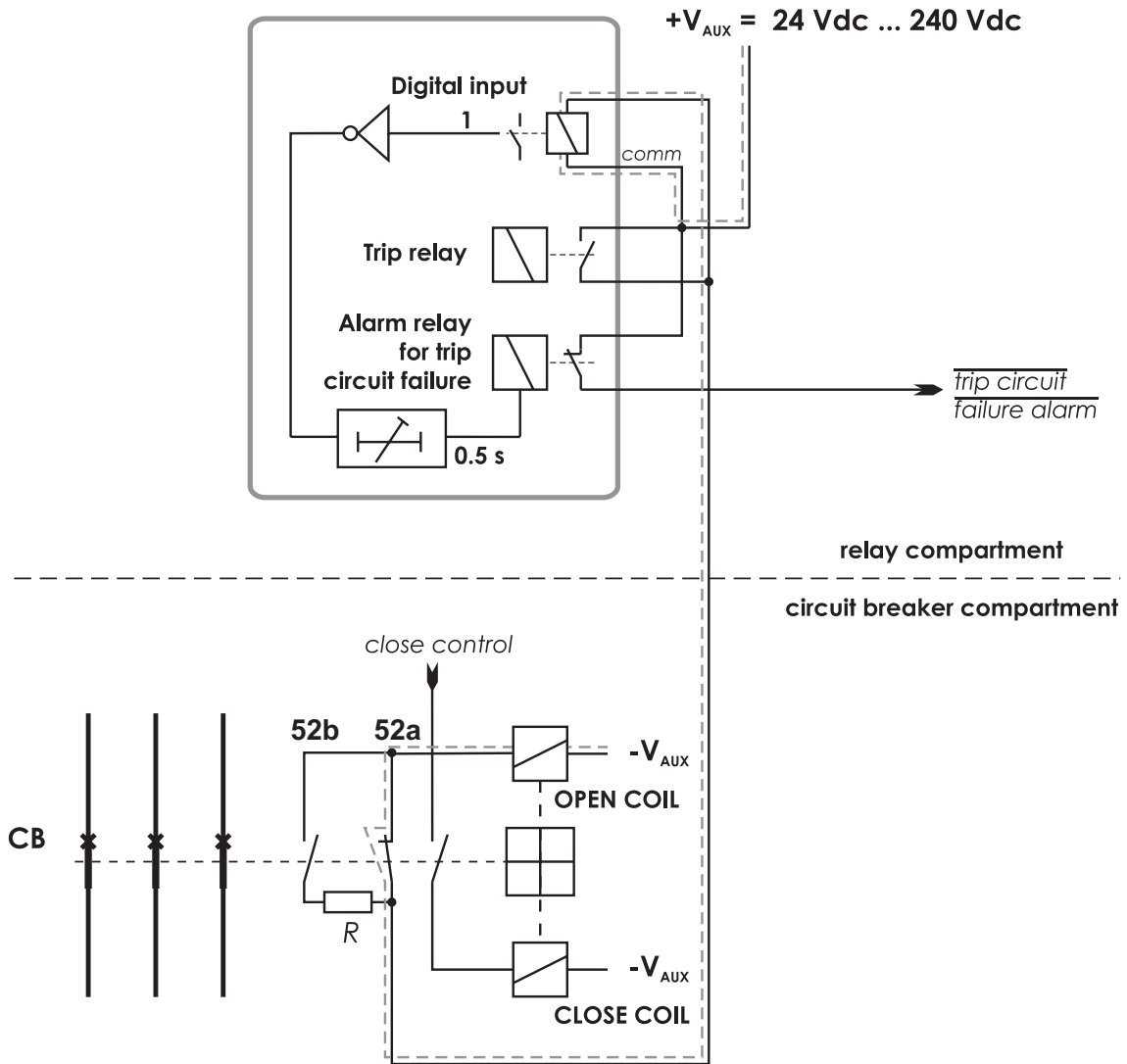


Figure 10.4: Trip circuit supervision using a single digital input and an external resistor R. The circuit-breaker is in the closed position. The supervised circuitry in this CB position is double-lined. The digital input is in active state when the trip circuit is complete. This is applicable for dry inputs.

**NOTE:** The need for the external resistor R depends on the application and circuit breaker manufacturer's specifications.



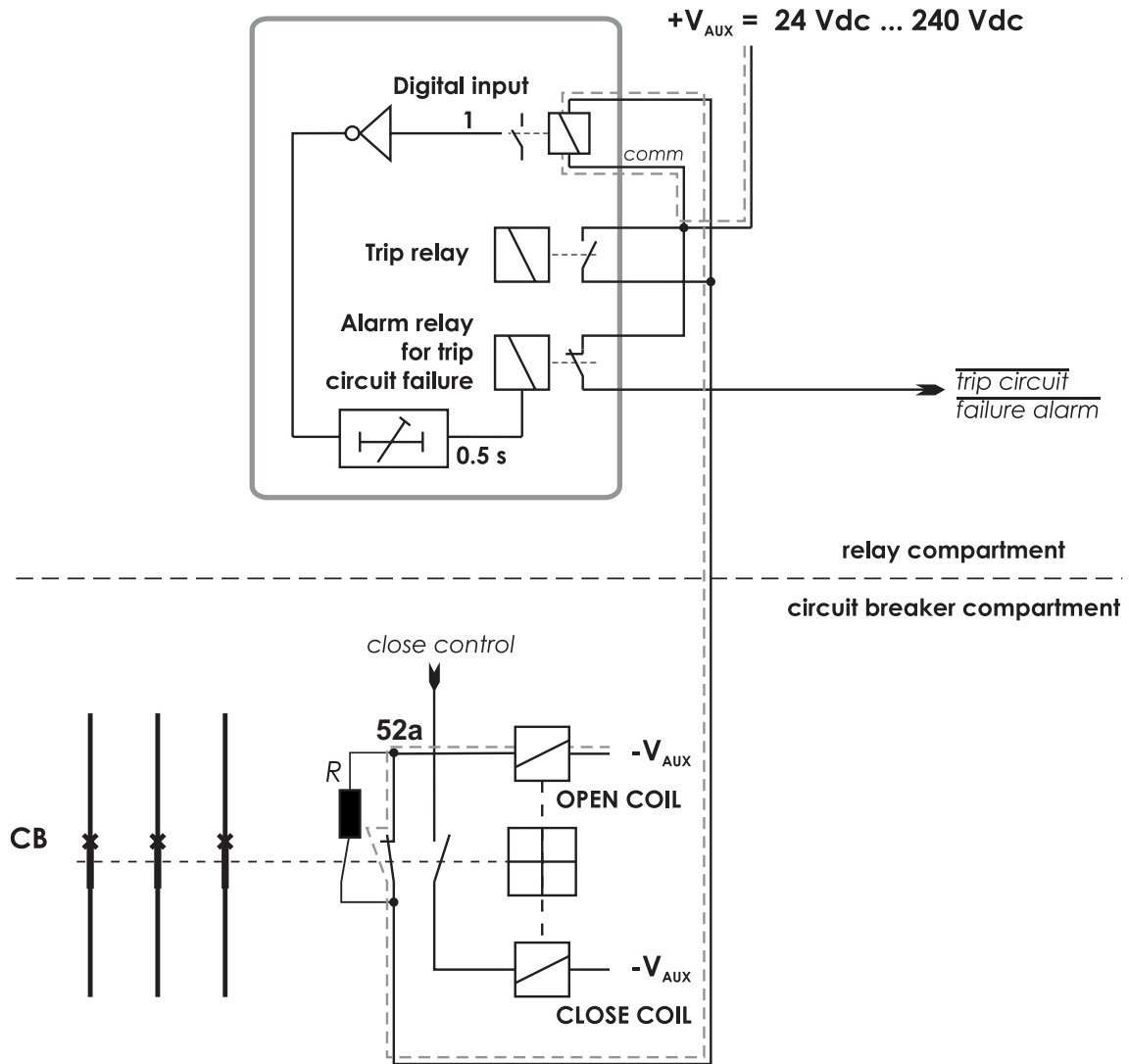


Figure 10.5: Alternative connection without using circuit breaker 52b auxiliary contacts. Trip circuit supervision using a single digital input and an external resistor R. The circuit-breaker is in the closed position. The supervised circuitry in this CB position is double-lined. The digital input is in active state when the trip circuit is complete. This is applicable for dry inputs.

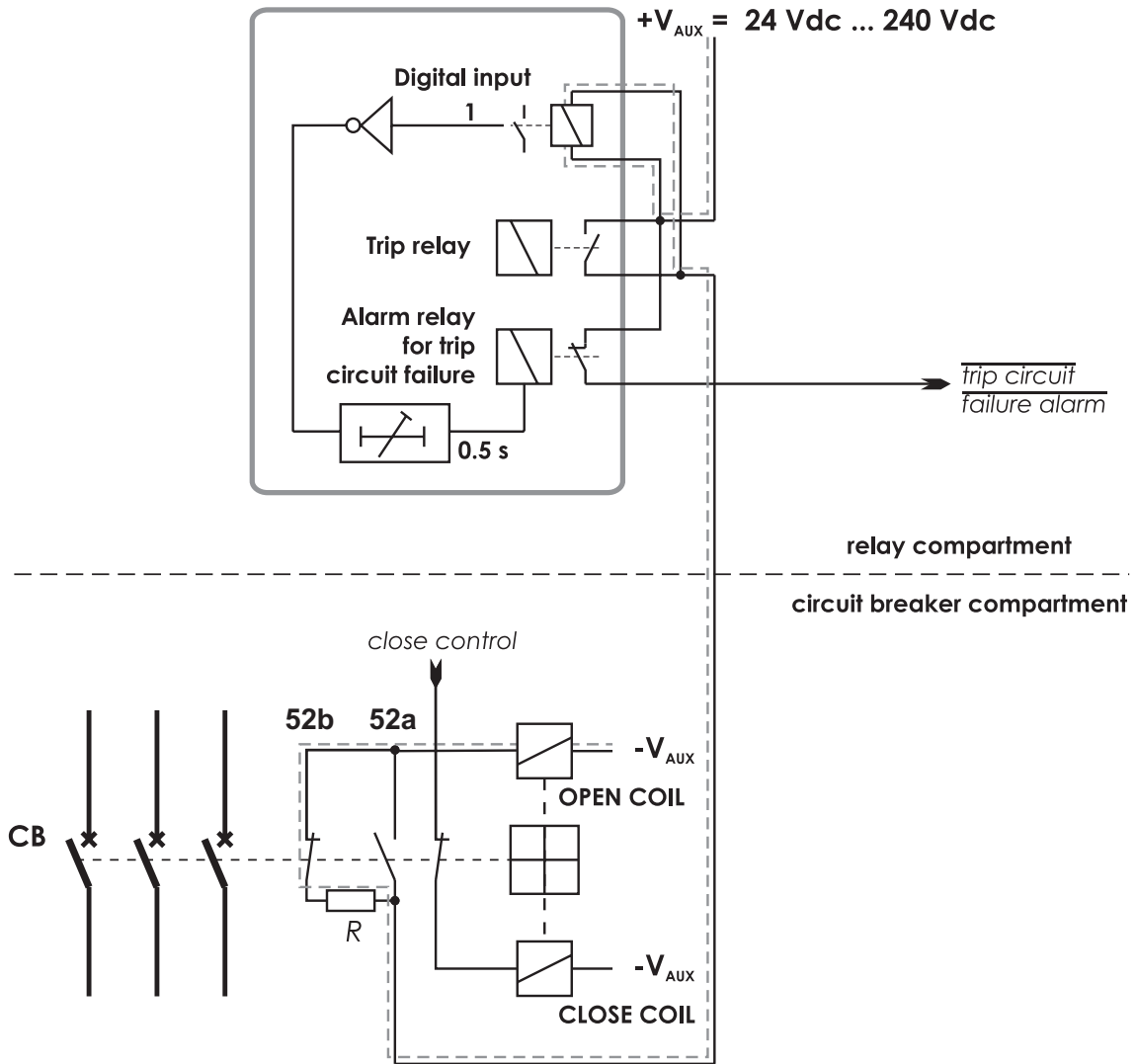


Figure 10.6: Trip circuit supervision using a single dry digital input, when the circuit breaker is in open position.

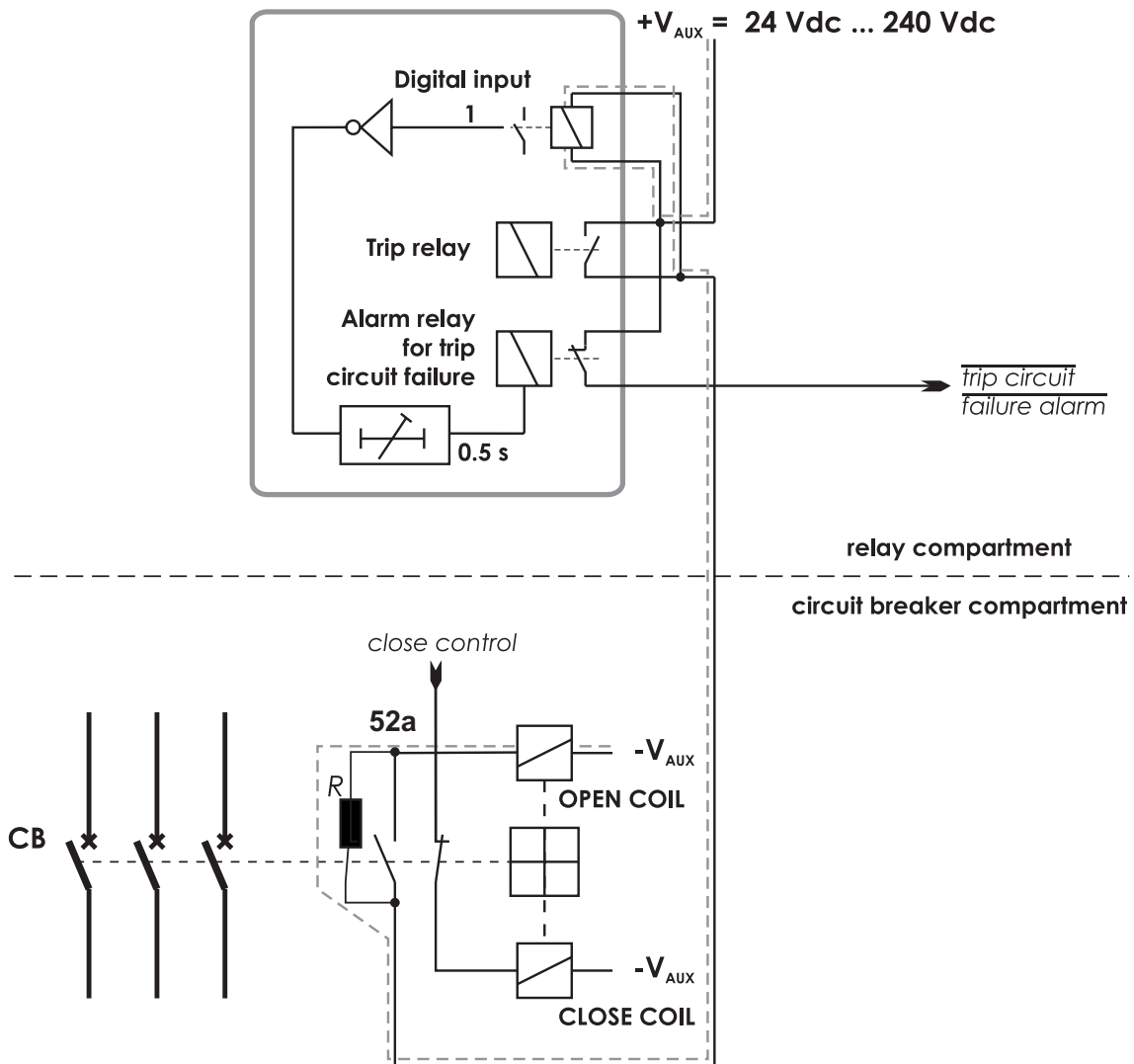


Figure 10.7: Alternative connection without using circuit breaker 52b auxiliary contacts. Trip circuit supervision using a single dry digital input, when the circuit breaker is in open position.

**NOTE:** If for example DI7 is used for trip circuit supervision, the usage of DI8 – DI14 is limited to the same circuitry sharing the  $V_{AUX}$  in the common terminal.

DIGITAL INPUTS							
Input	State	Polarity	Delay	On Event	Off Event	Alarm display	Counters
1	0	NO	0.20 s	On	On	On	0
2	0	NO	0.00 s	On	On	On	0
3	0	NO	0.00 s	On	On	On	0
4	0	NO	0.00 s	On	On	On	0
5	0	NO	0.00 s	On	On	On	0
6	0	NO	0.00 s	On	On	On	0
7	0	NC	0.5 s	Off	Off	Off	0

Figure 10.8: An example of digital input DI7 configuration for trip circuit supervision with one dry digital input.

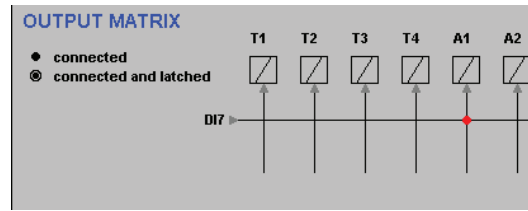


Figure 10.9: An example of output matrix configuration for trip circuit supervision with one digital input.

### Example of dimensioning the external resistor R:

$U_{AUX} =$  110 Vdc - 20 % + 10%, Auxiliary voltage with tolerance

$U_{DI} =$  18 Vdc, Threshold voltage of the digital input

$I_{DI} =$  3 mA, Typical current needed to activate the digital input including a 1 mA safety margin.

$P_{COIL} =$  50 W, Rated power of the open coil of the circuit breaker. If this value is not known, 0 Ω can be used for the  $R_{COIL}$ .

$U_{MIN} =$   $U_{AUX} - 20 \% = 88 \text{ V}$

$U_{MAX} =$   $U_{AUX} + 10 \% = 121 \text{ V}$

$R_{COIL} =$   $U_{AUX}^2 / P_{COIL} = 242 \text{ } \Omega$ .

The external resistance value is calculated using Equation 10.1.

Equation 10.1:

$$R = \frac{U_{MIN} - U_{DI} - I_{DI} \cdot R_{Coil}}{I_{DI}}$$

$$R = (88 - 18 - 0.003 \times 242) / 0.003 = 23.1 \text{ k}\Omega$$

(In practice the coil resistance has no effect.)

By selecting the next smaller standard size we get **22 kΩ**.

The power rating for the external resistor is estimated using Equation 10.2 and Equation 10.3. The Equation 10.2 is for the CB open situation including a 100 % safety margin to limit the maximum temperature of the resistor.

Equation 10.2:

$$P = 2 \cdot I_{DI}^2 \cdot R$$

$$P = 2 \times 0.003^2 \times 22000 = 0.40 \text{ W}$$

Select the next bigger standard size, for example **0.5 W**.

When the trip contacts are still closed and the CB is already open, the resistor has to withstand much higher power (Equation 10.3) for this short time.

*Equation 10.3:*

$$P = \frac{U_{MAX}^2}{R}$$

$$P = 121^2 / 22000 = 0.67 \text{ W}$$

A 0.5 W resistor will be enough for this short time peak power, too. However, if the trip relay is closed for longer time than a few seconds, a 1 W resistor should be used.

### **Using any of the non-dry digital inputs DI1 – DI6**

In this scheme an auxiliary relay is needed to connect the wet digital input to the trip circuit (Figure 10.10). The rated coil voltage of the auxiliary relay is selected according the rated auxiliary voltage used in the trip circuit. The operating voltage range of the relay should be as wide as possible to cover the tolerance of the auxiliary voltage.

In this application using the other wet inputs for other purposes is not limited unlike, when using the dry inputs.

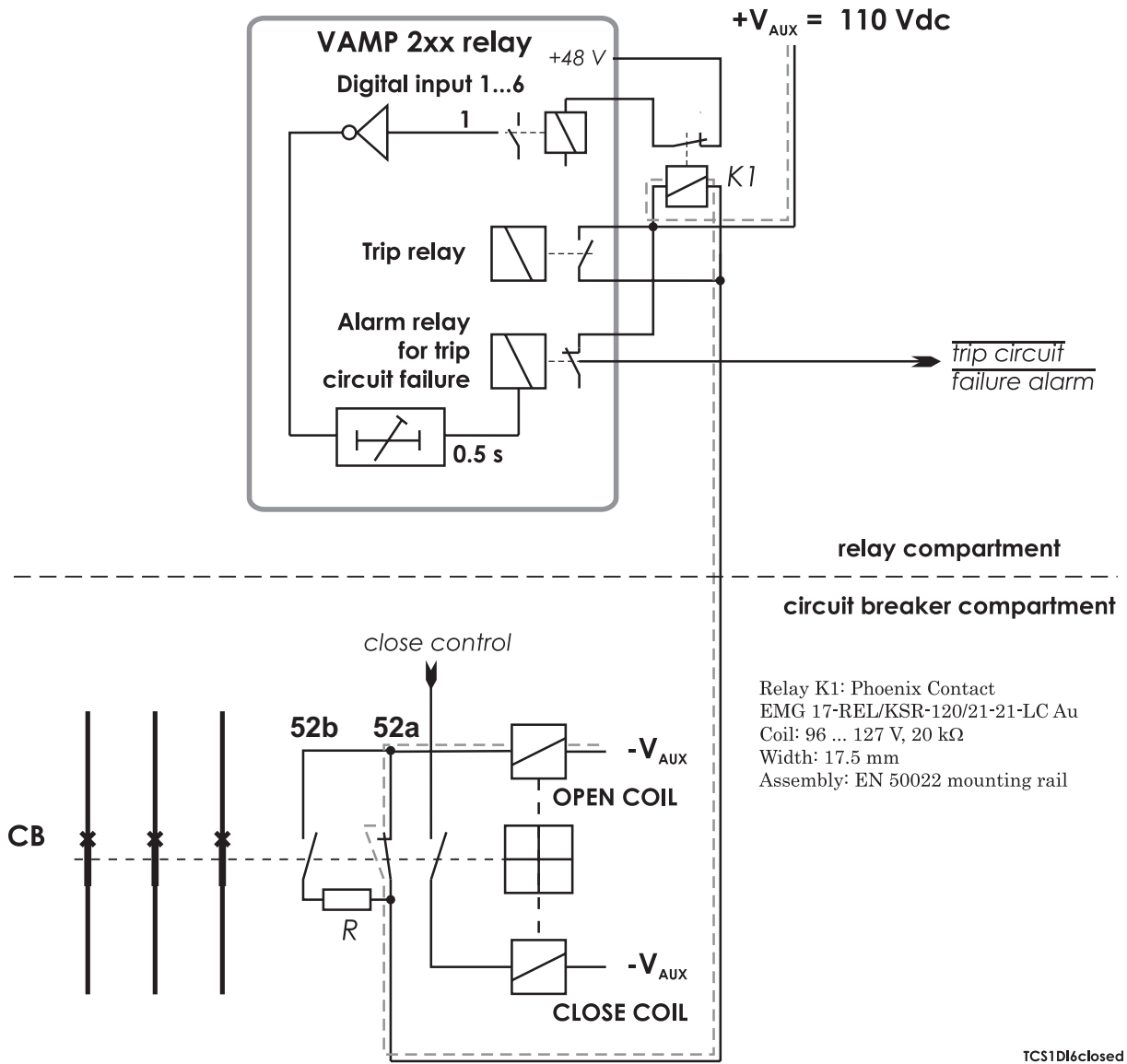


Figure 10.10: Trip circuit supervision using one of the VAMP 200 series internally wetted digital input (DI1 – DI6) and auxiliary relay K1 and an external resistor R. The circuit-breaker is in the closed position. The supervised circuitry in this CB position is double-lined. The digital input is in active state when the trip circuit is complete.

DIGITAL INPUTS							
Input	State	Polarity	Delay	On Event	Off Event	Alarm display	Counters
1	0	NC	0.5 s	Off	Off	On	0

Figure 10.11: An example of digital input DI1 configuration for trip circuit supervision with one wet digital input.

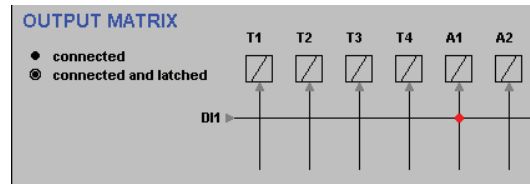


Figure 10.12: An example of output matrix configuration for trip circuit supervision with one wet digital input.

### Example of dimensioning the external resistor R:

$$U_{AUX} = 110 \text{ Vdc} - 5 \% + 10\%$$

Auxiliary voltage with tolerance. Short time voltage dips more than 5 % are not critical from the trip circuit supervision point of view.

Relay type for the K1 auxiliary relay:

Phoenix Contact 2941455

EMG 17-REL/KSR-120/21-21-LC Au

$$U_{K1} = 120 \text{ Vac/dc} - 20 \% + 10\%$$

Coil voltage of the auxiliary relay K1

$$I_{K1} = 6 \text{ mA}$$

Nominal coil current of the auxiliary relay K1

$$P_{CBcoil} = 50 \text{ W}$$

Rated power of the open coil of the circuit breaker.

$$U_{MIN} = U_{AUX} - 5 \% = 104.5 \text{ V}$$

$$U_{MAX} = U_{AUX} + 10 \% = 121 \text{ V}$$

$$U_{K1MIN} = U_{K1} - 20 \% = 96 \text{ V}$$

$$U_{K1MAX} = U_{K1} + 10 \% = 132 \text{ V}$$

$$R_{K1Coil} = U_{K1} / I_{K1} = 20 \text{ k}\Omega.$$

$$I_{K1MIN} = U_{K1MIN} / R_{K1Coil} = 4.8 \text{ mA}$$

$$I_{K1MAX} = U_{K1MAX} / R_{K1Coil} = 6.6 \text{ mA}$$

$$R_{CBCoil} = U_{AUX}^2 / P_{CBcoil} = 242 \Omega.$$

The external resistance value is calculated using Equation 10.4.

Equation 10.4:

$$R = \frac{U_{MIN} - U_{K1Min}}{I_{K1Min}} - R_{CBcoil}$$

$$R = (104.5 - 96) / 0.0048 - 242 = 1529 \Omega$$

By selecting the next smaller standard size we get **1.5 kΩ**.

The power rating for the external resistor is calculated using Equation 10.5. This equation includes a 100 % safety margin to limit the maximum temperature of the resistor, because modern resistors are extremely hot at their rated maximum power.

*Equation 10.5:*

$$P = 2 \cdot I_{K1,Max}^2 \cdot R$$

$$P = 2 \cdot 0.0066^2 \cdot 1500 = 0.13 \text{ W}$$

Select the next bigger standard size, for example 0.5 W.

When the trip contacts are still closed and the CB is already open, the resistor has to withstand much higher power (Equation 10.3) for this short time.

$$P = 121^2 / 1500 = 9.8 \text{ W}$$

A **1 W** resistor should be selected to withstand this short time peak power. However, if the trip relay can be closed for longer time than a few seconds, a 20 W resistor should be used.

### 10.4.3 Trip circuit supervision with two digital inputs

The benefits of this scheme is that no external resistor is needed.

The drawbacks are, that two digital inputs from two separate groups are needed and two extra wires from the relay to the CB compartment is needed. Additionally the minimum allowed auxiliary voltage is 48 Vdc, which is more than twice the threshold voltage of the dry digital input, because when the CB is in open position, the two digital inputs are in series.

- The first digital input is connected parallel with the auxiliary contact of the open coil of the circuit breaker.
- Another auxiliary contact is connected in series with the circuitry of the first digital input. This makes it possible to supervise also the auxiliary contact in the trip circuit.
- The second digital input is connected in parallel with the trip contacts.
- Both inputs are configured as normal closed (NC).
- The user's programmable logic is used to combine the digital input signals with an AND port. The delay is configured longer than maximum fault time to inhibit any superfluous trip circuit fault alarm when the trip contact is closed.
- The output from the logic is connected to a relay in the output matrix giving out any trip circuit alarm.
- Both digital inputs must have their own common potential.



Using the other digital inputs in the same group as the upper DI in the Figure 10.13 is not possible in most applications. Using the other digital inputs in the same group as the lower DI in the Figure 10.13 is limited, because the whole group will be tied to the auxiliary voltage  $V_{AUX}$ .

**NOTE:** In many applications the optimum digital inputs for trip circuit supervision are the optional inputs DI19 and DI20 because they don't share their terminals with any other digital inputs.

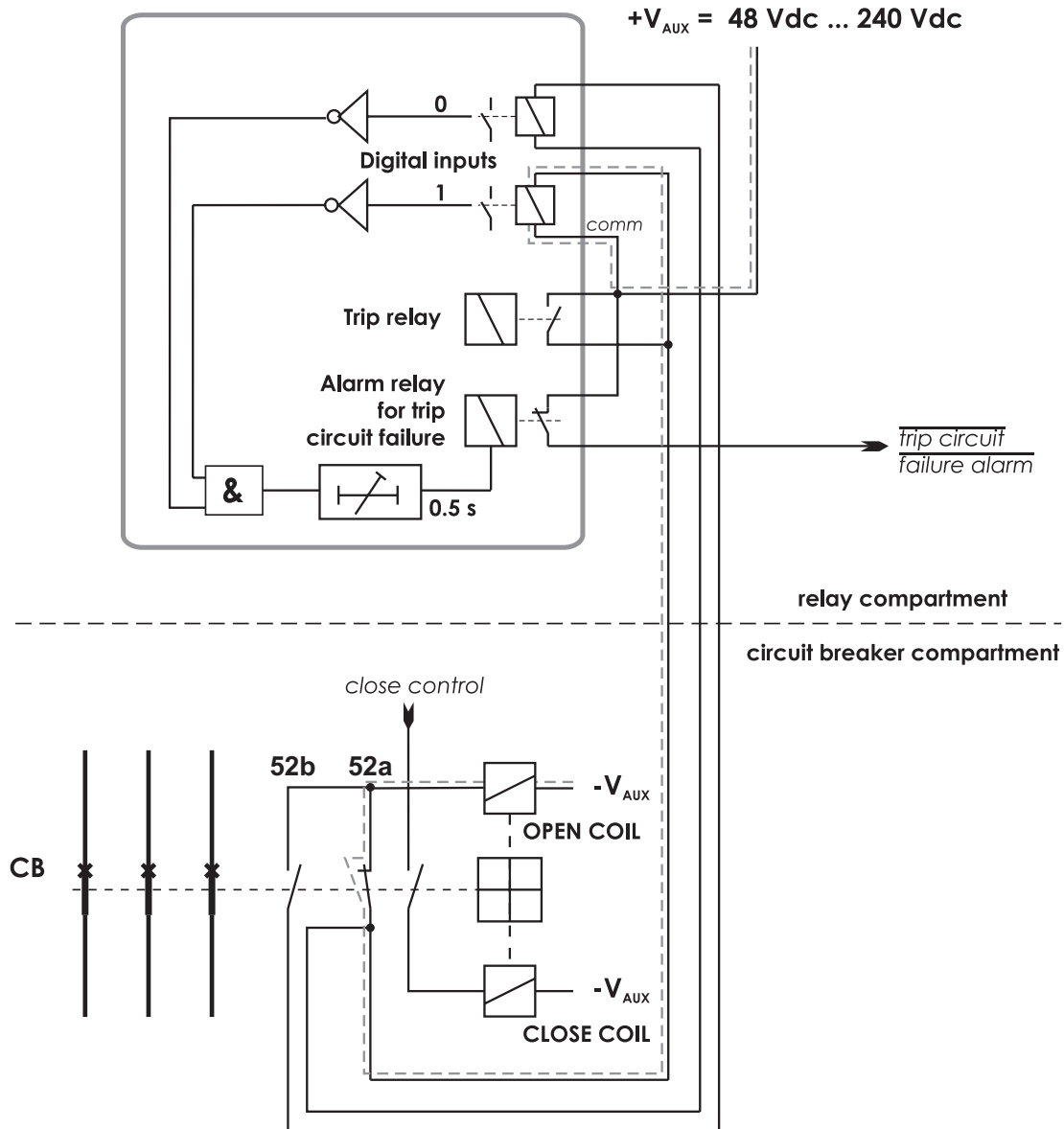


Figure 10.13: Trip circuit supervision with two digital inputs. The CB is closed. The supervised circuitry in this CB position is double-lined. The digital input is in active state when the trip circuit is complete. This is applicable for dry inputs only.

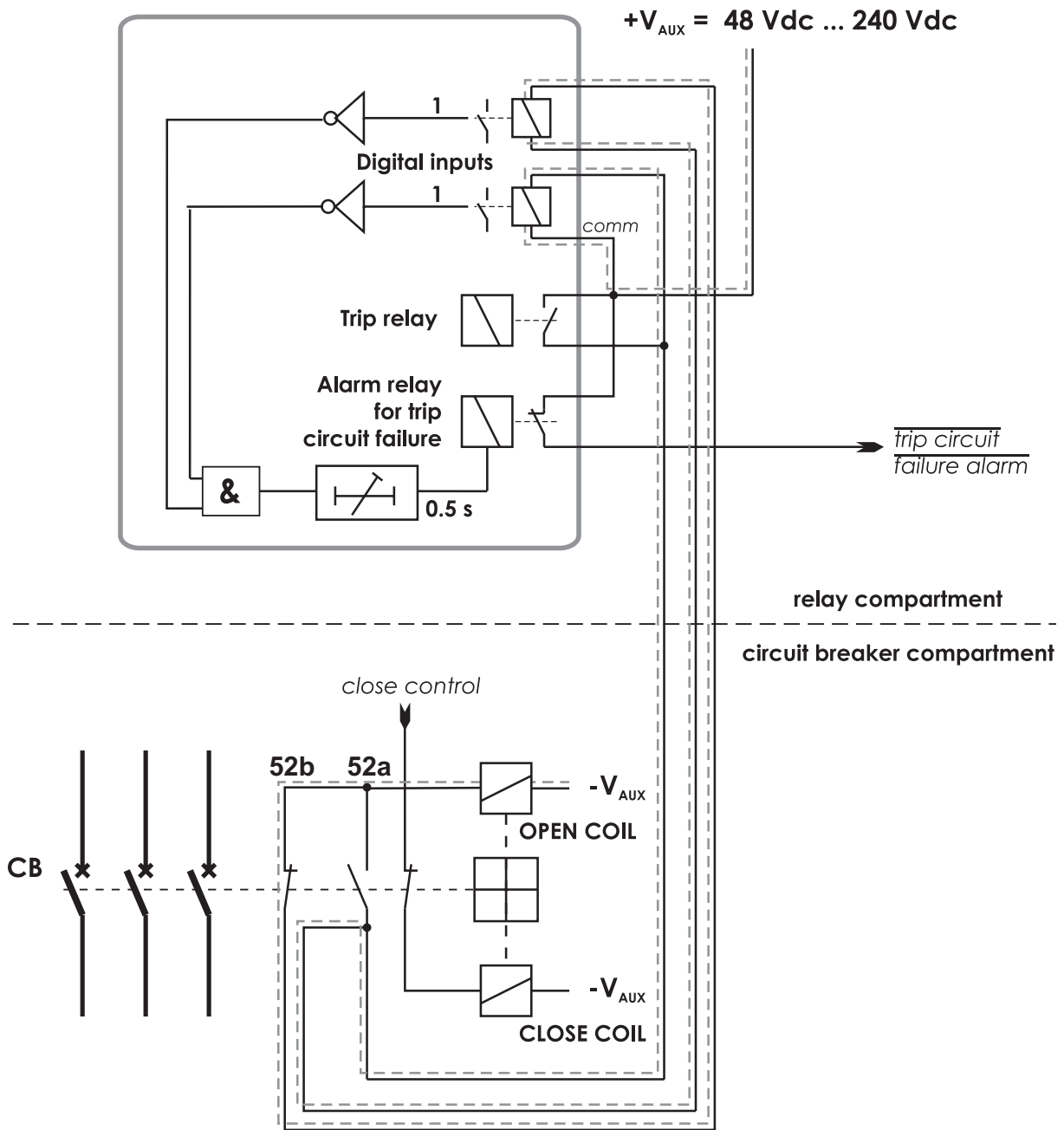


Figure 10.14: Trip circuit supervision with two digital inputs. The CB is in the open position. The two digital inputs are now in series.

**DIGITAL INPUTS**

DIGITAL INPUTS	
Mode	DC
Counters max value	16 bit

Input	State	Polarity	Delay	On Event	Off Event	Alarm display	Counters
1	0	NO	0.00 s	Off	Off	Off	70
2	0	NO	0.00 s	Off	Off	Off	0
3	0	NO	0.00 s	On	On	On	0
4	0	NO	0.00 s	On	On	On	0
5	0	NO	0.00 s	On	On	On	0
6	0	NO	0.00 s	On	On	On	0
19	0	NC	0.00 s	On	On	On	4
20	0	NC	0.00 s	On	On	On	0

Figure 10.15: An example of digital input configuration for trip circuit supervision with two dry digital inputs DI19 and DI20

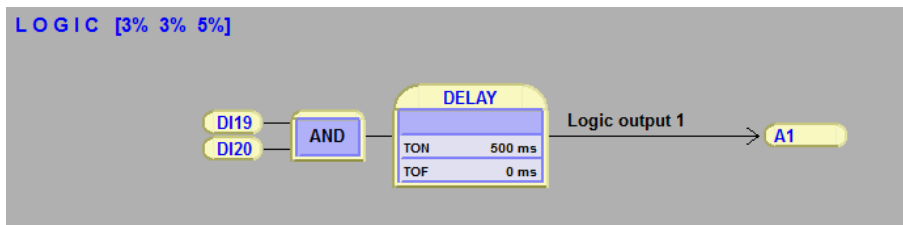


Figure 10.16: An example of logic configuration for trip circuit supervision with two dry digital inputs DI19 and DI20.

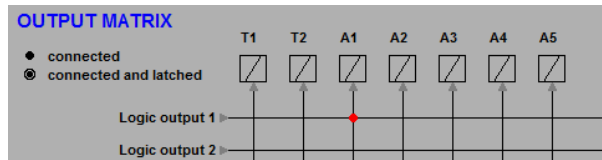


Figure 10.17: An example of output matrix configuration for trip circuit supervision with two digital inputs.

# 11 Connections

## 11.1 Rear panel

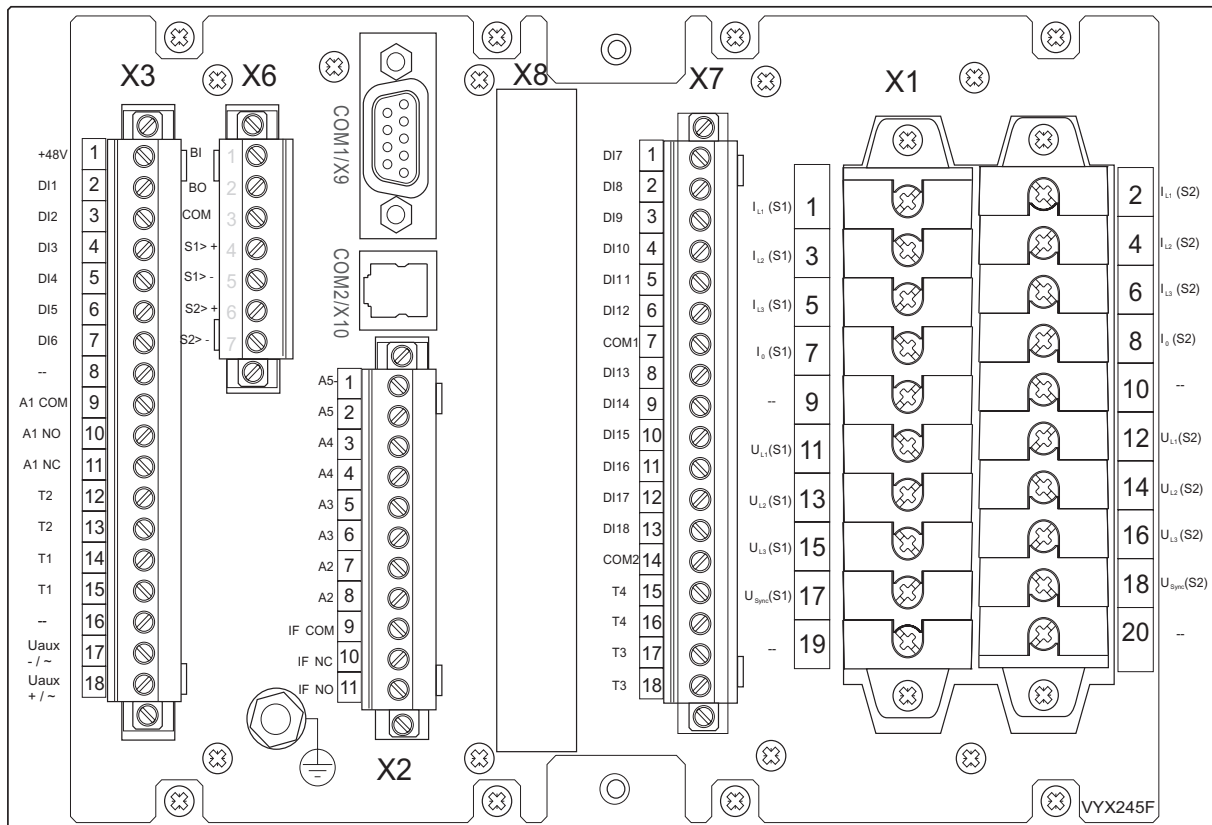


Figure 11.1: Connection on the rear panel of the VAMP 259-4C6

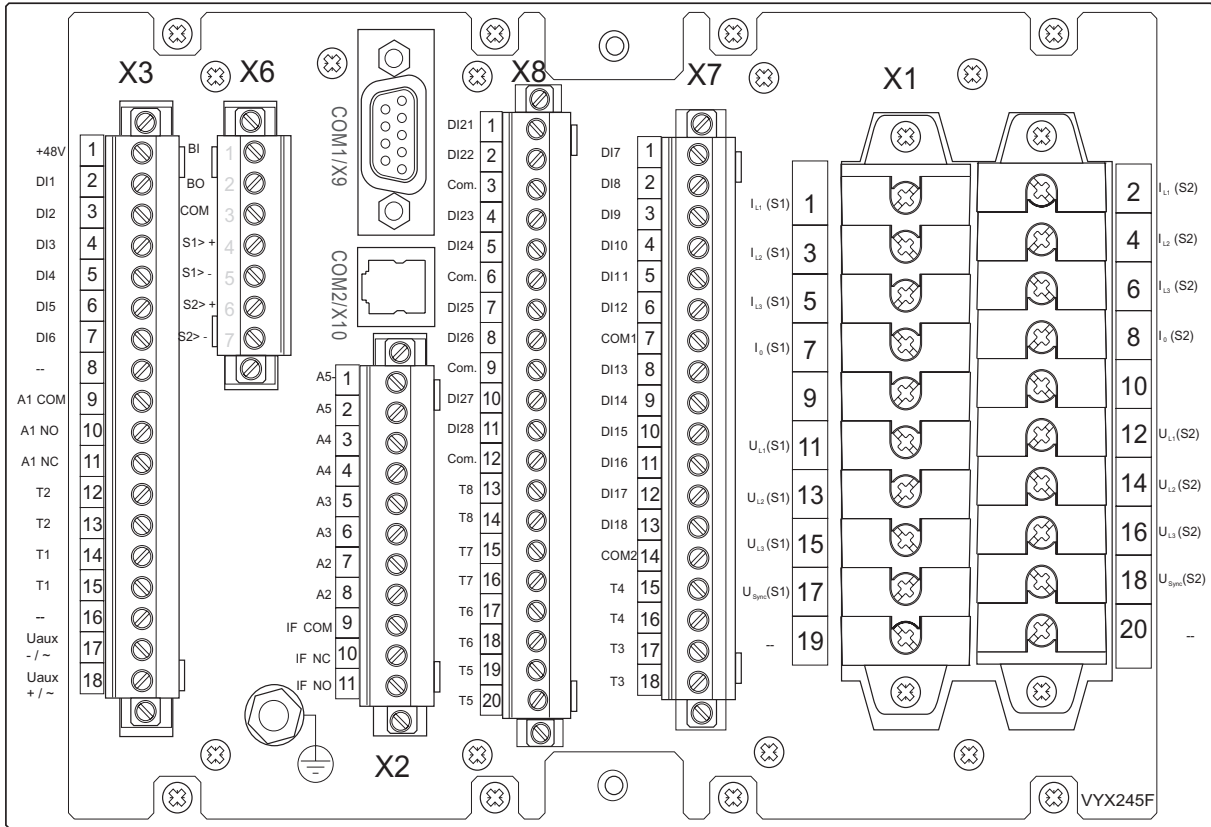


Figure 11.2: Connection on the rear panel of the VAMP 259-4C7

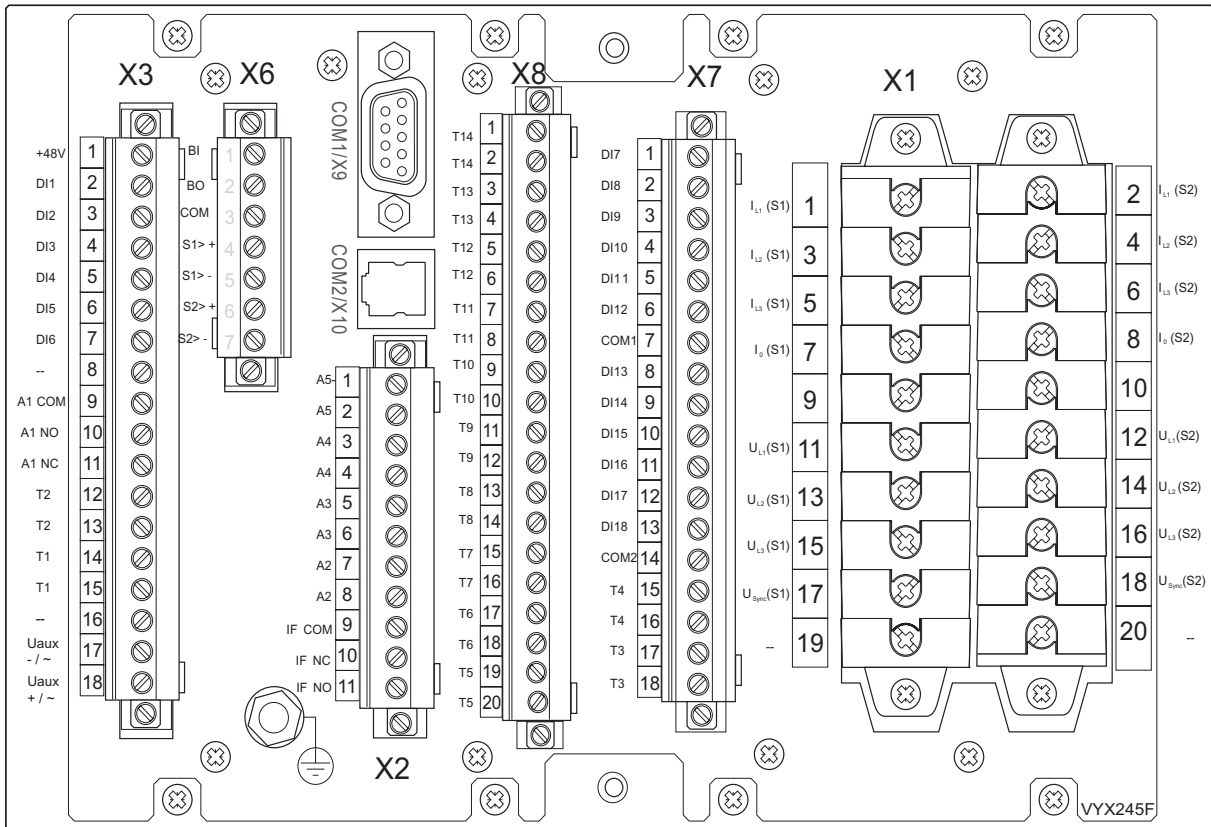
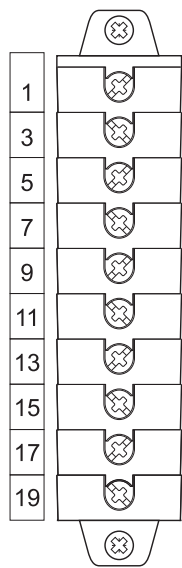


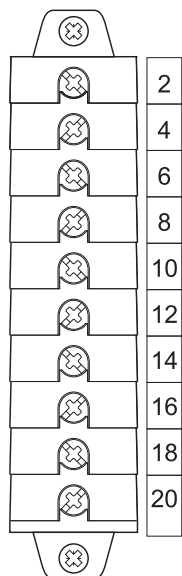
Figure 11.3: Connection on the rear panel of the VAMP 259-4C8

**Terminal X1 left side**



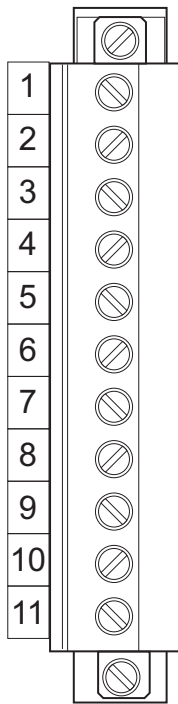
No	Symbol	Description
1	IL1(S1)	Phase current L1 (S1)
3	IL2(S1)	Phase current L2 (S1)
5	IL3(S1)	Phase current L3 (S1)
7	Io (S1)	Residual current I <sub>0</sub> (S1)
9	--	--
11	UL1 (S1)	Phase to ground voltage UL1 (S1)
13	UL2 (S1)	Phase to ground voltage UL2 (S1)
15	UL3 (S1)	Phase to ground voltage UL3 (S1)
17	USync (S1)	Synchrocheck voltage input (S1)
19	--	--

**Terminal X1 right side**



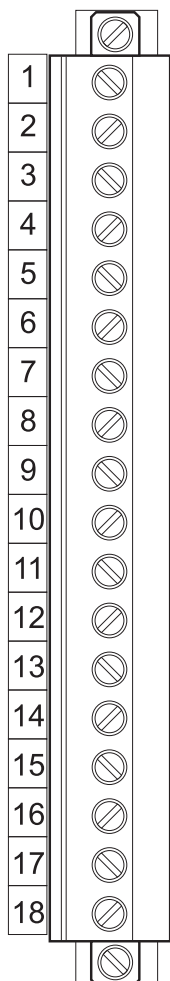
No	Symbol	Description
2	IL1(S2)	Phase current L1 (S2)
4	IL2(S2)	Phase current L2 (S2)
6	IL3(S2)	Phase current L3 (S2)
8	Io (S2)	Residual current I <sub>0</sub> (S2)
10	--	--
12	UL1 (S2)	Phase to ground voltage UL1 (S2)
14	UL2 (S2)	Phase to ground voltage UL2 (S2)
16	UL3 (S2)	Phase to ground voltage UL3 (S2)
18	U <sub>sync</sub> (S2)	Synchrocheck voltage input (S2)
20	--	--

**Terminal X2**





















No	Symbol	Description
1	A5	Alarm relay 5
2	A5	Alarm relay 5
3	A4	Alarm relay 4
4	A4	Alarm relay 4
5	A3	Alarm relay 3
6	A3	Alarm relay 3
7	A2	Alarm relay 2
8	A2	Alarm relay 2
9	SF COM	Internal fault relay, common terminal
10	SF NC	Internal fault relay, normal closed terminal
11	SF NO	Internal fault relay, normal open terminal

**Terminal X3**



No	Symbol	Description
1	+48V	Internal control voltage for digital inputs 1 – 6
2	DI1	Digital input 1
3	DI2	Digital input 2
4	DI3	Digital input 3
5	DI4	Digital input 4
6	DI5	Digital input 5
7	DI6	Digital input 6
8	--	--
9	A1 COM	Alarm relay 1, common terminal
10	A1 NO	Alarm relay 1, normal open terminal
11	A1 NC	Alarm relay 1, normal closed terminal
12	T2	Trip relay 2
13	T2	Trip relay 2
14	T1	Trip relay 1
15	T1	Trip relay 1
16	--	--
17	Uaux -/~	Auxiliary voltage
18	Uaux +/~	Auxiliary voltage

**Terminal X7**

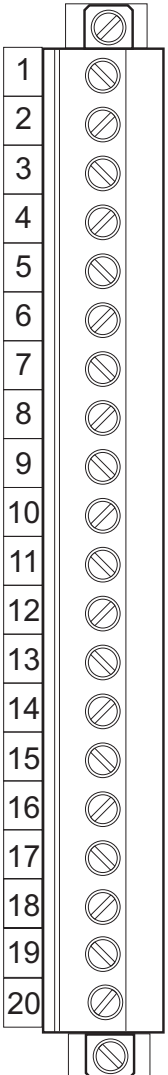
	No	Symbol	Description
	1	DI7	Digital input 7
	2	DI8	Digital input 8
	3	DI9	Digital input 9
	4	DI10	Digital input 10
	5	DI11	Digital input 11
	6	DI12	Digital input 12
	7	COM1	Common potential of digital inputs 7 – 12
	8	DI13	Digital input 13
	9	DI14	Digital input 14
	10	DI15	Digital input 15
	11	DI16	Digital input 16
	12	DI17	Digital input 17
	13	DI18	Digital input 18
	14	COM2	Common potential of digital inputs 13 – 18
	15	T4	Trip relay 4
	16	T4	Trip relay 4
	17	T3	Trip relay 3
	18	T3	Trip relay 3



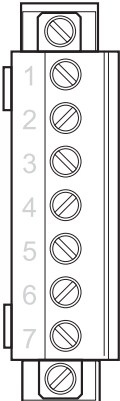
**Terminal X8 (VAMP 259-4C7)**

	No	Symbol	Description
1	1	DI21	Digital input 21
2	2	DI22	Digital input 22
3	3	COM1	Common potential of digital inputs 21-22
4	4	DI23	Digital input 23
5	5	DI24	Digital input 24
6	6	COM2	Common potential of digital inputs 23-24
7	7	DI25	Digital input 25
8	8	DI26	Digital input 26
9	9	COM3	Common potential of digital inputs 25-26
10	10	DI27	Digital input 27
11	11	DI28	Digital input 28
12	12	COM4	Common potential of digital inputs 27-28
13	13	T8	Trip relay 8/ Digital input 32
14	14	T8	Trip relay 8/ Digital input 32
15	15	T7	Trip relay 7/ Digital input 31
16	16	T7	Trip relay 7/ Digital input 31
17	17	T6	Trip relay 6/ Digital input 30
18	18	T6	Trip relay 6/ Digital input 30
19	19	T5	Trip relay 5/ Digital input 29
20	20	T5	Trip relay 5/ Digital input 29

**Terminal X8 (VAMP 259-4C8)**

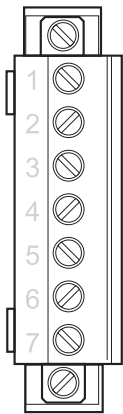
	No	Symbol	Description
	1	T14	Trip relay 14
	2	T14	Trip relay 14
	3	T13	Trip relay 13
	4	T13	Trip relay 13
	5	T12	Trip relay 12
	6	T12	Trip relay 12
	7	T11	Trip relay 11
	8	T11	Trip relay 11
	9	T10	Trip relay 10
	10	T10	Trip relay 10
	11	T9	Trip relay 9
	12	T9	Trip relay 9
	13	T8	Trip relay 8/ Digital input 32
	14	T8	Trip relay 8/ Digital input 32
	15	T7	Trip relay 7/ Digital input 31
	16	T7	Trip relay 7/ Digital input 31
	17	T6	Trip relay 6/ Digital input 30
	18	T6	Trip relay 6/ Digital input 30
	19	T5	Trip relay 5/ Digital input 29
	20	T5	Trip relay 5/ Digital input 29

**Terminal X6**

	No	Symbol	Description
	1	BI	External arc light input
	2	BO	Arc light output
	3	COM	Common terminal of arc light I/O
	4	S1>+	Arc sensor 1, positive terminal *
	5	S1>-	Arc sensor 1, negative terminal *
	6	S2>+	Arc sensor 2, positive terminal *
	7	S2>-	Arc sensor 2, negative terminal *

\*) Arc sensor itself is polarity free

## Terminal X6 with DI19/DI20 option



No	Symbol	Description
1	DI19	Digital input 19
2	DI19	Digital input 19
3	DI20	Digital input 20
4	DI20	Digital input 20
5	--	--
6	S1>+	Arc sensor 1, positive terminal *
7	S1>-	Arc sensor 1, negative terminal *

\*) Arc sensor itself is polarity free

## 11.2 Auxiliary voltage

The external auxiliary voltage  $U_{AUX}$  (standard 40 – 265 V ac/dc or optional 18 – 36 Vdc) for the pin is connected to the pins X3: 17 – 18.

**NOTE:** When optional 18 – 36 Vdc power module is used the polarity is as follows: X3:17 negative (-), X3:18 positive (+).

## 11.3 Serial communication connection

The device can be equipped with two optional communication interfaces:

Option 1: inbuilt **Ethernet ST-fiber interface** or option module 1

Option 2: inbuilt **Ethernet RJ-45 interface** or option module 2

The physical location of the communication options is at the back of the relay. The option modules can be installed at the site, but the inbuilt Ethernet modules are installed at the factory (see Chapter 14 Order information for more information).

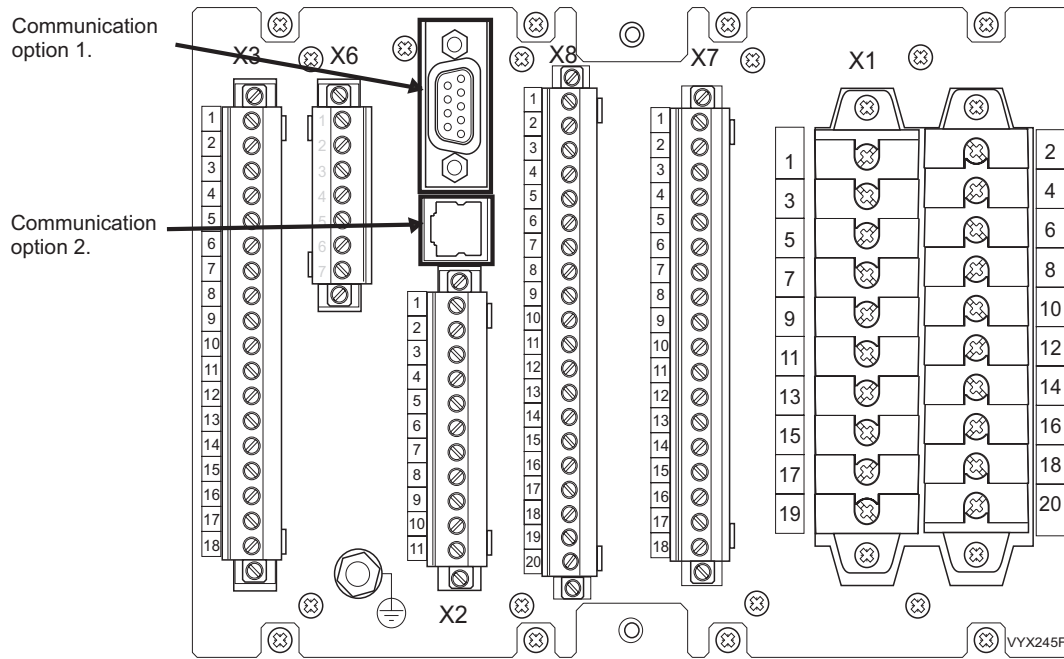


Figure 11.4: Example of VAMP 259 back panel serial communication connection

The internal connection in both communication modules is identical (see Figure 11.5). The transmit and receive lines of all the three “logical communication ports” REMOTE, LOCAL and EXTENSION port are available for both modules (RS-232 signal levels). Depending on the module type one or more of these ports are physically available at the external connector.

The communication modules convert the RS-232 signal levels to some other levels e.g. TTL, RS-485 or fibre-optics. The modules may also contain intelligence to make protocol conversion on software level.

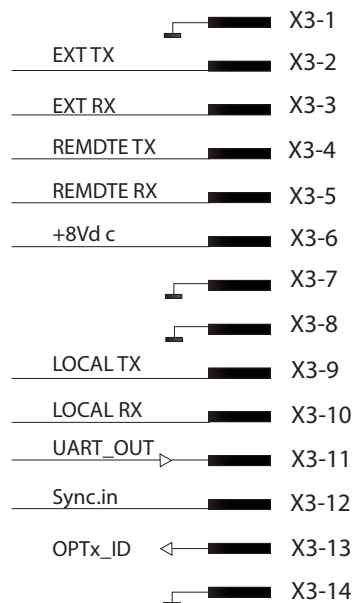


Figure 11.5: connection to communication modules

The internal connection of the communication modules contain the RX/TX signals from the communication ports, general output (UART\_OUT), clock sync/general input (Sync.in) and OPTx\_ID for module detection.

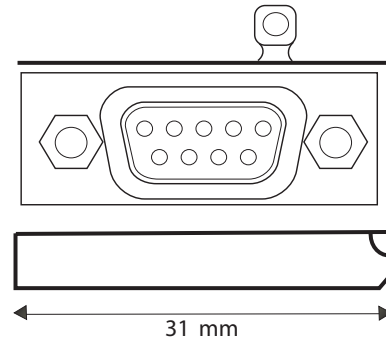
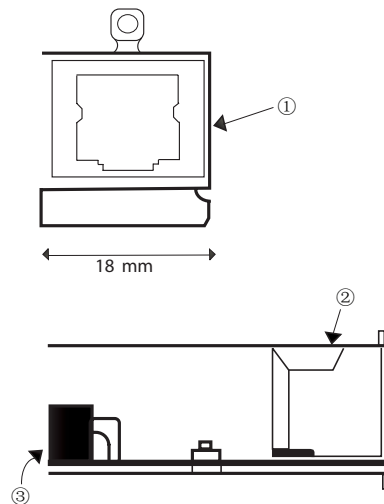


Figure 11.6: Communication module with a height of 31mm



1. External connector, signal levels depend on the type of the module
2. External connector
3. Internal 14 pin connector, RS-232 signal levels for REMOTE, LOCAL and EXTENSION ports

Figure 11.7: Communication module with a height of 18mm

The device has a 31mm high “slot” for Communication option 1 and 18mm high “slot” for Communication option 2. The option modules are either 31mm or 18mm high, the 18mm modules can be used either in the 31mm or 18mm slot.

**⚠ DANGER****HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH**


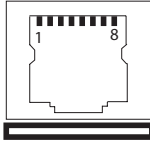
- Option cards are not allowed to be removed or added when relay has auxiliary power supply ON.
- Always use a properly rated voltage sensing device to confirm that the power is off.
- The equipment must be grounded.
- The unit contains components that can be damaged if exposed to an electrostatic discharge (ESD). Do not open the unit unless you have taken appropriate PPE measures against ESD.

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

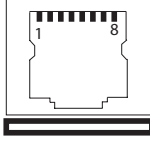
## 11.3.1 Pin assignments of communication options

The communication module types and their pin assignments are introduced in the following table.

**Table 11.1: Optional inbuilt Ethernet / 61850 interfaces (for software version 10.0 onwards):**

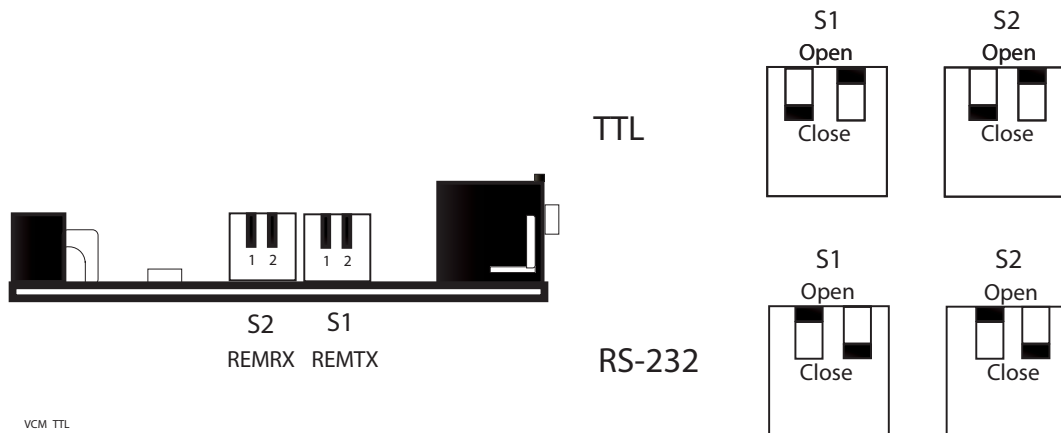
Type	Communication ports	Signal levels	Connector	Pin usage
ETHERNET 	TCP port	ETHERNET	RJ-45 connector 	1=Transmit+ 2=Transmit - 3=Receive+ 4=Reserved 5=Reserved 6=Receive- 7=Reserved 8=Reserved
ETHERNET	TCP port	Fiber ethernet	ST connectors	

**Table 11.2: 18 mm high modules:**

Type	Communication ports	Signal levels	Connector	Pin usage
VCM 232	REMOTE, LOCAL and EXTENSION	RS-232	RJ-45 connector 	1= LOC TX 2= EXT TX 3= +8V 4= GND 5= REM TX 6= REM RX 7= LOC RX 8= EXT RX
VCM 485-2	REMOTE, LOCAL or EXTENSION port selectable with a dip switch	RS-485 (2-wire connection)	3-pole screw connector	1= - 2= + 3= GND

**Table 11.3: 32 mm high modules:**

Type	Communication ports	Signal levels	Connector	Pin usage
VCM TTL	REMOTE	REMOTE: TTL or RS-232 selectable with a dip switch	D- connector	1= EXT TX 2= REM TX 3= REM RX 4= SYNC IN 5= LOC TX 6= LOC RX 7= GND 8= EXT RX 9= +8V
	LOCAL	LOCAL: RS-232		
	EXTENSION	EXTENSION: RS-232		
VCM 485-4	REMOTE, LOCAL or EXTENSION port selectable with a dip switch	RS-485 (2- or 4-wire connection)	5- pole screw connector	1= GND 2= T+ 3= T- 4= R+ 5= R-
VCM fiber PP	REMOTE or LOCAL selectable with a dip switch.	Light, switch for echo/no-echo and light/no-light selection	Snap-in connector	
VCM fiber GG	REMOTE or LOCAL selectable with a dip switch.	Light, switch for echo/no-echo and light/no-light selection	ST connector	
VCM fiber PG	REMOTE or LOCAL selectable with a dip switch.	Light, switch for echo/no-echo and light/no-light selection	Snap-in & ST connectors	
VCM fiber GP	REMOTE or LOCAL selectable with a dip switch.	Light, switch for echo/no-echo and light/no-light selection	ST & Snap-in connectors	



*Figure 11.8: VCM TTL- module's dip-switches*



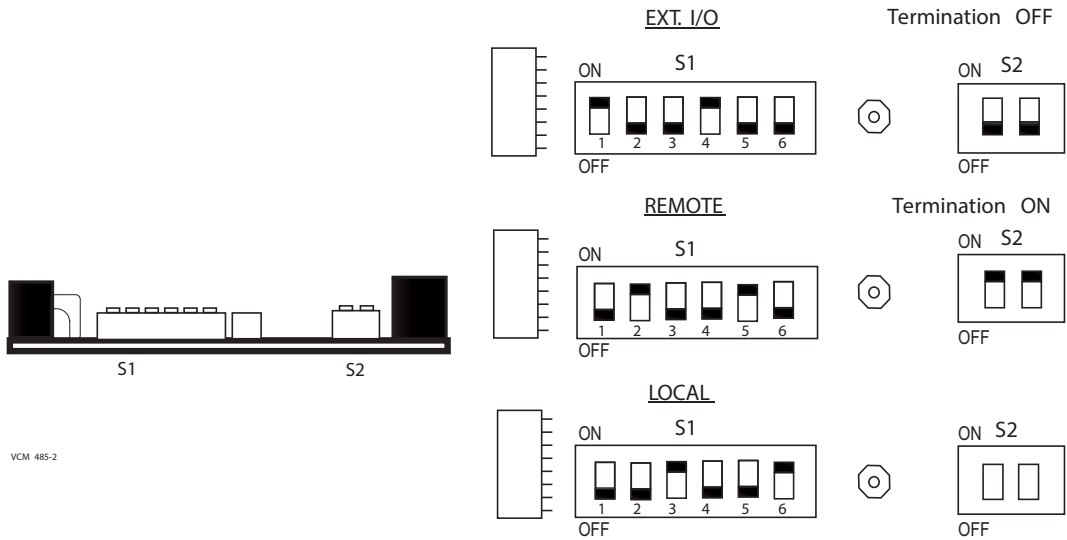


Figure 11.9: VCM 485-2- module's dip-switches

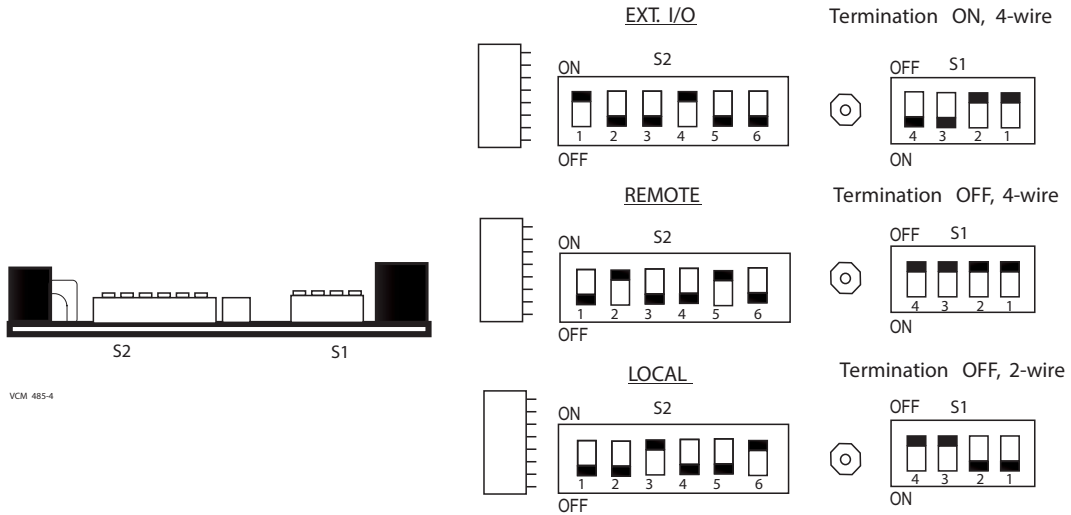


Figure 11.10: VCM 485-4- module's dip-switches

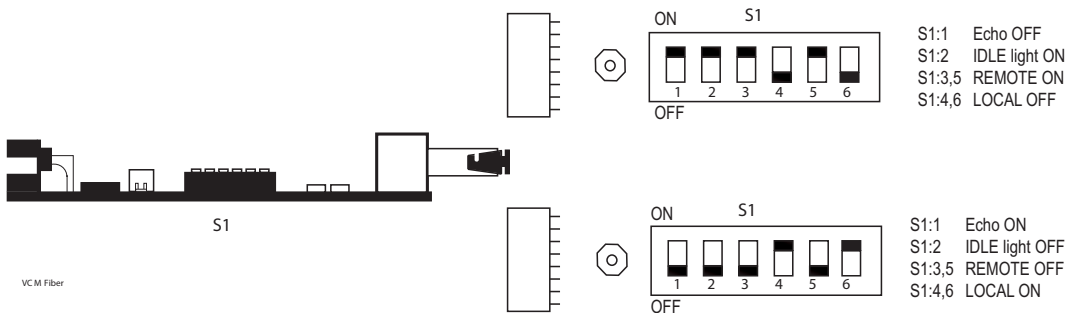


Figure 11.11: VCM Fiber- module's dip-switches

**NOTE:** Profibus will be supported by the external VPA 3CG module. This is connected with a VX007-F3 cable to VCM TTL module (VCM TTL dip-switch must be set to TTL).

## 11.3.2 Front panel connector

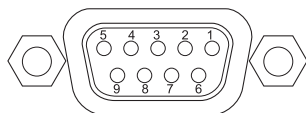


Figure 11.12: Pin numbering of the front panel D9S connector

Pin	RS232 signal
1	Not connected
2	Rx in
3	Tx out
4	DTR out (+8 V)
5	GND
6	DSR in (activates this port and disables the X4 RS232 port)
7	RTS in (Internally connected to pin 8)
8	CTS out (Internally connected to pin 7)
9	Not connected

**NOTE:** DSR must be connected to DTR to activate the front panel connector and disable the rear panel X4 RS232 port. (The other port in the same X4 connector will not be disabled.)

## 11.4 Optional two channel arc protection card

**NOTE:** When this option card is installed, the parameter "Arc card type" has value "2Arc+BI/O". Please check the ordering code in Chapter 14 Order information.

If the slot X6 is already occupied with the DI19 / DI20 digital input card, this option is not available, but there is still one arc sensor channel available. See Chapter 11.5 Optional digital I/O card (DI19/DI20).

The optional arc protection card includes two arc sensor channels. The arc sensors are connected to terminals X6: 4 – 5 and 6 – 7.

The arc information can be transmitted and/or received through digital input and output channels. This is a 48 V dc signal.

### Connections:

X6: 1	Binary input (BI)
X6: 2	Binary output (BO)
X6: 3	Common for BI and BO.
X6: 4-5	Sensor 1
X6: 6-7	Sensor 2

The binary output of the arc option card may be activated by the arc sensors or by any available signal in the output matrix. The binary output can be connected to an arc binary input of another VAMP protection device.

## 11.5 Optional digital I/O card (DI19/DI20)

**NOTE:** When this option card is installed, the parameter "Arc card type" has value "Arc+2DI". With DI19/DI20 option only one arc sensor channel is available. Please check the ordering code in Chapter 14 Order information.

If the slot X6 is already occupied with the two channel arc sensor card (Chapter 11.4 Optional two channel arc protection card), this option is not available.

The DI19/DI20 option enables two more digital inputs. These inputs are useful in applications where the contact signals are not potential free. For example trip circuit supervision is such application. The inputs are connected to terminals X6:1 – X6:2 and X6:3 – X6:4.

### Connections:

X6:1	DI19+
X6:2	DI19-
X6:3	DI20+
X6:4	DI20-
X6:5	NC
X6:6	L+
X6:7	L-

## 11.6 External option modules

### 11.6.1 External LED module VAM 16D

The optional external VAM 16D led module provides 16 extra led-indicators in external casing. Module is connected to the serial port of the device's front panel. Please refer the User manual VAM 16D for details.

### 11.6.2 Third-party external input / output modules

The device supports optional external input/output modules used to extend the number of digital inputs and outputs. Also modules for analogue inputs and outputs are available.

The following types of devices are supported:

- Analog input modules (RTD)
- Analog output modules (mA-output)
- Binary input/output modules

EXTENSION port is primarily designed for I/O modules. This port is found in the LOCAL connector of the device backplane and I/O devices should be connected to the port with VSE003 adapter.

**NOTE:** If External I/O protocol is not selected to any communication port, VAMPSET doesn't display the menus required for configuring the I/O devices. After changing EXTENSION port protocol to External I/O, restart the relay and read all settings with VAMPSET.

**External analog inputs configuration (VAMPSET only)**

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																																																											
<table border="1"> <thead> <tr> <th>Range</th> <th colspan="4">Description</th> </tr> </thead> <tbody> <tr> <td></td> <td colspan="4">Communication read errors</td> </tr> <tr> <td rowspan="5">                     X: -32000 – 32000                      Y: -1000 – 1000                 </td> <td>Scaling</td> <td>Y2</td> <td>Scaled value</td> <td rowspan="2">Point 2</td> </tr> <tr> <td></td> <td>X2</td> <td>Modbus value</td> </tr> <tr> <td></td> <td>Y1</td> <td>Scaled value</td> <td rowspan="2">Point 1</td> </tr> <tr> <td></td> <td>X1</td> <td>Modbus value</td> </tr> <tr> <td>-32000 – 32000</td> <td>Offset</td> <td colspan="3">Subtracted from Modbus value, before running XY scaling</td> </tr> <tr> <td>InputR or HoldingR</td> <td colspan="4">Modbus register type</td> </tr> <tr> <td>1 – 9999</td> <td colspan="4">Modbus register for the measurement</td> </tr> <tr> <td>1 – 247</td> <td colspan="4">Modbus address of the I/O device</td> </tr> <tr> <td>C, F, K, mA, Ohm or V/A</td> <td colspan="4">Unit selection</td> </tr> <tr> <td></td> <td colspan="4">Active value</td> </tr> <tr> <td>On / Off</td> <td colspan="4">Enabling for measurement</td> </tr> </tbody> </table>											Range	Description					Communication read errors				X: -32000 – 32000 Y: -1000 – 1000	Scaling	Y2	Scaled value	Point 2		X2	Modbus value		Y1	Scaled value	Point 1		X1	Modbus value	-32000 – 32000	Offset	Subtracted from Modbus value, before running XY scaling			InputR or HoldingR	Modbus register type				1 – 9999	Modbus register for the measurement				1 – 247	Modbus address of the I/O device				C, F, K, mA, Ohm or V/A	Unit selection					Active value				On / Off	Enabling for measurement			
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		Y1	Scaled value	Point 1																																																																		
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C, F, K, mA, Ohm or V/A	Unit selection																																																																					
	Active value																																																																					
On / Off	Enabling for measurement																																																																					

**Alarms for external analog inputs**

EXTERNAL ANALOG INPUT ALARMS			
AI Enabled	AI Slave Address	AI Modbus Address	AI Meas
On	1	1	0.00 C
Off	1	2	0.00 C
Off	1	3	0.00 C

Range	Description
0 – 10000	Hysteresis for alarm limits
-21x107 – +21x107	<b>Alarm &gt;&gt;</b> Limit setting
- / Alarm	Active state
-21x107 – +21x107	<b>Alarm &gt;</b> Limit setting
- / Alarm	Active state
	Active value
1 – 9999	Modbus register for the measurement
1 – 247	Modbus address of the I/O device
On / Off	Enabling for measurement

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

**External digital inputs configuration (VAMPSET only)**

EXTERNAL DIGITAL INPUTS							Range	Description
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		Communication read errors
Off	0	1	2	Coils	1	0	1 – 16	Bit number of Modbus register value
Off	0	1	3	Coils	1	0		Modbus register type CoilS, InputS, InputR or HoldingR
							1 – 9999	Modbus register for the measurement
							1 – 247	Modbus address of the I/O device
							0 / 1	Active state
							On / Off	Enabling for measurement

**External digital outputs configuration (VAMPSET only)**

EXTERNAL DIGITAL OUTPUTS							Range	Description
DO Enabled	DO State	DO Slave Address	DO ModBus Address	DO Error Counter				
On	0	1	1	0			Communication errors	
Off	0	1	2	0		1 – 9999	Modbus register for the measurement	
Off	0	1	3	0		1 – 247	Modbus address of the I/O device	
						0 / 1	Output state	
							Enabling for measurement	

External analog outputs configuration (VAMPSET only)

EXTERNAL ANALOG OUTPUTS	Range	Description																																																				
<table border="1" style="width: 100%; font-size: 8px;"> <thead> <tr> <th>AO Enabled</th> <th>mA Output</th> <th>mA Min</th> <th>mA Max</th> <th>AO Link</th> <th>Linked Val. Min</th> <th>Linked Val. Max</th> <th>AO Slave Address</th> <th>AO ModBus Address</th> <th>AO Register Type</th> <th>ModBus Min</th> <th>ModBus Max</th> <th>AO Error Counter</th> </tr> </thead> <tbody> <tr> <td>On</td> <td>0.00</td> <td>0</td> <td>20</td> <td>IL1</td> <td>0 A</td> <td>1000 A</td> <td>1</td> <td>1</td> <td>HoldingR</td> <td>0</td> <td>100</td> <td>0</td> </tr> <tr> <td>Off</td> <td>0.00</td> <td>0</td> <td>20</td> <td>IL2</td> <td>0 A</td> <td>1000 A</td> <td>1</td> <td>2</td> <td>HoldingR</td> <td>0</td> <td>100</td> <td>0</td> </tr> <tr> <td>Off</td> <td>0.00</td> <td>0</td> <td>20</td> <td>IL3</td> <td>0 A</td> <td>1000 A</td> <td>1</td> <td>3</td> <td>HoldingR</td> <td>0</td> <td>100</td> <td>0</td> </tr> </tbody> </table>	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		Communication errors
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																																										
-32768 – +32767		Modbus value corresponding Linked Val. Max																																																				
(0 – 65535)		Modbus value corresponding Linked Val. Min																																																				
InputR or HoldingR		Modbus register type																																																				
1 – 9999		Modbus register for the output																																																				
1 – 247		Modbus address of the I/O device																																																				
0 – 42x108,		Maximum limit for lined value, corresponding to “Modbus Max”																																																				
-21x108 – +21x108		Minimum limit for lined value, corresponding to “Modbus Min”																																																				
		Link selection																																																				
-21x107 – +21x107		Minimum & maximum output values																																																				
		Active value																																																				
On / Off		Enabling for measurement																																																				



# 11.7 Block optional diagrams

## 11.7.1 VAMP 259-4C6

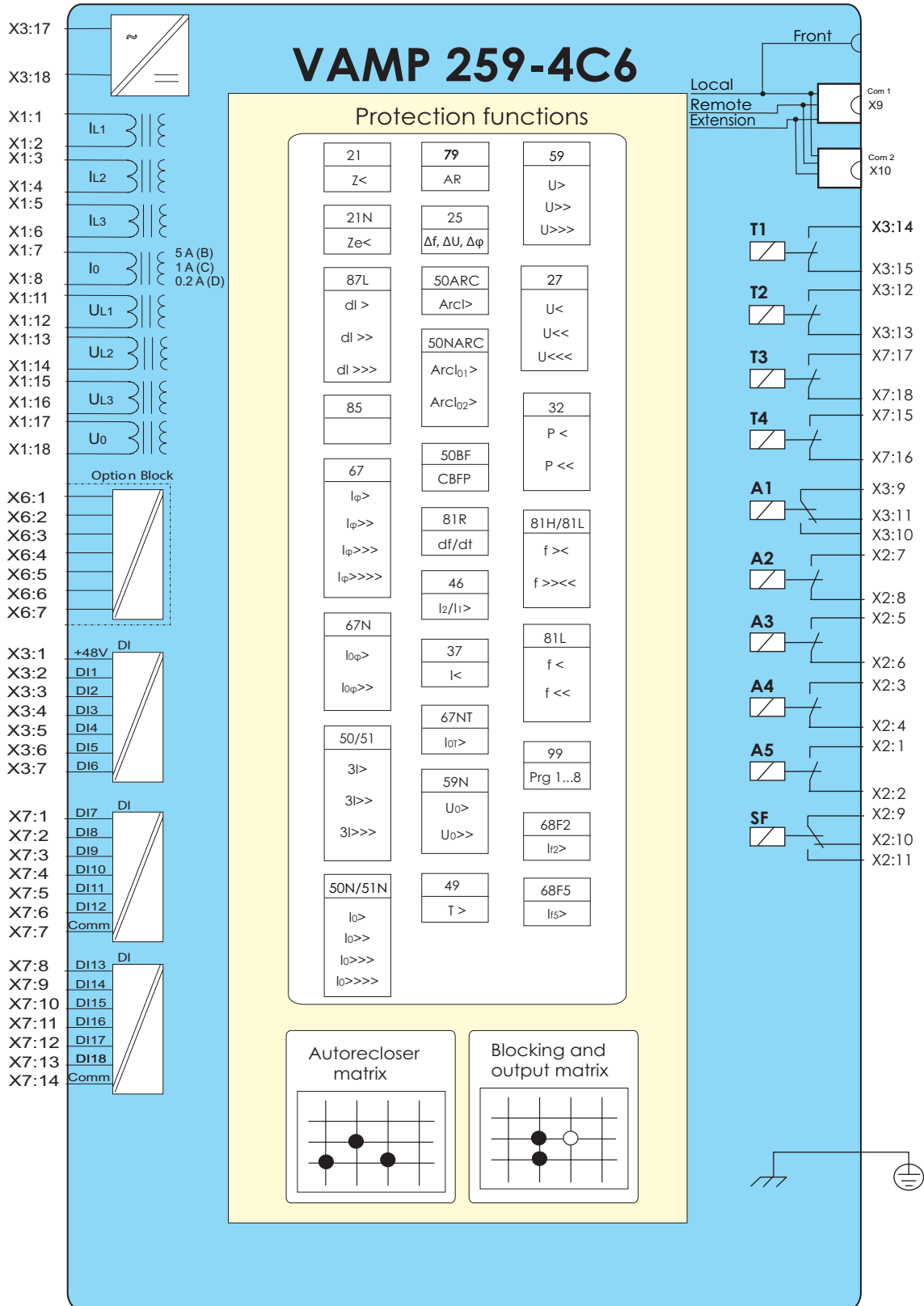


Figure 11.13: Block diagram of VAMP 259-4C6

### 11.7.2 VAMP 259-4C8

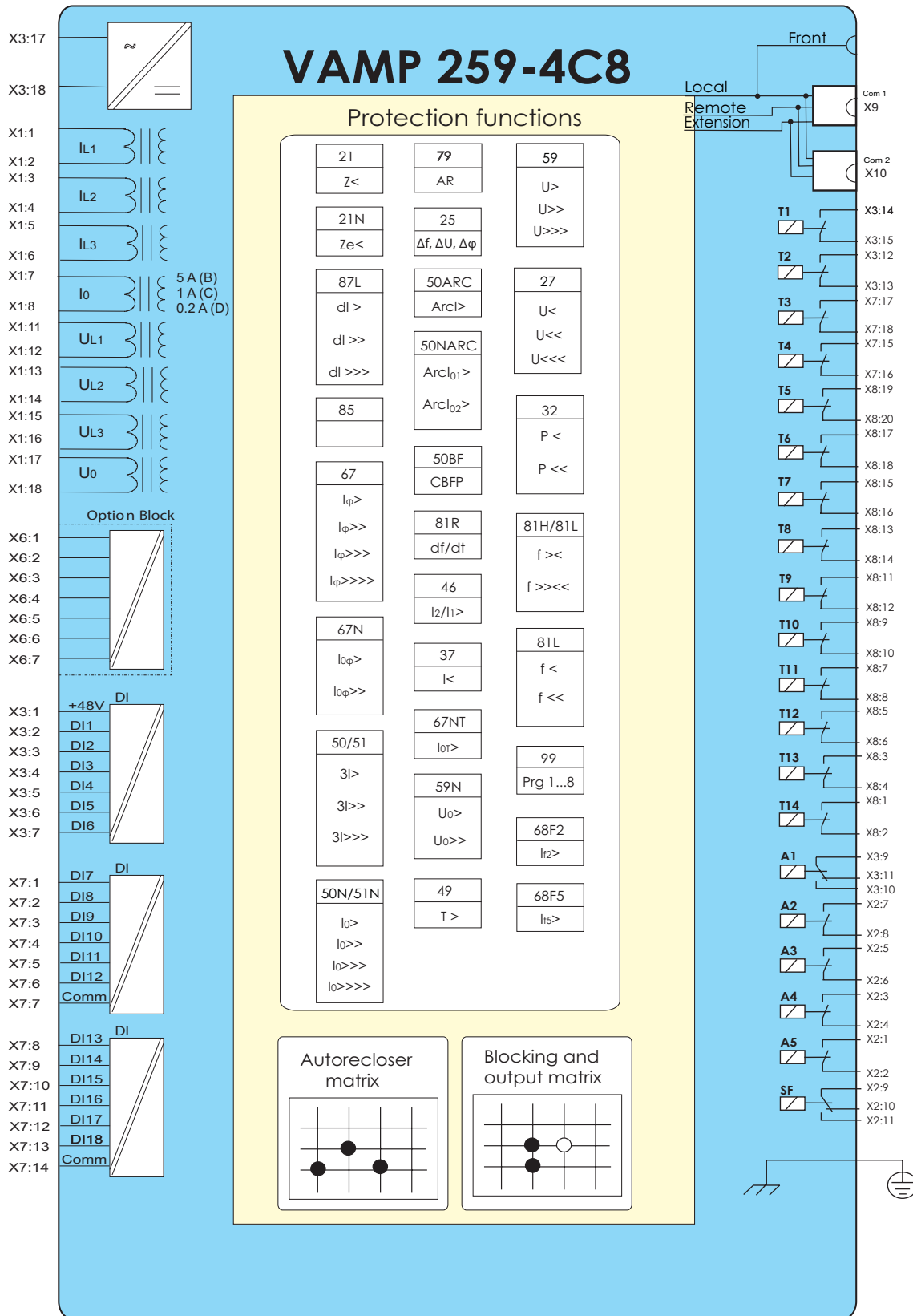


Figure 11.14: Block diagram of VAMP 259-4C8

### 11.7.3 VAMP 259-4C9

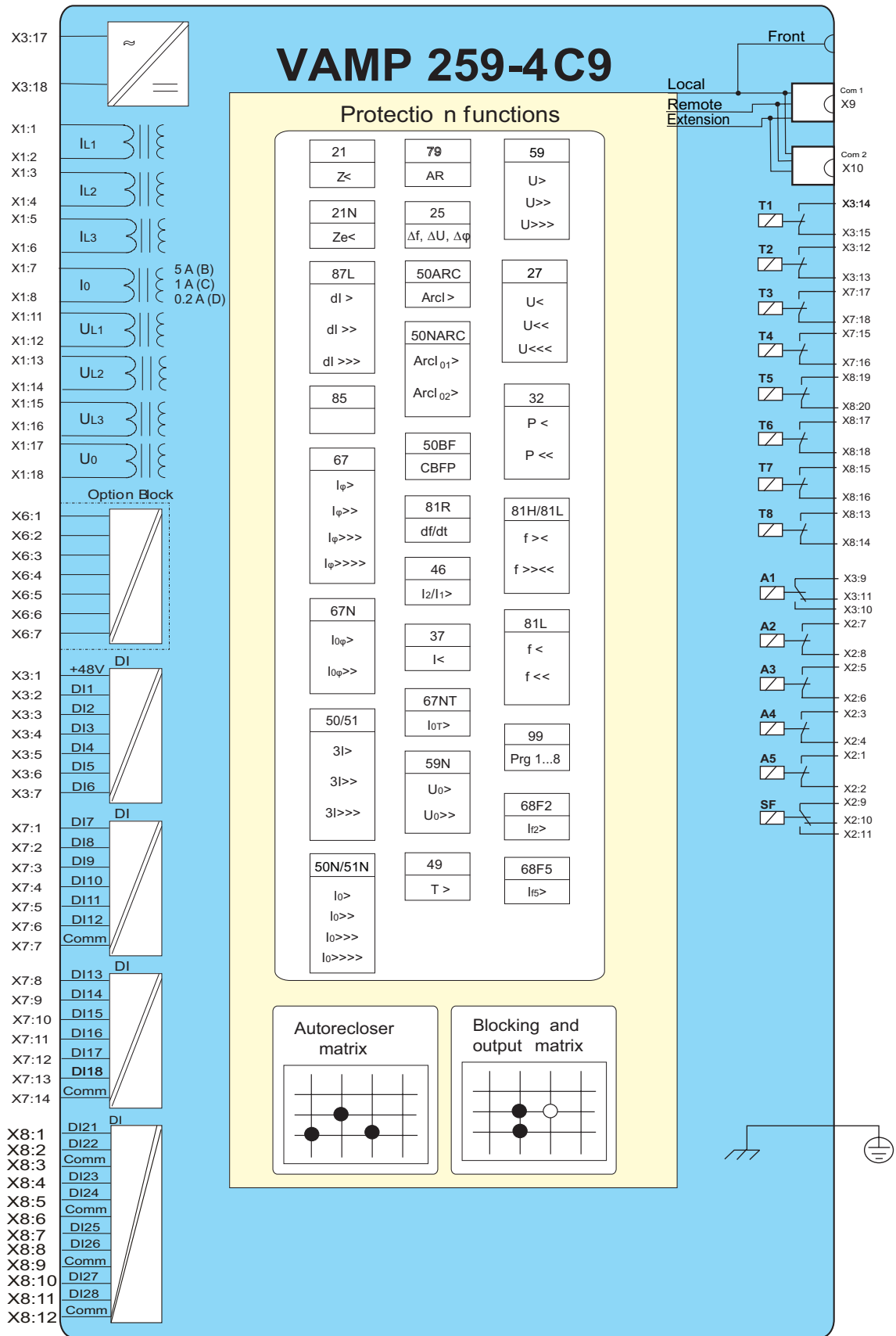


Figure 11.15: Block diagram of VAMP 259-4C9

# 11.8 Block diagrams of option modules

## 11.8.1 Block diagrams of optional modules

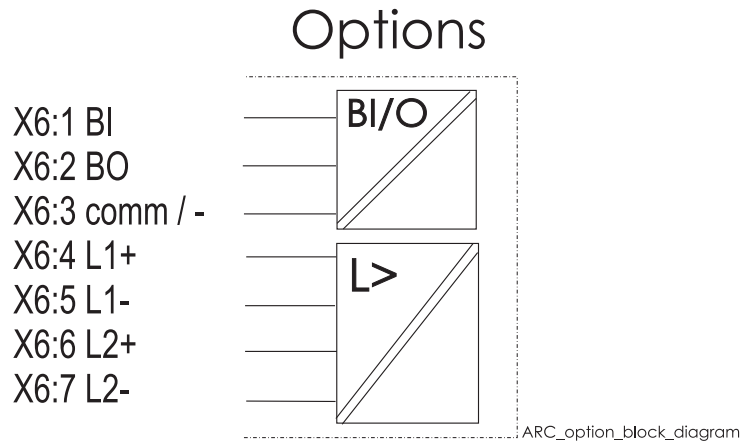


Figure 11.16: Block diagram of optional arc protection module.

## 11.8.2 Block diagram of optional DI19/DI20

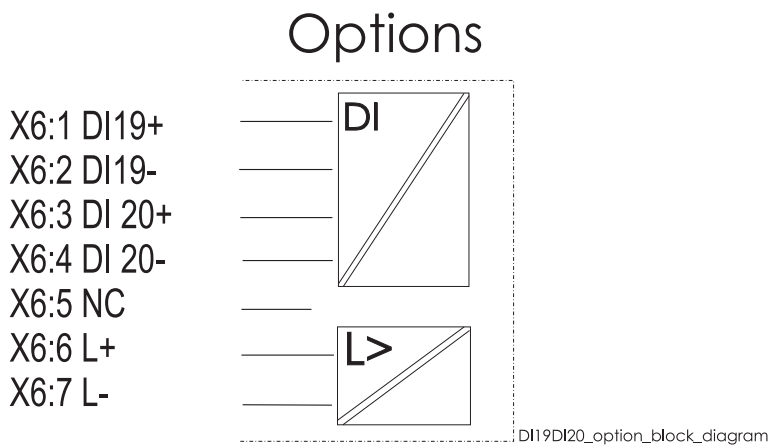


Figure 11.17: Block diagram of optional DI19/DI20 module with one arc channel.

# 11.9 Connection examples

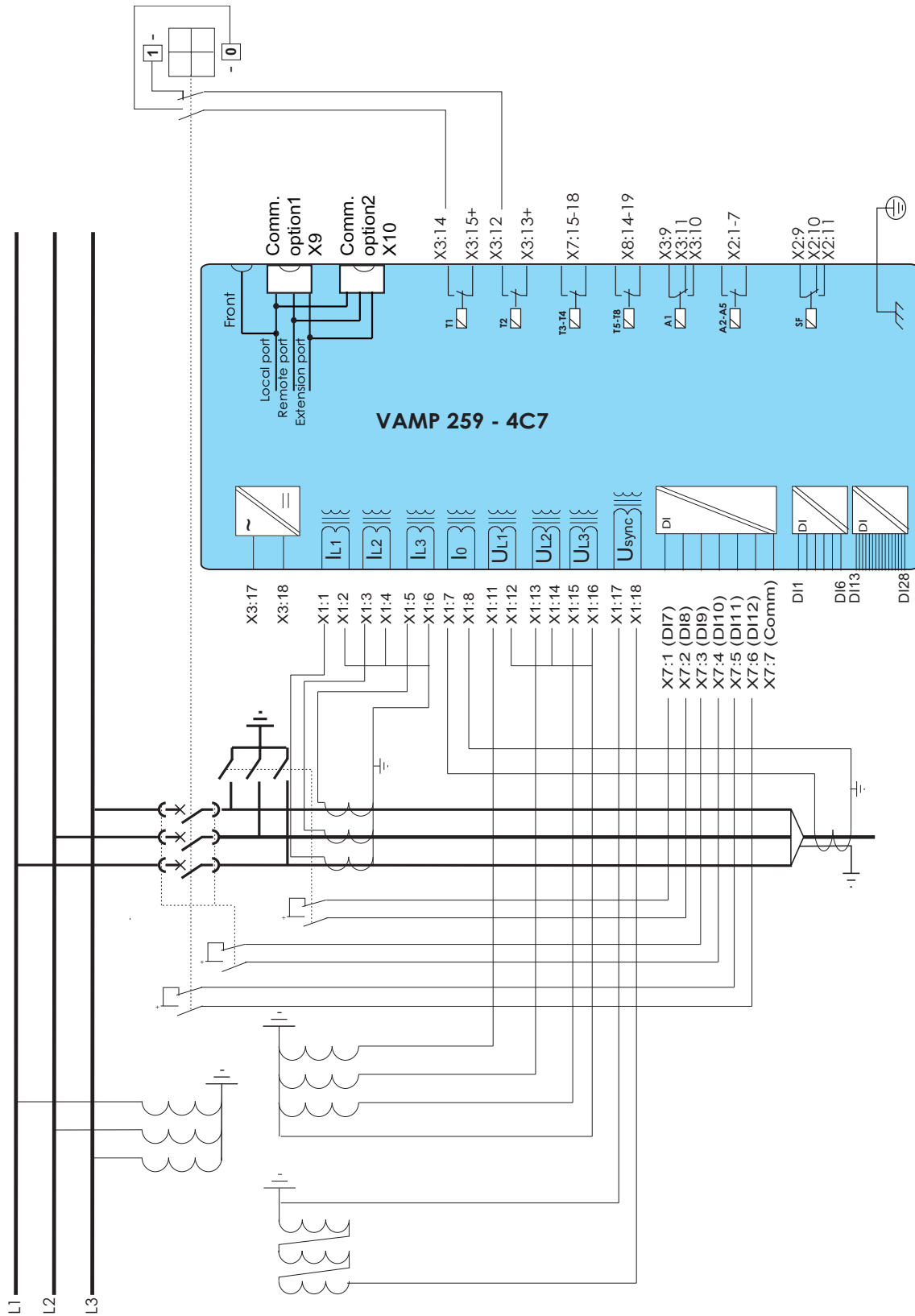


Figure 11.18: Connection example of VAMP 259-4C7 without a synchrocheck function in use. The voltage measurement mode is set to “3LN+U<sub>0</sub>”.

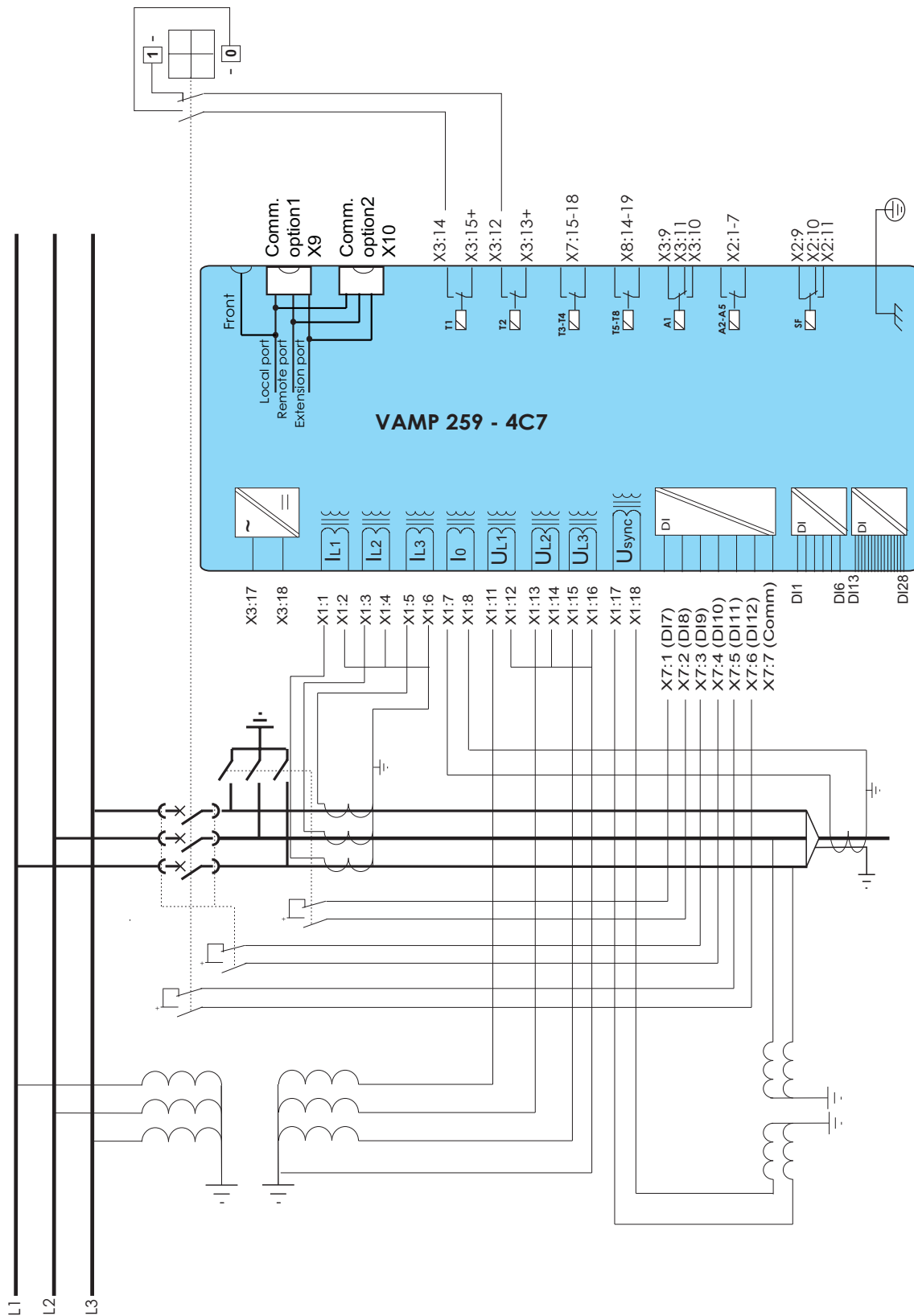


Figure 11.19: Connection example of VAMP 259-4C7 with a synchrocheck function from phase to phase voltage. The voltage measurement mode is set to “3LN/LLy”.

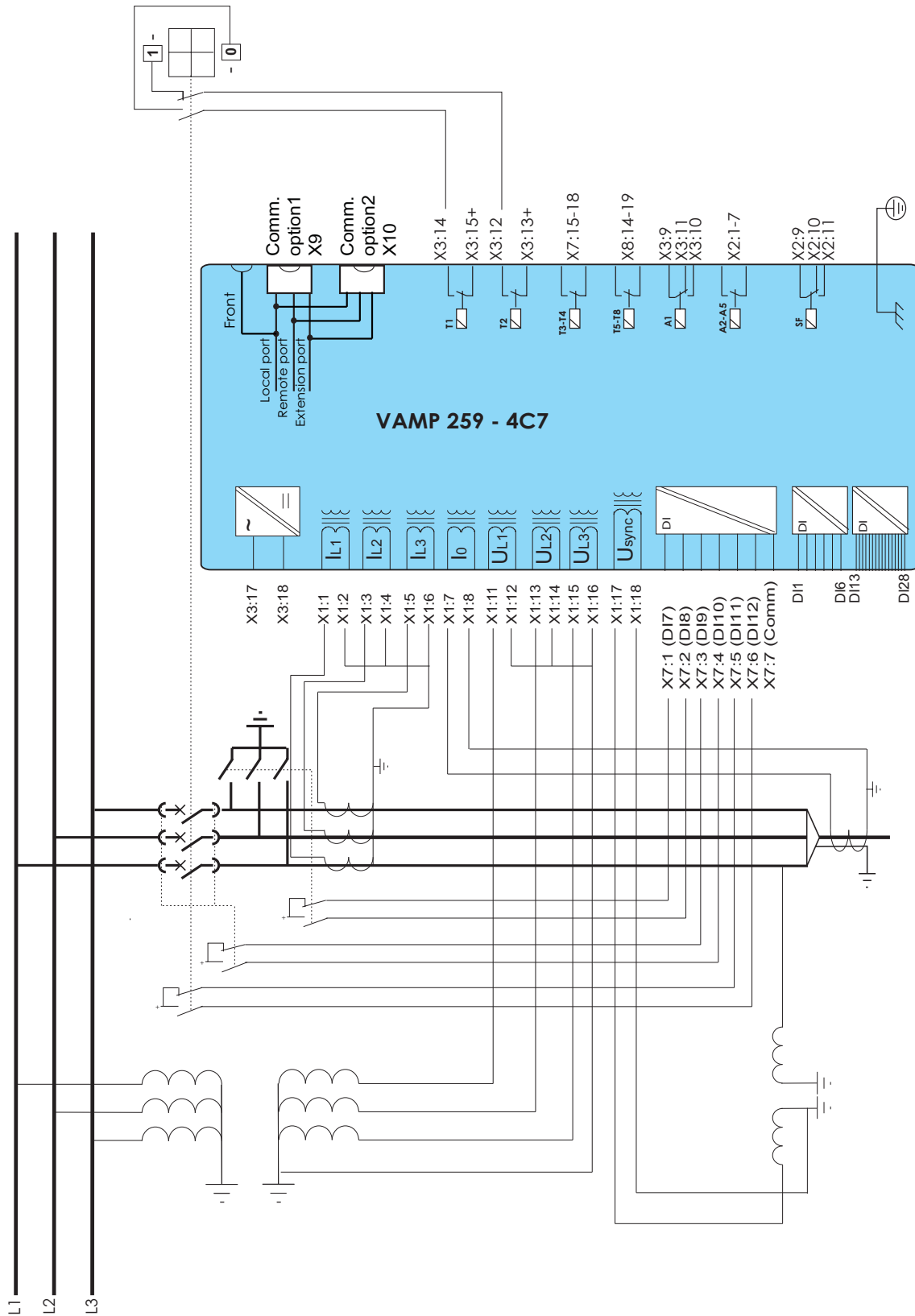


Figure 11.20: Connection example of VAMP 259-4C7 with a synchrocheck function from phase to ground voltage. The voltage measurement mode is set to “3LN/LNy”.

# 12 Technical data

## 12.1 Connections

**Table 12.1: Measuring circuits**

Rated phase current	5 A (configurable for CT secondaries 1 – 10 A)
- Current measuring range	0 – 250 A
- Thermal withstand	20 A (continuously) / 100 A (for 10 s) / 500 A (for 1 s)
- Burden	0.125 VA
- Impedance	0.005 Ohm
$I_0$ input option B	see Chapter 14 Order information
Rated residual current (optional)	5 A (configurable for CT secondaries 1 – 10 A)
- Current measuring range	0 – 50 A
- Thermal withstand	20 A (continuously) / 100 A (for 10 s) / 500 A (for 1 s)
- Burden	0.125 VA
- Impedance	0.005 Ohm
$I_0$ input option C	see Chapter 14 Order information
Rated residual current	1 A (configurable for CT secondaries 0.1 – 10.0 A)
- Current measuring range	0 – 10 A
- Thermal withstand	4 A (continuously) / 20 A (for 10 s) / 100 A (for 1 s)
- Burden	0.04 VA
- Impedance	0.04 Ohm
$I_0$ input option D	see Chapter 14 Order information
Rated residual current (optional)	0.2 A (configurable for CT secondaries 0.1 – 10.0 A)
- Current measuring range	0 – 2 A
- Thermal withstand	0.8 A (continuously) / 4 A (for 10 s) / 20 A (for 1 s)
- Burden	0.04 VA
- Impedance	0.04 Ohm
Rated voltage $U_N$	100 V (configurable for VT secondaries 50 – 120 V)
- Voltage measuring range	0 – 160 V (100 V/110 V)
- Continuous voltage withstand	250 V
- Burden	< 0.5V A
Rated frequency $f_N$	45 – 65 Hz
Terminal block:	Maximum wire dimension:
- Solid or stranded wire	4 mm <sup>2</sup> (10 – 12 AWG)



**Table 12.2: Auxiliary voltage**

	Type A (standard)	Type B (option)
Rated voltage $U_{AUX}$	40 – 265 V ac/dc	18 – 36 V dc <b>Note! Polarity</b> X3:17= negative (-) X3:18= positive (+)
Start-up peak (dc)		
110 V (Type A)	15 A with time constant of 1ms	
220 V (Type A)	25 A with time constant of 1ms	
Power consumption	< 15 W (normal conditions) < 25 W (output relays activated)	
Max. permitted interruption time	< 50 ms (110 V dc)	
Terminal block: - Phoenix MVSTBW or equivalent	Maximum wire dimension: 2.5 mm <sup>2</sup> (13 – 14 AWG)	

**Table 12.3: Digital inputs internal operating voltage**

Number of inputs	6
Internal operating voltage	48 V dc
Current drain when active (max.)	approx. 20 mA
Current drain, average value	< 1 mA
Terminal block: - Phoenix MVSTBW or equivalent	Maximum wire dimension: 2.5 mm <sup>2</sup> (13 – 14 AWG)

**NOTE:** Recommended channel activation delay is >20 ms.

**Table 12.4: Digital inputs external operating voltage**

Number of inputs	12/20/16 (depends on the ordering code)
External operating voltage	Rated voltage selectable in order code: 4: 24V dc/ac (max 265 V) 5: 24V dc/ac (max 265 V) (UL) 6: 110V dc/ac (max 265 V) 7: 220V dc/ac (max 265 V)
Current drain	approx. 2 mA
Activation time dc/ac	< 11 ms / < 15 ms
Reset time dc/ac	< 11 ms / < 15 ms
Terminal block: - Phoenix MVSTBW or equivalent	Maximum wire dimension: 2.5 mm <sup>2</sup> (13 – 14 AWG)

**Table 12.5: Trip contact**

Number of contacts	4/8/14 (depends on the order code)
Rated voltage	250 V ac/dc
Continuous carry	5 A
Make and carry, 0.5 s	30 A
Make and carry, 3 s	15 A
Breaking capacity, dc (L/R = 40ms)	
at 48 V dc:	5 A
at 110 V dc:	3 A
at 220 V dc:	1 A
Contact material	AgNi 90/10
Terminal block: - MSTB2.5 - 5.08	Wire dimension: Maximum 2.5 mm <sup>2</sup> (13 – 14 AWG) Minimum 1.5 mm <sup>2</sup> (15 – 16 AWG)

**Table 12.6: Signal contacts**

Number of contacts:	3 change-over contacts (relays A1, A2 and A3) 2 making contacts (relays A4 and A5) 1 change-over contact (SF relay)
Rated voltage	250 V ac/dc
Max. make current, 4s at duty cycle 10%	15 A
Continuous carry	5 A
Breaking capacity, ac	2 000 VA
Breaking capacity, dc (L/R = 40ms)	
at 48 V dc:	1.3 A
at 110 V dc:	0.4 A
at 220 V dc:	0.2 A
Contact material	AgNi 0.15 gold plated AgNi 90 / 10
Terminal block - MSTB2.5 - 5.08	Wire dimension Maximum 2.5 mm <sup>2</sup> (13 – 14 AWG) Minimum 1.5 mm <sup>2</sup> (15 – 16 AWG)

**Table 12.7: Ethernet connection**

Number of ports	1
Electrical connection	Ethernet RJ-45 (Ethernet 10-Base-T)
Protocols	VAMPSET Modbus TCP IEC 61850
Data transfer rate	10 Mb/s

**Table 12.8: Ethernet fiber interface**

Type	Multimode
Connector	ST
Physical layer	100 Base-Fx
Maximum cable distance	2 km
Optical wavelength	1300 nm
Cable core / cladding size	50/125 or 62.5/125 $\mu\text{m}$

**Table 12.9: Local serial communication port**

Number of ports	1 on front and 1 on rear panel
Electrical connection	RS 232 in the front RS 232 with VCM-TTL (standard) RS-485 with VCM 485-2 or VCM 485-4 Plastic fibre with VCM-fibre (option) Glass fibre with VCM-fibre (option)
Data transfer rate	2 400 – 38 400 kb/s

**Table 12.10: Remote control connection (option)**

Number of ports	1 on rear panel
Electrical connection	TTL with VCM TTL (standard) RS 485 with VCM 485-4 (option) RS 232 with VCM TTL (standard) Plastic fibre connection with VCM fiber (option) Glass fibre connection with VCM fiber (option) 100M Ethernet fiber 100M Ethernet copper (RJ 45)
Data transfer rate	1 200 – 19 200 kb/s
Protocols	Modbus, RTU master Modbus, RTU slave SPA-bus, slave IEC 60870-5-103 ProfiBus DP (option, with external module) Modbus TCP (internal / external optional module) IEC 60870-5-101 IEC 60870-5-101 TCP DNP 3.0 DNP 3.0 TCP IEC 61850

**Table 12.11: Arc protection interface (option)**

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

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

## 12.2 Test and environmental conditions

**Table 12.12: Disturbance tests**

Test	Standard & Test class / level	Test value
<b>Emission</b>	EN 61000-6-4 / IEC 60255-26	
- Conducted	EN 55011, Class A / IEC 60255-25	0.15 – 30 MHz
- Emitted	EN 55011, Class A / IEC 60255-25 / CISPR 11	30 – 1000 MHz
<b>Immunity</b>	EN 61000-6-2 / IEC 60255-26	
- 1 Mhz damped oscillatory wave	IEC 60255-22-1	±2.5kVp CM, ±1.0kVp DM
- Static discharge (ESD)	EN 61000-4-2 Level 4 / IEC 60255-22-2 Class 4	8 kV contact discharge 15 kV air discharge
- Emitted HF field	EN 61000-4-3 Level 3 / IEC 60255-22-3	80 - 1000 MHz, 10 V/m
- Fast transients (EFT)	EN 61000-4-4 Level 3 / IEC 60255-22-4 Class B	2 kV, 5/50 ns, 5 kHz
- Surge	EN 61000-4-5 Level 3 / IEC 60255-22-5	2 kV, 1.2/50 µs, CM 1 kV, 1.2/50 µs, DM
- Conducted HF field	EN 61000-4-6 Level 3 / IEC 60255-22-6	0.15 - 80 MHz, 10 Vrms
- Power-frequency magnetic field	EN 61000-4-8	300A/m (continuous)
- Pulse magnetic field	EN 61000-4-9 Level 5	1000A/m, 1.2/50 µs
- Voltage interruptions	IEC 60255-11	10ms / 100%
- Voltage dips and short interruptions	EN 61000-4-11	30%/10ms, 100%/10ms, 60%/100ms, >95%/5000ms
- Voltage alternative component	IEC 60255-11	12% of operating voltage (DC)

**Table 12.13: Electrical safety tests**

Test	Standard & Test class / level	Test value
- Impulse voltage withstand	EN 60255-5, Class III	5 kV, 1.2/50 µs, 0.5 J 1 kV, 1.2/50 µs, 0.5 J Communication
- Dielectric test	EN 60255-5, Class III	2 kV, 50 Hz 0.5 kV, 50 Hz Communication
- Insulation resistance	EN 60255-5	
- Protective bonding resistance	EN 60255-27	
- Power supply burden	IEC 60255-1	

**Table 12.14: Mechanical tests**

Vibration (IEC 60255-21-1) Class I	10 – 60 Hz, amplitude ±0.035 mm 60 – 150 Hz, acceleration 0.5g sweep rate 1 octave/min 20 periods in X-, Y- and Z axis direction
Shock (IEC 60255-21-1) Class I	half sine, acceleration 5 g, duration 11 ms 3 shocks in X-, Y- and Z axis direction

**Table 12.15: Environmental conditions**

Ambient temperature, in-service	-40 – 55°C (-40 – 131°F)
Ambient temperature, storage	-40 – 70°C (-40 – 158°F)
Relative air humidity	< 95%
Maximum operating altitude	2000 m (6561.68 ft)

**Table 12.16: Casing**

Degree of protection (IEC 60529)	Standard: IP30 front panel. IP20 rear panel Option: IP54 front panel, IP 20 rear panel
Dimensions (W x H x D)	208 x 155 x 225 mm / 8.19 x 6.10 x 8.86 in
Material	1 mm (0.039 in) steel plate
Weight	4.2 kg (9.272 lb)
Colour code	RAL 7032 (Casing) / RAL 7035 (Back plate)

**Table 12.17: Package**

Dimensions (W x H x D)	215 x 160 x 275 mm / 8.46 x 6.30 x 10.83 in
Weight (Terminal, Package and Manual)	5.2 kg (11.479 lb)

## 12.3 Protection functions

\* EI = Extremely Inverse, NI = Normal Inverse, VI = Very Inverse, LTI = Long Time Inverse, MI = Moderately Inverse

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

### 12.3.1 Differential protection

**Table 12.18: Line differential protection  $I_{dl}>$  (87L)**

$I_{Pick-Up}$	20 – 50 %
Start of slope 1	$0.5 - 1.0 \times I_N$
Slope 1	0 – 100 %
Start of slope 2	$1.0 - 3.0 \times I_N$
Slope 2	50 – 200 %
Second harmonic blocking	$5 - 30 \% I_N$ (step 1%)
Fifth harmonic blocking	$20 - 50 \% I_N$ (step 1%)
Reset time	< 95 ms
Reset ratio	0.95
Inaccuracy:	
- 2nd harmonic blocking	$\pm 1\%$ - unit
- 5th harmonic blocking	$\pm 1\%$ - unit
- Starting	$\pm 5\%$ of set value or $0.05 \times I_N$ when currents are > 200 mA
- Operating time ( $3.5 \times I_{SET}$ )	typically 35 ms

**NOTE:** The amplitude of second harmonic content has to be at least 2% of the nominal of CT. If the nominal current is 5 A, the 100 Hz component needs to exceed 100 mA.

**Table 12.19: Differential overcurrent stage  $I_{dl}>>$  (87L)**

Setting range	$1.2 - 20.0 \times I_N$ (step 0.1)
Second harmonic blocking	$5 - 30 \% I_N$ (step 1%)
Fifth harmonic blocking	$20 - 50 \% I_N$ (step 1%)
Inaccuracy:	
- 2nd harmonic blocking	$\pm 1\%$ - unit
- 5th harmonic blocking	$\pm 1\%$ - unit
- Starting	$\pm 5\%$ of the set value
- Operating time ( $3.5 \times I_{SET}$ )	typically 35 ms

**Table 12.20: Transformer settings (scaling menu)**

Connection group	None (no transformer) Yy0, Yy6, Yd1, Yd5, Yd7, Yd11, Dy1, Dy5, Dy7, Dy11, Dd0 and Dd6
Transformer side	HV (relay located on high voltage side) LV (relay located on low voltage side)
Transformer grounding: - $I_0$ compensation - $I'_0$ compensation	enabled or disabled depending whether starpoint is grounded or not

### 12.3.2

## Non-directional current protection

**Table 12.21: Overcurrent stage I> (50/51)**

Pick-up value	0.10 – 5.00 x $I_N$ (step 0.01)
Definite time function: - Operate time	DT** 0.04 – 300.00 s (step 0.01 s)
IDMT function:	
- Delay curve family	(DT), IEC, IEEE, RI Prg
- Curve type	EI, VI, NI, LTI, MI..., depends on the family*
- Time multiplier k	0.05 – 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time	Typically 30 ms
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio	0.97
Transient over-reach, any $\tau$	< 10 %
Inaccuracy:	
- Starting	±3% of the set value or 5 mA secondary
- Operate time at definite time function	±1% or ±25 ms
- Operate time at IDMT function	±5% or at least ±25 ms**



**Table 12.22: Overcurrent stage I>> (50/51)**

Pick-up value	0.10 – 20.00 x I <sub>N</sub> (step 0.01)
Definite time function:	DT**
Operate time	0.04 – 1800.00 s (step 0.01 s)
Start time	Typically 30 ms
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio	0.97
Transient over-reach, any τ	< 10 %
Inaccuracy:	
- Starting	±3% of the set value or 5 mA secondary
- Operate time	±1% or ±25 ms

**Table 12.23: Overcurrent stages I>>> (50/51)**

Pick-up value	0.10 – 40.00 x I <sub>N</sub> (step 0.01)
Definite time function:	DT**
Operate time	0.03 – 300.00 s (step 0.01 s)
Instant operate time:	
I <sub>M</sub> / I <sub>SET</sub> ratio > 1.5	<30 ms
I <sub>M</sub> / I <sub>SET</sub> ratio 1.03 – 1.5	< 50 ms
Start time	Typically 20 ms
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio	0.97
Inaccuracy:	
- Starting	±3% of the set value or 5 mA secondary
- Operate time DT (I <sub>M</sub> /I <sub>SET</sub> ratio > 1.5)	±1% or ±15 ms
- Operate time DT (I <sub>M</sub> /I <sub>SET</sub> ratio 1.03 – 1.5)	±1% or ±25 ms

**Table 12.24: Thermal overload stage T> (49)**

Maximum continuous current:	0.1 – 2.40 x I <sub>N</sub> (step 0.01)
Alarm setting range:	60 – 99 % (step 1%)
Time constant Tau:	2 – 180 min (step 1)
Cooling time coefficient:	1.0 – 10.0 x Tau (step 0.1)
Max. overload at +40°C	70 – 120 %I <sub>N</sub> (step 1)
Max. overload at +70°C	50 – 100 %I <sub>N</sub> (step 1)
Ambient temperature	-55 – 125°C (step 1°)
Resetting ratio (Start & trip)	0.95
Accuracy:	
- Operate time	±5% or ±1 s

**Table 12.25: Undercurrent protection stage I< (37)**

Current setting range:	20 – 70 %I <sub>N</sub> (step 1%)
Definite time characteristic:	
- Operate time	0.3 – 300.0 s (step 0.1)
Block limit	15 % (fixed)
Start time	Typically 200 ms
Reset time	< 450 ms
Reset ratio	1.05
Accuracy:	
- Starting	±2% of set value or ±0.5% of the rated value
- Operate time	±1 % or ±150 ms

**NOTE:** Stage Blocking is functional when all phase currents are below the block limit.

**Table 12.26: Current unbalance stage I<sub>2</sub>/I<sub>1</sub>> (46)**

Settings:	
- Setting range I <sub>2</sub> / I <sub>1</sub> >	2 – 70% (step 1%)
Definite time function:	
- Operate time	1.0 – 600.0 s (step 0.1 s)
Start time	Typically 300 ms
Reset time	< 450 ms
Reset ratio	0.95
Inaccuracy:	
- Starting	±1% - unit
- Operate time	±5% or ±200 ms

**Table 12.27: Earth fault stage  $I_0 >$  (50N/51N)**

Input signal	$I_0$ (input X1:7 – 8) $I_{0Calc}$ ( $= I_{L1} + I_{L2} + I_{L3}$ )
Pick-up value	0.005 – 8.00 pu (when $I_0$ ) (step 0.001) 0.05 – 20.0 pu (when $I_{0Calc}$ )
Definite time function:	DT**
- Operate time	0.04** – 300.00 s (step 0.01 s)
IDMT function:	
- Delay curve family	(DT), IEC, IEEE, RI Prg
- Curve type	EI, VI, NI, LT1, MI..., depends on the family*
- Time multiplier k	0.05 – 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time	Typically 60 ms
Reset time	<95 ms
Reset ratio	0.95
Inaccuracy:	
- Starting	$\pm 2\%$ of the set value or $\pm 0.3\%$ of the rated value
- Starting (Peak mode)	$\pm 5\%$ of the set value or $\pm 2\%$ of the rated value (Sine wave <65 Hz)
- Operate time at definite time function	$\pm 1\%$ or $\pm 25$ ms
- Operate time at IDMT function	$\pm 5\%$ or at least $\pm 25$ ms**

**Table 12.28: Earth fault stages  $I_0 >>$ ,  $I_0 >>>$ ,  $I_0 >>>>$  (50N/51N)**

Input signal	$I_0$ (input X1:7 – 8) $I_{0Calc}$ ( $= I_{L1} + I_{L2} + I_{L3}$ )
Pick-up value	0.01 – 8.00 pu (When $I_0$ ) (step 0.01) 0.05 – 20.0 pu (When $I_{0Calc}$ ) (step 0.01)
Definite time function:	
- Operate time	0.04** – 300.00 s (step 0.01 s)
Start time	Typically 30 ms
Reset time	<95 ms
Reset ratio	0.95
Inaccuracy:	
- Starting	$\pm 2\%$ of the set value or $\pm 0.3\%$ of the rated value
- Starting (Peak mode)	$\pm 5\%$ of the set value or $\pm 2\%$ of the rated value (Sine wave <65 Hz)
- Operate time	$\pm 1\%$ or $\pm 25$ ms

### 12.3.3 Directional current protection

**Table 12.29: Short circuit distance stages Z1 – Z5 (21)**

Pick-up setting range X	0.05 – 250 $\Omega$
Pick-up setting range R	0.05 – 250 $\Omega$
Definite time function:	
- Setting range	0.05** – 300.00 s (step 0.01 s)
Reset time	<65 ms
Retardation time	< 50 ms
Reset ratio	1.05
Inaccuracy:	
- Starting (when $U > 1V$ and $I > 0.5 A + UxI > 10 VA$ )	Typically $\pm 5\%$ of X (R if $R > X$ ) or 10 m $\Omega$
- Operating time at definite time function	1% or $\pm 25$ ms

**Table 12.30: Earth-fault distance stages Z1e – Z5e (21N)**

Pick-up setting range X	0.05 – 250 $\Omega$
Pick-up setting range R	0.05 – 250 $\Omega$
Definite time function:	
- Setting range	0.05** – 300.00 s (step 0.01 s)
Start I <sub>0</sub> current setting range	0.01 – 8.00 x I <sub>0N</sub> 0.05 – 20.0 When I <sub>0Calc</sub>
Start I <sub>0</sub> current input	I <sub>0</sub> (input X1-7 & 8) I <sub>0Calc</sub> (= IL1+IL2+IL3)
Reset time	<65 ms
Retardation time	< 50 ms
Reset ratio	1.05
Inaccuracy:	
- Starting (when $U > 1V$ and $I > 0.5 A + UxI > 10 VA$ )	Typically $\pm 5\%$ of X (R if $R > X$ ) or 10 m $\Omega$
- Operating time at definite time function	1% or $\pm 25$ ms

**Table 12.31: Distance common settings (21 and 21N)**

Line angle	60 – 90°
Load block:	
- Pick-up setting range R	0.05 – 250 $\Omega$
- Load angle	10 – 40°
Earth factor:	
- Setting range	0.00 – 10.00
- Earth factor angle	-60 – +60°
Power swing dZ	1.0 – 50.00
Low current block:	
Minimum S/C current	0.1 – 2.0
Inaccuracy:	
Starting	$\pm 0.2 \Omega$ of set value (when setting is 1.0 – 5.0)

**NOTE:** All distance zones are using angle memory when voltage of all phase is dropped below 0.5 V. Angle memory is active for maximum of 3.2s (default setting 500 ms). So if the tripping time of zones is more than 0.5 s, there won't be trip. Direction checkin of angle memory function is based on U1.

**Table 12.32: Directional overcurrent stages  $I_{\phi}>$ ,  $I_{\phi}>>$  (67)**

Pick-up value	0.10 – 4.00 x $I_N$ (step 0.01)
Mode	Directional/Directional+BackUp
Minimum voltage for the direction solving	2 $V_{SECONDARY}$
Base angle setting range	-180° – +179°
Operation angle	±88°
Definite time function:	DT**
- Operate time	0.04 – 300.00 s (step 0.01)
IDMT function:	
- Delay curve family	(DT), IEC, IEEE, RI Prg
- Curve type	EI, VI, NI, LTI, MI...depends on the family*
- Time multiplier k	0.05 – 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time	Typically 30 ms
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio	0.95
Reset ratio (angle)	2°
Transient over-reach, any $\tau$	< 10 %
Adjustable voltage memory length	0.2 – 3.2 s
Inaccuracy:	
- Starting (rated value $I_N= 1-5A$ )	±3% of the set value or ±0.5% of the rated value
- Angle	±2° $U>5 V$ ±30° $U= 0.1 – 5.0 V$
- Operate time at definite time function	±1% or ±25 ms
- Operate time at IDMT function	±5% or at least ±30 ms**

**Table 12.33: Directional overcurrent stages  $I_{\phi}>>>$ ,  $I_{\phi}>>>>$  (67)**

Pick-up value	0.10 – 20.00 x $I_N$ (step 0.01)
Mode	Directional/Directional+BackUp
Minimum voltage for the direction solving	2 $V_{SECONDARY}$
Base angle setting range	-180° – +179°
Operation angle	±88°
Definite time function:	DT**
- Operate time	0.04 – 300.00 s (step 0.01)
Start time	Typically 60 ms
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio	0.95
Reset ratio (angle)	2°
Transient over-reach, any $\tau$	< 10 %
Adjustable voltage memory length	0.2 – 3.2 s
Inaccuracy:	
- Starting (rated value $I_N= 1 – 5A$ )	±3% of the set value or ±0.5% of the rated value
- Angle	±2° $U > 5 V$ ±30° $U = 0.1 – 5.0 V$
- Operate time at definite time function	±1% or ±25 ms

**Table 12.34: Directional earth fault stages  $I_{0\phi}>$ ,  $I_{0\phi}>>$  (67N)**

Pick-up value	0.005 – 8.00 x $I_{0N}$ 0.05 – 20.0 When $I_{0Calc}$
Start voltage	1 – 50 % $U_{0N}$ (step 1%)
Input signal	$I_0$ (input X1:7 – 8) $I_{0Calc}$ (= $I_{L1} + I_{L2} + I_{L3}$ )
Mode	Non-directional/Sector/ResCap
Base angle setting range	-180° – 179°
Operation angle	±88°
Definite time function: - Operate time	0.10** – 300.00 s (step 0.02 s)
IDMT function:	
- Delay curve family	(DT), IEC, IEEE, RI Prg
- Curve type	EI, VI, NI, LTI, MI..., depends on the family*
- Time multiplier k	0.05 – 20.0, except 0.50 – 20.0 for RI, IEEE and IEEE2
Start time	Typically 60 ms
Reset time	<95 ms
Reset ratio	0.95
Reset ratio (angle)	2°
Inaccuracy:	
- Starting $U_0$ & $I_0$ (rated value $I_n = 1 – 5A$ )	±3% of the set value or ±0.3% of the rated value
- Starting $U_0$ & $I_0$ (Peak Mode when, rated value $I_{0n} = 1 – 10A$ )	±5% of the set value or ±2% of the rated value (Sine wave <65 Hz)
- Starting $U_0$ & $I_0$ ( $I_{0Calc}$ )	±3% of the set value or ±0.5% of the rated value
- Angle	±2° when $U > 1V$ and $I_0 > 5\%$ of $I_{0N}$ or $> 50$ mA else ±20°
- Operate time at definite time function	±1% or ±30 ms
- Operate time at IDMT function	±5% or at least ±30 ms**



**Table 12.35: Directional intermittent transient earth fault stage  $I_{0INT}>$  (67NI)**

Input selection for $I_0$ peak signal	$I_0$ Connectors X1:7 – 8 or X1:7 – 9
Direction selection	Forward Reverse
$I_0$ peak pick up level (fixed)	0.1 pu @ 50 Hz
$U_0$ pickup level	1 – 60 % $U_{0N}$ (step 1%)
Definite operate time	0.02 – 300.00 s (step 0.02)
Intermittent time	0.01 – 300.00 s (step 0.01)
Start time	Typically 30 ms
Reset time	0.06 – 300 s
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 operate time depends of the intermittent behaviour of the fault and the intermittent time setting.)

## 12.3.4

### Voltage protection

**Table 12.36: Overvoltage stage  $U>$  (59)**

Pick-up value	50 – 150 % $U_N$ (step 1%)  The measurement range is up to 160 V. This limit is the maximum usable setting when rated VT secondary is more than 100 V.
Definite time characteristic:	
- Operate time	0.08** – 300.00 s (step 0.02)
Hysteresis	0.99 – 0.800 (0.1 – 20.0 %, step 0.1 %)
Start time	Typically 60 ms
Release delay	0.06 – 300.00 s (step 0.02)
Reset time	<95 ms
Retardation time	< 50 ms
Inaccuracy:	
- Starting	±3% of the set value
- Operate time	±1% or ±30 ms

**Table 12.37: Overvoltage stage U>> (59)**

Pick-up value	50 – 150 %U <sub>N</sub> (step 1%)  The measurement range is up to 160 V. This limit is the maximum usable setting when rated VT secondary is more than 100 V.
Definite time characteristic:	
- Operate time	0.06** – 300.00 s (step 0.02)
Hysteresis	0.99 – 0.800 (0.1 – 20.0 %, step 0.1 %)
Start time	Typically 60 ms
Reset time	<95 ms
Retardation time	< 50 ms
Inaccuracy:	
- Starting	±3% of the set value
- Operate time	±1% or ±30 ms

**Table 12.38: Overvoltage stage U>>> (59)**

Pick-up value	50 – 160 %U <sub>N</sub> (step 1%)  The measurement range is up to 160 V. This limit is the maximum usable setting when rated VT secondary is more than 100 V.
Definite time characteristic:	
- Operate time	0.04** – 300.00 s (step 0.01)
Hysteresis	0.99 – 0.800 (0.1 – 20.0 %, step 0.1 %)
Start time	Typically 30 ms
Reset time	<95 ms
Retardation time	< 50 ms
Inaccuracy:	
- Starting	±3% of the set value
- Operate time	±1% or ±25 ms

**Table 12.39: Undervoltage stage  $U<$  (27)**

Pick-up value	20 – 120 % $U_N$ (step 1%)
Definite time characteristic:	
- Operate time	0.08** – 300.00 s (step 0.02)
Hysteresis	1.001 – 1.200 (0.1 – 20.0 %, step 0.1 %)
Self-blocking value of the undervoltage	0 – 80 % $U_N$
Start time	Typically 60 ms
Release delay	0.06 – 300.00 s (step 0.02 s)
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio (Block limit)	0.5 V or 1.03 (3 %)
Reset ratio	1.03 (depends on the hysteresis setting)
Inaccuracy:	
- Starting	±3% of the set value
- Blocking	±3% of set value or ±0.5 V
- Operate time	±1% or ±30 ms

**Table 12.40: Undervoltage stage  $U<<$  (27)**

Pick-up value	20 – 120 % $U_N$ (step 1%)
Definite time characteristic:	
- Operate time	0.06** – 300.00 s (step 0.02)
Hysteresis	1.001 – 1.200 (0.1 – 20.0 %, step 0.1 %)
Self-blocking value of the undervoltage	0 – 80 % $U_N$
Start time	Typically 60 ms
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio (Block limit)	0.5 V or 1.03 (3 %)
Reset ratio	1.03 (depends on the hysteresis setting)
Inaccuracy:	
- Starting	±3% of the set value
- Blocking	±3% of set value or ±0.5 V
- Operate time	±1% or ±30 ms

**Table 12.41: Undervoltage stage  $U_{<<<}$  (27)**

Pick-up value	20 – 120 % $U_N$ (step 1%)
Definite time characteristic:	
- Operate time	0.04** – 300.00 s (step 0.01)
Hysteresis	1.001 – 1.200 (0.1 – 20.0 %, step 0.1 %)
Self-blocking value of the undervoltage	0 - 80 % $U_N$
Start time	Typically 30 ms
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio (Block limit)	0.5 V or 1.03 (3 %)
Reset ratio	1.03 (depends on the hysteresis setting)
Inaccuracy:	
- Starting	±3% of the set value
- Blocking	±3% of set value or ±0.5 V
- Operate time	±1% or ±25 ms

**Table 12.42: Zero sequence voltage stage  $U_{0>}$  (59N)**

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

**Table 12.43: Zero sequence voltage stage  $U_{0>>}$  (59N)**

Pick-up value	1 – 60 % $U_{0N}$ (step 1%)
Definite time function:	
- Operate time	0.08 – 300.0 s (step 0.02 s)
Start time	Typically 60 ms
Reset time	<95 ms
Reset ratio	0.97
Inaccuracy:	
- Starting	±2% of the set value or ±0.3% of the rated value
- Starting $U_{0Calc}$ (3LN mode)	±1 V
- Operate time	±1% or ±30 ms

## 12.3.5 Frequency protection

**Table 12.44: Overfrequency and underfrequency stages  $f > <$ ,  $f >> <<$  (81H/81L)**

Frequency measuring area	16.0 – 75.0 Hz
Current and voltage meas. range	45.0 – 65.0 Hz
Frequency stage setting range	40.0 – 70.0 Hz (step 0.01)
Low voltage blocking	10 – 100 %U <sub>N</sub>  Suitable frequency area for low voltage blocking is 45 – 65 Hz. Low voltage blocking is checking the maximum of line to line voltages.
Definite time function:	
- Operate time	0.10** – 300.0 s (step 0.02 s)
Start time	< 100 ms
Reset time	<120 ms
Reset ratio ( $f >$ and $f >>$ )	0.998
Reset ratio ( $f <$ and $f <<$ )	1.002
Reset ratio (LV block)	Instant (no hysteresis)
Inaccuracy:	
- Starting	±20 mHz
- Starting (LV block)	3% of the set value or ±0.5 V
- Operate time	±1% or ±30 ms

**NOTE:** If device restarts for some reason there will be no trip even if the frequency is below the set limit during the start up (Start and trip is blocked). To cancel this block, frequency has to rise above the set limit.

**Table 12.45: Underfrequency stages  $f<$ ,  $f<<$  (81L)**

Frequency measuring area	16.0 – 75.0 Hz
Current and voltage meas. range	45.0 – 65.0 Hz
Frequency stage setting range	40.0 – 64.0 Hz
Low voltage blocking	10 – 100 % $U_N$  Suitable frequency area for low voltage blocking is 45 – 65 Hz. Low voltage blocking is checking the maximum of line to line voltages.
Definite time function:	
- Operate time	0.10** – 300.0 s (step 0.02 s)
Undervoltage blocking	2 – 100 %
Start time	< 100 ms
Reset time	<120 ms
Reset ratio	1.002
Reset ratio (LV block)	Instant (no hysteresis)
Inaccuracy:	
- Starting	±20 mHz
- Starting (LV block)	3% of the set value or ±0.5 V
- Operate time	±1% or ±30 ms

**Table 12.46: Rate of change of frequency (ROCOF) stage  $df/dt>$  (81R)**

Pick-up setting $df/dt$	0.2 – 10.0 Hz/s (step 0.1 Hz/s)
Definite time delay ( $t>$ and $t_{Min}>$ are equal):	
- Operate time $t>$	0.14** – 10.00 s (step 0.02 s)
Inverse time delay ( $t>$ is more than $t_{Min}>$ ):	
- Minimum operate time $t_{Min}>$	0.14** – 10.00 s (step 0.02 s)
Start time	Typically 140 ms
Reset time	150 ms
Retardation time	< 90 ms
Reset ratio	1
Inaccuracy:	
- Starting	10% of set value or ±0.1 Hz/s
- Operate time(overshoot ≥ 0.2 Hz/s)	±35 ms, when area is 0.2 – 1.0 Hz/s

**NOTE:** ROCOF stage is using the same low voltage blocking limit as the frequency stages.

## 12.3.6 Power protection

**Table 12.47: Directional power stages  $P<$ ,  $P<<$  (32)**

Pick-up value	-200.0 – +200.0 % $P_M$ (step 0.5)
Definite time function:	
- Operate time	0.3 – 300.0 s (step 0.1)
Start time	Typically 200 ms
Reset time	<500 ms
Reset ratio	1.05
Inaccuracy:	
- Starting	$\pm 3$ % of set value or $\pm 0.5$ % of rated value
- Operate time at definite time function	$\pm 1$ % or $\pm 150$ 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.

## 12.3.7 Synchrocheck function

**Table 12.48: Synchrocheck function  $\Delta f$ ,  $\Delta U$ ,  $\Delta \varphi$  (25)**

Sync mode	Off; Async; Sync;
Voltage check mode	DD; DL; LD; DD/DL; DD/LD; DL/LD; DD/DL/LD
CB closing time	0.04 – 0.6 s
$U_{DEAD}$ limit setting	10 – 120 % $U_N$
$U_{LIVE}$ limit setting	10 – 120 % $U_N$
Frequency difference	0.01 – 1.00 Hz
Voltage difference	1 – 60 % $U_N$
Phase angle difference	2° – 90°
Request timeout	0.1 – 600.0 s
Stage operation range	46.0 – 64.0 Hz
Reset ratio (U)	0.97
Inaccuracy:	
- Voltage	$\pm 3$ % $U_N$
- Frequency	$\pm 20$ mHz
- Phase angle	$\pm 2^\circ$ (when $\Delta f < 0.2$ Hz, else $\pm 5^\circ$ )
- Operate time	$\pm 1$ % or $\pm 30$ ms

**NOTE:** When “sync” mode is used,  $\Delta f$  should be less < 0.2 Hz.

## 12.3.8 Magnetising inrush 68F2

**Table 12.49: Magnetising inrush 68F2**

Settings:	
- Pick-up value	10 – 100 % (step 1%)
- Operate time	0.03 – 300.00 s (step 0.01 s)
Inaccuracy:	
- Starting	±1% - unit

**NOTE:** The amplitude of second harmonic content has to be at least 2% of the nominal of CT. If the nominal current is 5 A, the 100 Hz component needs to exceed 100 mA.

## 12.3.9 Over excitation 68F5

**Table 12.50: Over excitation 68F5**

Settings:	
- Setting range over excitation	10 – 100 % (step 1%)
- Operate time	0.03 – 300.00 s (step 0.01 s)
Inaccuracy:	
- Starting	±2%- unit

**NOTE:** The amplitude of fifth harmonic content has to be at least 2% of the nominal of CT. If the nominal current is 5 A, the 250 Hz component needs to exceed 100 mA.

## 12.3.10 Circuit-breaker failure protection CBFP (50BF)

**Table 12.51: Circuit-breaker failure protection CBFP (50BF)**

Relay to be supervised	T1 – T14 (depending the ordering code)
Definite time function:	
- Operate time	0.1** – 10.0 s (step 0.1 s)
Reset time	<95 ms
Inaccuracy	
- Operate time	±20 ms



## 12.3.11 Arc fault protection (option)

The operation of the arc protection depends on the setting value of the  $Arcl_{>}$  and  $Arcl_0_{>}$  current limits.

The arc current limits cannot be set, unless the relay is provided with the optional arc protection card.

**Table 12.52: Arc protection stage  $Arcl_{>}$  (50ARC),  $Arcl_0_{>}$  (50NARC)**

Pick-up value	$0.5 - 10.0 \times I_N$
Arc sensor connection:	S1, S2, S1/S2, BI, S1/BI, S2/BI, S1/S2/BI
- Operate time (Light only)	S1, S2, S1/S2
- Operate time ( $4 \times I_{SET} + \text{light}$ )	13 ms
- Operate time (Delayed Arc L>)	17ms
	0.01 – 0.15 s
Reset time	<95 ms
Reset time (Delayed ARC L)	<120 ms
Reset time (BO)	< 85 ms
Reset ratio	0.90
Inaccuracy:	
- Starting	10% of the set value
- Operate time	$\pm 5$ ms
- Delayed ARC light	$\pm 10$ ms

## 12.4 Supporting functions

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

**Table 12.53: Disturbance recorder (DR)**

Mode of recording	Saturated / Overflow
Sample rate:	
- Waveform recording	32/cycle, 16/cycle, 8/cycle
- Trend curve recording	10, 20, 200 ms 1, 5, 10, 15, 30 s 1 min
Recording time (one record)	0.1 s – 12 000 min (According recorder setting)
Pre-trigger rate	0 – 100%
Number of selected channels	0 – 12

The recording time and the number of records depend on the time setting and the number of selected channels.

**Table 12.54: Inrush current detection**

Cold load settings:	
- Idle current	0.01 – 0.50 x $I_N$
- Pickup current	0.30 – 10.00 x $I_N$
- Maximum time	0.01** – 300.00 s (step 0.01 s)
Inrush settings:	
- Pickup for 2nd harmonic	0 – 99 %

**Table 12.55: Current transformer supervision**

$I_{MAX}>$ setting	0.00 – 10.00 x $I_N$ (step 0.01)
$I_{MIN}<$ setting	0.00 – 10.00 x $I_N$ (step 0.01)
Definite time function:	
- Operate time	0.04 – 600.00 s (step 0.02 s)
Reset time	< 60 ms
Reset ratio $I_{MAX}>$	0.97
Reset ratio $I_{MIN}<$	1.03
Inaccuracy:	
- Activation	±3% of the set value
- Operate time at definite time function	±1% or ±30 ms

**Table 12.56: Voltage transformer supervision**

U <sub>2</sub> > setting	0.0 – 200.0 % (step 0.1%)
I <sub>2</sub> < setting	0.0 – 200.0 % (step 0.1%)
Definite time function:	DT
- Operate time	0.04 – 600.00 (step 0.02s)
Reset time	< 60 ms
Reset ratio	3% of the pick-up value
Inaccuracy:	
- Activation U <sub>2</sub> >	±1%-unit
- Activation I <sub>2</sub> <	±1%-unit
- Operate time at definite time function	±1% or ±30 ms

**Table 12.57: Voltage sag & swell**

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

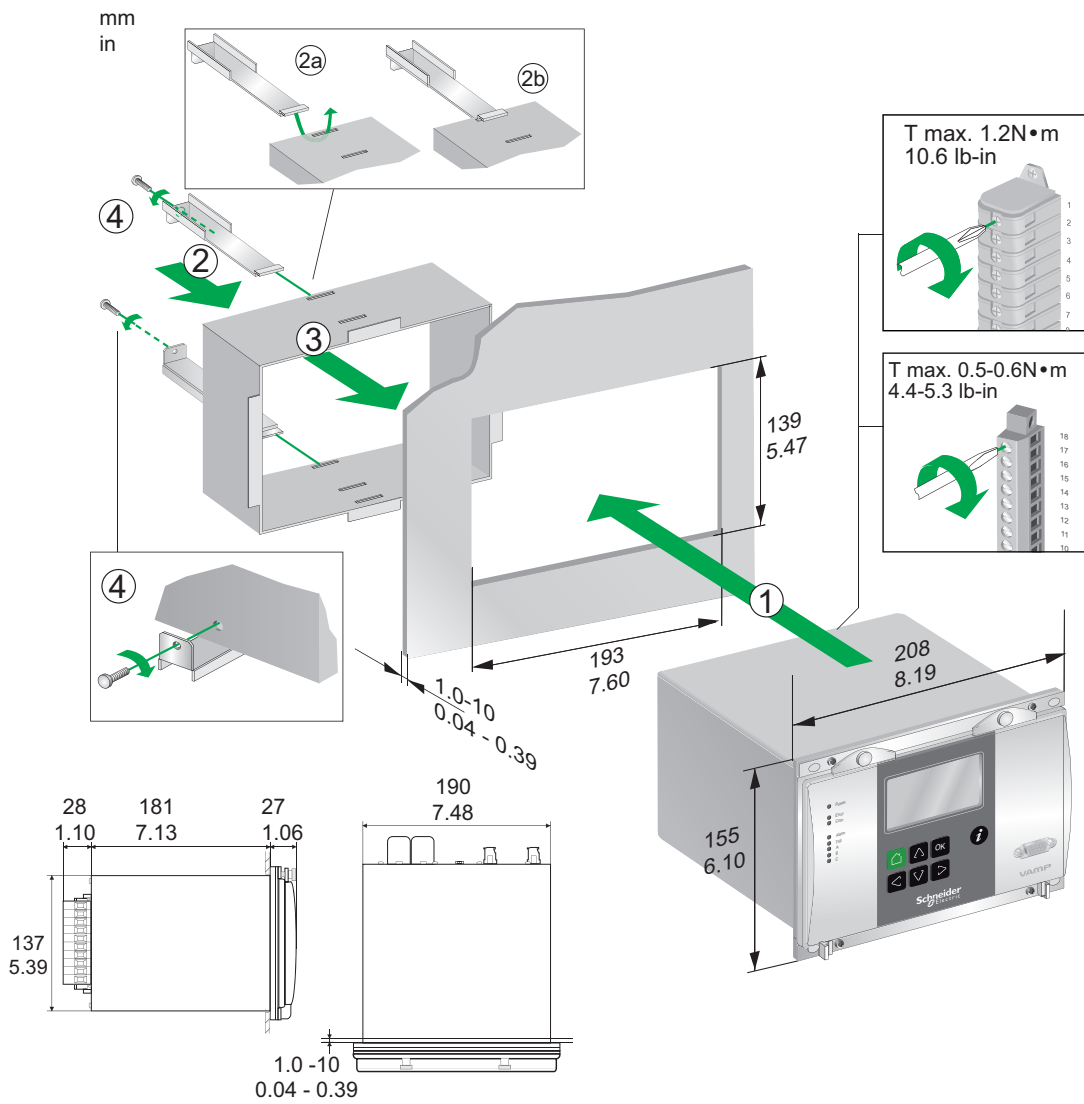
If one of the phase voltages is below sag limit and above block limit but another phase voltage drops below block limit, blocking is disabled.

**Table 12.58: Voltage interruptions**

Voltage low limit (U <sub>1</sub> )	10 – 120 %U <sub>N</sub> (step 1%)
Definite time function:	DT
- Operate time	<60 ms (Fixed)
Reset time	< 60 ms
Reset ratio	1.03
Inaccuracy:	
- Activation	3% of the set value

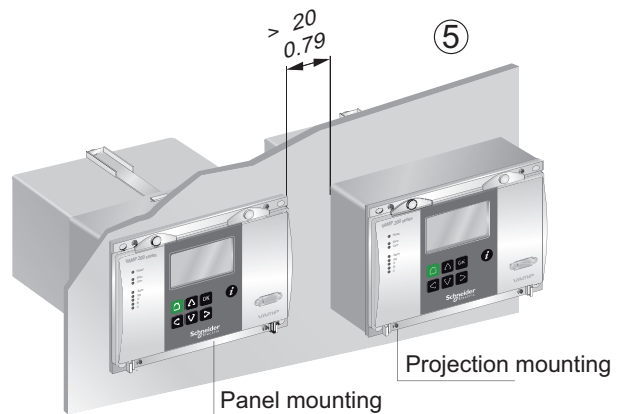
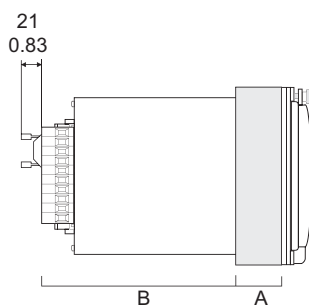
# 13 Mounting

## VAMP 200 SERIES PANEL MOUNTING

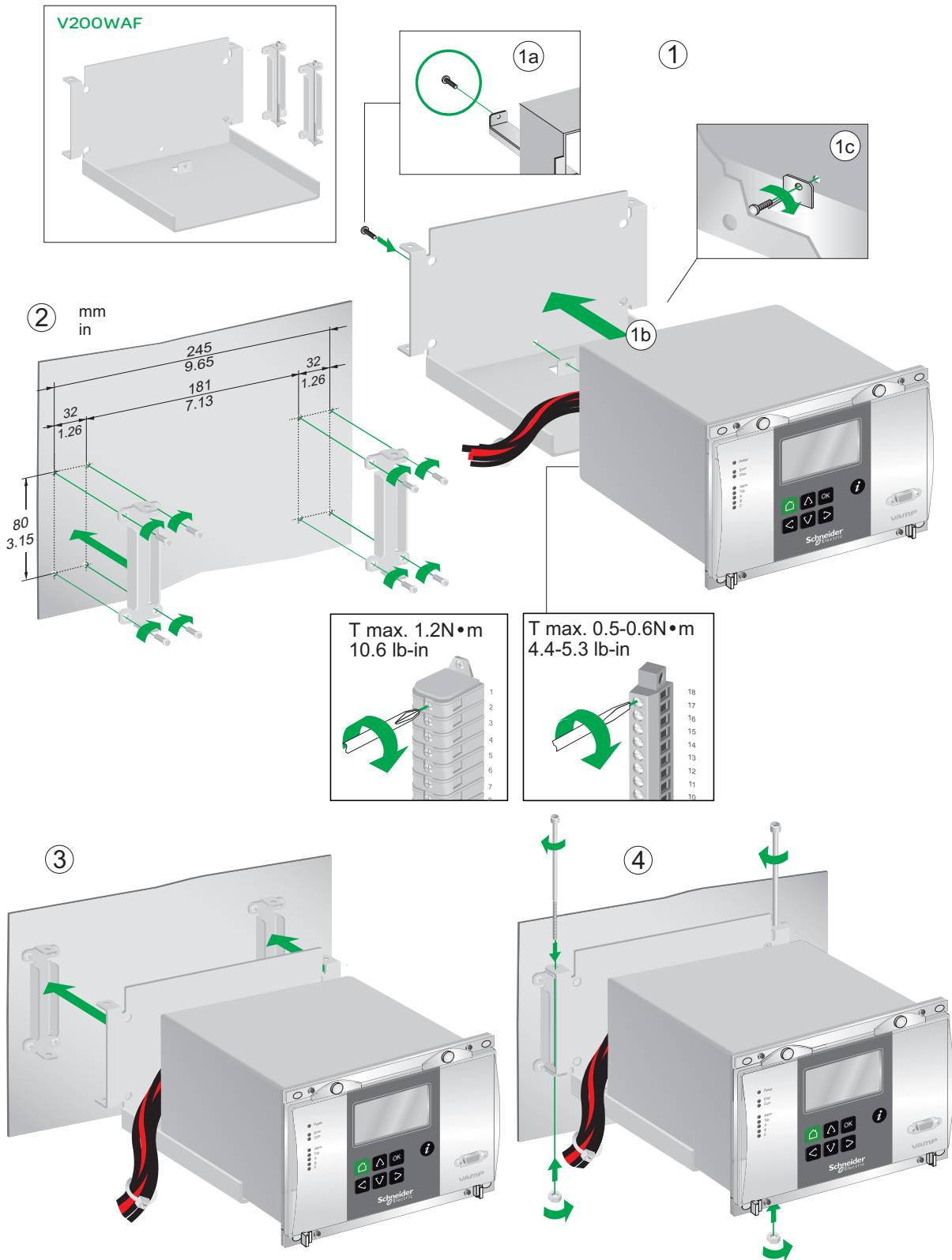


## PROJECTION MOUNTING VAMP 200 SERIES

Projection	A	B
VYX076	40 mm / 1.57"	169 mm / 6.65"
VYX077	60 mm / 2.36"	149 mm / 5.87"
VYX233	100 mm / 3.94"	109 mm / 4.29"



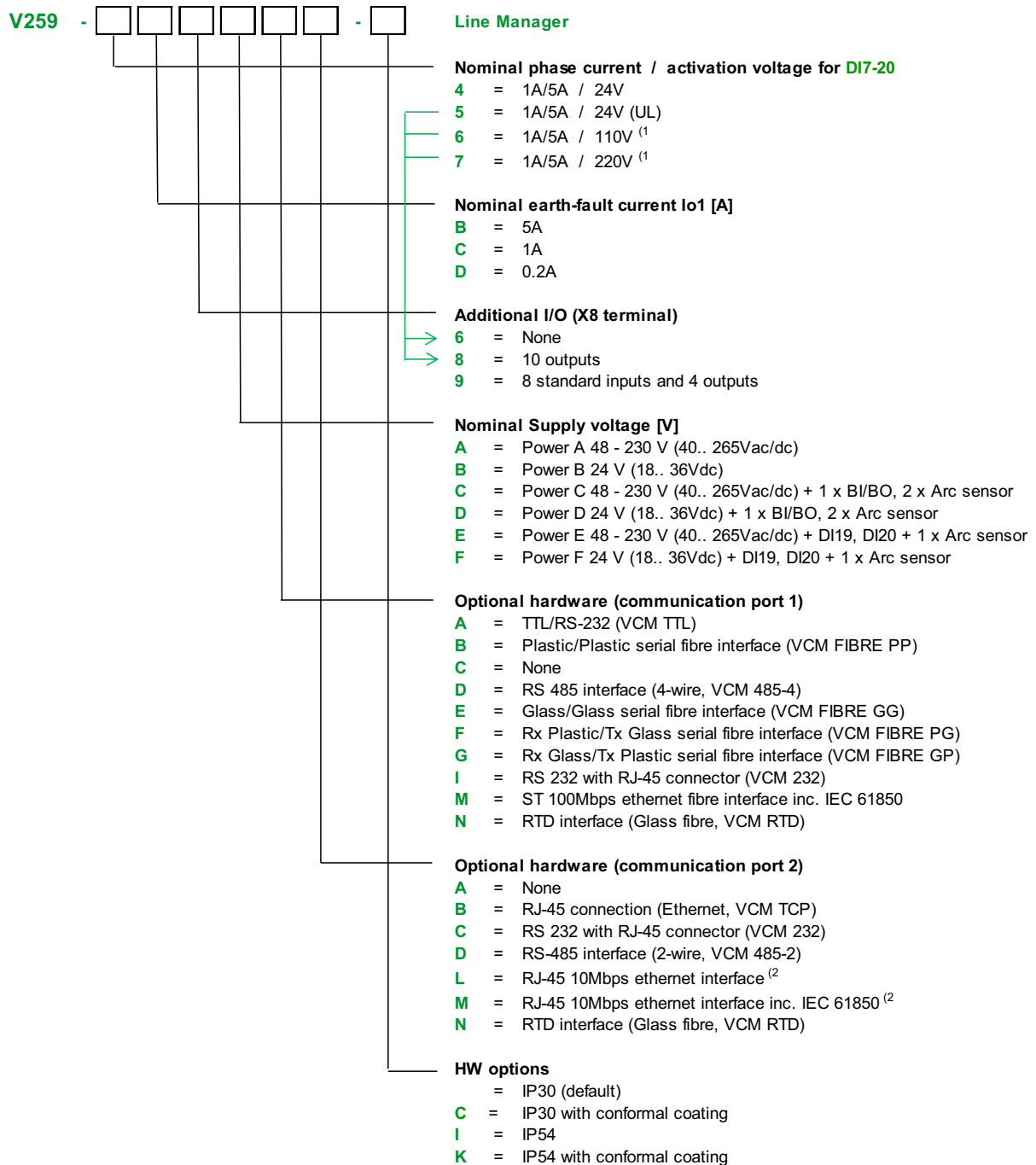
VAMP 200 SERIES WALL ASSEMBLY FRAME TYPE V200WAF



# 14 Order information

When ordering, please state:

- Type designation:
- Quantity:
- Accessories (see respective ordering code):



**Note:**

1) DI activation voltage selection applies to DI7 - DI20 only

2) NOT possible to order in combination with the following optional communication module 1: (M) ST 100Mbps ethernet fibre interface with IEC 61850

## Accessories

Order code	Description	Note
VEA 3CGi	Ethernet adapter	
VPA 3CG	Profibus DP fieldbus option board	
VSE001PP	Fibre optic Interface Module (plastic - plastic)	Max. distance 30 m (99 ft)
VSE002	RS485 Interface Module	
VIO 12 AA	RTD Module, 12 x RTD inputs, Optical Tx Communication (24-230 Vac/dc)	
VIO 12 AB	RTD Module, 12 x RTD inputs, RS 485 Communication (24-230 Vac/dc)	
VIO 12 AC	RTD/mA Module, 12 x RTD inputs, PTC, mA inputs/outputs, RS232, RS485 and Optical Tx/Rx Communication (24 Vdc)	
VIO 12 AD	RTD/mA Module, 12 x RTD inputs, PTC, mA inputs/outputs, RS232, RS485 and Optical Tx/Rx Communication (48-230 Vac/dc)	
VX003-3	RS232 programming cable (VAMPSET, VEA 3CGi)	Cable length 3 m (9.85 ft)
3P025	USB to RS232 adapter	
VX004-M3	TTL/RS232 converter cable (PLC, VEA 3CGi)	Cable length 3 m (9.85 ft)
VX007-F3	TTL/RS232 converter cable (VPA 3CG)	Cable length 3 m (9.85 ft)
VX048	RS232 converter cable for MOXA TCF-90	Cable length 3 m (9.85 ft)
VX062	RS232 converter cable for MOXA TCF-142-S-ST	Cable length 3 m (9.85 ft)
VX055	RJ45 (COM1=I or COM2=C) converter cable for MOXA TCF-90 (old Ldl>>>)	Cable length 3 m (9.85 ft)
VX056	RJ45 (COM1=I or COM2=C) converter cable for MOXA TCF-142-S-ST (old Ldl>>>)	Cable length 3 m (9.85 ft)
VX065	RJ45 (COM1=I or COM2=C) converter cable for MOXA TCF-90 (new Ldl>/Ldl>>)	Cable length 3 m (9.85 ft)
VX066	RJ45 (COM1=I or COM2=C) converter cable for MOXA TCF-142-S-ST (new Ldl>/Ldl>>)	Cable length 3 m (9.85 ft)
3P014	MOXA TCF-90	Max. distance 40 km (24.86 miles)
3P022	MOXA TCF-142-S-ST	Max. distance 40 km (24.86 miles)
3P032	WESTERMO ODW-720-F1	(Base module)
3P033	WESTERMO SLC20 (1310 nm)	Max. distance 20 km (12.43 miles)
3P034	WESTERMO SLC40 (1310 nm)	Max. distance 40 km (24.86 miles)
3P035	WESTERMO SLC80 (1550 nm)	Max. distance 80 km (49.71 miles)
3P036	WESTERMO SLC120 (1550 nm)	Max. distance 120 km (74.57 miles)
VX063	RS232 converter cable for WESTERMO ODW-720-F1	Cable length 3 m (9.85 ft)
VX064	RJ45 (COM1=I or COM2=C) converter cable for WESTERMO ODW-720-F1	Cable length 3 m (9.85 ft)
VA 1 DA-6	Arc sensor	Cable length 6 m (19.69 ft)
VAM 16D	External LED module	Disables rear local communication
VYX 076	Projection for 200 series	Height 40 mm (1.58 in)
VYX 077	Projection for 200 series	Height 60 mm (2.37 in)
VYX 233	Projection for 200 series	Height 100 mm (3.94 in)
V200WAF	V200 wall assembly frame	

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**Available option-cards possible to be ordered separately**

<b>Order code</b>	<b>Description</b>
VCM 485-4	RS 485 interface (4-wire)
VCM 485-2	RS 485 interface (2 wire)
VCM FIBRE PP	Serial fibre interface (Plastic/Plastic)
VCM FIBRE GG	Serial fibre interface (Glass/Glass)
VCM FIBRE PG	Serial fibre interface (Plastic/Glass)
VCM FIBRE GP	Serial fibre interface (Glass/Plastic)
VCM 232	RS 232 with RJ45 connector
VCM RTD	RTD interface (Glass fibre)
VCM TTL	TTL/RS-232 interface



# 15 Revision history

## 15.1 Hardware revision history

Hybrid DI/DO module type "7=8 standard inputs, 4 TCS Hybrid Inputs/outputs" has been removed from active offering. For current installed base and service installation please refer separate Application Note "AN257.EN003" and earlier User's Manual "V259\_EN\_M\_B010" for configuration conditions.

Download the latest software and manual at [www.schneider-electric.com/vamp-protection](http://www.schneider-electric.com/vamp-protection) or [m.vamp.fi](mailto:m.vamp.fi).

## 15.2 Firmware revision history

10.74	<p><math>I_{&gt;}</math> and <math>I_{0&gt;} - I_{0&gt;&gt;&gt;&gt;}</math> -stages with faster operate time</p> <p>Harmonic driver to 10 ms priority</p> <p><math>I_{0Calc}</math> driver to 10 ms priority</p> <p>Logic outputs to GOOSE</p> <p>Double earth fault blocking first version added</p>
10.85	LN for intermittent E/F function added
10.97	<p>Autoreclose:</p> <ul style="list-style-type: none"> <li>when two CB's are used and both closed, AR is blocked</li> <li>start counter is not increased after manual CB close</li> </ul> <p>5th harmonic blocking stage added</p>
10.106	<p>GOOSE supervision signals added</p> <p>IEC 61850 new LNs for <math>Ldl_{&gt;}</math>, <math>Ldl_{&gt;&gt;}</math> and <math>I_{f5&gt;}</math></p>
10.108	Various additions to IEC 61850
10.113	<p>U12y voltage measurement to IEC 60870-5-101 protocol</p> <p><b>NOTE! Vampset version 2.2.59 required</b></p>
10.116	<p>IP and other TCP parameters are able to change without reboot</p> <p>Logic output numbering is not changed when changes are made in the logic</p> <p><b>NOTE! Vampset version 2.2.97 required</b></p>
10.118	<p>Enable sending of analog data in GOOSE message</p> <p>Day light saving (DST) rules added for system clock</p> <p>HMI changes:</p> <ul style="list-style-type: none"> <li>Order of the first displays changed, 1.measurement, 2. mimic, 3. title</li> <li>timeout does not apply if the first 3 displays are active</li> </ul>
10.122	<p>Distance function <math>Z_{e&lt;}</math>: overflow error fixed</p> <p>RMS power measurements show wrong values</p>

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10.175	>: Pick-up limit setting minimum value changed from 0.10 to 0.05 Number of setting groups increased from 2 to 4 When accept zero delay enabled, stages' definite operation delay can be set to 0 Relay name can be 10 characters long
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Publication version: V259/en M/A012

Publishing: Schneider Electric

01/2018