Multifunction Protection and Switchgear Control Unit REF 542plus

Protection Manual

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This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2014/30/EU) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2014/35/EU). This conformity is the result of tests conducted by ABB in accordance with the product standard EN 60255-26 for the EMC directive, and with the product standards EN 60255-1 and EN 60255-27 for the low voltage directive. The product is designed in accordance with the international standards of the IEC 60255 series.

Safety information

The safety warnings should always be observed. Guarantee claims might not be accepted when safety warnings are not respected.

Dangerous voltages can occur on the connectors, even though the auxiliary voltage has been disconnected.

Non-observance can result in death, personal injury or substantial property damage.

Only a competent electrician is allowed to carry out the electrical installation.

National and local electrical safety regulations must always be followed.

The frame of the protection relay has to be carefully earthed.

The protection relay contains components which are sensitive to electrostatic discharge. Unnecessary touching of electronic components must therefore be avoided.

Whenever changes are made in the protection relay, measures should be taken to avoid inadvertent tripping.

Do not make any changes to the REF 542plus configuration unless you are familiar with the REF 542plus and its Operating Tool. This might result in disoperation and loss of warranty.

Table of contents

Section 1 Introduction

1.1 This manual

This manual describes how to use the protection functions available in REF 542plus.

This manual is addressed to engineering personnel and to anyone who needs to configure REF 542plus.

1.2 Intended audience

This manual is intended for operators, supervisors and administrators to support normal use of the product.

1.3 Product documentation

1.3.1 Document revision history

Document revision/date	Product version	History
2003-07-15		First release
2003-12-10		Content updated
2004-05-01		Content updated
A/2006-02-28		Content updated
B/2006-09-30	2.5	Content updated to correspond to the product version
C/2007-04-30	2.5 SP1	Content updated to correspond to the product version
D/2008-12-19	2.6	Content updated to correspond to the product version
E/2009-11-04	3.0	Content updated to correspond to the product version
F/2016-06-27	3.0	Content updated
G/2019-08-16	3.0	Content updated

Download the latest documents from the ABB Web site http://www.abb.com/substationautomation.

1.3.2 Related documentation

Name of the document	Document ID
Real Time Clock Synchronization, IRIG-B Input Time Master	1MRS755870
Product Guide	1MRS756269
Configuration Manual	1MRS755871
iButton Programmer User Manual	1MRS755863
Manual Part 3, Installation and Commission	1 VTA100004
Manual Part 4, Communication	1VTA100005
Motor Protection with ATEX Certification, Manual	1MRS755862
SCL Tool Configuration Manual	1MRS756342
Technical Reference Manual	1MRS755859
Technical Reference Modbus RTU	1MRS755868
Web Manual, Installation	1MRS755865
Web Manual, Operation	1MRS755864
IEC 61850 PIXIT	1MRS756360
IEC 61850 Conformance Statement	1MRS756361
IEC61850 TISSUES Conformance Statement	1MRS756362
Lifecycle Service Tool	1MRS756725

1.4 Symbols and conventions

1.4.1 Symbols

The warning icon indicates the presence of a hazard which could result in personal injury.

The caution icon indicates important information or warning related to the concept discussed in the text. It might indicate the presence of a hazard which could result in corruption of software or damage to equipment or property.

The information icon alerts the reader of important facts and conditions.

The tip icon indicates advice on, for example, how to design your project or how to use a certain function.

Although warning hazards are related to personal injury, it is necessary to understand that under certain operational conditions, operation of damaged equipment may result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms are spelled out in the glossary. The glossary also contains definitions of important terms.
- Parameter names are shown in italics.
  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks.
  The corresponding parameter values are "On" and "Off".
- Input/output messages and monitored data names are shown in Courier font.
  When the function starts, the `START` output is set to TRUE.

Section 2 Analog measurement

The 8 available Analog Input channel measures are acquired and processed according to the following flowchart.

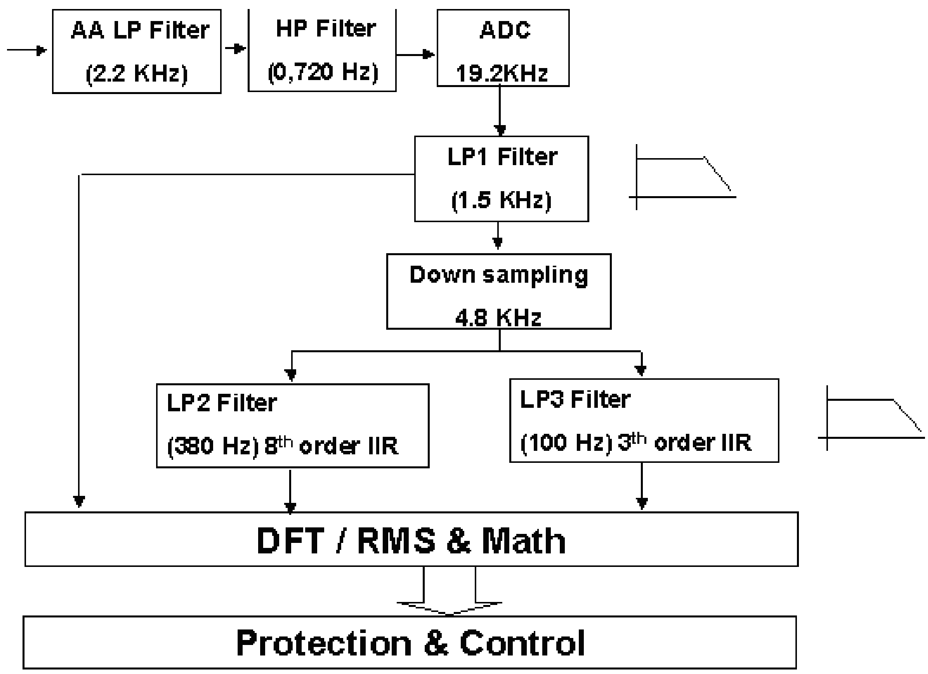


Figure 1: Analog measurement

The analog signal entering the Analog Input board goes through two hardware filters to reduce noise. It is then sampled and converted to digital information by a sigma-delta Analog/Digital converter with an acquisition rate of 19.2 kHz.

The acquisition is performed in parallel on all 8 analog channels, and therefore the data samples of the network currents and voltages are contemporary, that is, no phase shift/time delay is introduced between the network quantities.

The digital data is processed by a digital filter LP1 to reduce the information bandwidth to 1,5 kHz.

This information is provided directly to the DFT / RMS and Math block, performing the Discrete Fourier Transformation and RMS value analysis for the protection working on the full RMS harmonic content up to the 25^{th} harmonic (switching resonance, high harmonic) and to the frequency protection for higher discrimination of zero crossing.

For all the other protection functions, the digital data is down sampled, that is, one sample each 4 is used to 4800 samples/s, maintaining the same information bandwidth.

Furthermore, the signal is digitally filtered by LP2 and LP3 (HSTS function analog quantities only) and provided to the DFT/ RMS and math block, performing the Discrete Fourier Transformation and RMS value analysis.

Almost all protection functions are based on the DFT calculation for the selected network rated frequency. Only the thermal overload protection performs the temperature calculation by applying the RMS current values, in which all harmonics are considered.

In addition the following functions use:

- Overcurrent instantaneous

To function the peak value of the measured current under transient condition for a faster response. This is when the instantaneous peak value is over three times higher.

SQRT (2) the RMS value:

$$I_{x\_peak} \Big/ \sqrt{2} > 3 \cdot I_{x\_RMS}$$

(Equation 1)

- Inrush harmonic

The function evaluates the ratio between the current values at 2^{nd} harmonic and at fundamental frequency.

- Differential protection

The function evaluates the measured amount of differential current at the fundamental, 2^{nd} and 5^{th} harmonic frequencies.

Section 3 Analog Inputs

The Analog Inputs dialog allows the user to configure:

- Analog input channels
- Network characteristics (REF 542plus can handle currents or voltages from two different networks)
- Calculated values (power, THD, mean and maximum current values over the desired time interval)

3.1 Analog Inputs

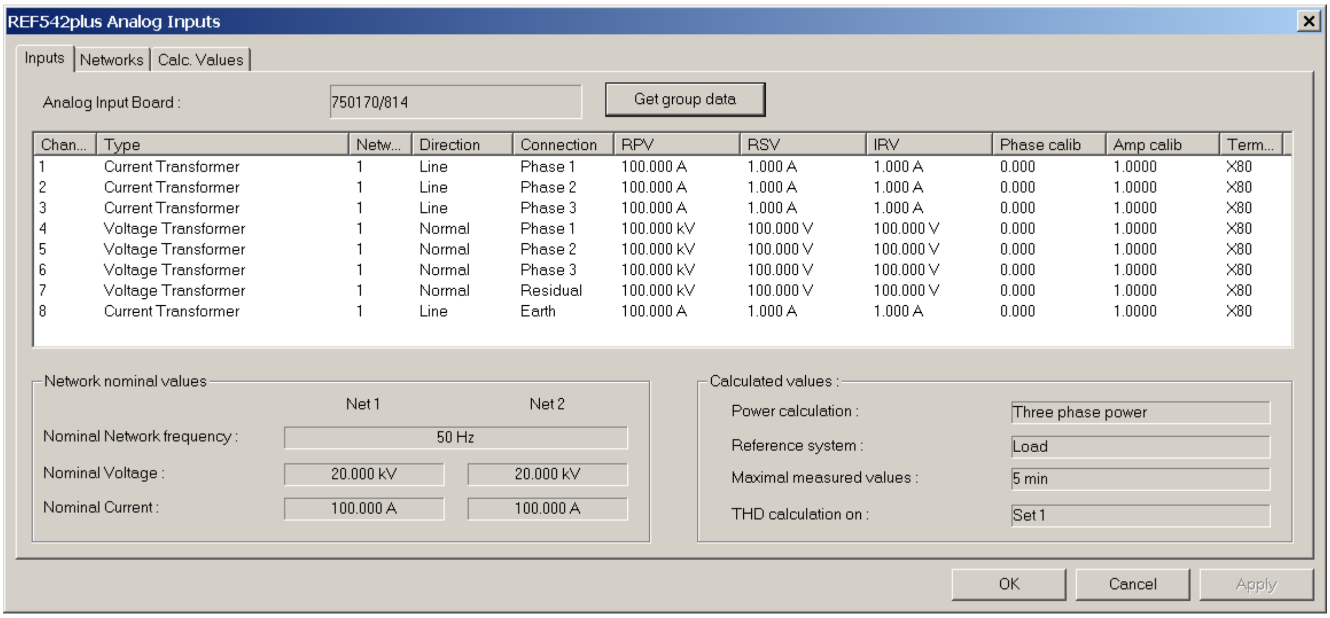


Figure 2: Analog Inputs

To ease the input of analog input channels, the user can push the Get group data button in the Inputs tab of Analog Inputs dialog and then select the used board from the list. This configures the used analog input channels to the proper sensor type and sets default values for each sensor type.

3.1.1 Analog board selection

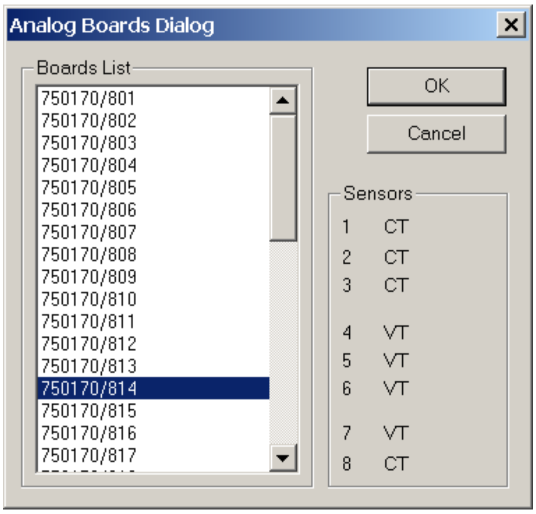


Figure 3: Analog board selection

To complete the configuration of each analog input channel, that is, to set the appropriate Rated Primary and Secondary Values, the user must double-click the line in the Inputs tab of Analog Inputs dialog.

3.1.2 Current transformer

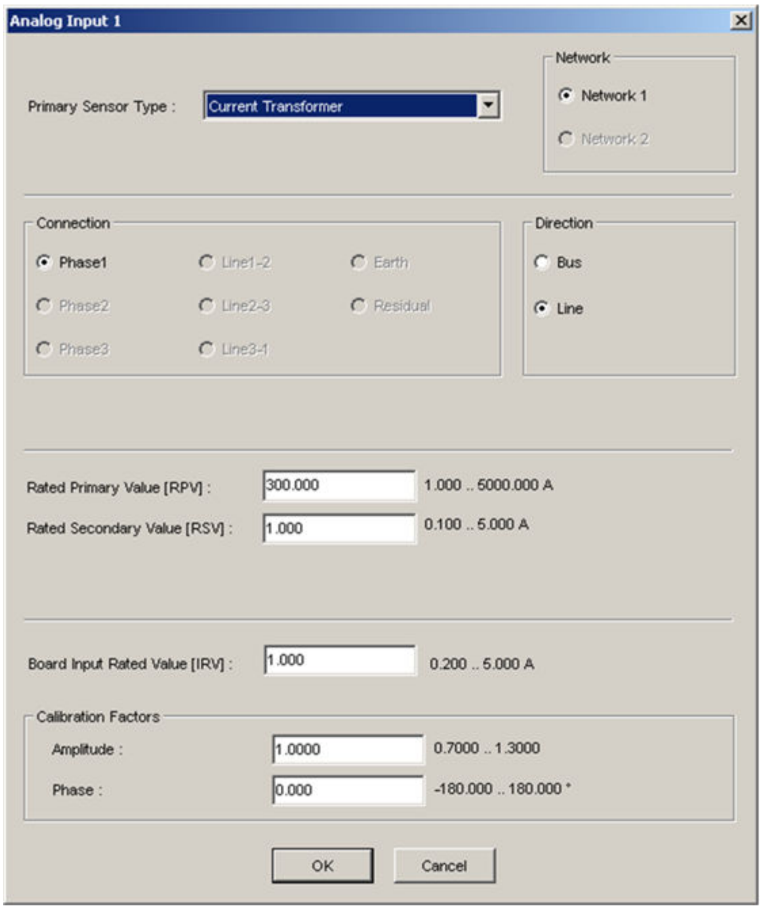


Figure 4: Current transformer

Board Input Rated Value (RV) at present can be 0.2, 1 or 5 A only depending on the type of CT mounted on Analog Input board.

In case of a mismatch between *Rated Secondary Value (RSV)* and *Board Input Rated Value (RSV)*, REF 542plus automatically compensates the protection function thresholds.

Default direction of the polarity for the CT is “Line”. If “Bus” is selected, the polarity of analog signal will be inverted to preserve directions in directional protections. The amplitude and phase corrections can be introduced.

3.1.3 Current Rogowski

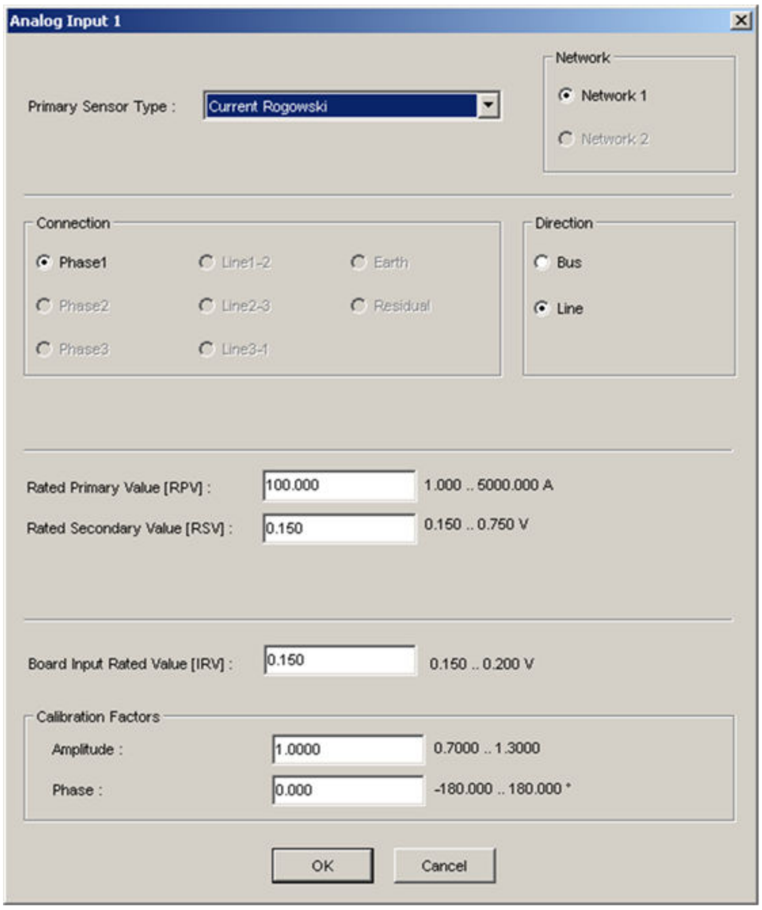


Figure 5: Current Rogowski

The current sensors usually cover a rated primary current range, for example the type KEVCD 24 A covers the primary current range 80...1250A.

One value should be chosen as *Rated Primary Value (RPV)*, usually the value matching through the current sensor rated transformation ratio the *Rated Secondary Value (RSV)* and *Board Input Rated Value (IRV)*. For example, with a transformation ratio 80 A/0.150 V and RSV, IRV value of 0.150 V a RPV of 80 A can be chosen. The RPV value introduced will be used as the rated current in protection functions.

The rated transformation ratio of current sensors, typically 80 A/0.150 V, shall always be correctly introduced to avoid incorrect measurements. Such ratio shall equal the ratio of RPV over RSV.

IRV at present can be only 0.150 V depending on the Rogowski sensor input on Analog Input board. In case of a mismatch between RSV and IRV, REF 542plus automatically compensates the protection function thresholds.

Default direction for the polarity of the Rogowski current sensors is “Line”. If “Bus” is selected, the polarity of analog signal will be inverted to preserve directions in directional protections. The amplitude and phase corrections can be introduced.

3.1.4 Voltage transformer

Voltage transformers can be phase, line or residual (open delta) voltage transformers.

Phase-voltage transformer

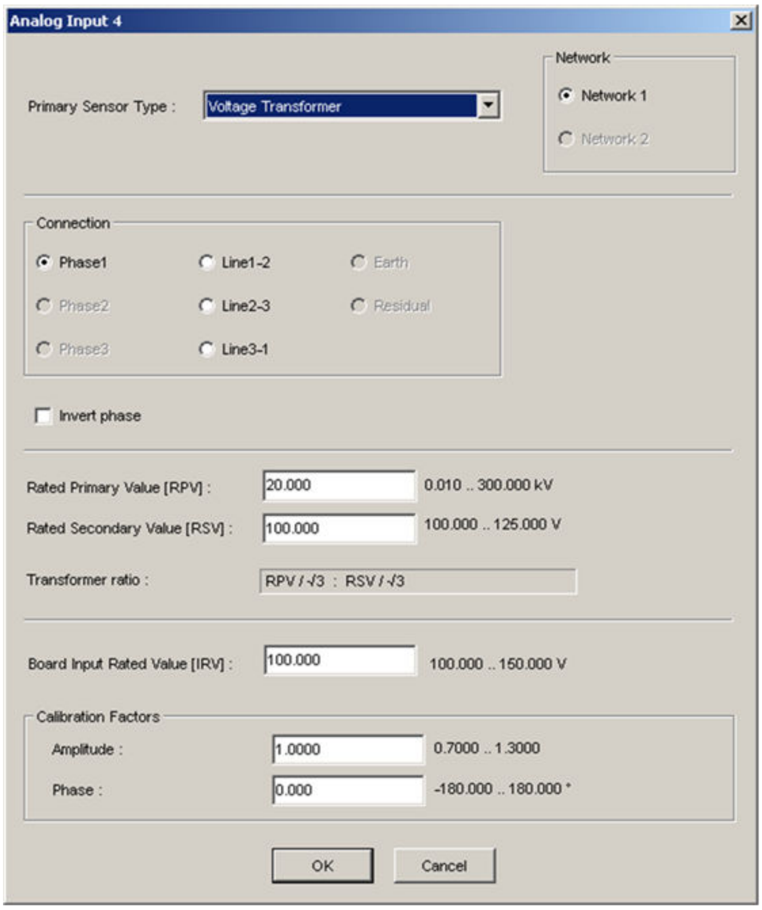


Figure 6: Phase-voltage transformer

Phase-voltage transformers normally refer the rated phase-voltage at primary side with rated phase voltage on the secondary side, for example:

$$\frac{20\text{kV}}{\sqrt{3}} : \frac{100\text{V}}{\sqrt{3}}$$

(Equation 2)

This is shown below RSV in the Transformer ratio box. When entering the VT rated voltage data, it is not necessary to perform division by:

$$\sqrt{3}$$

(Equation 3)

IRV at present can be 100 V only depending on the input transformer mounted on Analog Input Board.

In case of a mismatch between RSV and IRV, REF 542plus automatically compensates protection function thresholds. If *Invert phase* is selected, the polarity of analog signal will be inverted. The amplitude and phase corrections can be introduced.

Line voltage transformer

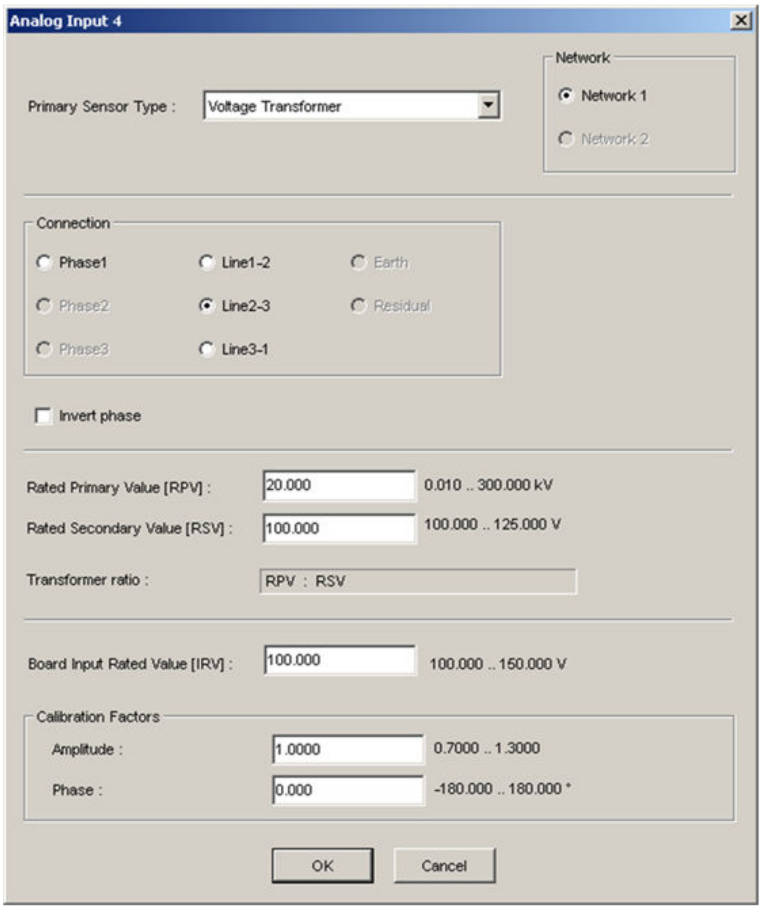


Figure 7: Line voltage transformer

Line voltage transformers normally refer rated line voltage at primary side with rated voltage on secondary side, for example 20 kV:100 V. This is shown below RSV in the Transformer ratio box.

IRV at present can be 100 V only depending on the input transformer mounted on Analog Input Board.

In case of a mismatch between RSV and IRV, REF 542plus automatically compensates protection function thresholds. If *Invert phase* is selected, the polarity of analog signal will be inverted. The amplitude and phase corrections can be introduced.

Residual voltage transformer (open delta)

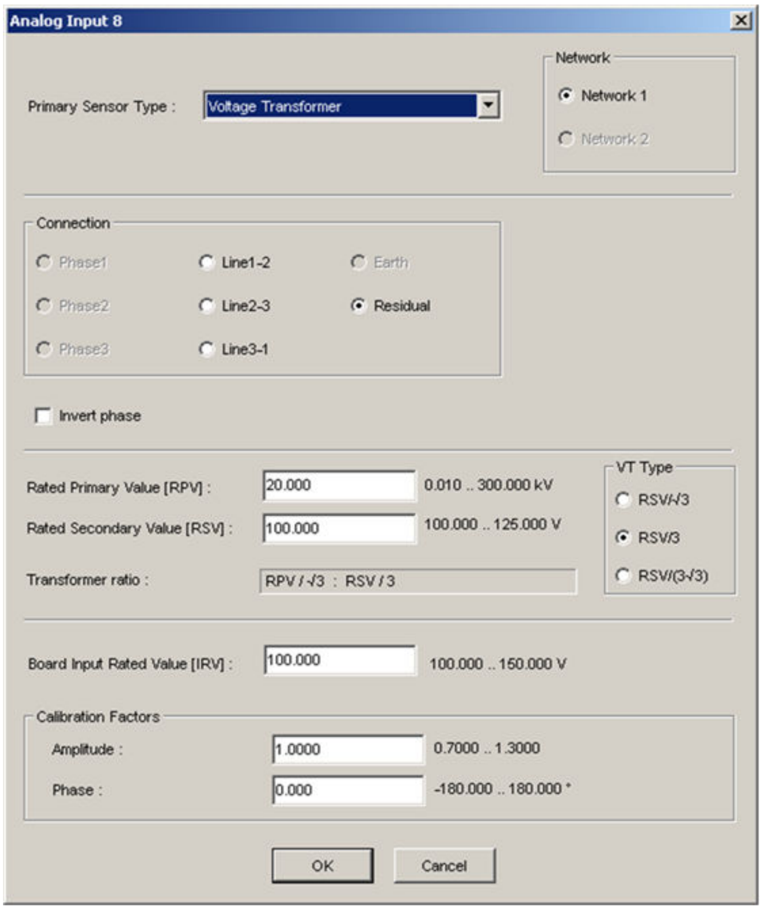


Figure 8: Residual voltage transformer (open delta)

Residual voltage transformers normally refer rated phase-voltage at the primary side with secondary side rated voltage of each winding in the open delta, for example:

$$\frac{20kV}{\sqrt{3}} : \frac{100}{3}$$

(Equation 4)

This is shown below RSV in the Transform ratio box.

When entering VT rated voltage data, it is not necessary for the user to perform any division. The user must simply select the corresponding secondary winding denominator as the *VT type*.

IRV at present can be 100 V only depending on the input transformer mounted on Analog Input Board.

In case of a mismatch between RSV and IRV, REF 542plus automatically compensates the protection function thresholds. If *Invert phase* is selected, the polarity of analog signal will be inverted. The amplitude and phase corrections can be introduced.

3.2 General constraints

- Channels 1...6 can be used only for phase currents, phase voltages or line voltages.
- Channels 7 and 8 can be used also either for neutral current, residual voltage or line voltage for synchronism check function.
- Current and voltage sensors inside the triples 1...3 and 4...6 must have the same characteristics (RPV, RSV and IRV)

3.3 Network characteristics

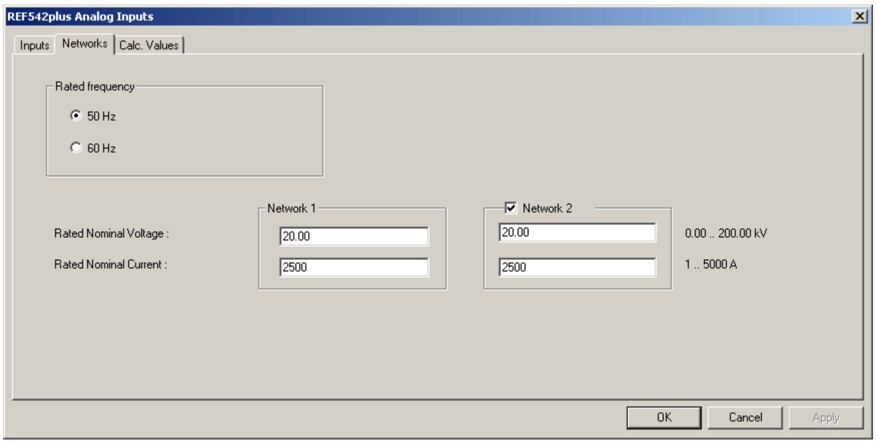


Figure 9: Networks tab

REF 542plus can handle two different networks or network parts having the same frequency. By default only one network is used.

If the second network is needed, it must be enabled in the Networks tab of Analog Inputs dialog.

The rated nominal voltage and current can be configured for each network. These values are used by HMI LED bars to scale the displayed quantities.

All the protection functions refer to Analog Input RPV as In, Un to scale Start values.

3.4 Calculated values

The three-phase power or the Aaron power calculation scheme can be applied for the power calculation. Also active and reactive energies are calculated. Thereby, the preferred reference system for the calculation can either be load or generator.

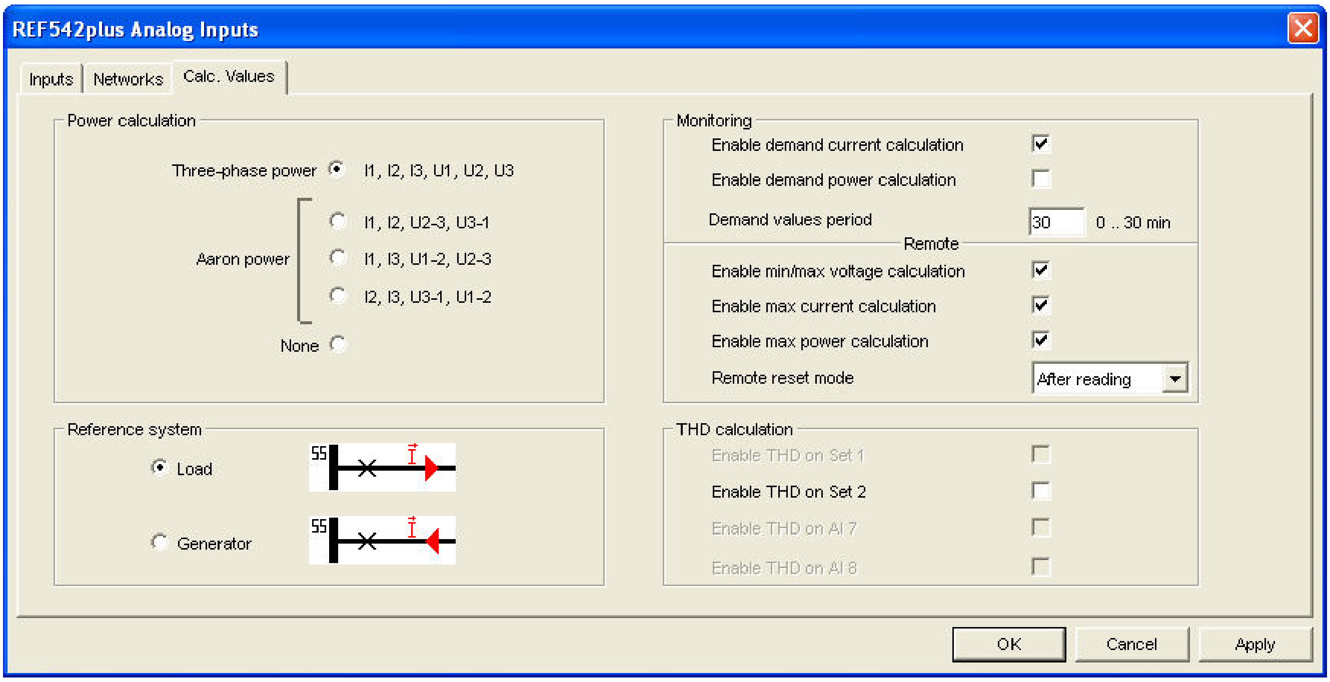


Figure 10: Calculated values

For monitoring purposes, the following values are calculated:

- Demand and maximal demand current
  - The demand current is calculated as the mean value within a certain demand value period up to 30 min. The maximal demand current is the maximal of the demand currents from the last reset command.
  - The equation used to calculate the demand current is (IIR filter):

$$I_{mean(t)} = \frac{I_{value(t)} + (4095 \times I_{mean(t-1)})}{4096}$$

(Equation 5)

  - The calculation period is 2.5 ms and the refresh time is 1 min.
- Demand and maximal demand active and reactive power
  - The demand power is calculated as the mean value within a certain demand values period up to 30 min. The maximal demand power is the maximal of the demand powers from the last reset command.
  - The equation used to calculate the demand power is (IIR filter):

$$P_{mean(t)} = \frac{P_{value(t)} + (4095 \times P_{mean(t-1)})}{4096}$$

(Equation 6)

    - The calculation period is 2.5 ms and the refresh time is 1 min.
- Minimum/maximum voltage calculation
    - Minimum/maximum voltages are the minimum/maximum of the measured line voltages (RMS on fundamental component) from the last reset command.
- Maximum current calculation
    - Maximum current is the maximum of the measured phase currents (RMS on fundamental component) belonging to a network from the last reset command.
- Maximum active and reactive power calculation
    - Maximum active and reactive power is the maximum measured active and reactive power (negative, positive and absolute values) from the last reset command.

The following calculated values are shown on the HMI and available for transmission to remote control center:

- Demand and maximal demand current
- Demand and maximal demand active and reactive power

The reset of the maximal demand values can be done by the related command from the HMI or from the remote control center. The following calculated values are not shown on the HMI and they are available only for transmission to the remote control center:

- Minimum/maximum voltage
- Maximum current
- Maximum active and reactive power

The reset of the remote calculated values is selectable:

- After reading
  The measurements are reset automatically by REF 542plus after the values are read out. This mode is used when the measurement values are read only by the remote control center and not polled for periodic reading by the communication module.
- By command
  The measurements are reset by the related reset command. This mode is used when the measurement values are polled for periodic reading by the communication module. This mode is mandatory when selecting the IEC61850 protocol.

The following calculated values are saved at power-down:

- Maximal demand current
- Maximal demand active and reactive power
- Minimum/maximum voltage
- Maximum current
- Maximum active and reactive power

The THD (Total Harmonic Distortion) is calculated, only on voltages, as percentage of the RMS voltage of the harmonics excluding the fundamental component:

$$THD(\%) = 100 \times \frac{\sqrt{V_{RMS}^2 - V_{FUND}^2}}{V_{RMS}}$$

(Equation 7)

Section 4 Control and monitoring

4.1 Measurement supervision NPS and PPS

REF 542plus provides two types of measurement supervision functions. Each of them can be independently activated:

- Positive Phase Sequence (PPS)
- Negative Phase Sequence (NPS)

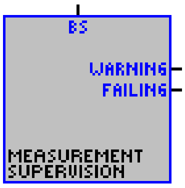


Figure 11: Measurement supervision

4.1.1 Input/output description

Table 1: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the measurement supervision function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 2: Output

Name	Type	Description
WARNING	Digital signal (active high)	Warning signal
FAILING	Digital signal (active high)	Failing signal

WARNING is the start signal. WARNING signal will be activated when the start conditions are true. The negative phase sequence value exceeds the setting threshold value for NPS , and the positive phase sequence value falls below the setting threshold value for PPS.

FAILING signal will be activated when the start conditions are true and the operating time has elapsed.

4.1.2 Configuration

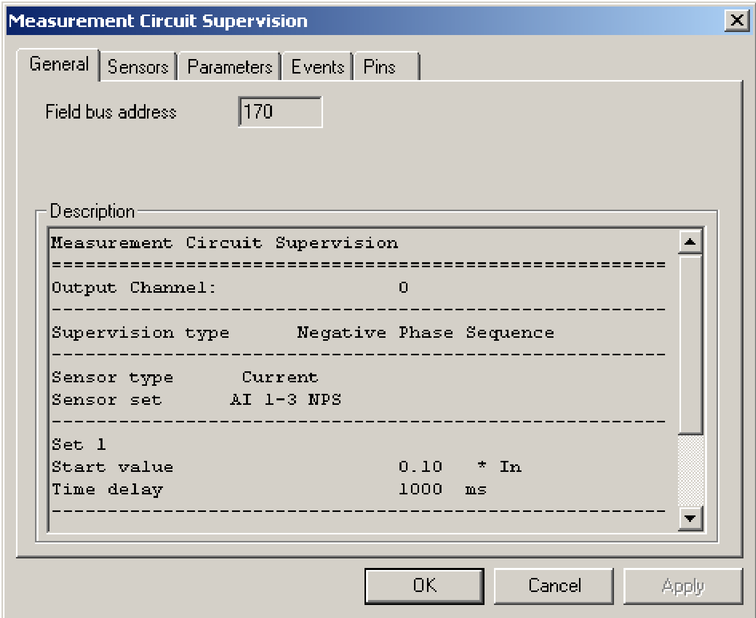


Figure 12: General

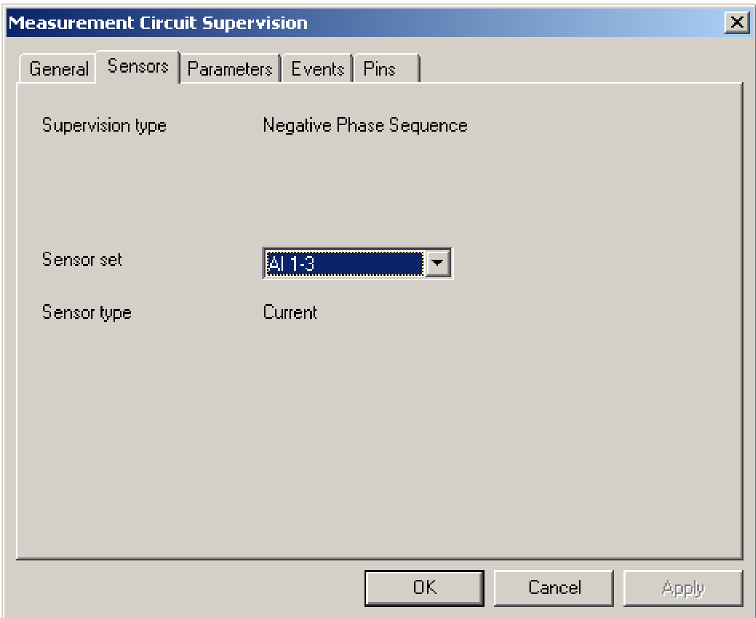


Figure 13: Sensors

The measurement supervision functions operate on all sensors in a triple. The analog channels 1-3 or 4-6 can be used to supervise the phase currents, phase voltages or line voltages.

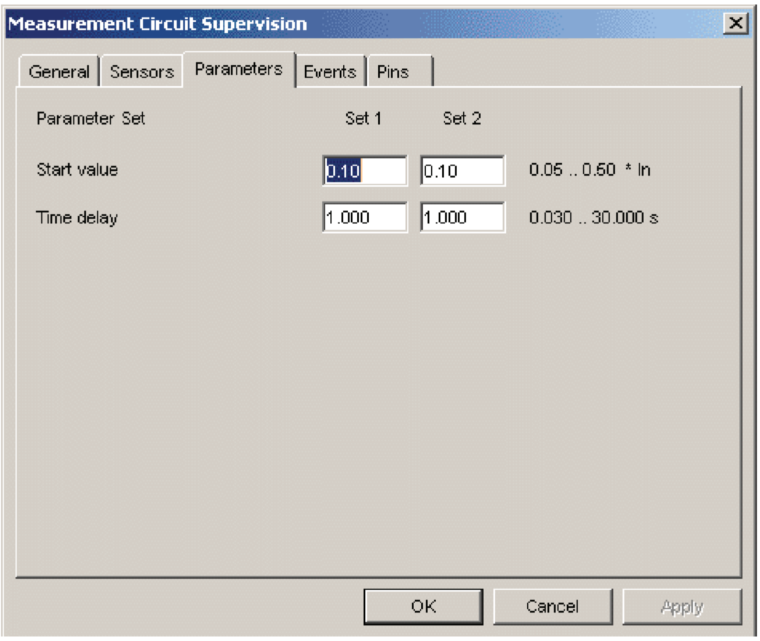


Figure 14: Parameters

Start value	Positive/Negative phase sequence threshold for Start condition detection.
Time delay	Time delay for Trip condition detection.

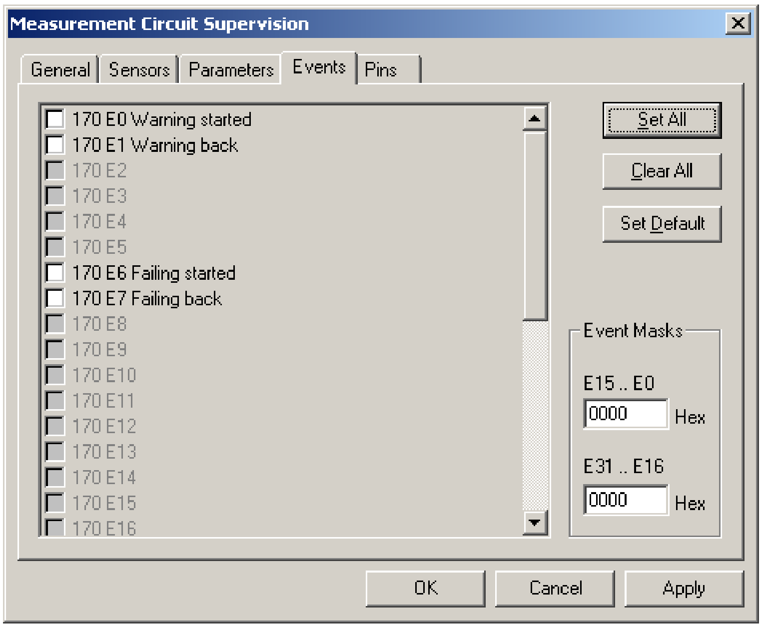


Figure 15: Events

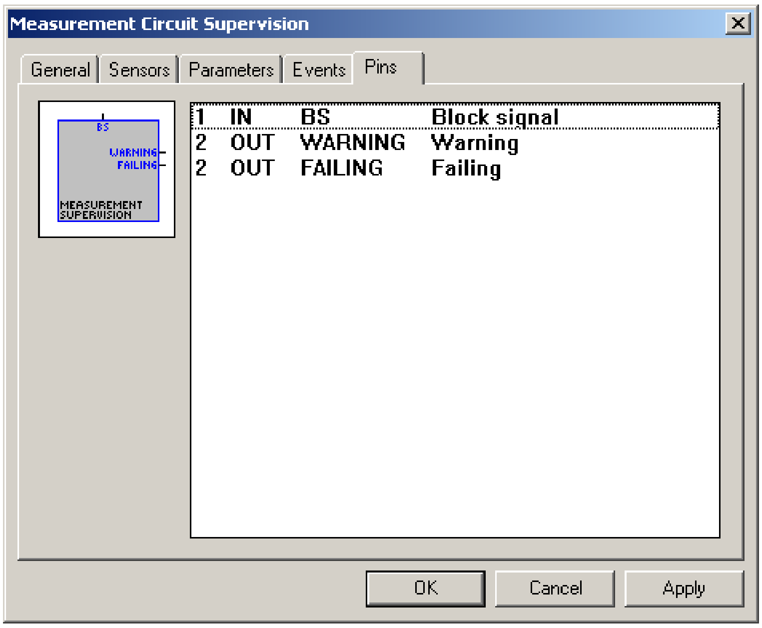


Figure 16: Pins

4.1.3 Measurement mode

Measurement supervision functions evaluate the measured amount of positive and negative phase sequence values at the fundamental frequency.

4.1.4 Operation criteria

If the negative phase sequence value exceeds the setting threshold value (*Start value*) in the NPS based functions, or if the positive phase sequence value falls below the setting threshold (*Start value*) the function enters the START status and raises the warning. After the preset operating time (*Time delay*) has elapsed, the failing signal is generated.

The measurement function will come back in passive status and the `WARNING` signal will be cleared, if the negative phase sequence value falls below 0.95 the setting threshold value for NPS, or if the positive phase sequence value exceed 1.05 the setting threshold value for PPS.

The measurement function will exit the failing status and the `FAILING` signal will be cleared when the negative phase sequence value falls below 0.4 the setting threshold value for NPS, or if the positive phase sequence value exceed 1.05 the setting threshold value for PPS.

4.1.5 Setting groups

Two parameter sets can be configured for each of the measurement supervision functions.

4.1.6 Parameters and events

Table 3: Setting values

Parameter	Values	Unit	Default	Explanation
Start value (PPS)	0.10...0.90	In or Un	0.85	PPS threshold to undergo.
Time delay	30...30000	ms	1000	Time delay from start condition (warning signal) to failing signal.
Start value (NPS)	0.05...0.50	In or Un	0.10	NPS threshold to be exceeded.
Time delay	30...30000	ms	1000	Time delay from start condition to failing signal.

Table 4: Events

Code	Event reason
E0	Warning signal is active
E1	Warning signal cancelled
E6	Failing signal is active
E7	Failing signal is back to inactive state
E18	Function block signal is active
E19	Function block signal is back to inactive state

By default all events are disabled.

4.2 Power factor controller

The power factor controller is designed to control reactive power compensation in power systems. The magnitude of the reactive power in the network is derived from the measured power factor. Consequently, the power factor controller permanently monitors the power factor, which is defined as the ratio of the effective power to the active power. The PFC then controls the switching ON/OFF the available capacitors banks to reach the set power factor target.

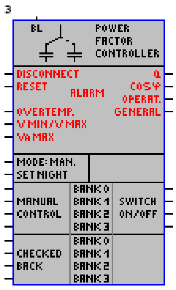


Figure 17: Power factor controller

4.2.1 Input/output description

Table 5: Input

Name	Type	Description
BL	Digital signal (active high)	Blocking signal
DISCONNECT	Digital signal (active high)	Disconnect all capacitor banks
RESET	Digital signal (active high)	Reset the function
OVERTEMP.	Digital signal (active high)	Overtemperature
VMIN / VMAX	Digital signal (active high)	Voltage out of range
VA MAX	Digital signal (active high)	Overload due to overvoltage
MODE: MAN.	Digital signal (active high)	Mode manual
SET NIGHT	Digital signal (active high)	Set night parameter
MANUAL CONTROL BANK 0	Digital signal (active high)	Switch bank 0 manually
MANUAL CONTROL BANK 1	Digital signal (active high)	Switch bank 1 manually
MANUAL CONTROL BANK 2	Digital signal (active high)	Switch bank 2 manually
MANUAL CONTROL BANK 3	Digital signal (active high)	Switch bank 3 manually
CHECKED BACK BANK 0	Digital signal (active high)	Status on indication bank 0
CHECKED BACK BANK 1	Digital signal (active high)	Status on indication bank 1
CHECKED BACK BANK 2	Digital signal (active high)	Status on indication bank 2
CHECKED BACK BANK 3	Digital signal (active high)	Status on indication bank 3

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until BS signal goes low.

Table 6: Output

Name	Type	Description
Q ALARM	Digital signal (active high)	Alarm indication Q
COS Φ ALARM	Digital signal (active high)	Alarm indication cos Φ
OPERAT. ALARM	Digital signal (active high)	Operation Alarm (reset only by power off)
GENERAL ALARM	Digital signal (active high)	General alarm
SWITCH ON/OFF BANK 0	Digital signal (active high)	Bank 0 on (high), off (low)
SWITCH ON/OFF BANK 1	Digital signal (active high)	Bank 1 on (high), off (low)
SWITCH ON/OFF BANK 2	Digital signal (active high)	Bank 2 on (high), off (low)
SWITCH ON/OFF BANK 3	Digital signal (active high)	Bank 3 on (high), off (low)

4.2.2 Configuration

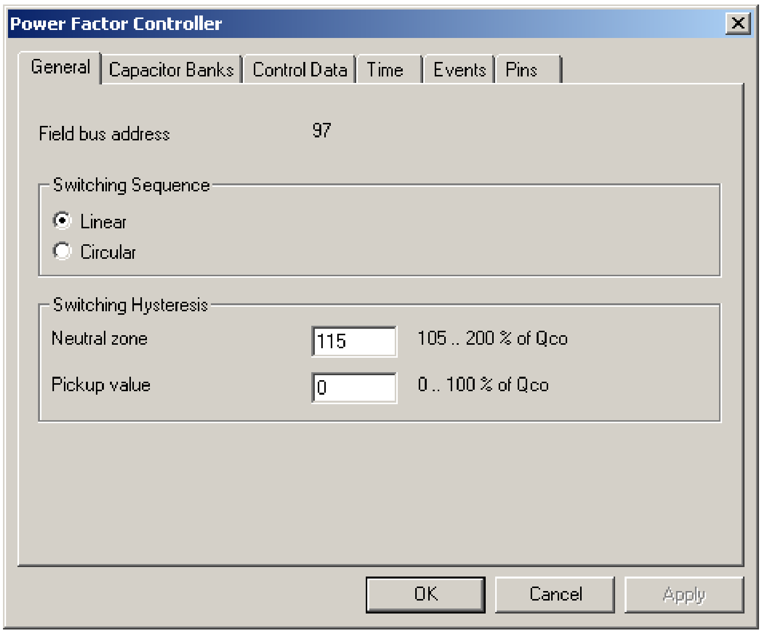


Figure 18: General

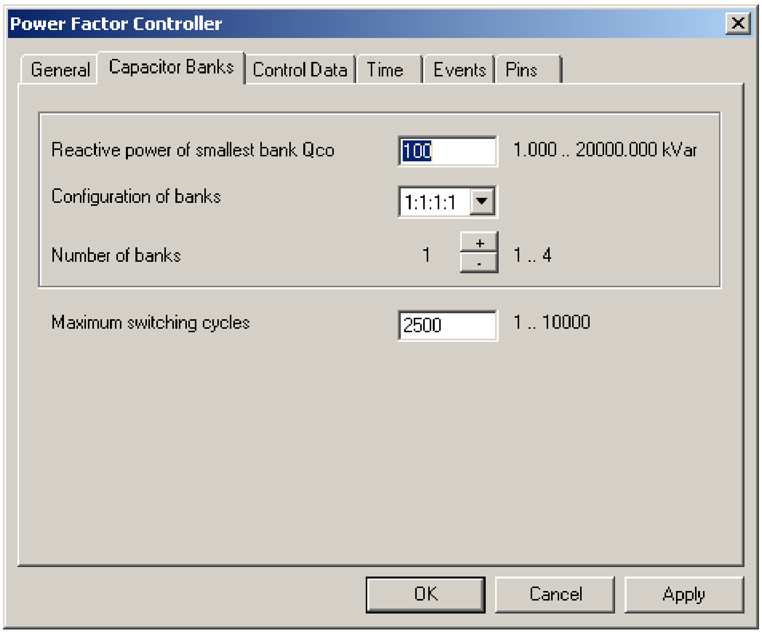


Figure 19: *Capacitor banks*

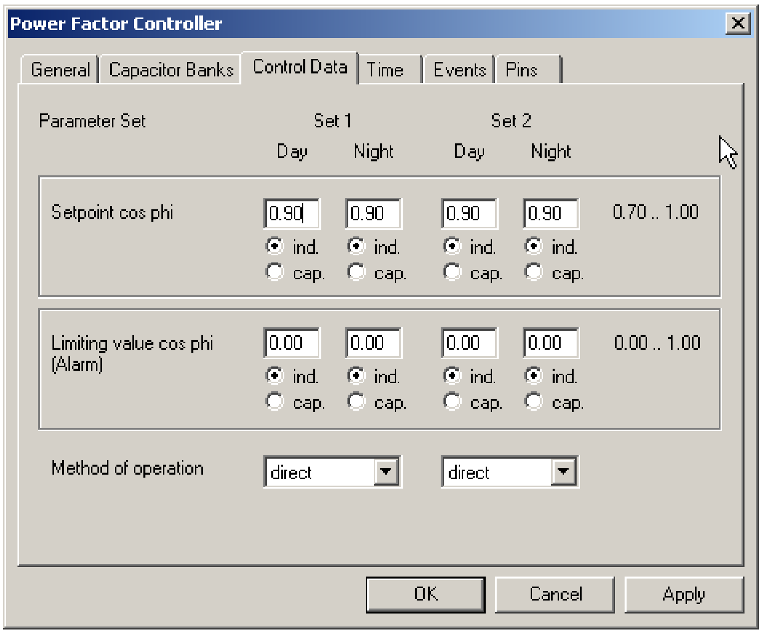


Figure 20: *Control data*

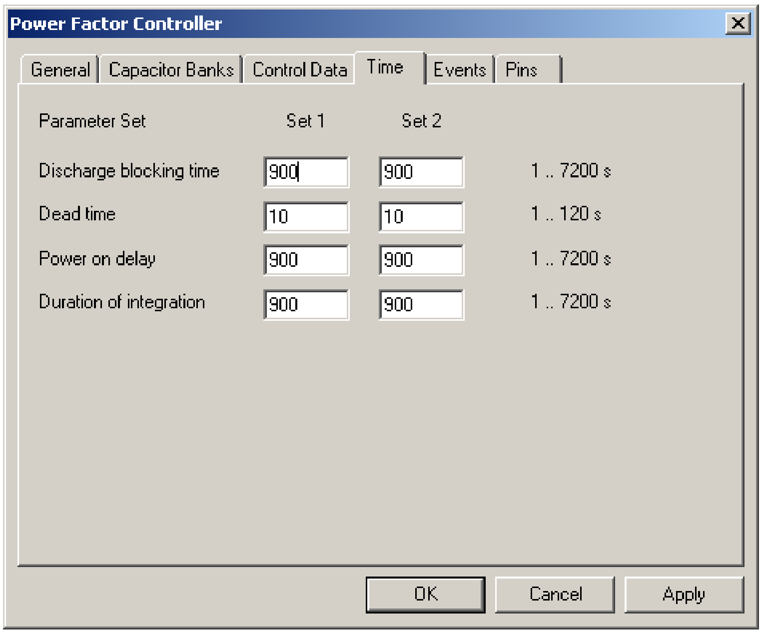


Figure 21: Time

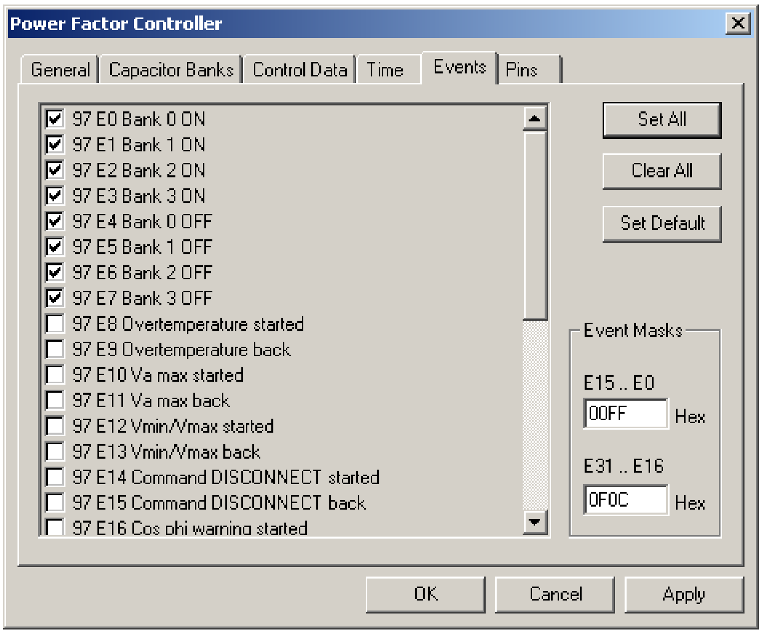


Figure 22: Events

By default all events are disabled.

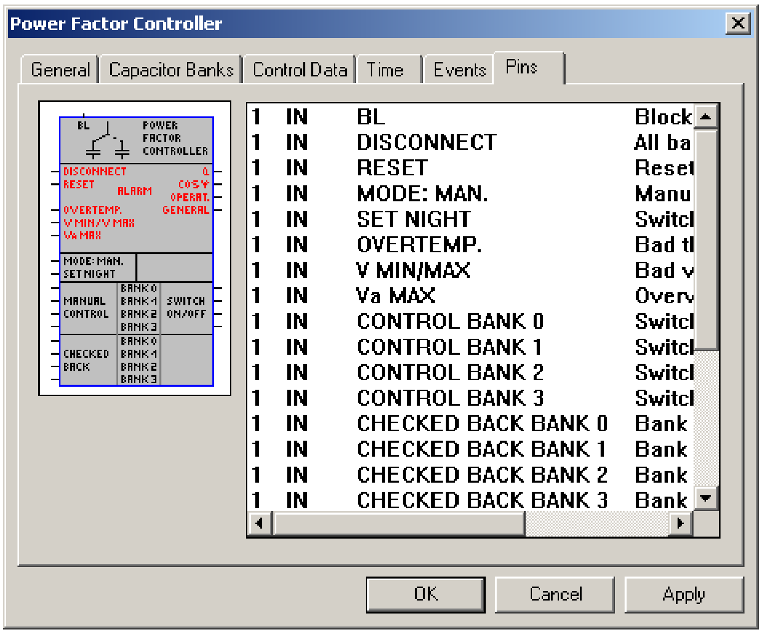


Figure 23: Pins

4.2.3 Measurement mode

When a reactive power consumer is switched into the network, the current variable increases. Simultaneously, the phase displacement increases in relation to the related voltage quantity. As a result, the reactive power increases and the power factor is reduced correspondingly. Because of the increase in the current measured quantity and the angle of the phase displacement, an increased voltage drop in the power system must be taken into account. For more detailed information please refer to the corresponding application notes.

4.2.4 Parameters and events

Table 7: Setting values

Parameter	Values	Unit	Default	Explanation
Neutral zone	105…200	% Q_{CO}	115	
Pickup zone	0…100	% Q_{CO}	0	
Reactive power of smallest Q_{CO}	1…20000	kVA	100	
Number of banks	1…4		1	
Maximum switching cycles	1…10000		2500	
Set point cos phi	0.7...1.0	Ind/cap	0.9 ind	
Limiting value cos phi	0…1	Ind/cap	0	

Table continues on next page

Parameter	Values	Unit	Default	Explanation
Discharge blocking time	1…7200	s	900	
Dead Time	1…120	s	10	
Power on delay	1…7200	s	900	
Duration of integration	1…7200	s	900	

Table 8: Events

Code	Event reason
E0	Bank 0 on
E1	Bank 1 on
E2	Bank 2 on
E3	Bank 3 on
E4	Bank 0 off
E5	Bank 1 off
E6	Bank 2 off
E7	Bank 3 off
E8	Overtemperature started
E9	Overtemperature back
E10	Va max started
E11	Va max back
E12	Vmin/Vmax started
E13	Vmin/Vmax back
E14	Command DISCONNECT started
E15	Command DISCONNECT back
E16	Cos phi warning started
E17	Cos phi warning back
E18	Alarm Q started
E19	Alarm Q back
E20	Warning switching cycle
E21	Alarm reset
E22	Block signal started
E23	Block signal back
E24	Manual operating mode
E25	Automatic operating mode
E26	Night mode
E27	Day mode

4.3 Circuit breaker monitoring

Circuit breaker monitoring can be used to supervise the contact wear condition by calculating the switched current and to help to analyze faults by storing all configured measurements in case of a CB trip.

4.3.1 Configuration

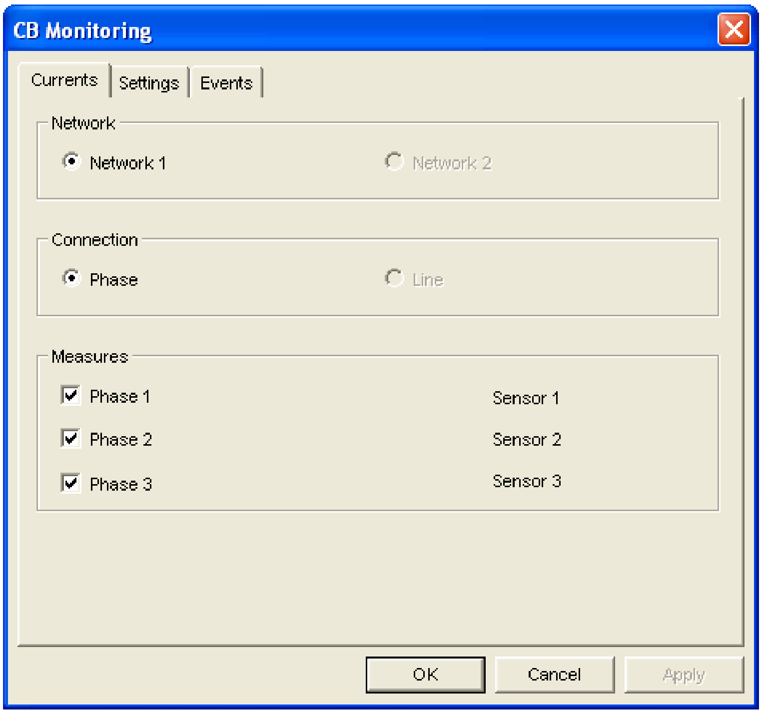


Figure 24: Currents

Current sensors used for CB Switched Currents calculation.

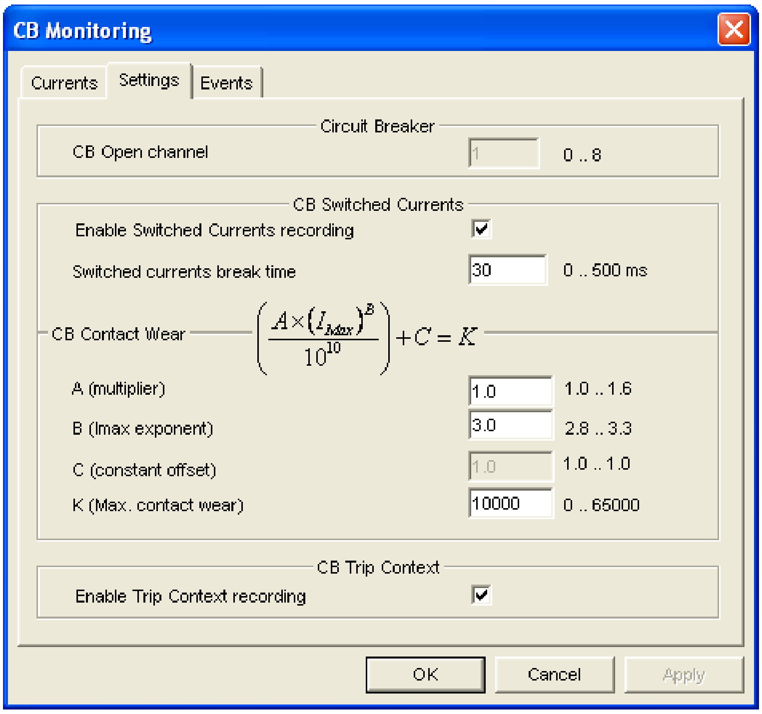


Figure 25: Settings

Circuit Breaker

CB Open channel	Number of the output channel used to open the circuit breaker. In case a Switching Object 2-2 configured as CB or the PTRC General are installed, the REF 542plus Configuration Tool will take automatically the configured CB open channel and disable the edited channel of this setting.

CB Switched Currents

Enable Switched Currents recording	If enabled, the values of the last six CB Switched Currents are stored in the non-volatile memory with the date and time of switching.
Switched currents break time	If enabled, the values of the last six CB Switched Currents are stored in the non-volatile memory with the date and time of switching.

CB Contact Wear

Parameters (*A*, *B*, *C*, *K*)	These parameters are used for the internal Contact Wear calculation done with the equation presented in the dialog box.

CB Trip Context

Enable Trip Context recording	If enabled, the values of the last six CB Trip Contexts are stored in the non-volatile memory with the date and time of tripping.

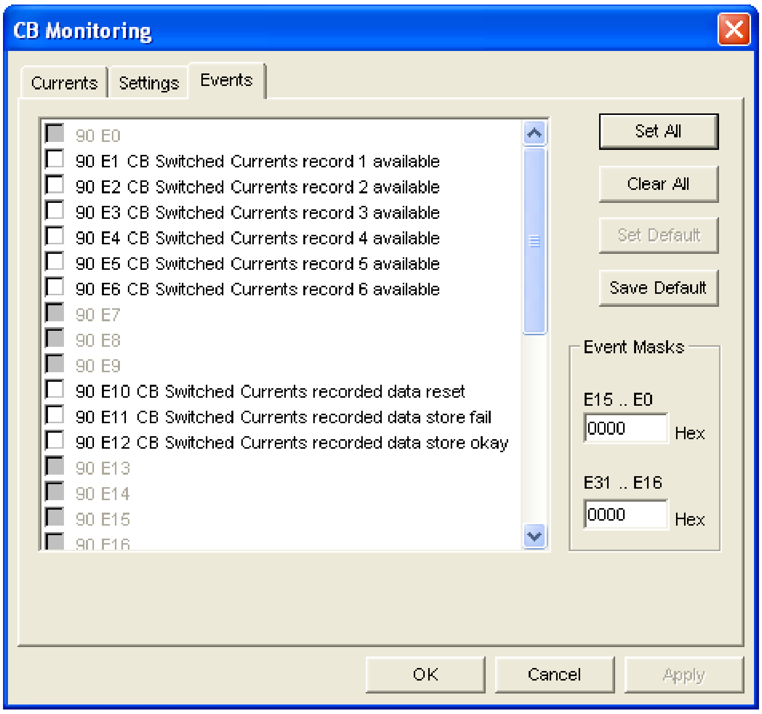


Figure 26: Events

4.3.2 Measurement mode

The switched current is calculated as the maximum RMS value at the fundamental frequency until the moment of contact separation.

The trip context is represented by all the configured measurements at the instant of CB Trip. Maximum six switched current/trip context values are stored in order to cover system operation using autoreclose with up to five multi-shots.

4.3.3 Operation criteria

The switched currents are recorded each time the circuit breaker is opened. The trip context is recorded each time the circuit breaker is opened due to a protection trip.

4.3.4 Parameters and events

Table 9: Setting values

Parameter	Values	Unit	Default	Explanation
Enable Switched Currents recording	Enabled/ Disabled		Disabled	Enable/Disable CB Switched Currents recording
Switched currents break time	0…500	ms	30	CB contact separation time
A (multiplier)	1.0…1.6		1.0	Parameter for contact wear calculation
B (max exponent)	2.8…3.3		3.000	Parameter for contact wear calculation
C (constant offset)	1.0…1.0		1.000	Parameter for contact wear calculation
K (Max. contact wear)	0…65000		10000	Parameter for contact wear calculation
Enable Trip Context recording	Enabled/ Disabled		Enabled	Enable/Disable CB Trip Context recording

Table 10: Events

Code	Event reason
E1	CB switched currents record 1 available
E2	CB switched currents record 2 available
E3	CB switched currents record 3 available
E4	CB switched currents record 4 available
E5	CB switched currents record 5 available
E6	CB switched currents record 6 available
E10	CB switched currents recorded data reset
E11	CB switched currents recorded data store fail
E12	CB switched currents recorded data store okay
E17	Trip context record 1 available
E18	Trip context record 2 available
E19	Trip context record 3 available
E20	Trip context record 4 available
E21	Trip context record 5 available
E22	Trip context record 6 available
E26	Trip context recorded data reset
E27	Trip context recorded data store fail
E28	Trip context recorded data store okay

By default all events are disabled.

4.3.5 Data reading

The function for reading of the circuit breaker monitoring data can be used for:

- Uploading data from the connected REF 542plus
- Reset data in the connected REF 542plus
- Save uploaded data to a recorded file (text format)
- Uploading data from the recorded file

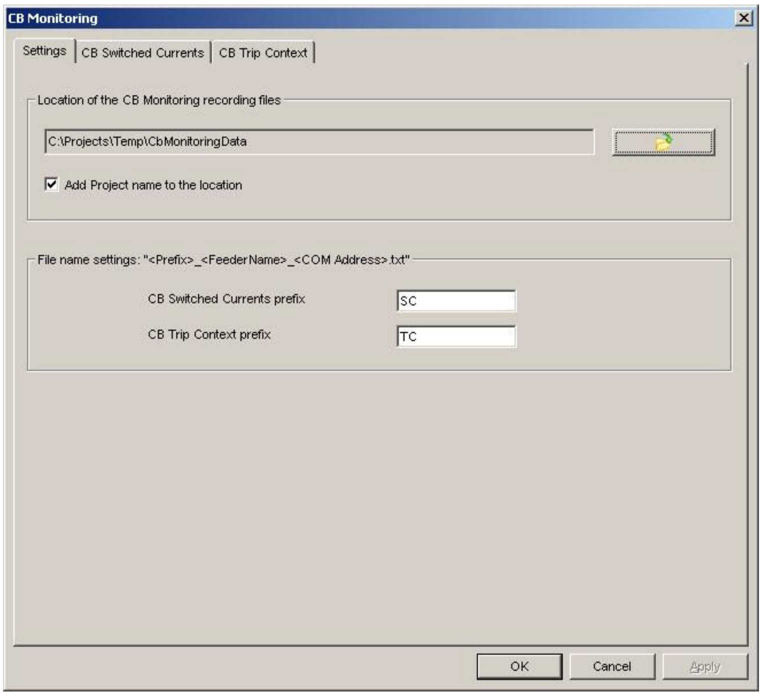


Figure 27: Settings

Click the Settings tab to select the location of the CB Monitoring recording files and file prefixes. The recording file name is automatically composed by the REF 542plus Configuration Tool with the following items:

- User editable prefix
- Feeder name
- Device communication address

An example of a CB Switched Currents recording file name:

SC_Feeder_98.txt

Where:

SC	The prefix of the recorded file
Feeder	The feeder name from the device configuration. In case the feeder name is empty, the default (Feeder) is used.
98	The device communication address (SPA, IEC103, LON, and so on) read from the device configuration. In case the address is an IP address (ETHERNET board), the standard dot separator is replaced by dash to avoid confusion on file extension (for example 198-162-2-112).

The file name is unique in a project, because two devices cannot have the same feeder name and communication address.

Click the CB Switched Currents or the CB Trip Context tab to upload the information relating to the circuit breaker switched currents or circuit breaker trip context from file or from REF 542plus.

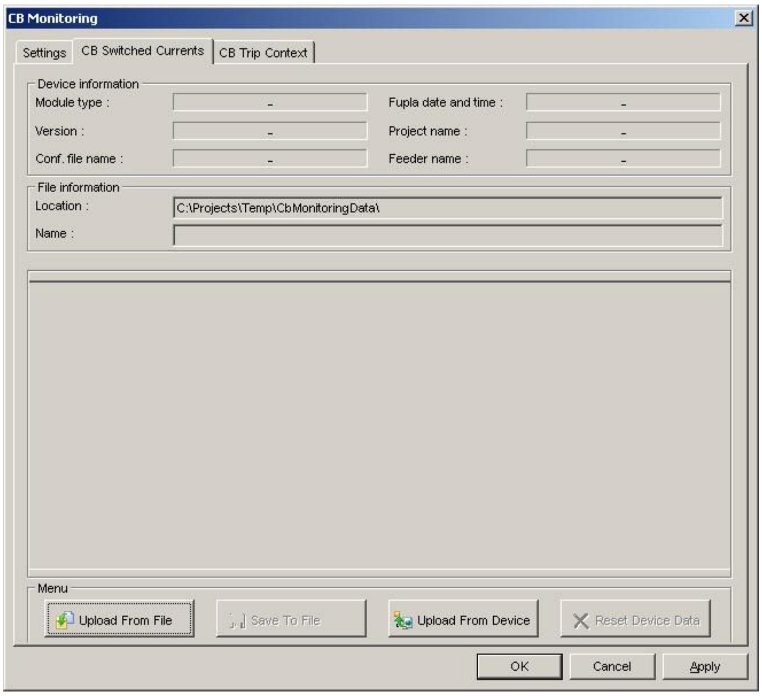


Figure 28: CB Switched Currents

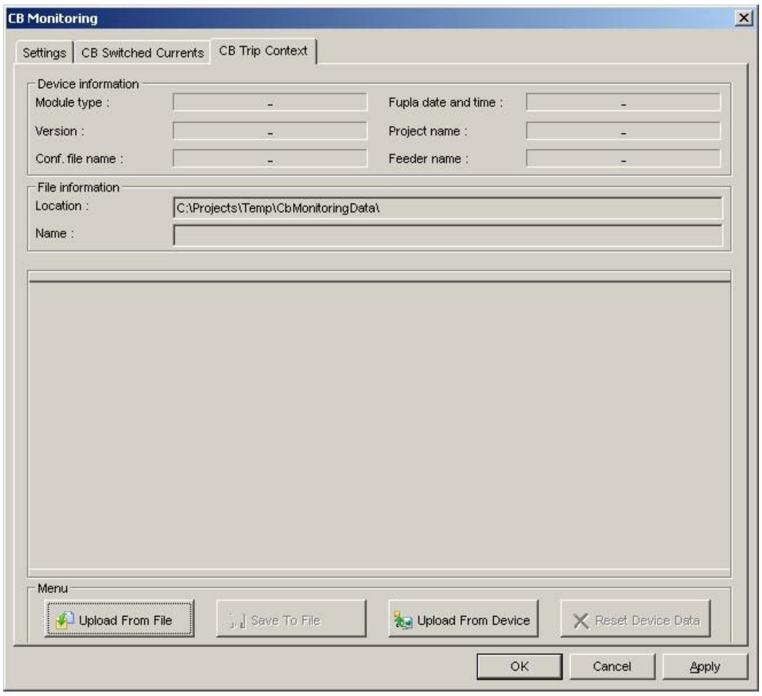


Figure 29: CB Trip Context

Figure 30: Upload from file

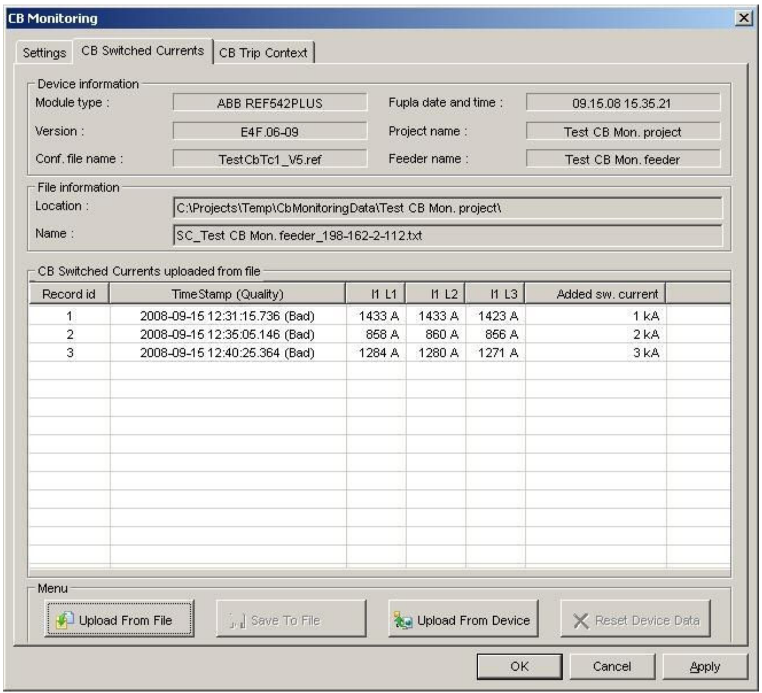


Figure 31: Upload from REF 542plus

- Device information
  Device information displays data regarding REF 542plus and its configuration.
- File information
  When uploading from REF 542plus, File information displays the location and the file name where the data is saved when clicking **Save To File**. When uploading from file, it displays the location and the file name of the uploaded file. The data table displays the CB Monitoring data type (CB Switched Currents or CB Trip Context) and the upload source (device/file). The information is presented in a table where each row contains the data relevant to one record.

> The time stamp contains also its quality. It is set to "Good" in case the record has been time-stamped when the device time was synchronized; otherwise it is set to "Bad".

- Save To File
  You can use **Save To File** after a successful upload from REF 542plus. In case the file does not exist, the file is created. Otherwise the file is saved into a backup file (*.bak) and the new uploaded records are appended to the file. In order to save the file, the uploaded and the saved file has to be compatible. The files are compatible when they have the same device information and the same record format (number of data and measurements name). In case the files are not compatible the existing file is replaced by the uploaded one. In case a new configuration has been downloaded to REF 542plus, the user can choose to append the new records to the saved file or to save only the new ones.
- Reset Device Data

You can use **Reset Device Data** after a successful upload from REF 542plus. After a requested confirmation, the CB Monitoring data stored in REF 542plus is reset.

Section 5 Protection functions

5.1 Current protection functions

5.1.1 Inrush blocking

REF 542plus has one inrush blocking protection function. This function is appropriate for application in motor protection scheme in order to block the corresponding overcurrent protection.

The following current protection functions are blocked by the inrush blocking protection function without the need of additional wiring in the FUPLA, that is, the block to the protection functions is implicit.

- Overcurrent instantaneous
- Overcurrent high
- Overcurrent low
- Directional overcurrent high
- Directional overcurrent low
- IDMT
- Earthfault IDMT

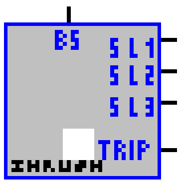


Figure 32: Inrush blocking

5.1.1.1 Input/output description

Table 11: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 12: Output

Name	Type	Description
S L1	Digital signal (active high)	Start signal of IL1
S L2	Digital signal (active high)	Start signal of IL2
S L3	Digital signal (active high)	Start signal of IL3
TRIP	Digital signal (active high)	Trip signal

`S L1`, `S L2` and `S L3` are the phase selective start signals. The phase starting signal will be activated when the respective phase current start conditions are true and the overcurrent protection will be implicitly blocked until the operating time (*Time*) has elapsed.

The `TRIP` signal will be activated when the start conditions are true (inrush detection), the maximum measured current exceeds the threshold (limit N•I>>) and the relevant overcurrent protection operating time has elapsed.

5.1.1.2 Configuration

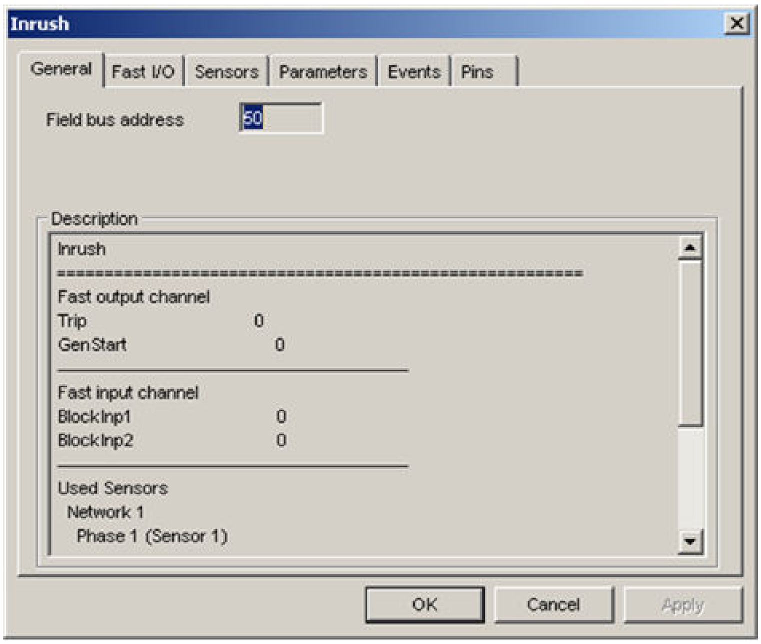


Figure 33: General

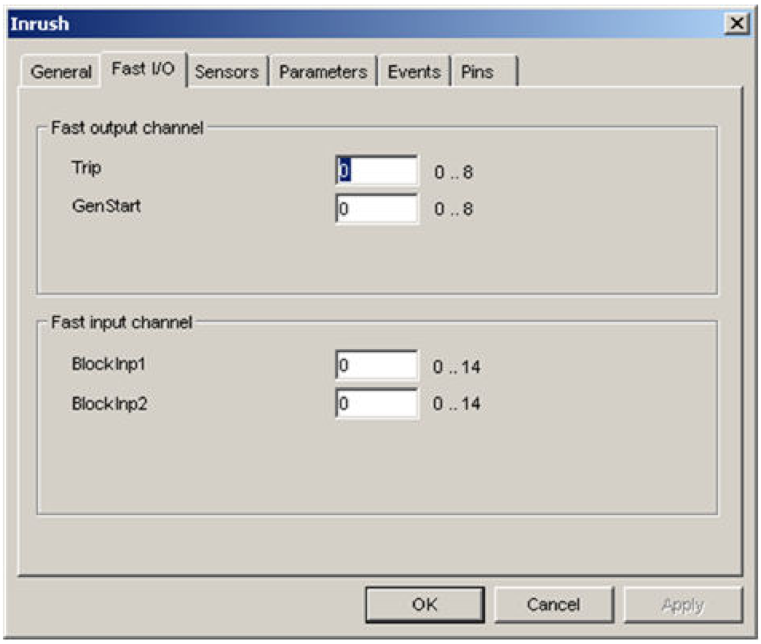


Figure 34: Fast I/O

Output Channel different from 0 means a direct execution of the trip or the general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, skipping the FUPLA cyclic evaluation.

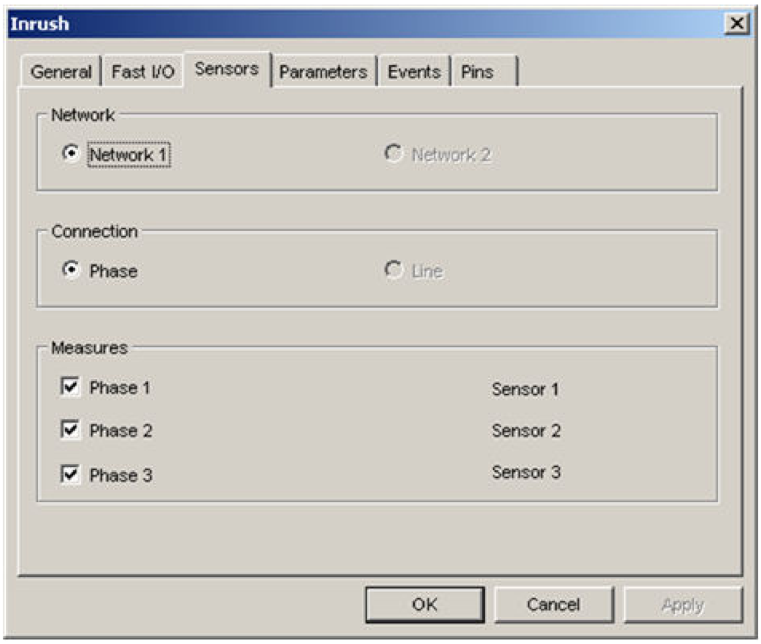


Figure 35: Sensors

The protection function operates on any combination of current phases in a triple, for example, it can operate as single phase, double phase or three-phase protection on phase currents belonging to the same system.

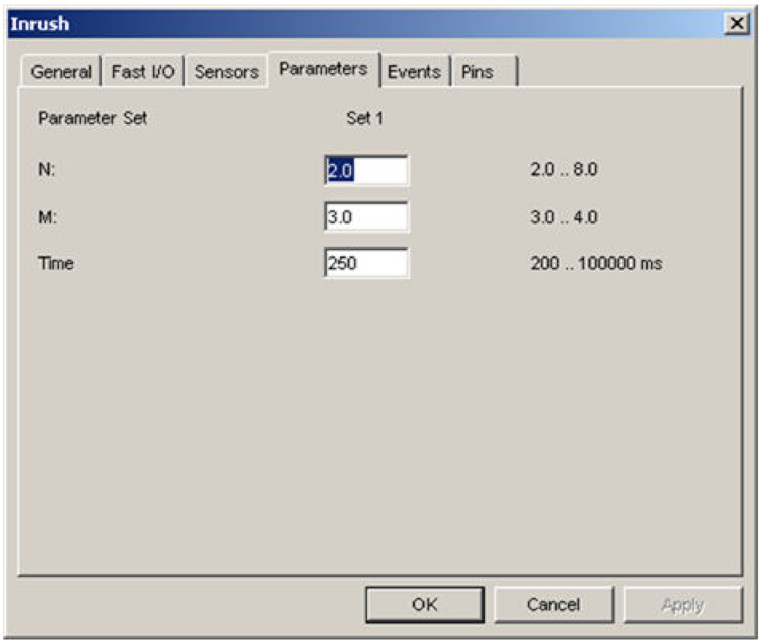


Figure 36: Parameters

N	Threshold I>> multiplier for fault detection and inrush protection trip
M	Threshold I> multiplier for inrush detection
Time	Overcurrent protection blocking Time at inrush detection

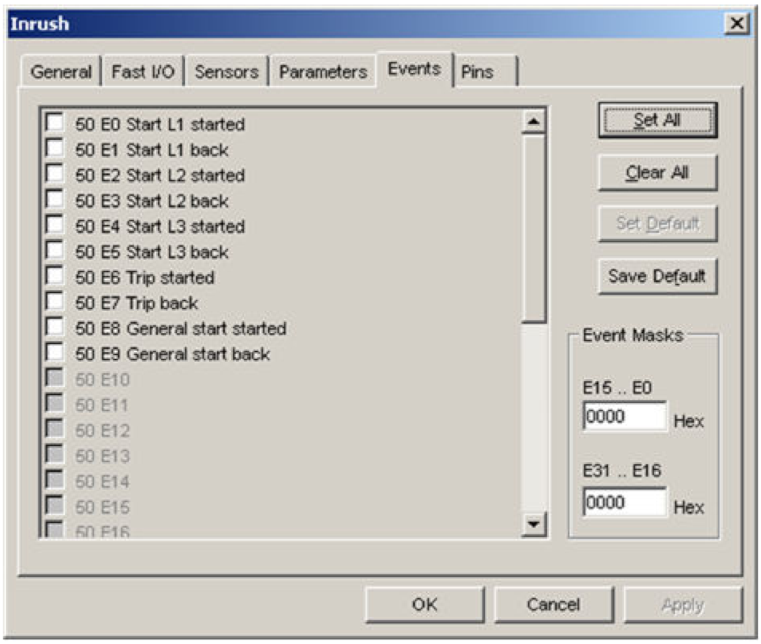


Figure 37: Events

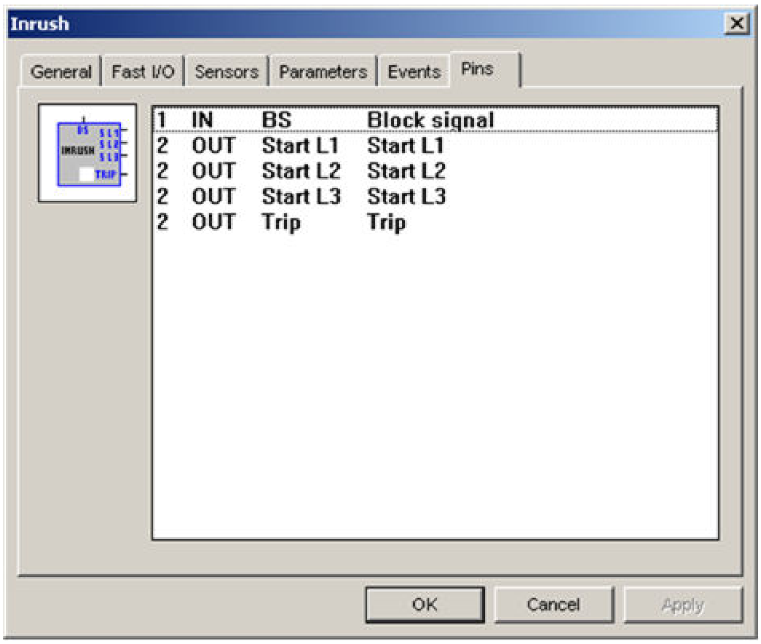


Figure 38: Pins

5.1.1.3 Measurement mode

Inrush blocking function evaluates the current at the fundamental frequency.

5.1.1.4 Operation criteria

An inrush is detected if the maximum measured current exceeds the threshold M•I> within 60 ms after it exceeded 10% of current threshold I>.

Here I> is the threshold (*Start value I>*) of the overcurrent low protection function. If this protection function is not installed, the threshold of IDMT protection function (*Base current Ieb*, if installed) is used or a standard value of 0.05•I_N (if IDMT also is not installed).

If an inrush is detected, the above-listed protection functions are blocked until the end of inrush has been detected or the maximum preset inrush duration, that is, *Time* has elapsed.

The end of inrush condition is detected when the maximum measured current falls below M•0.65•I>. A counter is then started and 100 ms later the end of inrush is assumed. The current protection functions are then released from the block.

At feeder start-up, with current zero, the implicit block of the overcurrent protection function is already active. Only as the current increases, the inrush condition is evaluated and the block can be released if an inrush is not present.

The inrush blocking itself becomes a protection function, if the maximum measured current exceeds the limit N•I>> after the inrush detection. The operating time is that of the overcurrent instantaneous (if installed) or 80 ms.

Here I>> is the threshold (*Start value I>>*) of the overcurrent high protection function. If this protection function is not installed, the threshold of overcurrent instantaneous protection function (if installed) is used or a standard value of 0.10•I_N (if overcurrent instantaneous also is not installed).

The following three diagrams are not scaled, but they are provided solely for a better understanding of the explanations of how the inrush blocking works.

Tesb is the operation counter that is compared to the set overcurrent protection blocking time, that is, *Time*.

In Figure 39 inrush is detected within the 60 ms window. Then the end of inrush condition is detected and the block released before protection-blocking time expires.

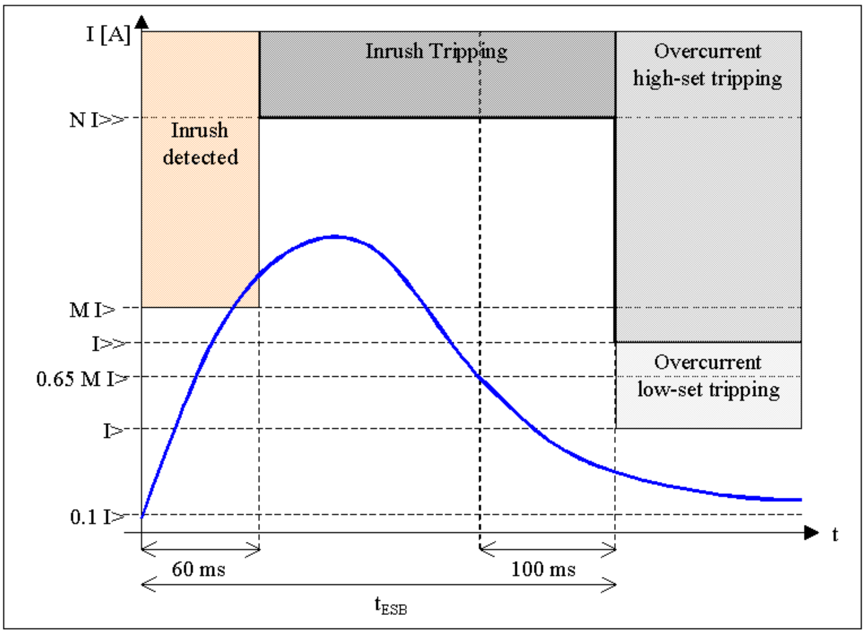


Figure 39: Current-time characteristic of the detected inrush process

In Figure 40 inrush is detected within the 60 ms window. Then the end of inrush condition is detected and the block released before protection-blocking time expires. The current value is over the I> threshold and that protection function will start timing and trip in due time.

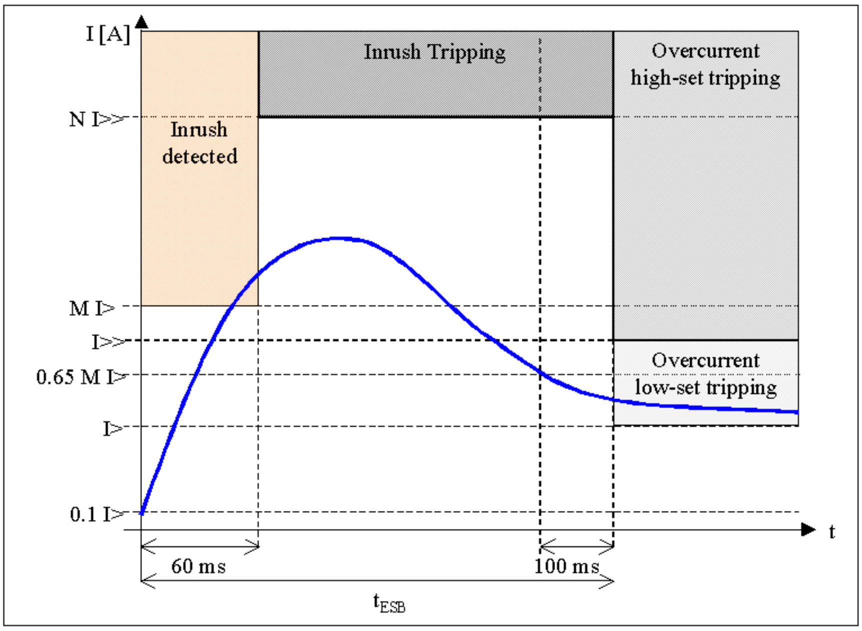


Figure 40: Current-time characteristic of the detected overload

In Figure 41 inrush is detected within the 60 ms window, no end of inrush condition is detected and the protection-blocking time expires. The current value is over the I>> threshold and that protection function will start timing and trip in due time.

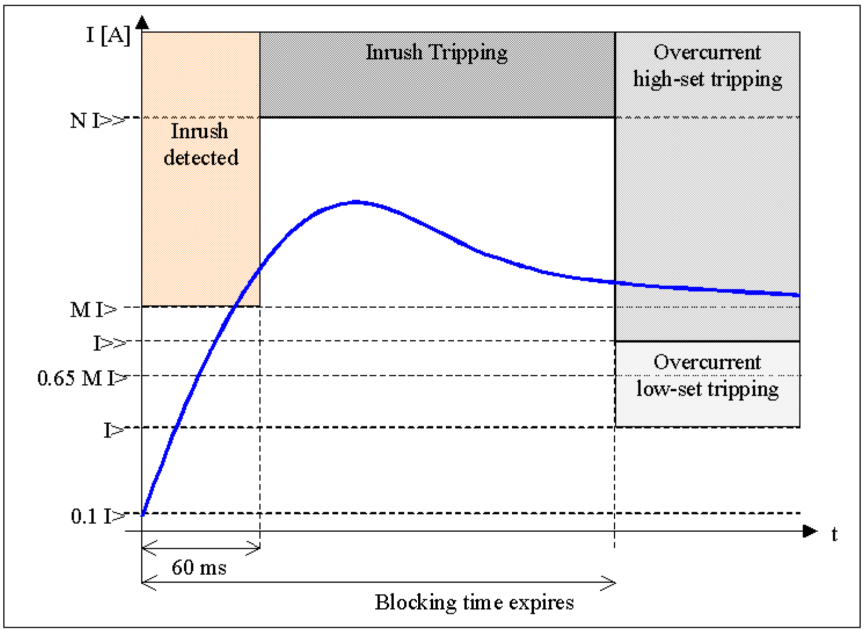


Figure 41: Current-time characteristic when no inrush condition is detected

5.1.1.5 Setting groups

Two parameter sets can be configured for the inrush blocking protection function.

5.1.1.6 Parameters and events

Table 13: Setting values

Parameter	Values	Unit	Default	Explanation
N	2.0...8.0		2.0	Threshold I>> multiplier for fault detection and trip
M	3.0...4.0		3.0	Threshold I> multiplier for inrush detection
Time	200...100000	ms	250	overcurrent protection blocking Time after inrush detection

Table 14: Events

Code	Event reason
E0	Start L1 started
E1	Start L1 back
E2	Start L2 started

Table continues on next page

Code	Event reason
E3	Start L2 back
E4	Start L3 started
E5	Start L3 back
E6	Trip started
E7	Trip back
E18	Protection block started
E19	Protection block back

By default all events are disabled.

5.1.2 Inrush harmonic

REF 542plus has an inrush harmonic function which can be used to temporarily block protection functions.

The following current protection functions are blocked by the inrush harmonic protection function without the need of additional wiring in the FUPLA, that is, the block to the protection functions is implicit.

- Overcurrent instantaneous
- Overcurrent high
- Overcurrent low
- Directional overcurrent high
- Directional overcurrent low
- IDMT
- Earthfault IDMT

Other protection functions, such as distance protection, can be blocked by wiring them to FUPLA.

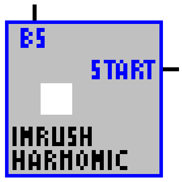


Figure 42: Inrush harmonic

5.1.2.1 Input/output description

Table 15: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 16: Output

Name	Type	Description
START	Digital signal (active high)	Start signal

START signal can be wired in FUPLA to signal inrush condition status or to the protection functions BS input pins (different from those listed above and implicitly blocked) to temporarily block during an inrush transient. This means that the block to the protection functions is explicit.

5.1.2.2 Configuration

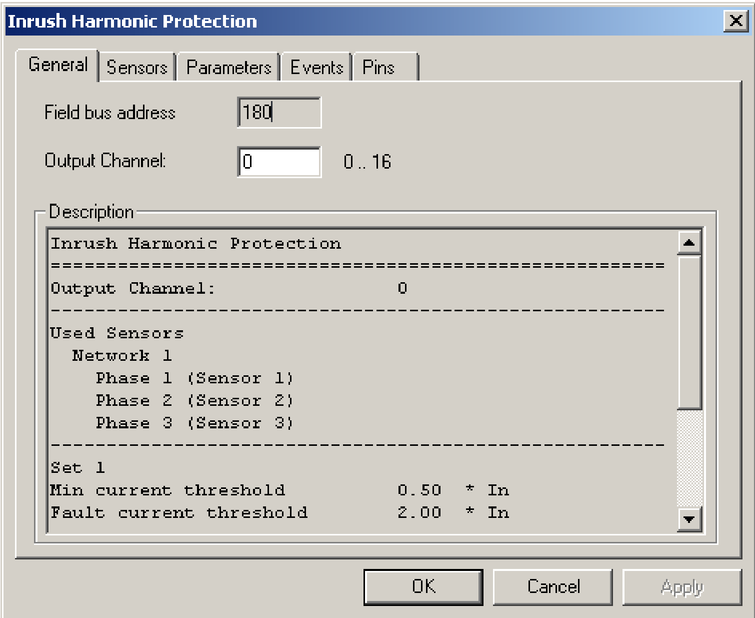


Figure 43: General

Output Channel different from 0 means direct execution of the trip command, that is, skipping FUPLA cyclic evaluation.

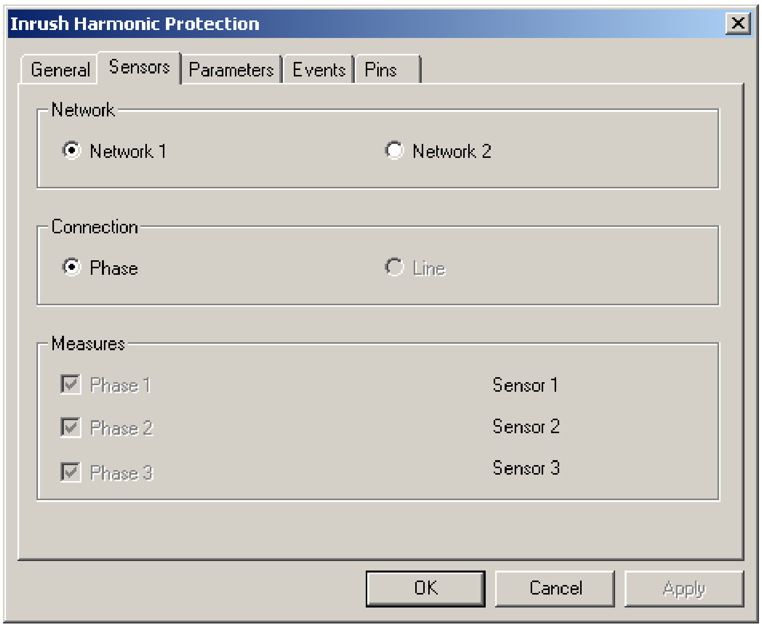


Figure 44: Sensors

The protection function operates on any set of phase currents in a triple.

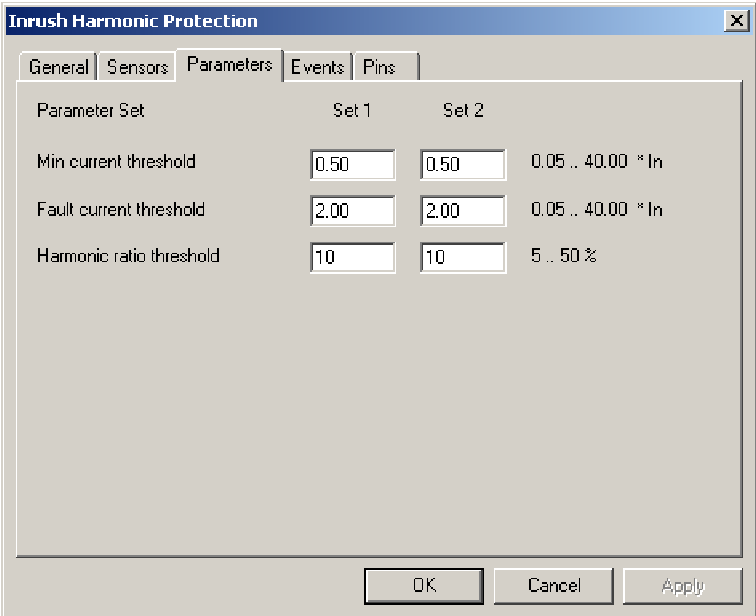


Figure 45: Parameters

Min current threshold	Minimum current threshold for inrush detection
Fault current threshold	Current threshold for fault detection
Harmonic ratio threshold	2nd/fundamental current ratio threshold for inrush detection

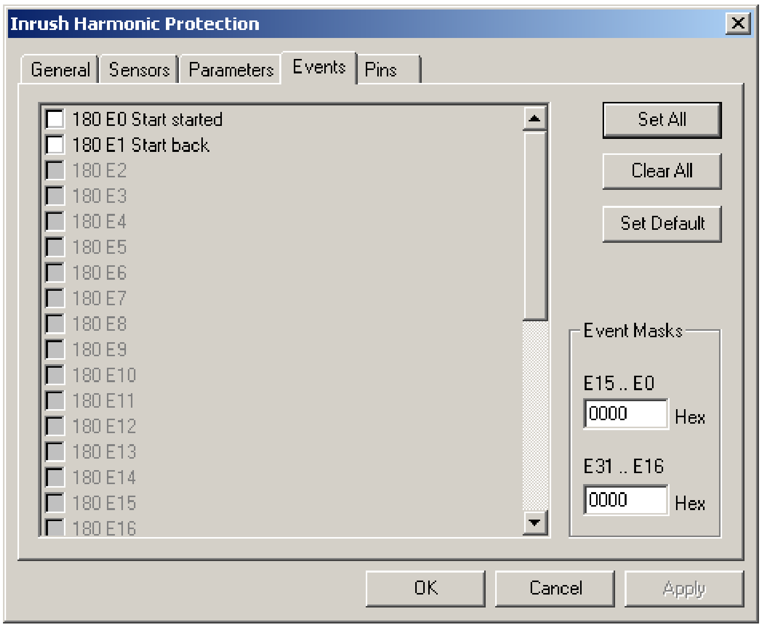


Figure 46: Events

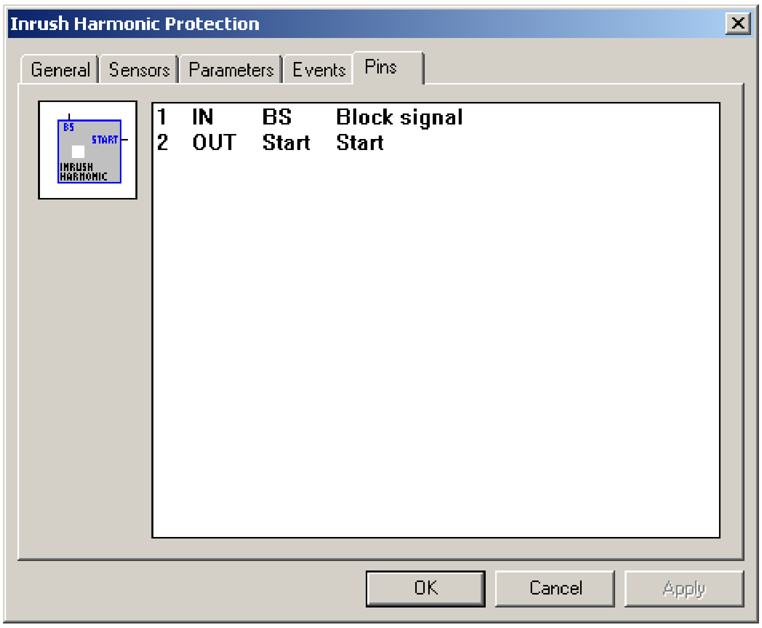


Figure 47: Pins

5.1.2.3 Measurement mode

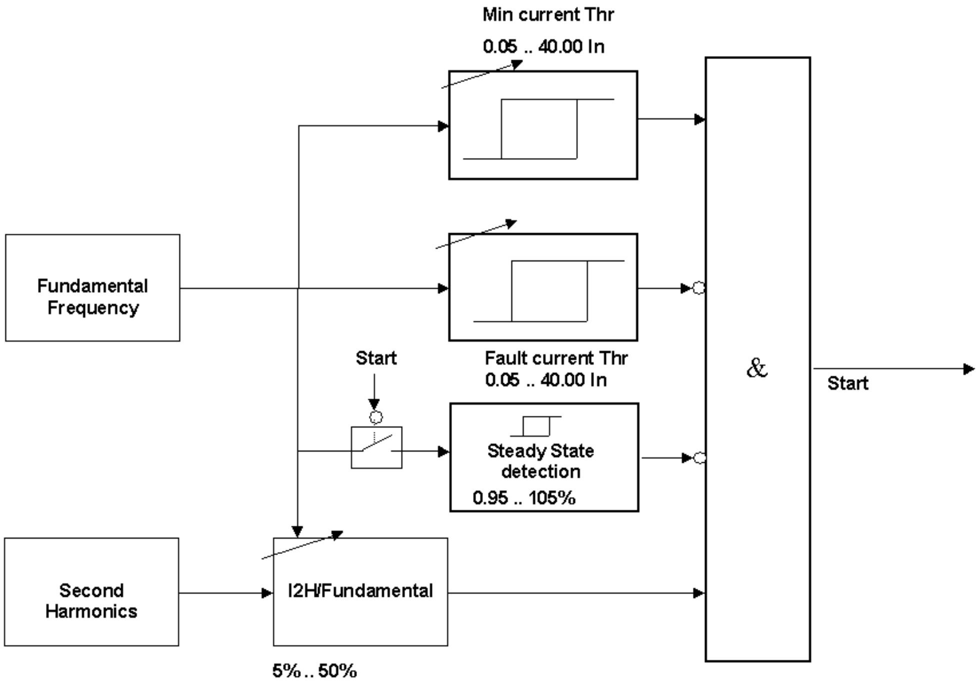
Inrush harmonic protection function evaluates the ratio between current values at 2nd harmonic and at fundamental frequency.

5.1.2.4 Operation criteria

If all of the following conditions are true for at least one phase current, the protection function is started and the `START` signal will be activated.

- The current is not in steady-state condition.
- The current value at fundamental frequency is above the preset minimum current threshold, that is, *Min current threshold*.
- The current value is below the preset maximum current threshold, that is, *Fault current threshold*.
- The harmonic ratio between the current values at 2nd harmonic and at fundamental frequency exceeds the preset threshold, that is, *Harmonic ratio threshold*.

The start criteria are illustrated in Figure 47.



The protection function will remain in START status until at least for one phase the above conditions, steady state excluded, are true. It will come back in passive status with a 10 ms delay when either one of the following conditions is met.

- For all the phases at least one condition falls below 0.95 the setting threshold value, that is, *Min Current threshold* or *Harmonic ratio threshold* respectively.
- At least for one phase the current value exceeds the preset maximum current threshold, that is, *Fault current threshold*.

5.1.2.5 Steady-state detection

Steady-state condition is detected if the current value at fundamental frequency falls below the preset minimum current threshold, that is, *Min current threshold*for at least 10 ms, or the current value at fundamental frequency is between 95% and 105% of the previous period for at least one period.

5.1.2.6 Setting groups

Two parameter sets can be configured for the harmonic inrush protection function.

5.1.2.7 Parameters and events

Table 17: Setting values

Parameter	Values	Unit	Default	Explanation
Minimum current threshold	0.05...40.00	In	0.5	Current threshold for inrush detection, if exceeded the inrush conditions are evaluated.
Fault current threshold	0.05...40.00	In	2	Current threshold for fault detection, if exceeded the inrush start is set to low.
Harmonic ratio threshold	5...50	%	10	2^{nd}/fundamental current ratio threshold for in-rush detection.

Table 18: Events

Code	Event reason
E0	Protection has started
E1	Start is cancelled
E18	Protection block signal is active started
E19	Protection block signal is back to inactive state

By default all events are disabled.

5.1.3 Non-directional overcurrent protection

In the non-directional overcurrent protection can up to eight instances be applied.

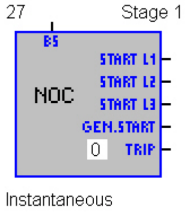


Figure 48: Non-directional overcurrent protection

5.1.3.1 Input/output description

Table 19: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function remains in idle state until the BS signal goes low.

Table 20: Outputs

Name	Type	Description
START L1	Digital signal (active high)	Start signal of IL1
START L2	Digital signal (active high)	Start signal of IL2
START L3	Digital signal (active high)	Start signal of IL3
GEN.START	Digital signal (active high)	General start signal (logical OR combination of all start signal inclusive reset time)
TRIP	Digital signal (active high)	Trip signal

The START signal is activated when the respective phase current start conditions are true. START L1, START L2 and START L3 are the phase selective start signals. The GEN.START is a logical OR combination of the start signals START L1, START L2 and START L3, and remains active until the reset time, if used, is expired. The TRIP signal is activated when the start conditions are true and the operating time has elapsed at least for one phase current.

5.1.3.2 Configuration

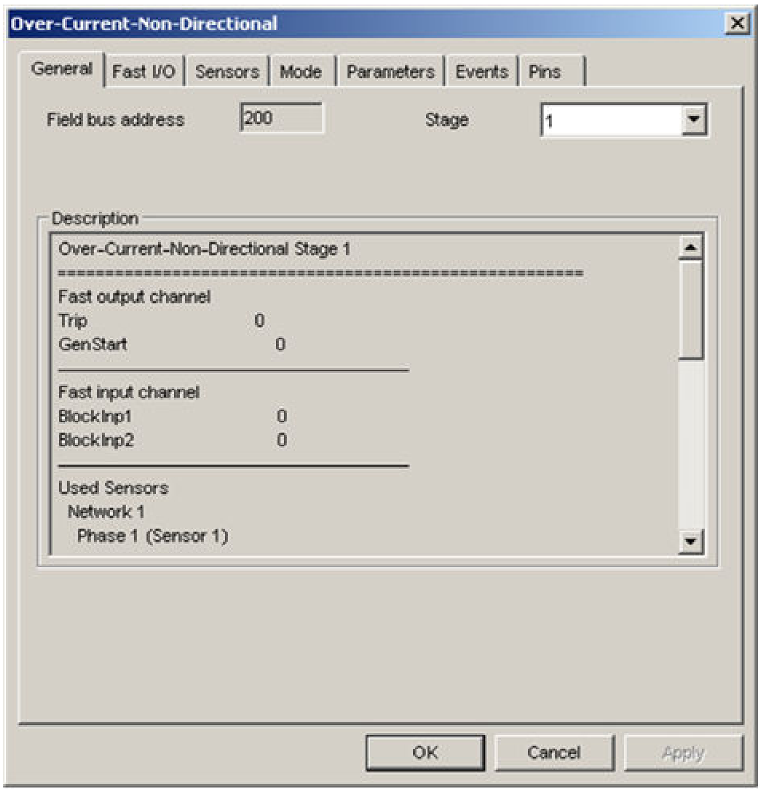


Figure 49: General

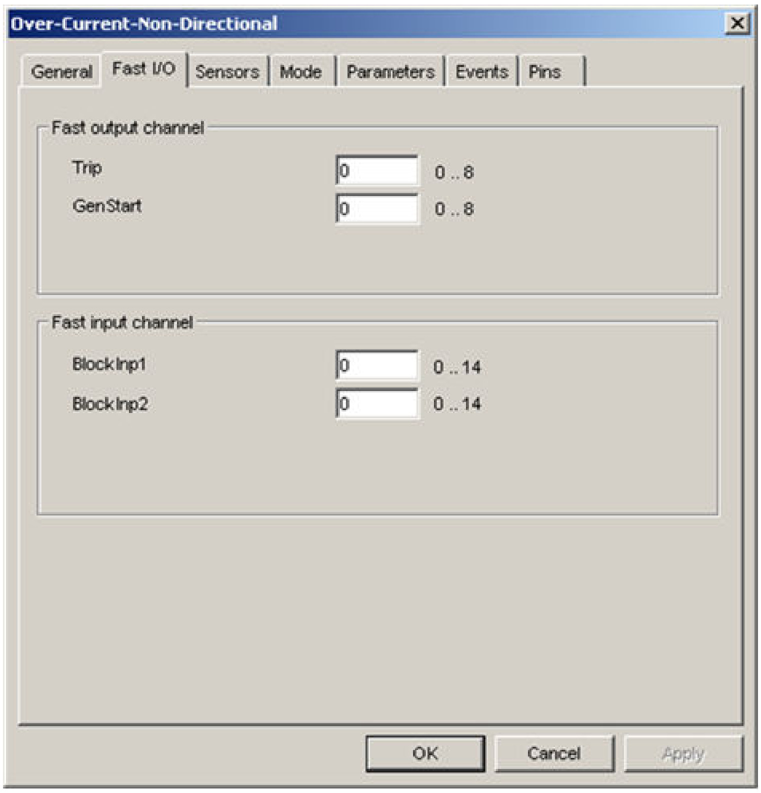


Figure 50: Fast I/O

Output channel different from 0 means a direct execution of the trip command or general start command, that is, skipping the FUPLA cyclic evaluation.

Input channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

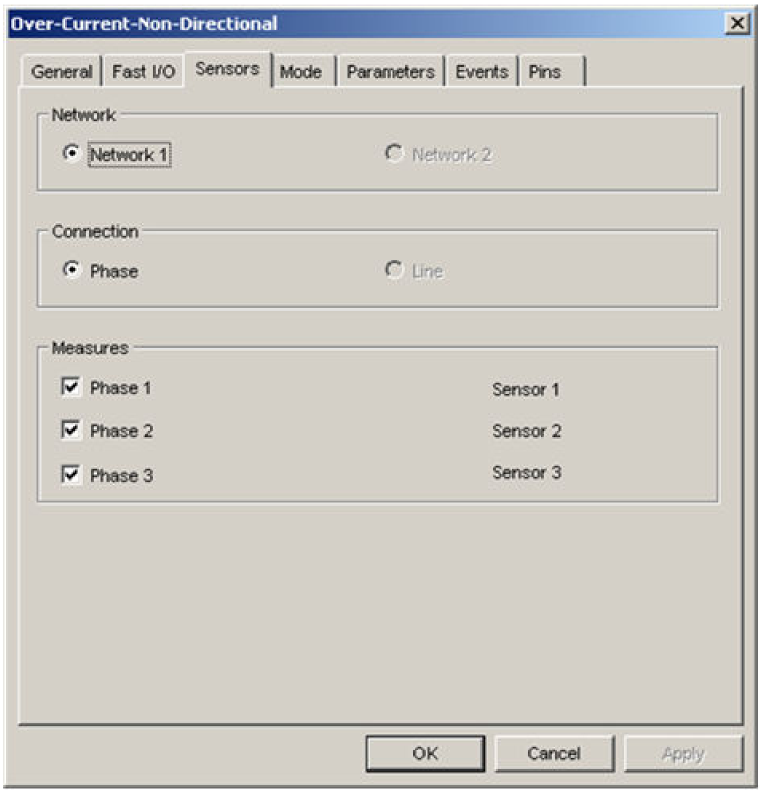


Figure 51: Sensors

The protection function operates on any combination of the phase current in a triple, for example, it can operate as single-phase, double-phase or three-phase protection on the phase currents belonging to the same network.

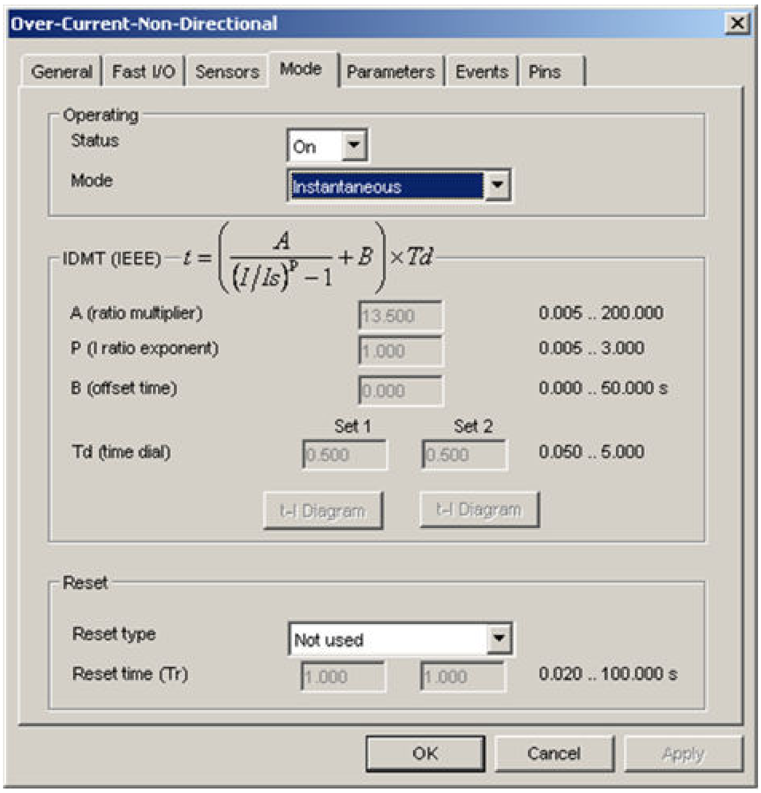


Figure 52: Mode

Status	Mode of the operating status on or off
Mode	Mode for the overcurrent, instantaneous, definite or inverse time
IDMT (IEEE)	Free programmable inverse time curve according to equation
A, *P*, *B*, *Td*	Parameter for the free programmable inverse time curve
t-I Diagram	Diagram of the inverse time operation characteristic
Reset type	Mode of the reset time
Reset time	Timer resets after start current condition is not valid anymore

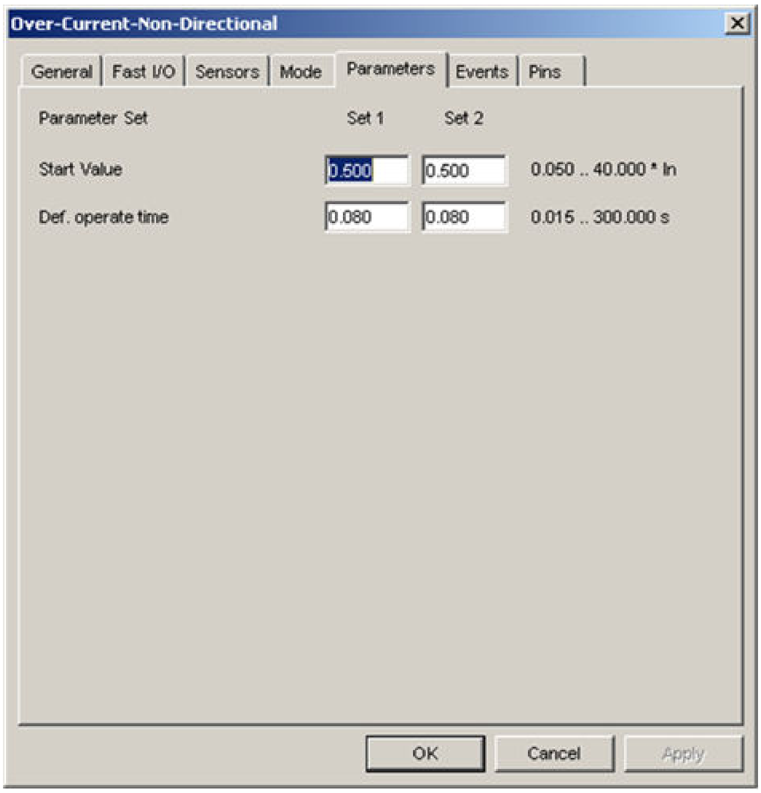


Figure 53: Parameter

Start Value	Current threshold for start
Def. operate time	Operation time in mode definite time

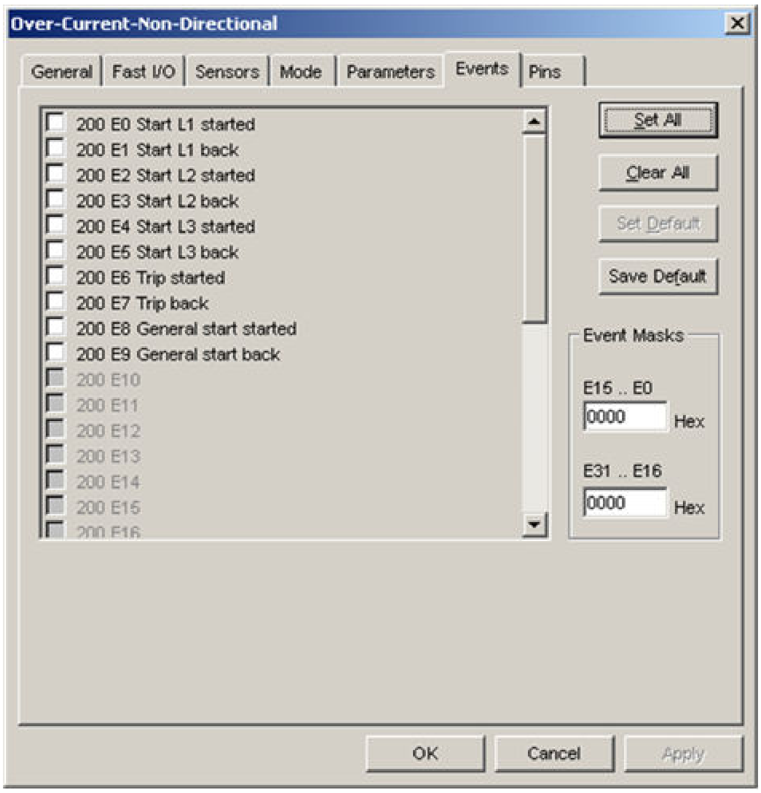


Figure 54: Events

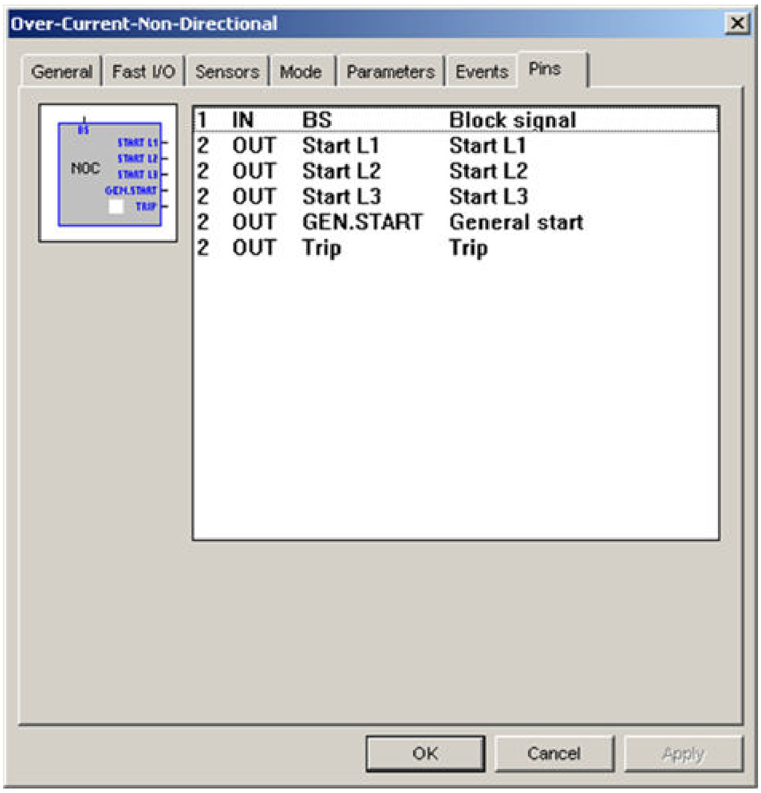


Figure 55: Pins

5.1.3.3 Measurement mode

All overcurrent functions evaluate the current RMS value at the fundamental frequency. In case of the overcurrent definite time instantaneous, the peak value of the measured current is also used under transient condition for a faster response. When the instantaneous peak value is higher than three times the peak value, in relation to the RMS value, a trip is generated.

5.1.3.4 Operation criteria

If the measured current exceeds the setting threshold value (*Start Value*), the overcurrent protection function is started. The start signal is phase selective, that is, when at least a value of one phase current is above the setting threshold value the relevant start signal is activated. The protection function remains in START status until there is at least one phase started. It returns to passive status and the start signal is cleared if for all the phases the current falls below 0.95 the setting threshold value.

After the protection has entered the start status and the preset operating time (*Time*) has elapsed, function goes in TRIP status and the trip signal is generated. The protection function exits the TRIP status and the trip signal is cleared when the measured current value falls below 0.4 the setting threshold value. The tripping can be applied according to definite time or inverse time characteristic, which is defined according to an equation.

$$t = \left(\frac{A}{M^{P} - 1} + B \right) td$$

(Equation 8)

t Operation time to trip

A Curve parameter for the time value (according to IEC 60255-3)

P Value for the exponent

M Ratio of actual current to the pickup current I/In

B Additional offset time

td Time-dial to adapt the operation time

The inverse time characteristic (IDMT) is applied after the condition M > 1 is valid. The operation range is, as defined in the IEC 60255-3 standard, from 1.2 to 20 In. Each time the protection is started due to a system fault condition (M>1.2), the IDMT operating counter is incremented according to the equation. When it reaches the operation time to trip the function operates activating the trip output signal. If required, a reset type with Inverse time characteristic can be set according to an equation.

$$t = \left(\frac{tr}{M^{P} - 1} \right) td$$

(Equation 9)

t Operation time to reset

tr Reset time (for M = 0)

M Ratio of actual current to the pickup current I/In

td Time-dial to adapt the operation time additionally

The reset type inverse time characteristic is valid for 0 < M < 1. In this case the inverse-time overcurrent protection enters the reset state and decrements the operating counter according to equation above. If the condition is 1 ≤ M < 1.2, the counter remains unchanged.

Instead of inverse time reset type a definite time can also be selected. The purpose of the definite reset time is to enable fast clearance of intermittent faults, for example self-sealing insulation faults, and severe faults, which may produce high asymmetrical fault currents that partially saturate the current transformers. It is typical for an intermittent fault that the fault current contains so called drop-off periods during which the fault current falls below the set start current including hysteresis. Without the reset time function, the operating counter would be stopped, when the current has dropped off. In the same way, an apparent drop-off period of the secondary current of the saturated current transformer might also reset the operating counter.

The reset type inverse time can only be applied in conjunction with inverse time overcurrent protection. For definite time overcurrent protection only reset type definite time may be used.

5.1.3.5 Setting groups

Two parameter sets can be configured for the non-directional overcurrent protection. A switch over between the parameter sets can be performed in dependency of the network configuration. If this is not required, set 1 and set 2 can be parameterized identically to avoid wrong setting if switch over of parameters has happened accidentally.

5.1.3.6 Parameters and events

Table 21: Setting values

Parameter	Values	Unit	Default	Explanation
Status	On/Off		On	Operating status
Mode	Instantaneous/ IDMT		Instantaneous	Operation characteristic
A (ratio multiplier)	0.005...200.000		13.500	Parameter for operation characteristic
P (ratio exponent)	0.005...3.000		1.000	Parameter for operation characteristic
B (offset time)	0.000...50.000	s	0.000	Parameter for operation characteristic
Td (time dial)	0.050...5.000	s	0.5000	Parameter for operation characteristic
Reset type	Not used/Definite time/Inverse time		Not used	Reset Characteristic
Reset time (Tr)	0.020...100.000	s	1.000	Parameter for reset characteristic
Start Value	0.050...40.000	In	0.5000	Current threshold for start condition
Def. operate time	0.015...300.000	s	0.080	Time delay for trip condition

Table 22: Events

Code	Event reason
E0	Protection start on phase L1
E1	Start on phase L1 cancelled
E2	Protection start on phase L2
E3	Start on phase L2 cancelled
E4	Protection start on phase L3
E5	Start on phase L3 cancelled

Table continues on next page

Code	Event reason
E6	Trip signal is active
E7	Trip signal is back to inactive state
E8	Protection general start (logical OR combination of all start signal)
E9	General start is cancelled (after expiration of the reset time)
E18	Protection block signal is active
E19	Protection block signal is back to inactive status

By default all events are disabled.

5.1.4 Directional overcurrent protection

In the directional overcurrent protection can up to eight instances be applied.

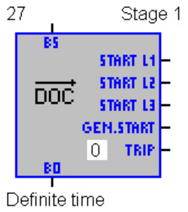


Figure 56: Directional overcurrent protection

5.1.4.1 Input/output description

Table 23: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the `BS` signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function remains in idle state until the `BS` signal goes low.

Table 24: Output

Name	Type	Description
START L1	Digital signal (active high)	Start signal of IL1 (fault in set direction)
START L2	Digital signal (active high)	Start signal of IL2 (fault in set direction)
START L3	Digital signal (active high)	Start signal of IL3 (fault in set direction)
GEN.START	Digital signal (active high)	General start signal (logical OR combination of all starts including reset time)
TRIP	Digital signal (active high)	Trip signal
BO	Digital signal (active high)	Block output signal (fault in opposite direction)

START L1, START L2 and START L3 are the phase selective start signals. The phase starting signal is activated when respective phase current start conditions are true, that is, current exceeds the setting threshold value and the fault is in the specified direction.

GEN.START is a logical OR combination of the start signals START L1, START L2 and START L3 and remains active until the reset time, if used, has expired.

The TRIP signal is activated when at least for a phase current the start conditions are true and the operating time has elapsed.

Block Output (BO) signal becomes active when the protection function detects a current exceeding the preset value and the fault direction opposite to the specified direction.

5.1.4.2 Configuration

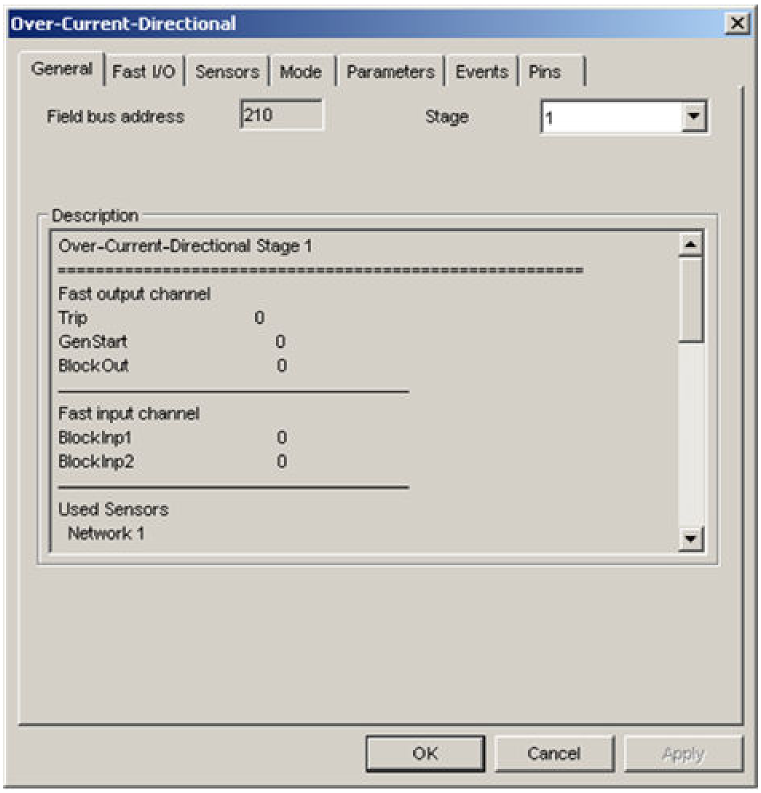


Figure 57: General

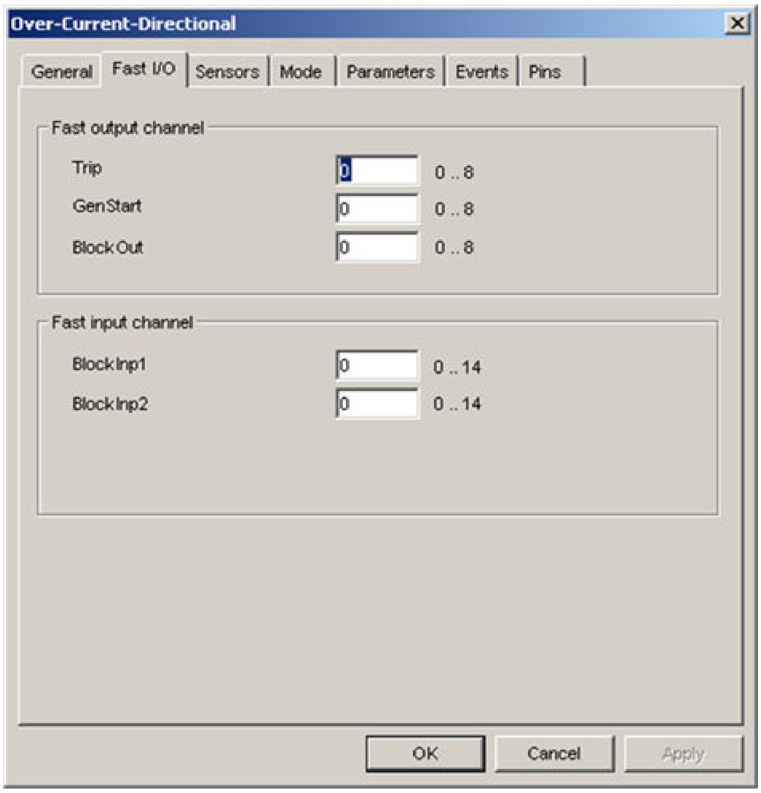


Figure 58: Fast I/O

Output Channel different from 0 means a direct execution of the trip or general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

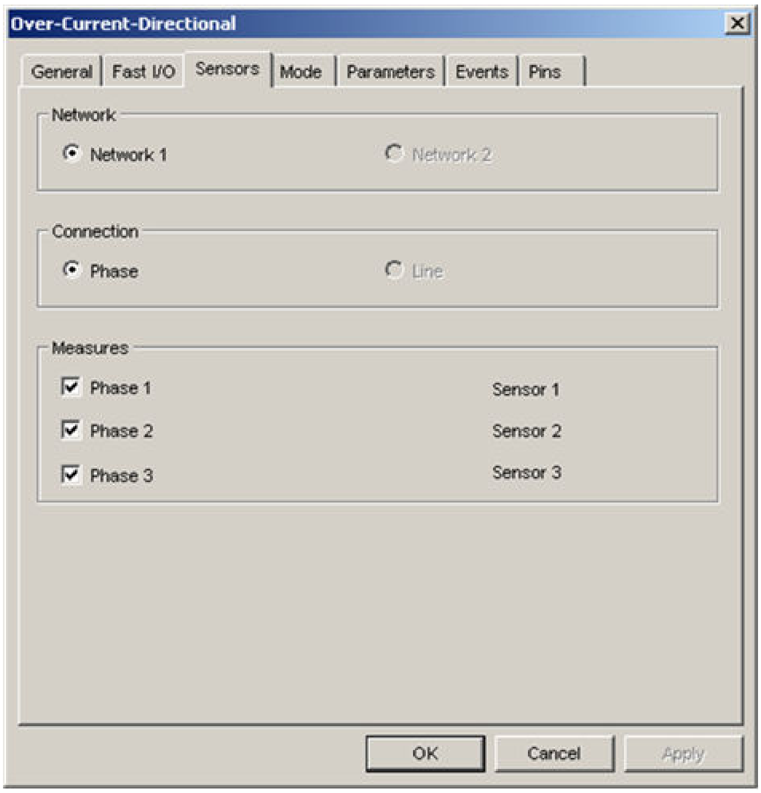


Figure 59: Sensors

The protection function operates on any combination of current phases in a triple, for example, it can operate as single-phase, double-phase or three-phase protection on the phase currents belonging to the same network. The faulty phase current is combined with the voltage of the corresponding sound phases. The required voltage measure is automatically selected and displayed in the General dialog box.

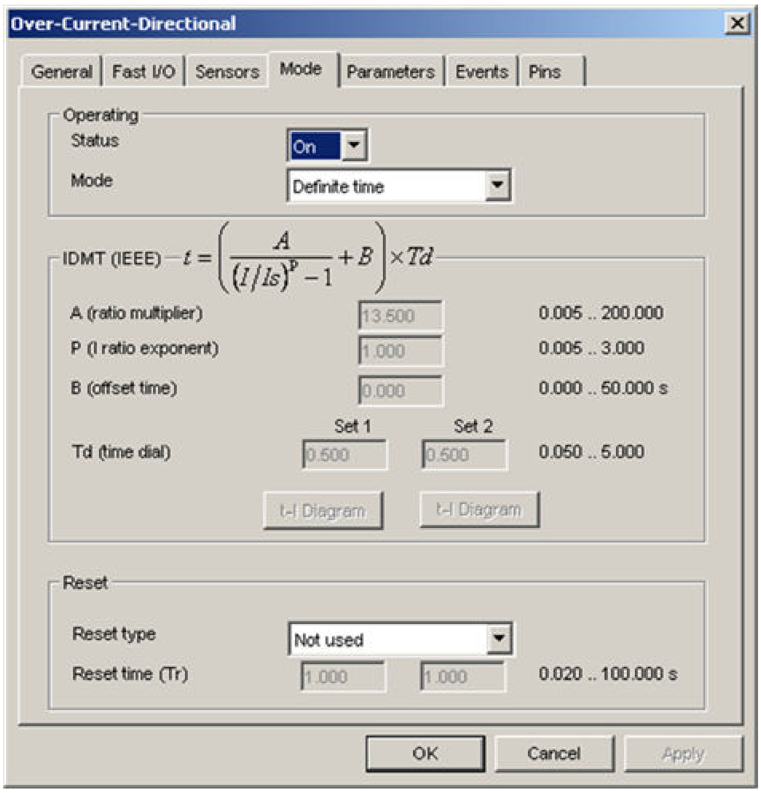


Figure 60: Mode

Status	Mode of the operating status on or off
Mode	Mode for the directional overcurrent, definite or inverse time
IDMT (IEEE)	Free programmable inverse-time curve according to equation
A, *P*, *B*, *Td*	Parameter for the free programmable inverse-time curve
t-I Diagram	Diagram of the inverse time operation characteristic
Reset type	Mode of the reset time
Reset time	Timer resets after the start current condition not valid any more

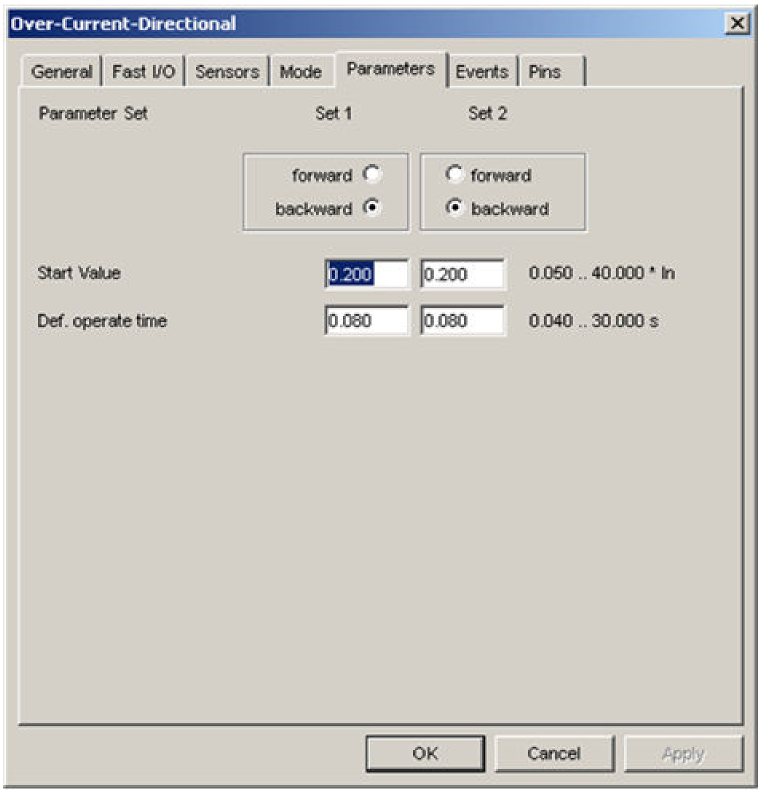


Figure 61: Parameter

Direction	Directional criteria to be accessed together to overcurrent condition for the start detection
"Start Value"	Current threshold for start
Def. operate time	Operation time in mode definite time

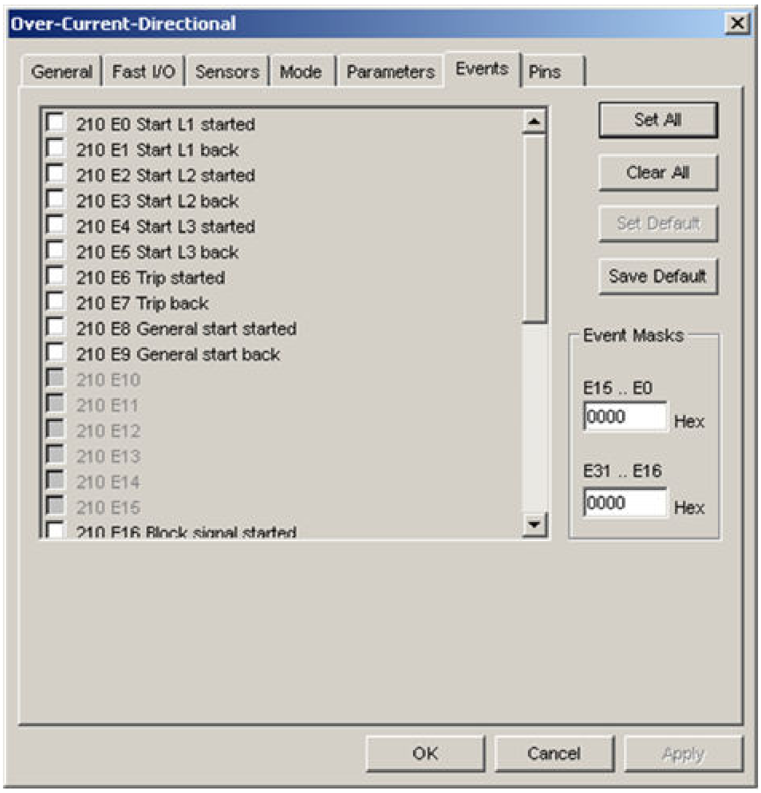


Figure 62: Events

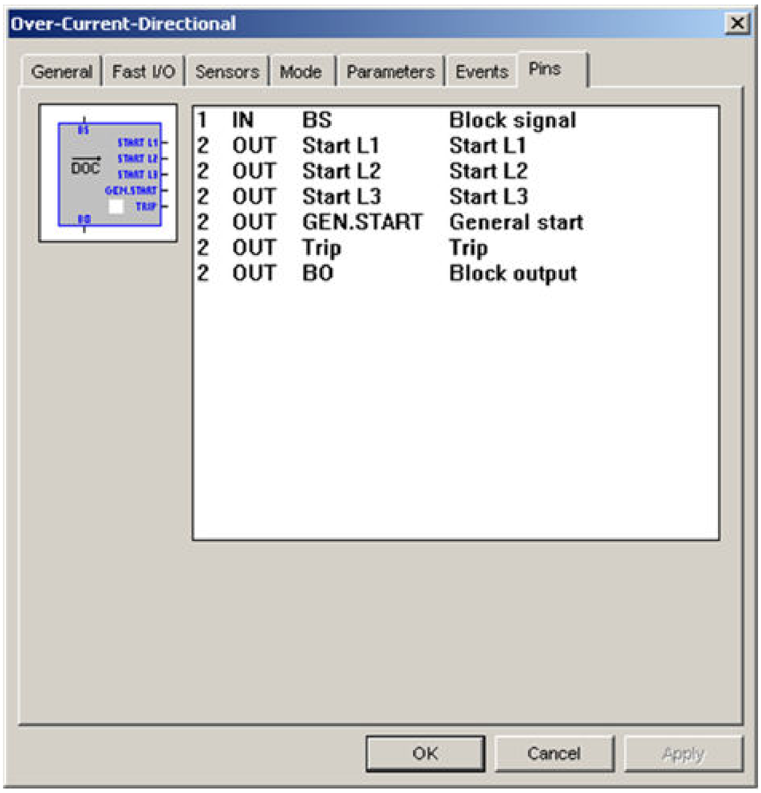


Figure 63: Pins

5.1.4.3 Measurement mode

All overcurrent directional protection functions evaluate the current RMS value at the fundamental frequency.

5.1.4.4 Operation criteria

If the measured current exceeds the setting threshold value (*Start Value*), the overcurrent directional protection function is started, if at least the value of one phase current is above the setting threshold value. At the same time the general start signal is activated.

If the general start condition exists and the fault is in a specified direction (“backward”/”forward”), the timer for the operation time is started. The start signal is phase selective. In case of fault in the opposite direction to the specified one, the Block Output signal becomes active. The protection function remains in START status if there is at least one phase started. It comes back in passive status and the start signal is cleared if for all the phases the current falls below 0.95 the setting threshold value (or the fault current changes direction).

When the protection has entered the start status and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated. The protection function exits the TRIP status and the trip signal is cleared when the measured current value falls below 0.4 the setting threshold value.

To determine the fault direction, REF 542plus must be connected to the three-phase voltages. The protection function has a voltage memory, which allows a directional decision to be produced even if a fault occurs in the close-up area of the voltage transformer/sensor (when the voltage falls below 0.1 Un).

The inverse time tripping characteristic is defined according to an equation.

$$t = \left(\frac{A}{M^{P} - 1} + B \right) td$$

(Equation 10)

t Operation time to trip

A Curve parameter for the time value (according to IEC 60255-3)

P Value for the exponent

M Ratio of actual current to the pickup current I/In

B Additional offset time

td Time dial to adapt the operation time

The inverse time characteristic (IDMT) is applied after the condition M > 1 is valid. The operation range is, as defined in the IEC 60255-3 standard, from 1.2 to 20 In.

Each time the protection function is started due to a system fault condition (M>1.2) the IDMT operating counter is incremented according to the equation (1). When it reaches the operation time to trip, the function will operate activating the trip output signal.

If required, a reset type with Inverse time characteristic can be set according to an equation.

$$t = \left(\frac{tr}{M^{P} - 1} \right) td$$

(Equation 11)

t Operation time to reset

tr Reset time

M Ratio of actual current to the pickup current I/In

td Time dial to adapt the reset time

The reset type inverse time characteristic is valid for $0 < M < 1$. In this case the inverse time overcurrent protection enters the reset state and decrements the operating counter according to above equation. If the condition is $1 \leq M < 1.2$, the counter remains unchanged.

Instead of inverse time reset type a definite time can also be selected. The purpose of the definite reset time is to enable fast clearance of intermittent faults, for example self-sealing insulation faults, and severe faults, which may produce high asymmetrical fault currents that partially saturate the current transformers. It is typical for an intermittent fault that the fault current contains so called drop-off periods during which the fault current falls below the set start current including hysteresis. Without the reset time function, the operating counter would be stopped, when the current has dropped off. In the same way, an apparent drop-off period of the secondary current of the saturated current transformer might also reset the operating counter.

The reset type inverse time can only be applied in conjunction with inverse time overcurrent protection. For definite time overcurrent protection only reset type definite time may be used.

5.1.4.5 Current direction

Detection of the current direction is obtained by calculating the reactive power, which is computed combining the faulty phase current with the voltage of the corresponding sound phases. The reactive power calculation uses voltage and current measurements at the fundamental frequency. Before the calculations, the voltages are shifted to a lagging angle of 45°.

$$Q = \left(I_{L1} \times U_{23} \times \sin\varphi_1\right) + \left(I_{L2} \times U_{31} \times \sin\varphi_2\right)\left(I_{L3} \times U_{12} \times \sin\varphi_3\right)$$

(Equation 12)

Q	Reactive power
$IL_{1,2,3}$	Current of phase 1, 2 and 3
$U_{12,23,31}$	Line voltages between phases 1-2, 2-3 and 3-1 after shifting -45°
$\varphi_{1,2,3}$	Angles between the currents and the corresponding voltages

Only the phases in which the current exceeds preset threshold are used in the calculation. If the result of the calculation leads to a negative reactive power, which is greater than 5% of the nominal apparent power, the fault is in forward direction. Otherwise, the fault is in backward direction.

A directional signal can be sent to the opposite station using the output (TRIP) and/or the Block Output (BO) signal. The content of a directional signal from the opposite station (BO output) can be used to release tripping of its own directional protective function. This enables a directional comparison protection to be established.

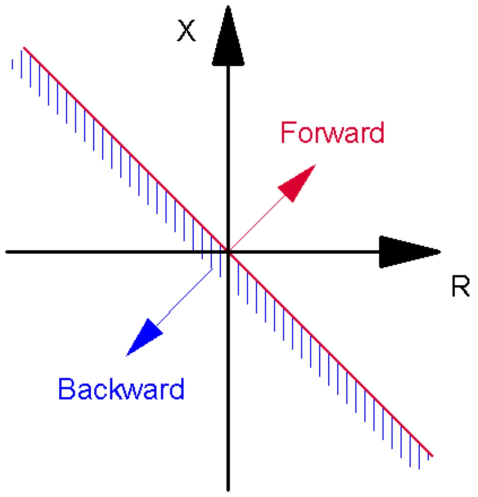


Figure 64: Forward and backward direction in the impedance plane in case of a balanced three-phase fault

Because the application of the fault current is in combination with the sound voltages, the directional decision area can change. This change depends on the power system parameters in case of nonsymmetrical fault condition. The criteria for forward and backward direction are derived from the calculated reactive power.

5.1.4.6 Voltage memory

The directional overcurrent protection function includes a voltage memory feature. This allows a directional decision to be produced even if a fault occurs in the close-up area of the voltage transformer/sensor. At a sudden loss of voltage, a fictive voltage is used for direction detection. The fictive voltage is the voltage measured before the fault has occurred, assuming that the voltage is not affected by the fault. The memory function enables the function block to operate up to 300 seconds after a total loss of voltage.

When the voltage falls below 0.1 x Un, the fictive voltage is used. The actual voltage is applied again as soon as the voltage rises above 0.1 x Un for at least 100 ms. The fictive voltage is also discarded if the measured voltage stays below 0.1 x Un for more than 300 seconds.

5.1.4.7 Setting groups

Two parameter sets can be configured for the directional overcurrent protection function. Switchover between the parameter sets can be performed in dependency of the network configuration. If this is not required, set 1 and set 2 can be parameterized identically to avoid wrong setting if switchover of parameters has happened accidentally.

5.1.4.8 Parameters and events

Table 25: Parameters

Parameter	Values	Unit	Default	Explanation
Status	On/Off		On	Operating status
Mode	Definite time/ IDMT		Definite time	Operation characteristic
A (ratio multiplier)	0.005...200.000		13.500	Parameter for operation characteristic
P (ratio exponent)	0.005...3.000		1.000	Parameter for operation characteristic
B (offset time)	0.000...50.000	s	0.000	Parameter for operation characteristic
Td (time dial)	0.050...5.000	s	0.5000	Parameter for operation characteristic
Reset type	Not used/Definite time/Inverse time		Not used	Reset Characteristic
Reset time (Tr)	0.020...100.000	s	1.000	Parameter for reset characteristic
Direction	Forward/ backward		backward	Setting for fault direction
Start Value	0.050...40.000	In	0.5000	Current threshold for start condition
Def. operate time	0.015...300.000	s	0.080	Time delay for trip condition

Table 26: Events

Code	Event reason
E0	Protection start on phase L1 (fault in set direction)
E1	Start on phase L1 cancelled
E2	Protection start on phase L2 (fault in set direction)
E3	Start on phase L2 cancelled
E4	Protection start on phase L3 (fault in set direction)
E5	Start on phase L3 cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E8	Protection general start (logical OR combination of starts)
E9	General start is cancelled (after expiration of reset time)
E16	Block signal is active
E17	Block signal is back to inactive status
E18	Protection block signal is active
E19	Protection block signal is back to inactive status
E20	Protection operation[1)] on phase L1
E21	Operation on phase L1 cancelled
E22	Protection operation on phase L2
Table continues on next page	

Code	Event reason
E23	Operation on phase L2 cancelled
E24	Protection operation on phase L3
E25	Operation on phase L3 cancelled
E26	Protection general operation (logical OR combination of all faults)
E27	General operation cancelled (after expiration of reset time)
E28	Operation on fault direction forward
E29	Operation on fault direction backward
E30	Operation on fault direction unknown

1) Start of protection on faults independent of the direction

By default all events are disabled.

5.1.5 Overcurrent protection (single stage)

REF 542plus provides three overcurrent definite time protection functions, see the following figures. Each of them can be independently activated.

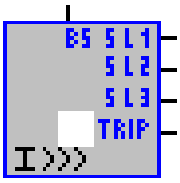


Figure 65: Overcurrent definite time instantaneous (I>>>)

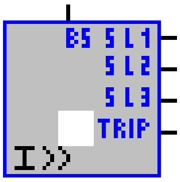


Figure 66: Overcurrent definite time high set (I>>)

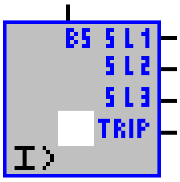


Figure 67: Overcurrent definite time low set (I>)

5.1.5.1 Input/output description

Table 27: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until BS signal goes low.

Table 28: Outputs

Name	Type	Description
S L1	Digital signal (active high)	Start signal of IL1
S L2	Digital signal (active high)	Start signal of IL2
S L3	Digital signal (active high)	Start signal of IL3
TRIP	Digital signal (active high)	Trip signal

S L1, S L2 and S L3 are the phase selective start signals. The phase starting signal will be activated when the respective phase current start conditions are true.

The TRIP signal will be activated when at least for a phase current the start conditions are true and the operating time has elapsed.

5.1.5.2 Configuration

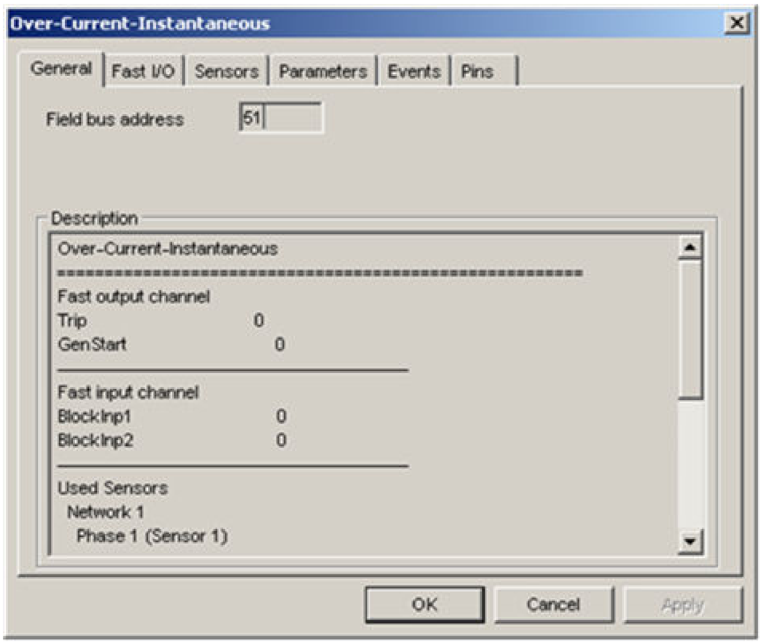


Figure 68: General

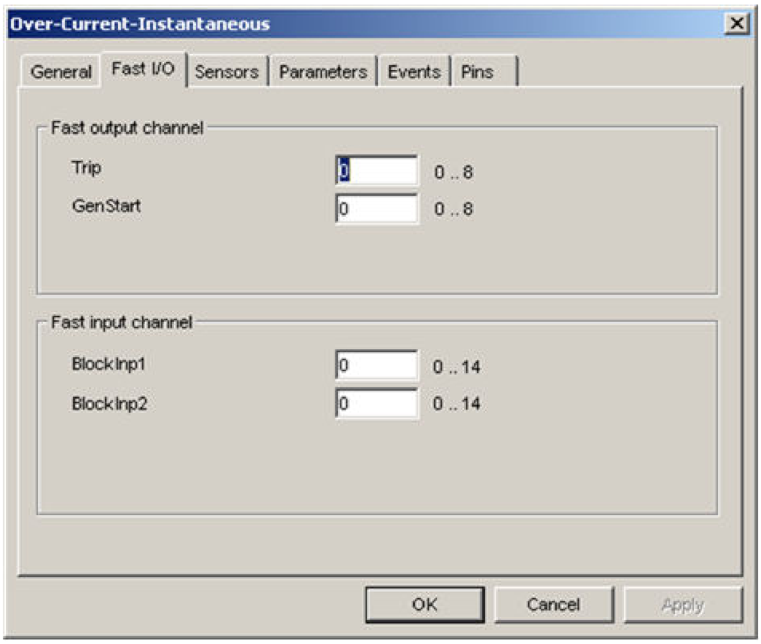


Figure 69: Fast I/O

Output Channel different from 0 means a direct execution of the trip or general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping FUPLA cyclic evaluation.

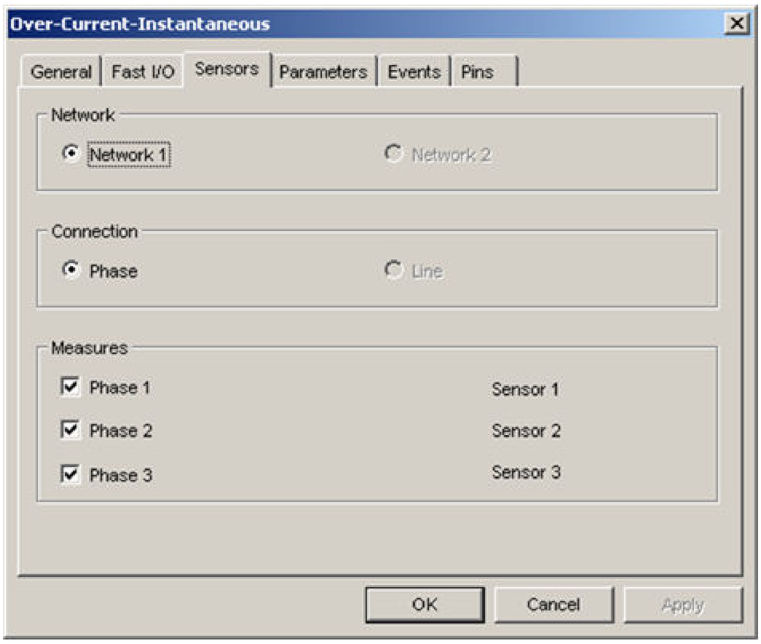


Figure 70: Sensors

The protection functions operate on any combination of phase currents in a triple, for example, it can operate as single phase, double phase or three-phase protection on the phase currents belonging to the same system.

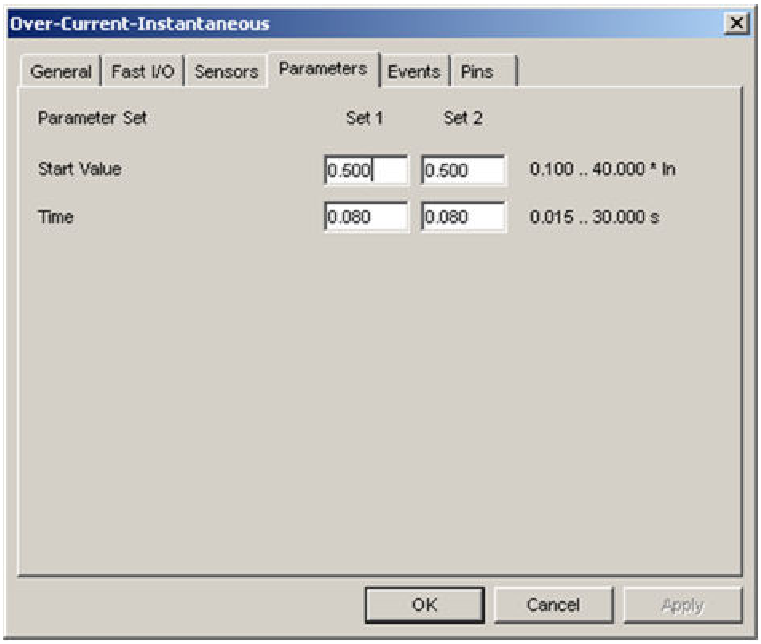


Figure 71: Parameters

Start Value	Current threshold for overcurrent condition detection
Time	Time delay for overcurrent Trip condition detection

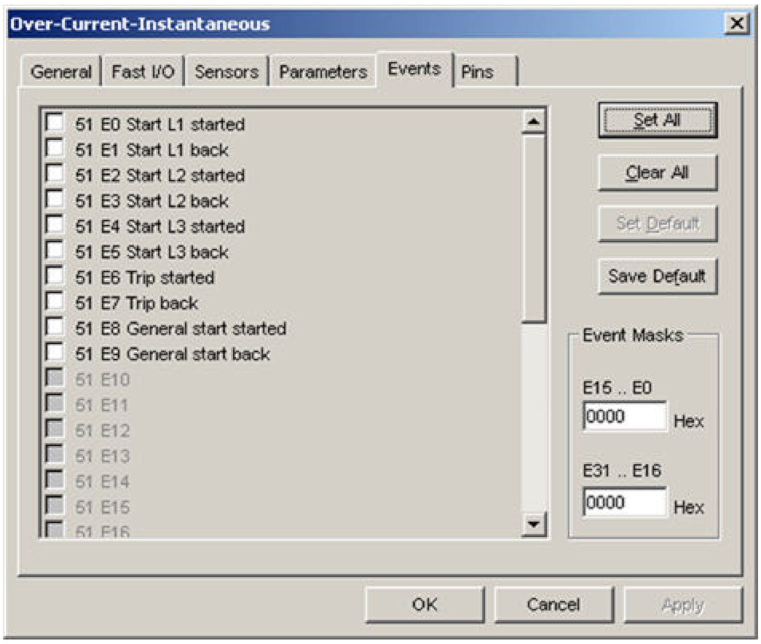


Figure 72: Events

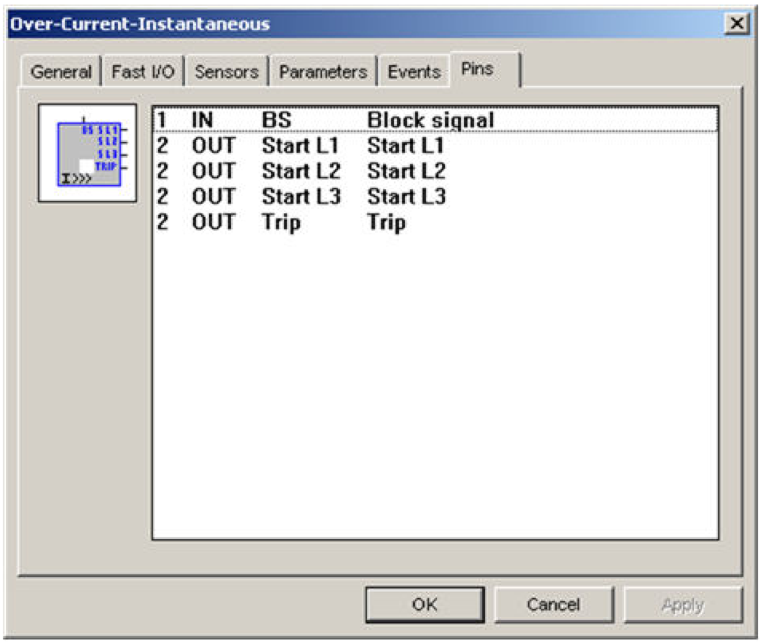


Figure 73: Pins

5.1.5.3 Measurement mode

All overcurrent definite time functions evaluate the current RMS value at the fundamental frequency. In case of the overcurrent definite time instantaneous, the peak value of the measured current is also used under transient condition for a faster response. When the instantaneous peak value is higher than three times SQRT (2) the RMS value:

$$I_{x\_peak} / \sqrt{2} > 3 \cdot I_{x\_RMS}$$

(Equation 13)

5.1.5.4 Operation criteria

If the measured current exceeds the setting threshold value (Start Value), the overcurrent protection function is started. The start signal is phase selective, that is, when at least the value of one phase current is above the setting threshold value the relevant start signal will be activated.

The protection function will remain in START status until there is at least one phase started. It will come back in passive status and the start signal will be cleared, if for all the phases the current falls below 0.95 the setting threshold value. After the protection has entered the start status and the preset operating time (Time) has elapsed, function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured current value falls below 0.4 the setting threshold value.

All overcurrent definite time functions can be used in parallel to generate a current time-step characteristic, as shown in the following figure.

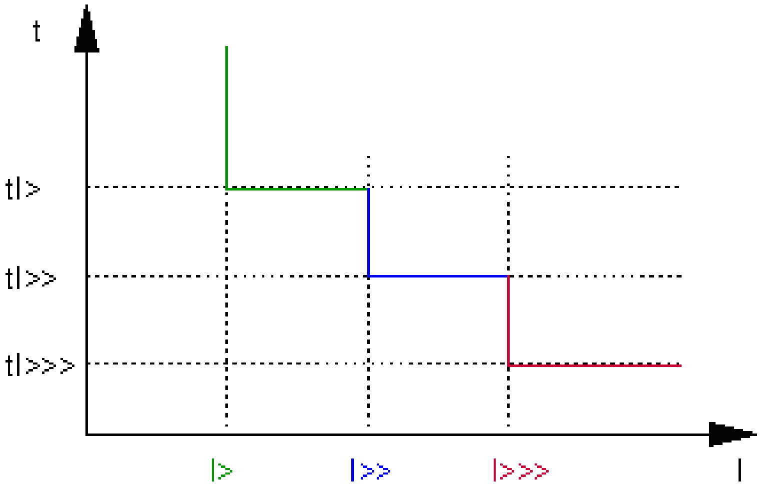


Figure 74: Current time-step characteristic

5.1.5.5 Setting groups

Two parameter sets can be configured for each of the overcurrent definite time protection functions.

5.1.5.6 Parameters and events

Table 29: Setting values

Parameter	Values	Unit	Default	Explanation
Start Value I>, I>>	0.05...40.00	In	0.50	Current threshold for overcurrent condition detection.
Time	20...300000	ms	80	Time delay for overcurrent Trip condition.
Start Value I>>>	0.1...40.00	In	0.50	Current threshold for overcurrent condition detection.
Time	15...30000	ms	80	Time delay for overcurrent Trip condition.

Table 30: Events

Code	Event reason
E0	Protection start on phase L1
E1	Start on phase L1 cancelled
E2	Protection start on phase L2
E3	Start on phase L2 cancelled

Table continues on next page

Code	Event reason
E4	Protection start on phase L3
E5	Start on phase L3 cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E18	Protection block signal is active
E19	Protection block signal is back to inactive state

By default all events are disabled.

5.1.6 Directional overcurrent protection (single stage)

REF 542plus has two directional definite time functions, each of which can be independently activated:

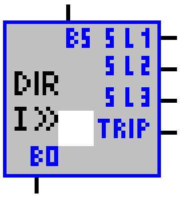


Figure 75: Overcurrent directional high set (I>>>)

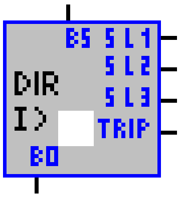


Figure 76: Overcurrent directional low set (I>>)

5.1.6.1 Input/output description

Table 31: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the *BS* signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the *BS* signal goes low.

Table 32: Outputs

Name	Type	Description
S L1	Digital signal (active high)	Start signal of IL1
S L2	Digital signal (active high)	Start signal of IL2
S L3	Digital signal (active high)	Start signal of IL3
TRIP	Digital signal (active high)	Trip signal
BO	Digital signal (active high)	Block output signal

S L1, S L2 and S L3 are the start signals phase selective. The phase starting signal will be activated when respective phase current start conditions are true (current exceeds the setting threshold value and the fault is in the specified direction).

The TRIP signal will be activated when at least for a phase current the start conditions are true and the operating time has elapsed.

The Block Output (BO) signal becomes active when the protection function detects a current exceeding the preset value and the fault direction opposite to the specified direction.

5.1.6.2 Configuration

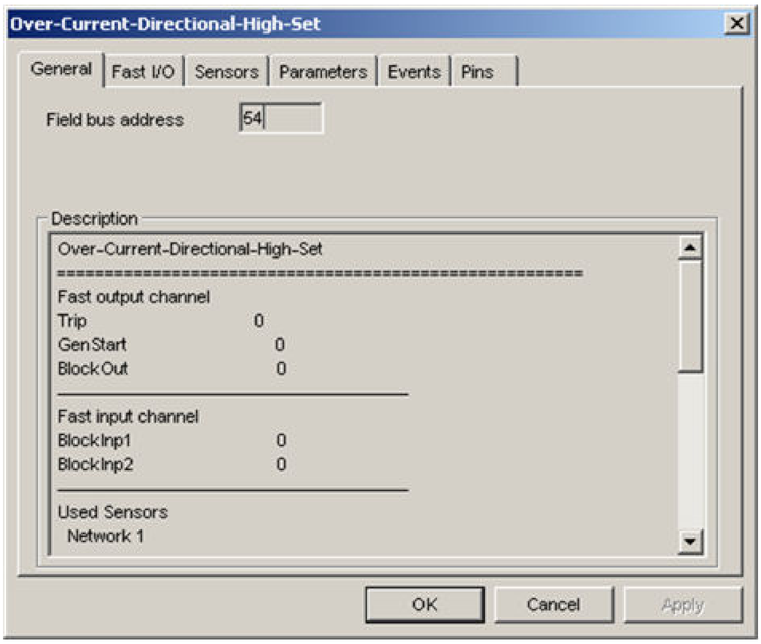


Figure 77: General

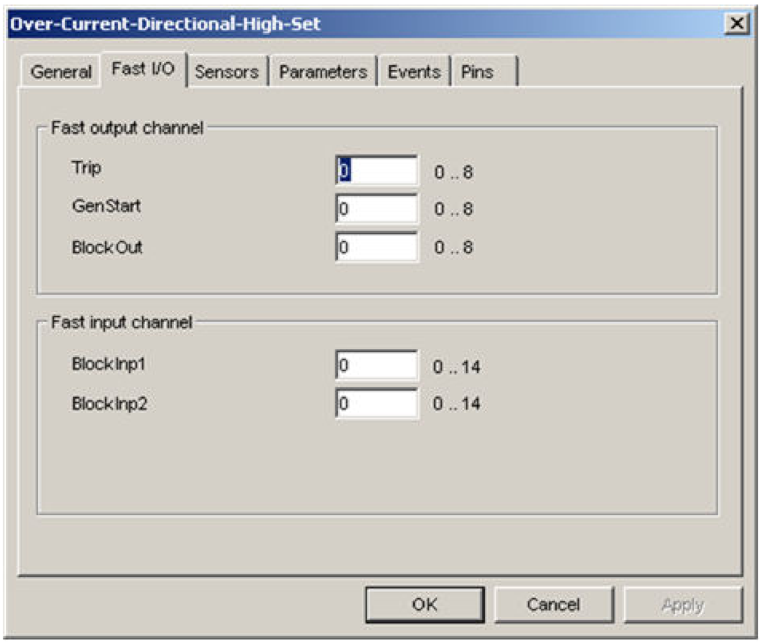


Figure 78: Fast I/O

Output Channel different from 0 means a direct execution of the trip, general start or block-out command, that is, skipping the FUPLA cyclic evaluation.

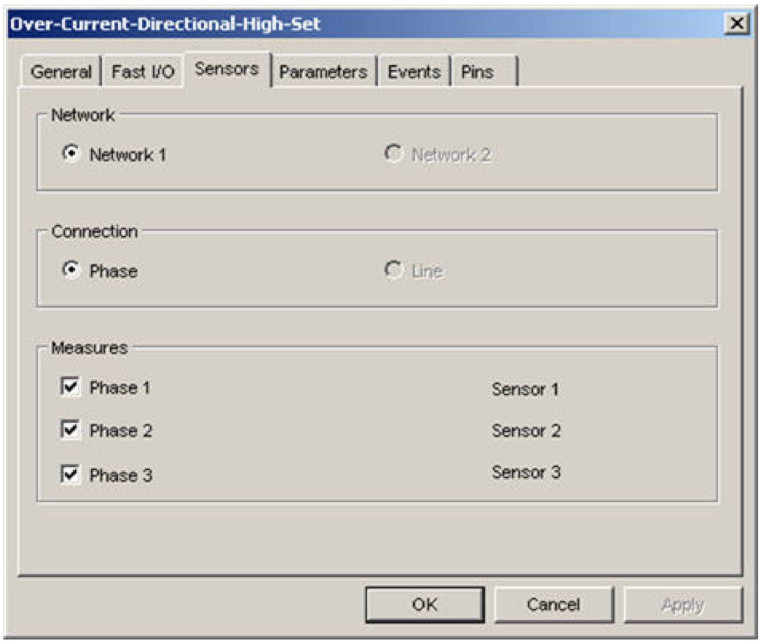


Figure 79: Sensors

The protection function operates on any combination of current phases in a triple, for example, it can operate as single phase, double phase or three-phase protection on the phase currents belonging to the same system.

The faulty phase current is combined with the voltage of the corresponding sound phases. The required voltage measure is automatically selected and displayed in the General tab.

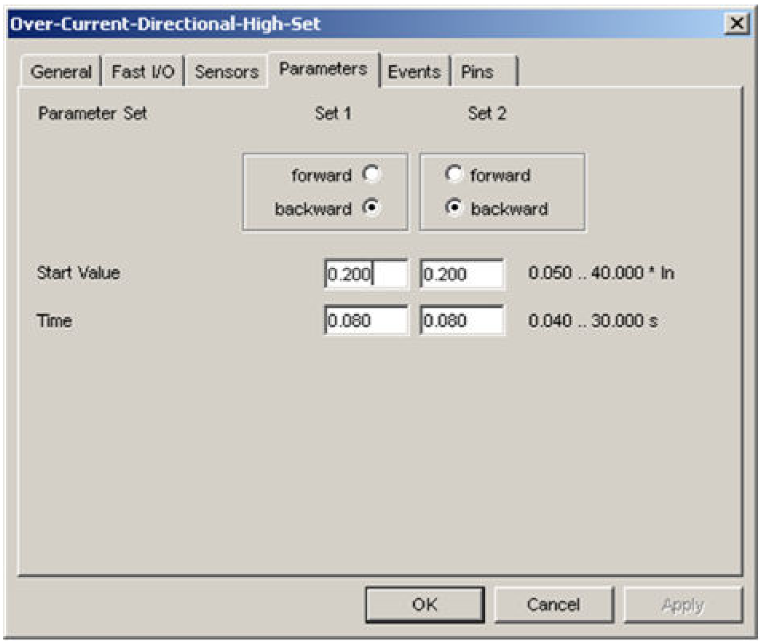


Figure 80: Parameters

Direction	Directional criteria to be assessed together to overcurrent condition for the START detection
Start Value	Current threshold for overcurrent condition detection
Time	Time delay for overcurrent trip condition detection

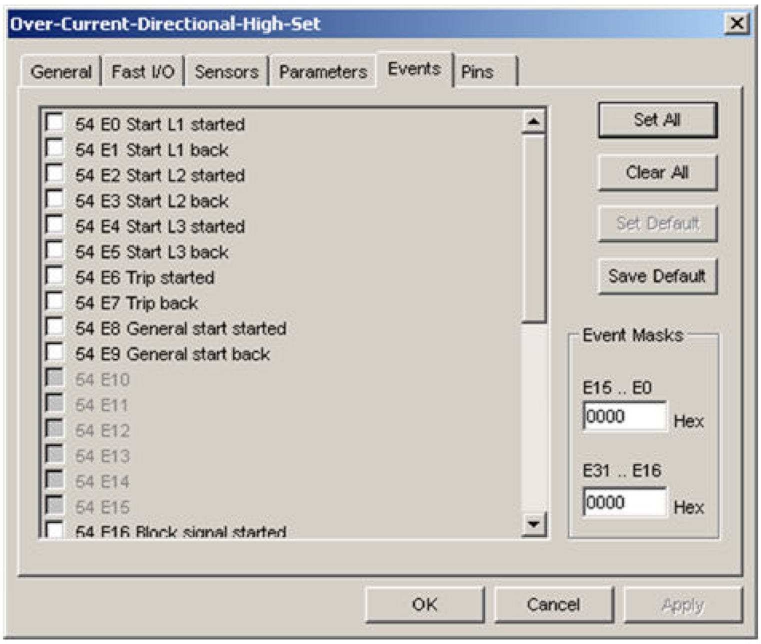


Figure 81: Events

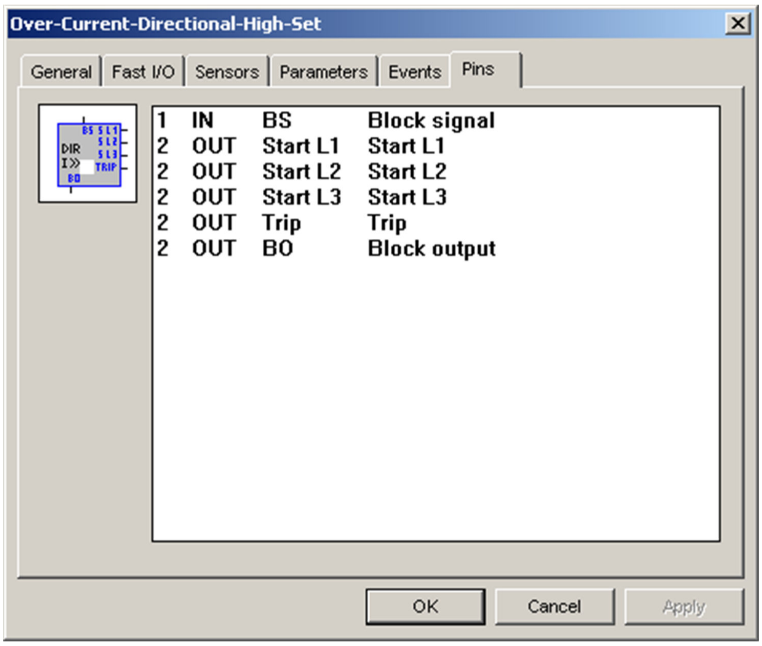


Figure 82: Pins

5.1.6.3 Measurement mode

The directional overcurrent protection function evaluates the current and voltage at the fundamental frequency.

5.1.6.4 Operation criteria

If the measured current exceeds the setting threshold value (*Start Value*), and the fault is in the specified direction ("backward"/"forward"), the protection function is started. The start signal is phase selective. It means that when at least for one phase current the above conditions are true, the relevant start signal will be activated.

If the preset threshold value (*Start Value*) is exceeded and the fault is in the opposite direction to the specified one, the Block Output signal becomes active. The protection function will remain in START status until there is at least one phase started. It will come back in passive status and the start signal will be cleared if for all the phases the current falls below 0.95 the setting threshold value (or the fault current changes direction).

When the protection has entered the start status and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured current value falls below 0.4 the setting threshold value.

To determine the fault direction REF 542plus must be connected to the three-phase voltages. The protection function has a voltage memory, which allows a directional decision to be produced even if a fault occurs in the close up area of the voltage transformer/sensor (when the voltage falls below 0.1 x Un).

5.1.6.5 Current direction

Detection of the current direction is obtained by calculating the reactive power, which is computed combining the faulty phase current with the voltage of the corresponding sound phases. The reactive power calculation uses voltage and current measurements at the fundamental frequency. Before the calculations, the voltages are shifted to a lagging angle of 45°.

The reactive power is calculated:

$$\mathrm{Q} = (I_{\mathrm{L1}} \times U_{23} \times \sin\varphi_1) + (I_{\mathrm{L2}} \times U_{31} \times \sin\varphi_2) + (I_{\mathrm{L3}} \times U_{12} \times \sin\varphi_3)$$

(Equation 14)

Q	Reactive power
$I_{L1,2,3}$	Current of phase 1, 2 and 3
$U_{12,23,31}$	Line voltages between phases 1-2, 2-3 and 3-1 after shifting -45°
$\varphi_{1,2,3}$	Angles between the currents and the corresponding voltages

Only the phases whose current exceeds preset threshold are used in the calculation.

If the result of the calculation leads to a negative reactive power, which is greater than 5% of the nominal apparent power, the fault is in forward direction. Otherwise, the fault is in backward direction.

A directional signal can be sent to the opposite station using the output (trip) and/or the Block Output (BO) signal. The content of a directional signal from the opposite station (BO output) can be used to release tripping of its own directional protective function. This enables a directional comparison protection to be established.

Figure 5.1.6.5 shows the forward and backward direction in the impedance plane in case of a balanced three-phase fault.

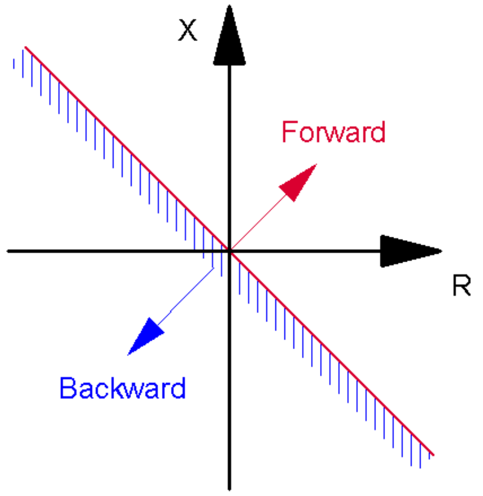


Figure 83: Diagram of the directional overcurrent protection in case of balanced three-phase faults

Because the application of the fault-current is in combination with the sound voltages, the directional decision area can change. This change depends on the power system parameters in case of nonsymmetrical fault condition. The criteria for forward and backward direction is derived from the calculated reactive power.

5.1.6.6 Voltage memory

The directional overcurrent protection function includes a voltage memory feature. This allows a directional decision to be produced even if a fault occurs in the close up area of the voltage transformer/sensor.

At a sudden loss of voltage, a fictive voltage is used for direction detection. The fictive voltage is the voltage measured before the fault has occurred, assuming that the voltage is not affected by the fault. The memory function enables the function block to operate up to 300 seconds after a total loss of voltage.

When the voltage falls below 0.1 x Un, the fictive voltage is used. The actual voltage is applied again as soon as the voltage rises above 0.1 x Un for at least 100 ms. The fictive voltage is also discarded if the measured voltage stays below 0.1 x Un for more than 300 seconds.

5.1.6.7 Setting groups

Two parameter sets can be configured for each of the overcurrent directional definite time protection functions.

5.1.6.8 Parameters and events

Table 33: Setting values

Parameter	Values	Unit	Default	Explanation
Start Value	0.05...40	In	0.2	Current threshold for fault detection
Time	40...30000	ms	80	Operating Time between start and trip
Direction	forward/ backward	-	backward	Direction criteria

Table 34: Events

Code	Event reason
E0	Protection start on phase L1
E1	Start on phase L1 cancelled
E2	Protection start on phase L2
E3	Start on phase L2 cancelled
E4	Protection start on phase L3
E5	Start on phase L3 cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E16	Block signal is active
E17	Block signal is back
E18	Protection block started
E19	Protection block back

By default all events are disabled.

5.1.7 Overcurrent IDMT (single stage)

REF 542plus makes available an IDMT function in which one at the time of the four current-time characteristics can be activated:

- Normal inverse
- Very inverse
- Extremely inverse
- Long-term inverse

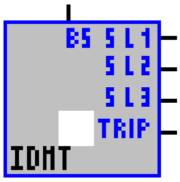


Figure 84: Overcurrent IDMT

5.1.7.1 Input/output description

Table 35: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 36: Output

Name	Type	Description
S L1	Digital signal (active high)	Start signal of IL1
S L2	Digital signal (active high)	Start signal of IL2
S L3	Digital signal (active high)	Start signal of IL3
TRIP	Digital signal (active high)	Trip signal

S L1, S L2 and S L3 are the phase selective start signals. The phase starting signal will be activated when the respective phase current start conditions are true, that is, the phase current value is above 1.2 times the setting threshold value.

The TRIP signal will be activated when at least for a phase current the start conditions are true and the calculated operating time has elapsed.

5.1.7.2 Configuration

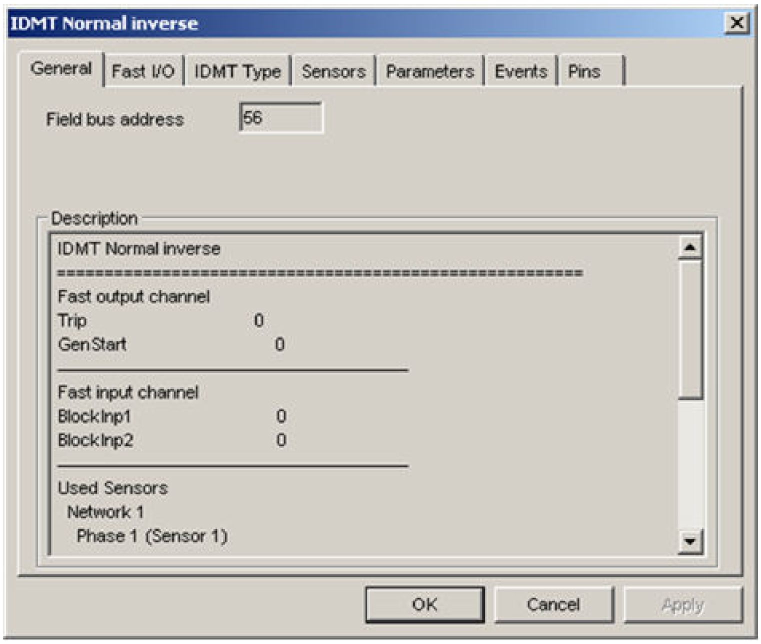


Figure 85: General

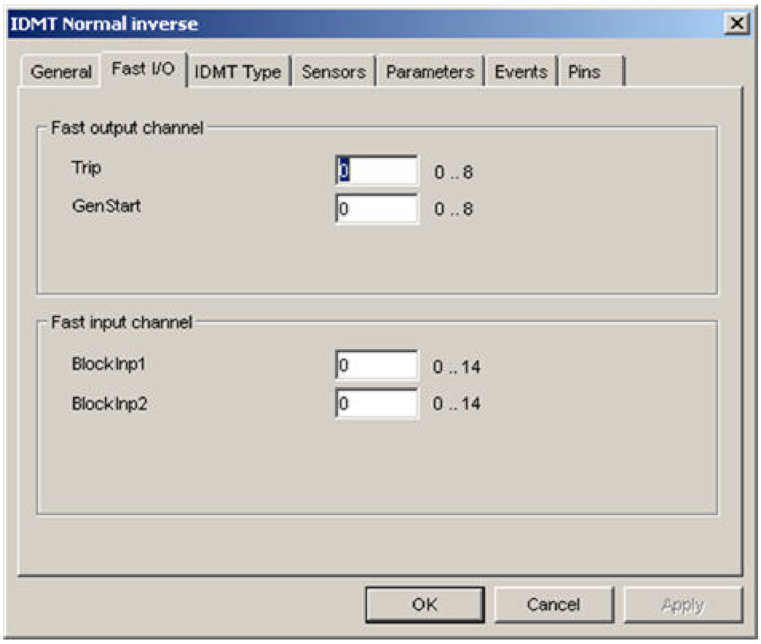


Figure 86: Fast I/O

Output Channel different from 0 means a direct execution of the trip or general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

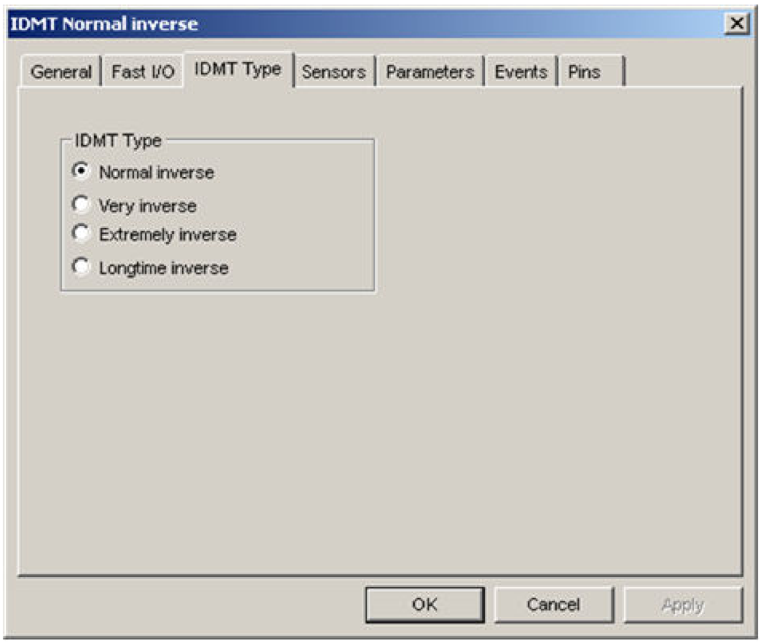


Figure 87: IDMT type

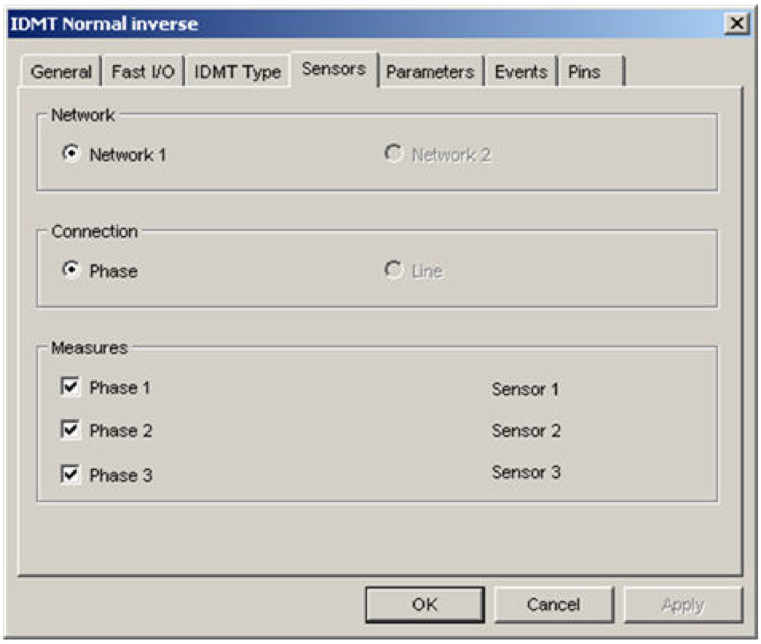


Figure 88: Sensors

The protection functions operate on any combination of phase currents in a triple, for example, it can operate as single phase, double phase or three-phase protection on phase currents belonging to the same system.

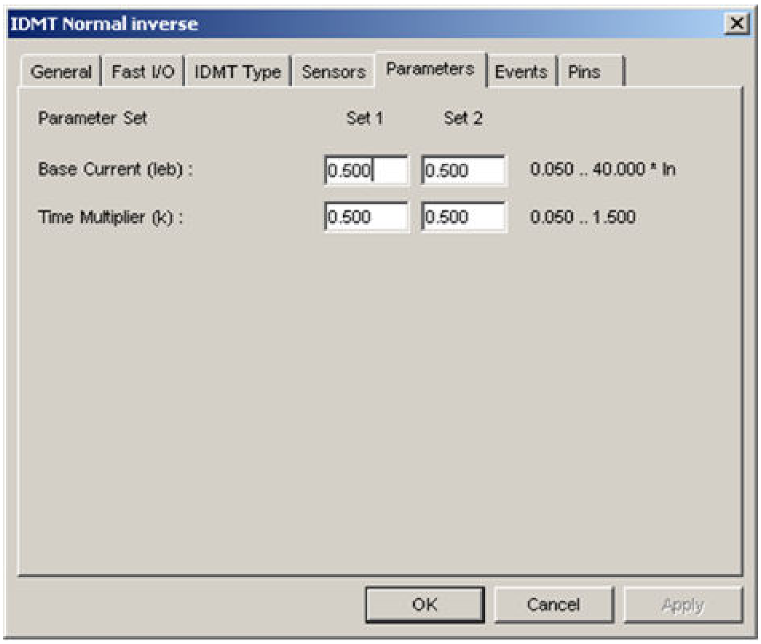


Figure 89: *Parameters*

Base current (Ieb)	Current threshold for overcurrent condition detection
Time multiplier (k)	Parameter to vary time delay for Trip condition

The trip time is calculated according to the British Standard (BS 142) when the time multiplier k is used; when the time multiplier k is set to one (k=1) the IDMT curve is in accordance to the IEC 60255-3.

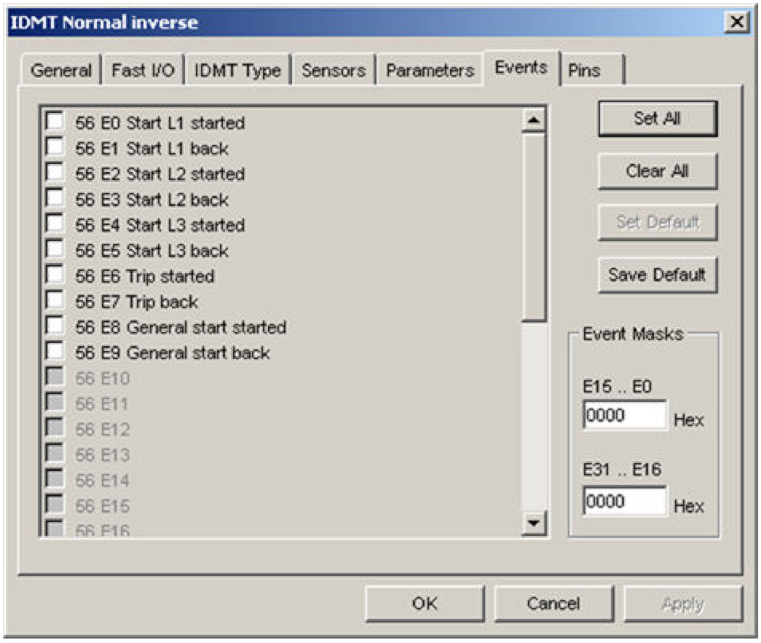


Figure 90: Events

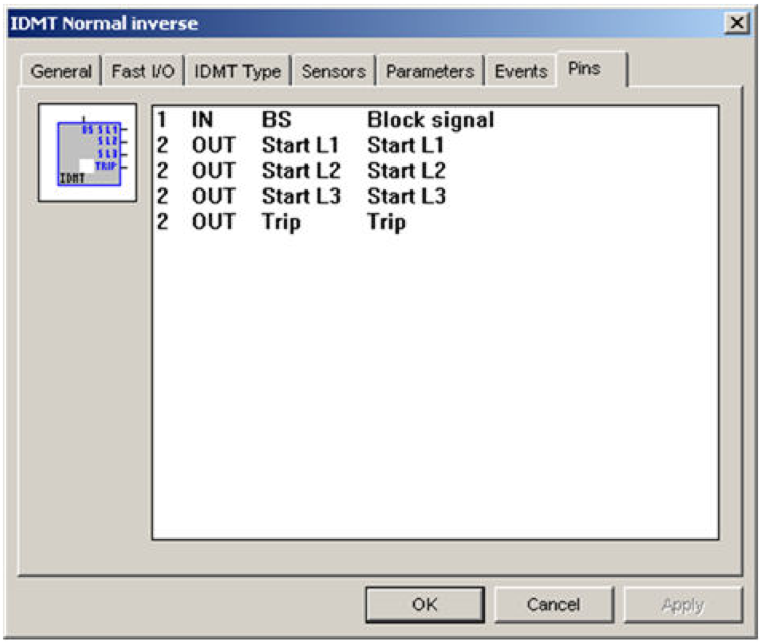


Figure 91: Pins

5.1.7.3 Measurement mode

IDMT protection function evaluates the RMS value of phase currents at the fundamental frequency.

5.1.7.4 Operation criteria

If the measured current exceeds the setting threshold value (*Base current Ieb*) by a factor 1.2 the protection function is started. The start signal is phase selective, that is, when at least one phase current is above 1.2 times the setting threshold value, the relevant start signal will be activated.

The protection function will remain in START status until there is at least one phase started. It will come back in passive status and the start signal will be cleared, if for all the phases the current falls below 1.15 the setting threshold value. When the protection enters the start status the operating time is continuously recalculated according to the set parameters and measured current value. If the calculated operating time is exceeded, the function goes in TRIP status and the trip signal becomes active.

The operating time depends on the measured current and the selected current-time characteristic. The protection function will exit the TRIP status and the trip signal will be cleared when the measured current value falls below 0.4 the setting threshold value.

5.1.7.5 Setting groups

Two parameter sets can be configured for the IDMT protection function.

5.1.7.6 Parameters and events

Table 37: Setting values

Parameter	Values	Unit	Default	Explanation
Type	NI/VI/EI/LTI	-	NI	Tripping characteristic according to the IEC 60255-3; curve definition
Base current (Ieb)	0.05...40	In	0.5	Fault current factor threshold for start condition detection
Time multiplier (k)	0.05...1.50	-	0.50	Time multiplier to vary time delay for Trip condition according to BS 142

Table 38: Events

Code	Event reason
E0	Protection start on phase L1.
E1	Start on phase L1 cancelled.
E2	Protection start on phase L2.
E3	Start on phase L2 cancelled.
E4	Protection start on phase L3.
E5	Start on phase L3 cancelled.
E6	Trip signal is active.
E7	Trip signal is back to inactive state.
E18	Protection block signal is active.
E19	Protection block signal is back to inactive state.

By default all events are disabled.

5.1.8 Non-directional earth fault protection

In the non-directional earth fault protection can up to eight instances be applied.

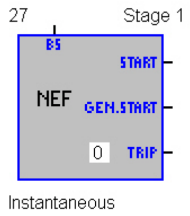


Figure 92: Non-directional earth fault protection

5.1.8.1 Input/output description

Table 39: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function remains in idle state until the BS signal goes low.

Name	Type	Description
START	Digital signal (active high)	Start signal
GEN.START	Digital signal (active high)	General start signal (including reset time)
TRIP	Digital signal (active high)	Trip signal

START signal is activated when earth fault protection start condition is true. The GEN.START includes the expiration of the reset time. The TRIP signal is activated when the start condition is true and the operating time has elapsed.

5.1.8.2 Configuration

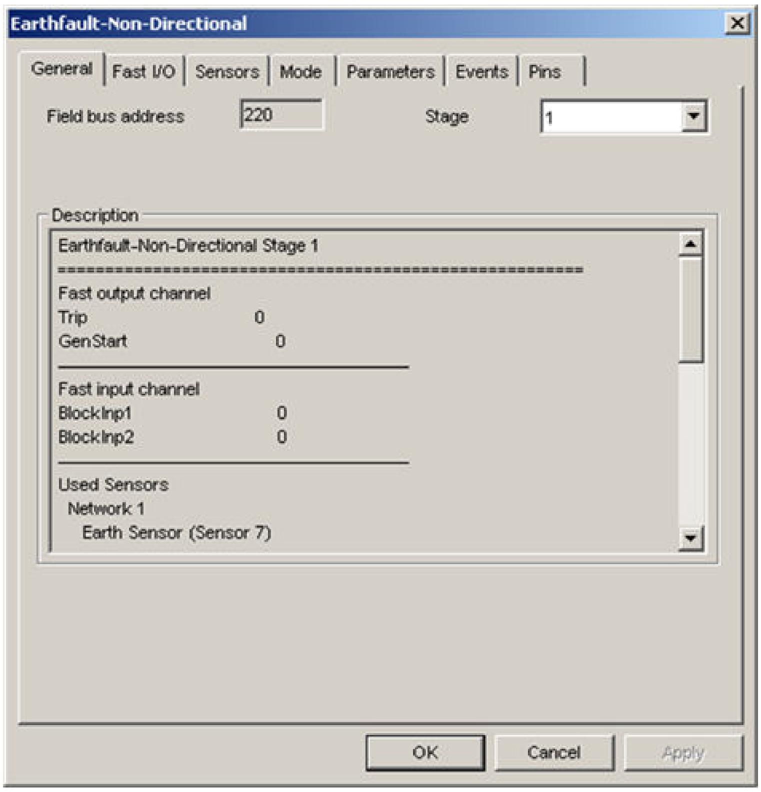


Figure 93: General

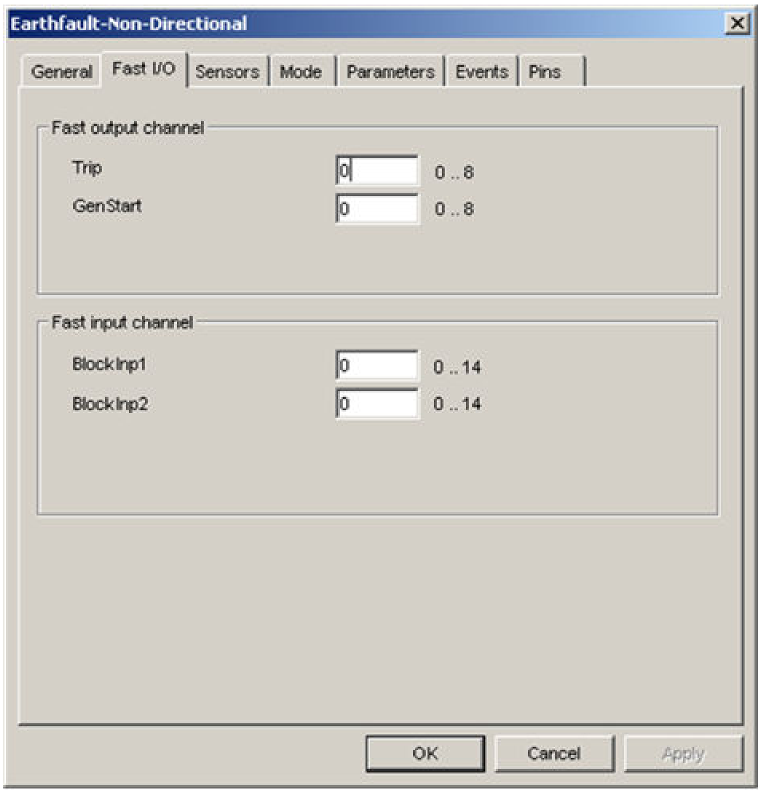


Figure 94: Fast I/O

Output Channel different from 0 means a direct execution of the trip or general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

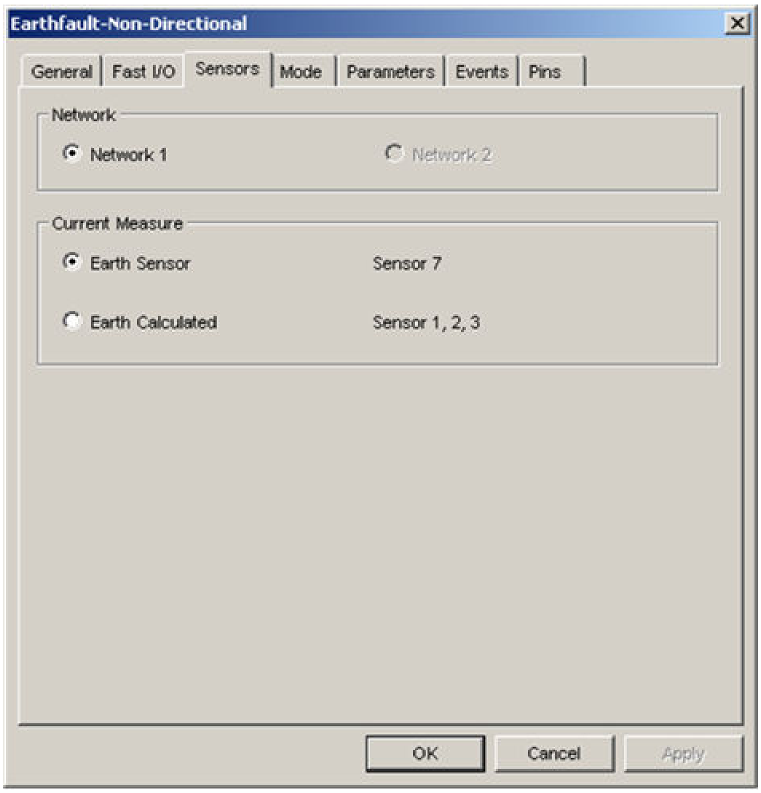


Figure 95: Sensors

The protection function can operate on measured or calculated (on any set of phase current in a triple) neutral current.

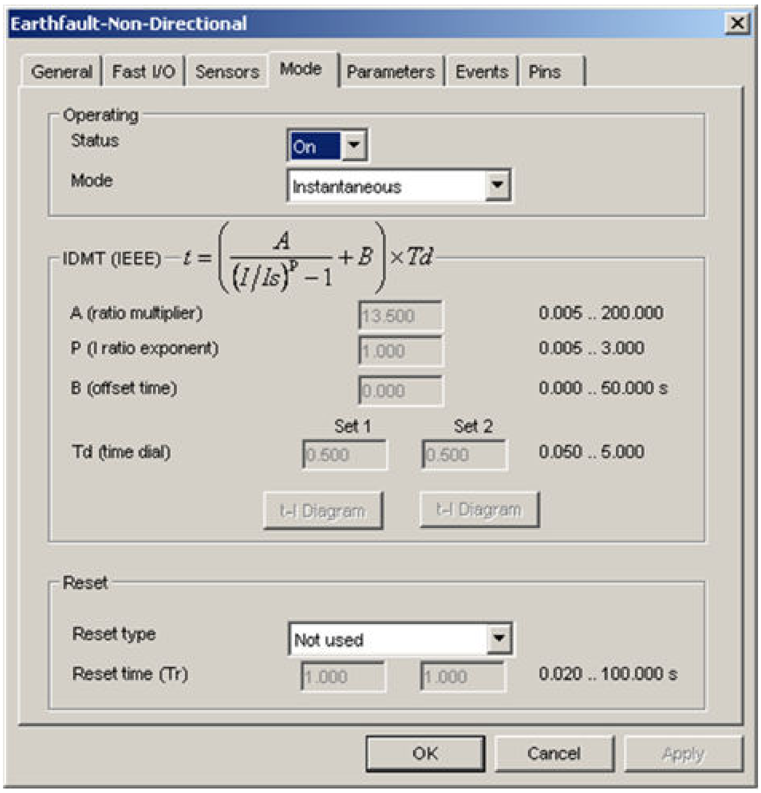


Figure 96: Mode

Status	Mode of the operating status on or off
Mode	Mode for the earth fault, instantaneous, definite or inverse time
IDMT (IEEE)	Free programmable inverse time curve according to equation
A,*P*,*B*, *Td*	Parameter for the free programmable inverse time curve
t-I Diagram	Diagram of the inverse time operation characteristic
Reset type	Mode of the reset time
Reset time	Timer to reset start current condition disappeared

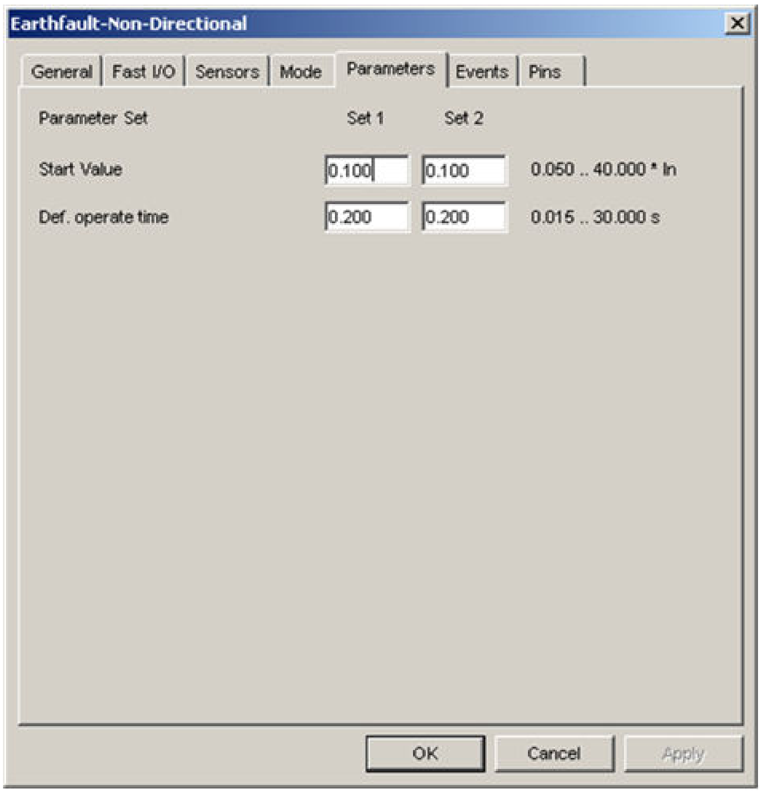


Figure 97: Parameter

Start Value	Current threshold for start
Def. operate time	Operation time in mode definite time

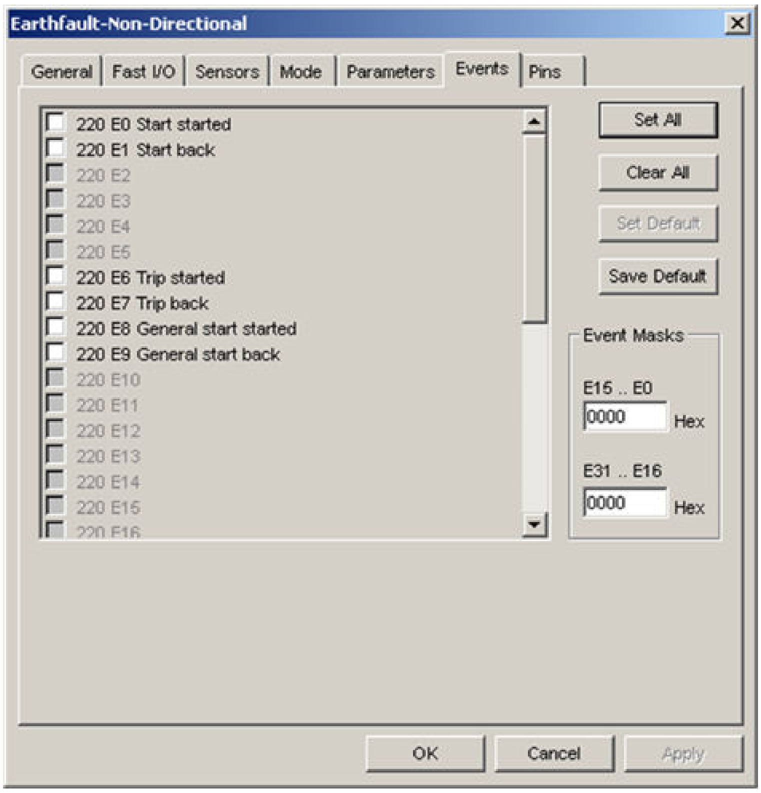


Figure 98: Events

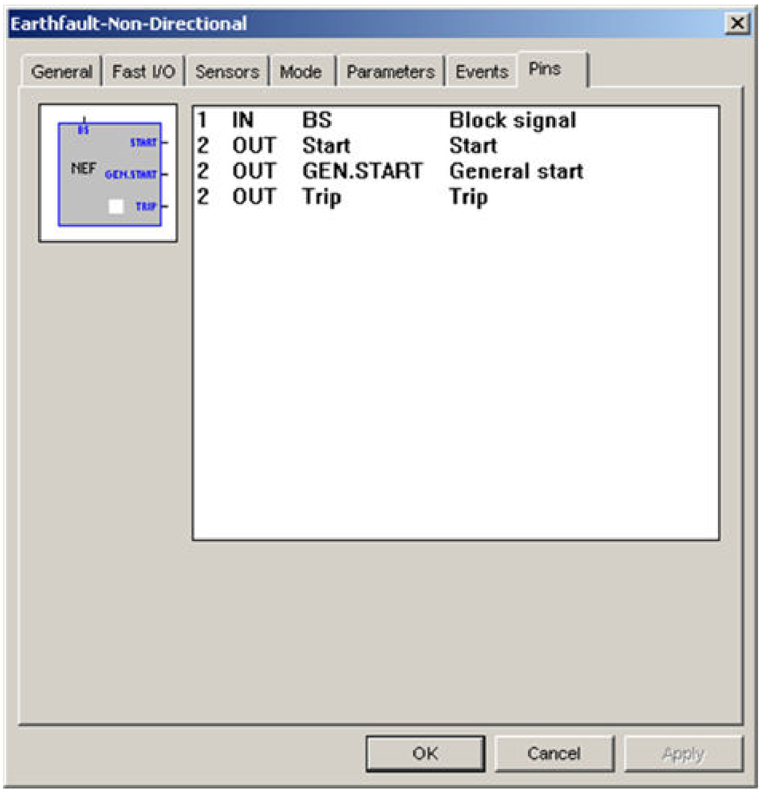


Figure 99: Pins

5.1.8.3 Measurement mode

All earth fault protection functions evaluate the RMS value of the measured residual current or the calculated neutral current at the fundamental frequency.

5.1.8.4 Operation criteria

If the measured current exceeds the setting threshold value (*Start Value*), the earth fault protection function is started.

The protection function remains in START status and comes back in passive status and the start signal is cleared, if the residual current falls below 0.95 the setting threshold value. After the protection has entered the start status and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated.

The protection function exits the TRIP status and the trip signal is cleared when the residual current value falls below 0.4 the setting threshold value. The inverse time tripping characteristic is defined according to an equation.

$$t = \left(\frac{A}{M^P - 1} + B \right) td$$

(Equation 15)

t Operation time to trip

A Curve parameter for the time value (according to IEC 60255-3)

P Value for the exponent

M Ratio of actual current to the pickup current I/In

B Additional offset time

td Time dial to adapt the operation time

The inverse time characteristic (IDMT) is applied after the condition M > 1 is valid. The operation range is, as defined in the IEC 60255-3 standard, from 1.2 to 20 In.

Each time the protection is started due to a system fault condition (M > 1.2) the IDMT operating counter is incremented according to the equation. When it reaches the operation time to trip the function operates activating the trip output signal. If required, a reset type with Inverse time characteristic can be set according to an equation.

$$t = \left(\frac{tr}{M^P - 1} \right) td$$

(Equation 16)

t Operation time to reset

tr Reset time (for M = 0)

M Ratio of actual current to the pickup current I/In

td Time dial to adapt the reset time

The reset type inverse time characteristic is valid for 0 < M < 1. In this case the inverse time earth-fault protection enters the reset state and decrements the operating counter according to above equation. If the condition is 1 ≤ M < 1.2, the counter remains unchanged.

Instead of inverse time reset type a definite time can also be selected. The purpose of the definite reset time is to enable fast clearance of intermittent faults, for example self-sealing insulation faults, and severe faults, which may produce high asymmetrical fault currents that partially saturate the current transformers. It is typical for an intermittent fault that the fault current contains so called drop-off periods during which the fault current falls below the set start current including hysteresis. Without the reset time function, the operating counter would be stopped, when the current has dropped off. In the same way, an apparent drop-off period of the secondary current of the saturated current transformer might also reset the operating counter.

The reset type inverse time can only be applied in conjunction with inverse time earth-fault protection. For definite time earth-fault protection only reset type definite time may be used.

5.1.8.5 Setting groups

Two parameter sets can be configured for the earth fault protection. Switch-over between the parameter sets can be performed in dependency of the network configuration. If this is not required, set 1 and set 2 can be parameterized identically to avoid wrong setting if switch-over of parameters has happened accidentally.

5.1.8.6 Parameters and events

Table 40: Settings values

Parameter	Values	Unit	Default	Explanation
Status	On/Off		On	Operating status
Mode	Instantaneous/ IDMT		Instantaneo us	Operation characteristic
A (ratio multiplier)	0.005...200.000		13.500	Parameter for operation characteristic
P (ratio exponent)	0.005...3.000		1.000	Parameter for operation characteristic
B (offset time)	0.000...50.000	s	0.000	Parameter for operation characteristic
Td (time dial)	0.050...5.000	s	0.5000	Parameter for operation characteristic
Reset type	Not used/Definite time/Inverse time		Not used	Reset Characteristic
Reset time (Tr)	0.020...100.000	s	1.000	Parameter for reset characteristic
Start Value	0.050...40.000	In	0.5000	Current threshold for start condition
Def. operate time	0.015...300.000	s	0.080	Time delay for trip condition

Table 41: Events

Code	Event reason
E0	Protection start on phase L1
E1	Start cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E8	Protection general start
E9	General start is cancelled (after expiration of the reset time)
E18	Protection block signal is active
E19	Protection block signal is back to inactive status

By default all events are disabled.

5.1.9 Directional earth-fault protection

In the directional earth-fault protection up to eight instances can be applied.

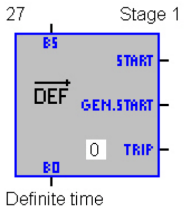


Figure 100: Directional earth-fault protection

5.1.9.1 Input/output description

Table 42: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function remains in idle state until the BS signal goes low.

Table 43: Output

Name	Type	Description
START	Digital signal (active high)	Start signal (fault in set direction)
GEN.START	Digital signal (active high)	General start signal (logical OR combination of all starts including reset time)
TRIP	Digital signal (active high)	Trip signal
BO	Digital signal (active high)	Block output signal (fault in opposite direction)

The START signal is activated when the measured or calculated neutral current exceeds the setting threshold value (*Start Value*) and the fault is in the specified direction.

GEN.START remains active as long as the start signal is high until the reset time, if used, has expired.

`TRIP` signal is activated when the start conditions are true and the operating time has elapsed.

Block Output (`BO`) signal becomes active when the protection function detects a current exceeding the preset value and the fault direction opposite to the specified direction.

5.1.9.2 Configuration

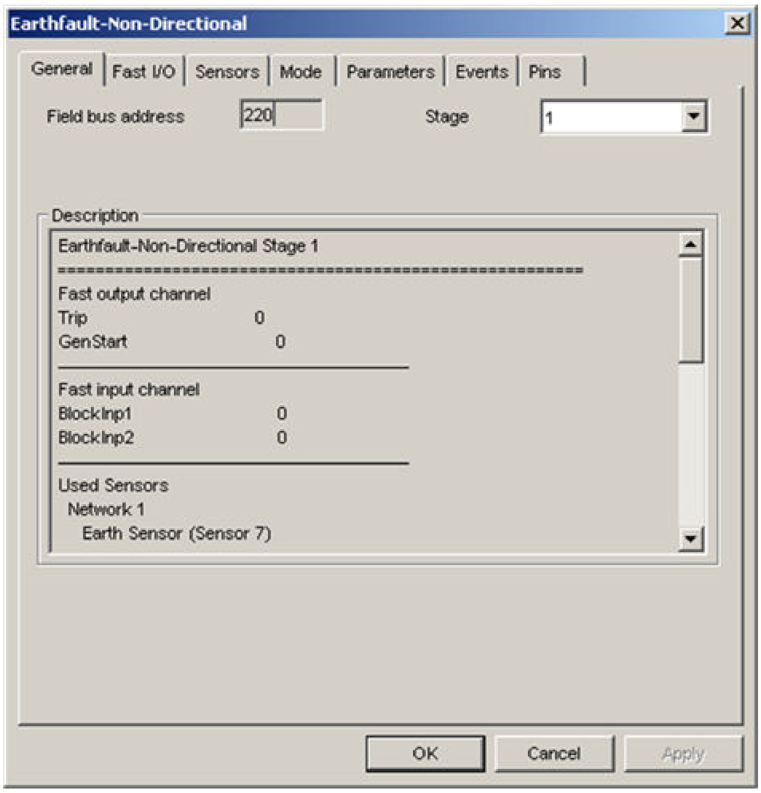


Figure 101: General

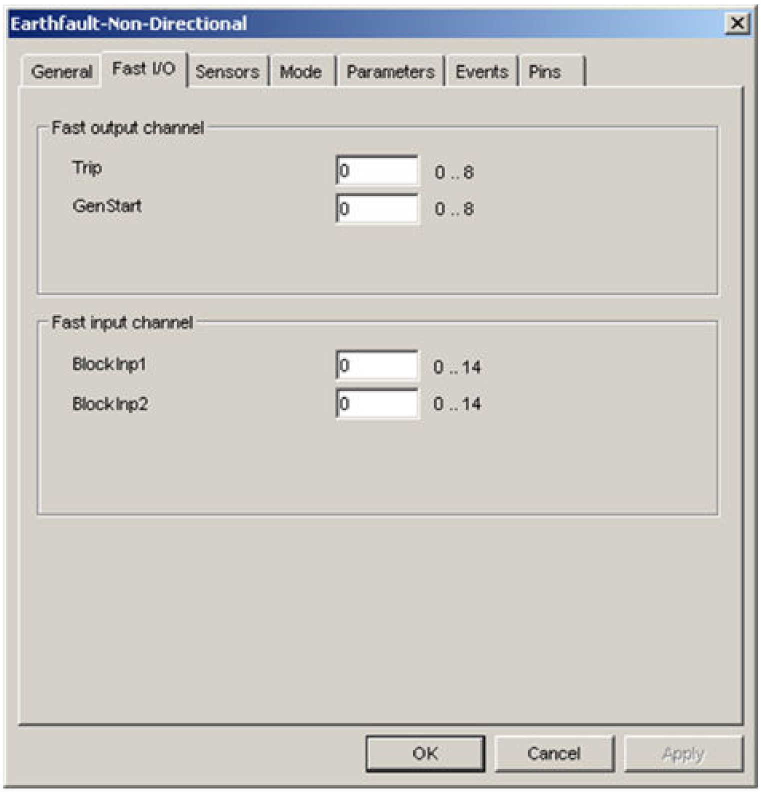


Figure 102: Fast I/O

Output Channel different from 0 means a direct execution of the trip or general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

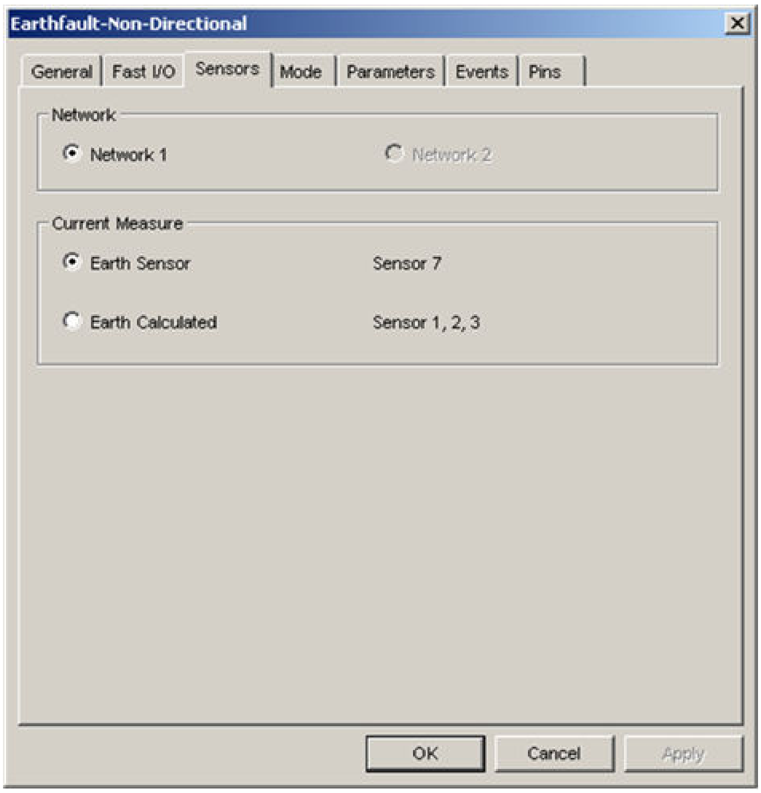


Figure 103: Sensors

The protection functions can operate on neutral current and residual voltage quantities measured through dedicated sensor(s) or calculated from the current and voltage phase components in a triple.

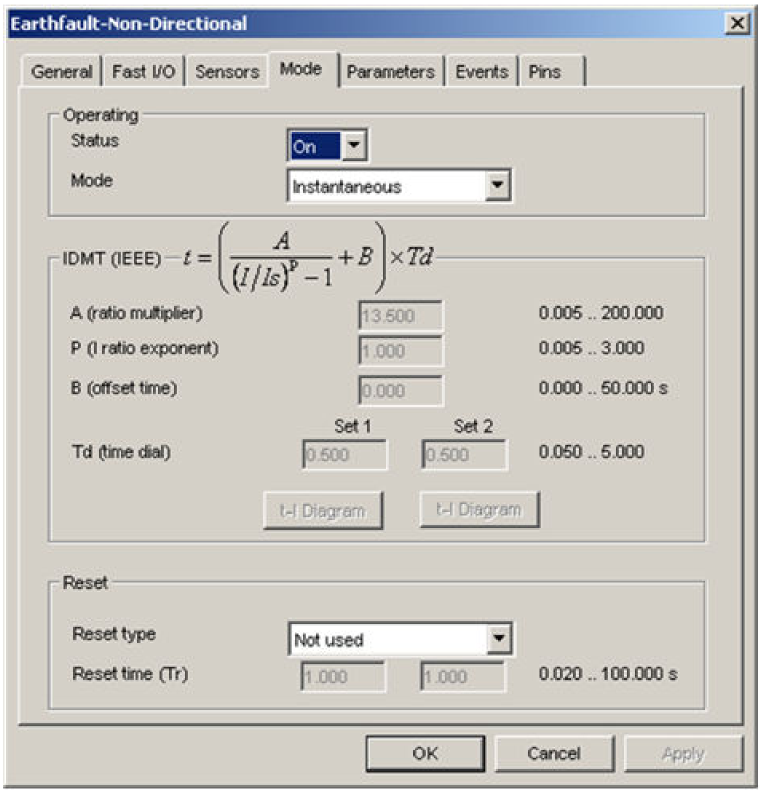


Figure 104: Mode

Status	Mode of the operating status on or off
Mode	Mode for the earth fault definite or inverse time
IDMT (IEEE)	Free programmable inverse time curve according to equation
t-I Diagram	Parameter for the free programmable inverse time curve
A, *P*, *B*, *Td*	Diagram of the inverse time operation characteristic
Reset type	Mode of the reset time
Reset time	Timer is reset after the start current condition is not valid any more

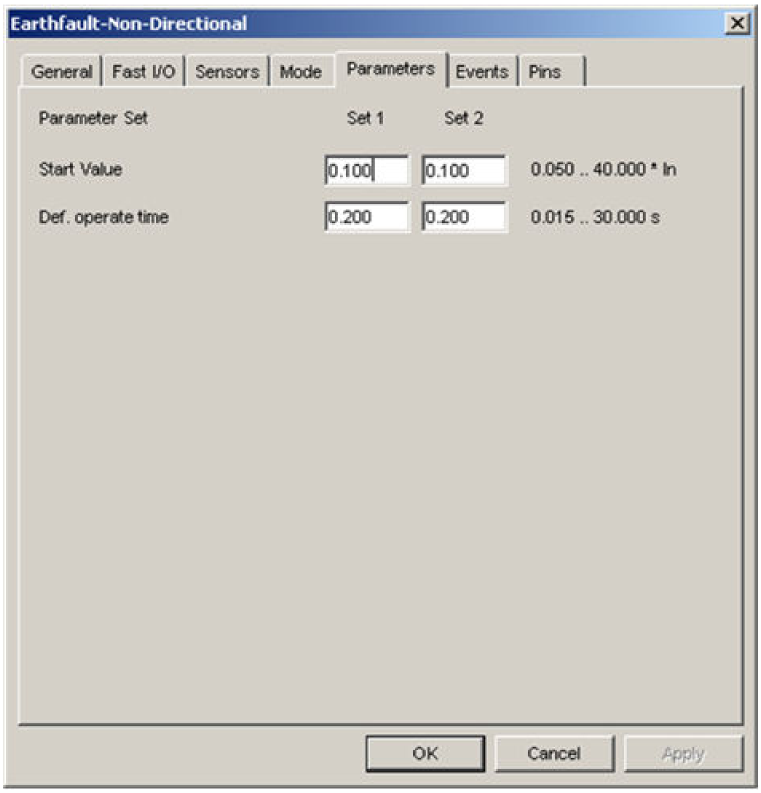


Figure 105: Parameters

Net type	Parameter defining the connection to ground network topology
Direction	Directional criteria to be assessed together to earth fault condition for start detection
Start Value	Current threshold for start
Def. operate time	Operation time in mode definite time
Voltage Uo	Voltage threshold for start

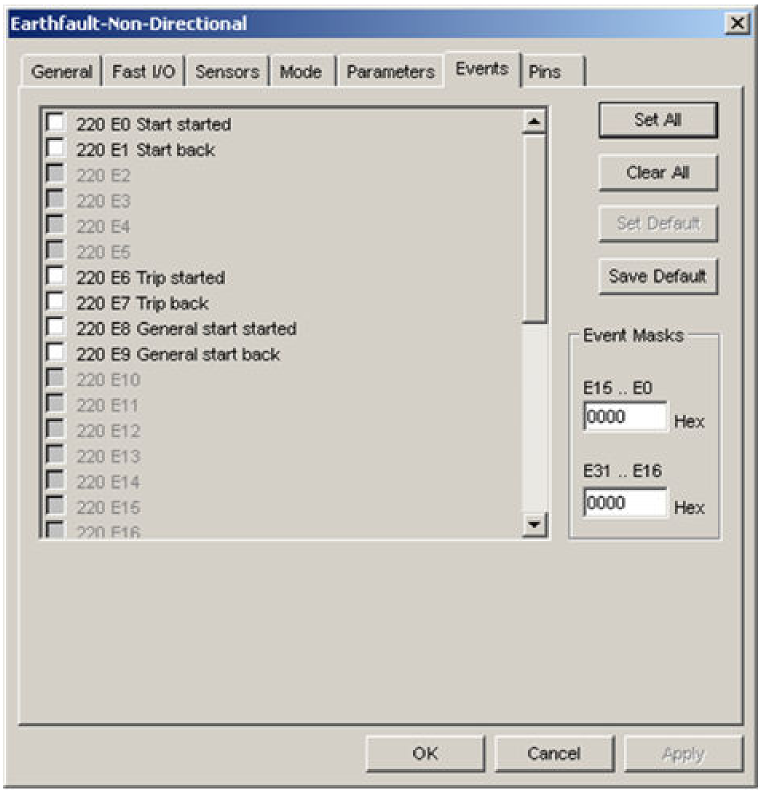


Figure 106: Events

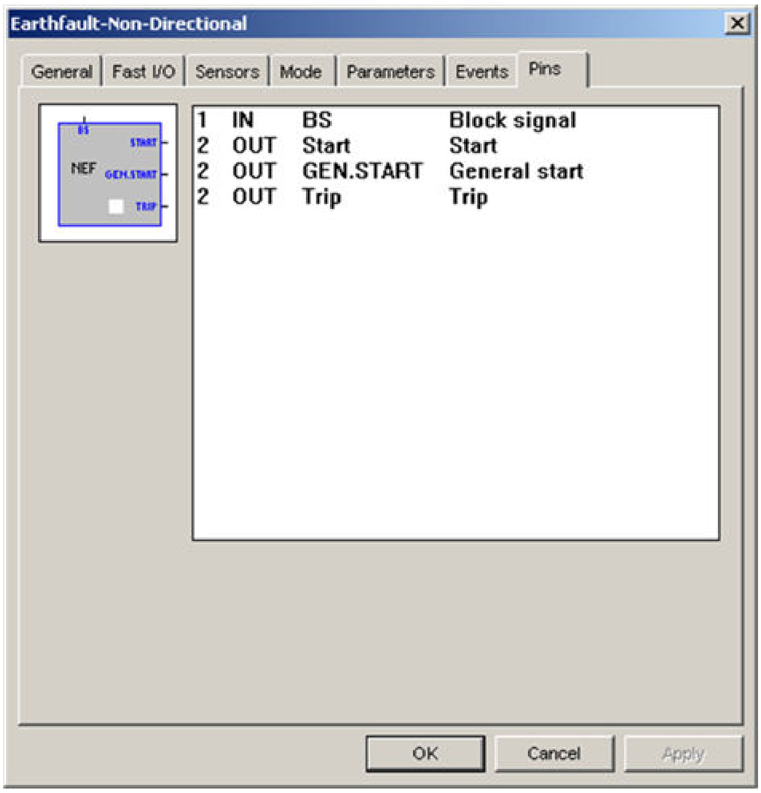


Figure 107: Pins

5.1.9.3 Measurement mode

All directional earth-fault protection functions evaluate the current RMS value at the fundamental frequency.

5.1.9.4 Operation criteria

The directional earth-fault protection functions evaluate the measured or calculated amount of neutral current I_0 and voltage U_0 at the fundamental frequency. If the residual current and simultaneously the residual voltage exceed the related setting threshold value (*Start Value* and Uo) the directional earth-fault protection function is started. At the same time the general start signal is activated.

If the general start condition exists and the fault is in the specified direction (“backward”/”forward”), the timer for the operation time is started. The way the direction is determined depends on the selected network type (“isolated”/”earthed”).

The protection function remains in START status and comes back in passive status by clearing the start signal if the current falls below 0.95 the setting threshold value (or the fault current changes direction).

When the protection has entered the start status and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated. The protection function exits the TRIP status and the trip signal is cleared when the measured current value falls below 0.4 the setting threshold value.

The direction can be determined only if the neutral voltage is above the preset threshold, that is, Voltage Uo.

If parameter *Net type* is set to isolated, then the neutral current is of capacitive type. Then its main component is on an orthogonal projection with respect to the neutral or residual voltage.

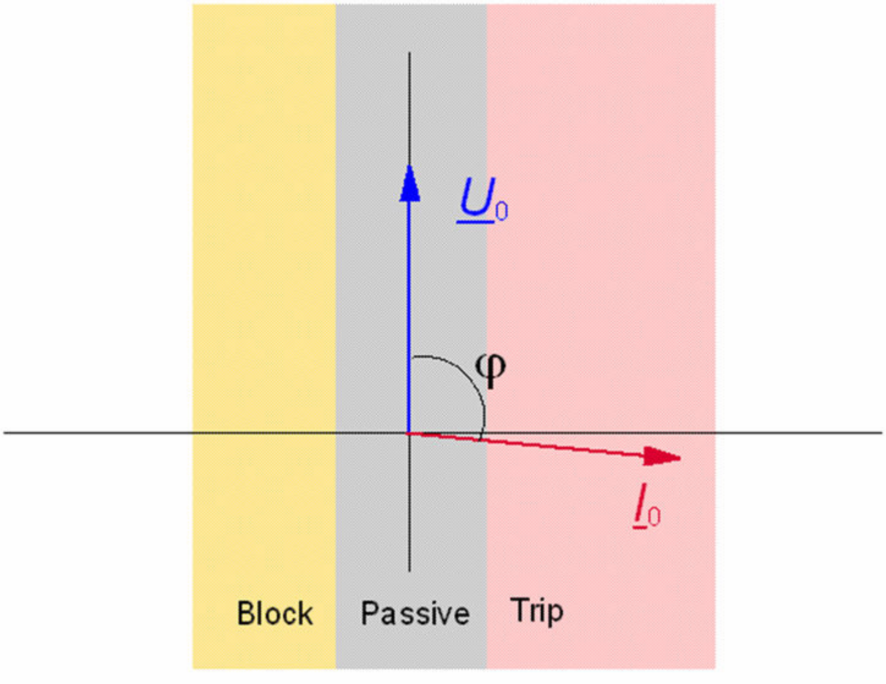


Figure 108: Operating characteristic of the directional earth-fault protection (isolated network sin φ)

If parameter *Net type* is set to earthed, then the neutral current is of resistive type. Then its main component is on a projection parallel to the neutral voltage.

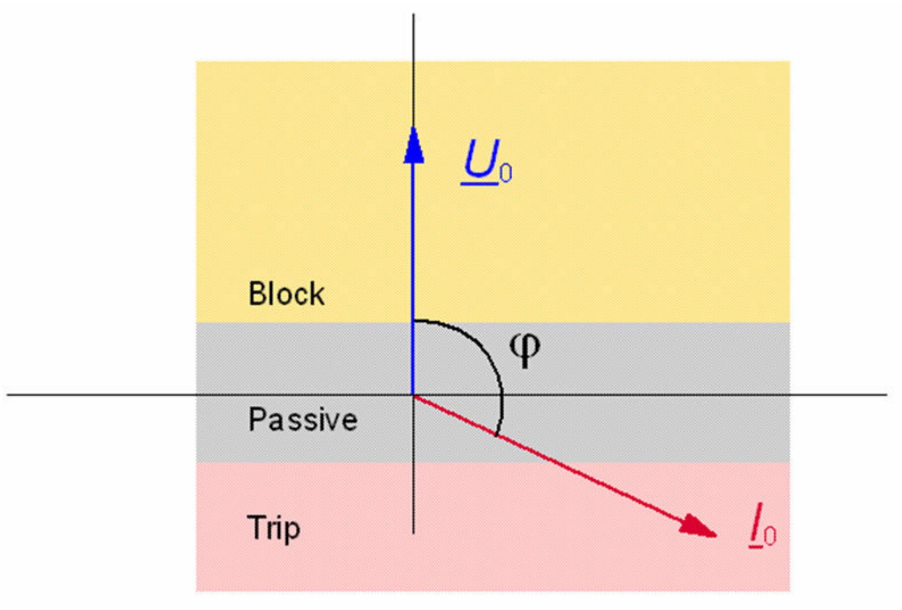


Figure 109: Operating characteristic of the directional earth-fault protection (earthed network cos φ)

The protection function is started, if the all of the following conditions are true:

- Neutral voltage value is above the preset threshold (that is, Voltage U_o).
- The significant component of neutral current value exceeds the setting threshold value (*Start Value*).
- The direction is as selected, that is, “backward”/”forward”.

When the preset threshold values (*Start Value* and Uo) are exceeded and the first two conditions are true but the fault is in the opposite direction to the specified one, the Block Output signal becomes active. The tripping can be selected as definite time or as inverse time characteristic. The inverse time characteristic is defined according to an equation.

$$t = \left(\frac{A}{M^P - 1} + B \right) td$$

(Equation 17)

t	Operation time to trip
A	Curve parameter for the time value (according to IEC 60255-3)
P	Value for the exponent
M	Ratio of actual current to the pickup current I/In
B	Additional offset time
td	Time dial to adapt the operation time

The inverse time characteristic (IDMT) is applied after the condition M > 1 is valid. The operation range is, as defined in the IEC 60255-3 standard, from 1.2 to 20 In.

Each time the protection is started due to a system fault condition (M > 1.2) the IDMT operating counter is incremented according to the equation. When it reaches the operation time to trip the function operates activating the trip output signal. If required, a reset type with Inverse time characteristic can be set according to an equation.

$$t = \left(\frac{tr}{M^{P} - 1} \right) td$$

(Equation 18)

t Operation time to reset

tr Reset time (for M = 0)

M Ratio of actual current to the pickup current I/In

td Time dial to adapt the reset time

The reset type inverse time characteristic is valid for 0 < M < 1. In this case the inverse time directional earth-fault protection enters the reset state and decrements the operating counter according to above equation. If the condition is 1 ≤ M < 1.2, the counter remains unchanged.

Instead of inverse time reset type a definite time can also be selected. The purpose of the definite reset time is to enable fast clearance of intermittent faults, for example self-sealing insulation faults, and severe faults, which may produce high asymmetrical fault currents that partially saturate the current transformers. It is typical for an intermittent fault that the fault current contains so called drop-off periods during which the fault current falls below the set start current including hysteresis. Without the reset time function, the operating counter would be stopped, when the current has dropped off. In the same way, an apparent drop-off period of the secondary current of the saturated current transformer might also reset the operating counter.

The reset type inverse time can only be applied in conjunction with inverse time overcurrent protection. For definite time overcurrent protection only reset type definite time may be used.

5.1.9.5 Setting groups

Two parameter sets can be configured for the directional earth-fault protection. Switch-over between the parameter sets can be performed in dependency of the network configuration. If this is not required, set 1 and set 2 can be parameterized identically to avoid wrong setting if switch-over of parameters has happened accidentally.

5.1.9.6 Parameters and events

Table 44: Parameters

Parameter	Values	Unit	Default	Explanation
Status	On/Off		On	Operating status
Mode	Definite time/ IDMT		Definite time	Operation characteristic
A (ratio multiplier)	0.005...200.000		13.500	Parameter for operation characteristic
P (ratio exponent)	0.005...3.000		1.000	Parameter for operation characteristic
B (offset time)	0.000...50.000	s	0.000	Parameter for operation characteristic
Td (time dial)	0.050...5.000	s	0.5000	Parameter for operation characteristic
Reset type	Not used/Definite time/Inverse time		Not used	Reset Characteristic
Reset time (Tr)	0.020...100.000	s	1.000	Parameter for reset characteristic
Net type	isolated (sin phi) / earthed (cos Phi)			Setting for network earthing
Direction	Forward/ backward		backward	Setting for fault direction
Start Value	0.050...40.000	In	0.5000	Current threshold for start condition
Def. operate time	0.015...300.000	s	0.080	Time delay for trip condition

Table 45: Events

Code	Event reason
E0	Protection start on earth fault (fault in set direction)
E1	Start on earth fault cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E8	Protection general start
E9	General start is cancelled (after expiration of reset time)
E16	Block signal is active
E17	Block signal is back to inactive status
E18	Protection block signal is active
E19	Protection block signal is back to inactive status
E20	Protection operation[1)]
E21	Operation cancelled
E26	Protection general operation
E27	General operation cancelled (after expiration of reset time)
Table continues on next page	

Code	Event reason
E28	Operation on fault direction forward
E29	Operation on fault direction backward
E30	Operation on fault direction unknown

1) Start of protection on faults independent of the direction

By default all events are disabled.

5.1.10 Earth fault protection (single stage)

REF 542plus has two earth fault definite time protection functions, which can be activated and the parameters set independently of each other, see the following figures.

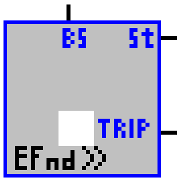


Figure 110: Earth fault high

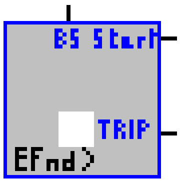


Figure 111: Earth fault low

5.1.10.1 Input/output description

Table 46: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 47: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal

The `START` signal will be activated when the measured or calculated neutral current exceeds the setting threshold value (*Start Value*).

The `TRIP` signal will be activated when the start conditions are true and the operating time (*Time*) has elapsed.

5.1.10.2 Configuration

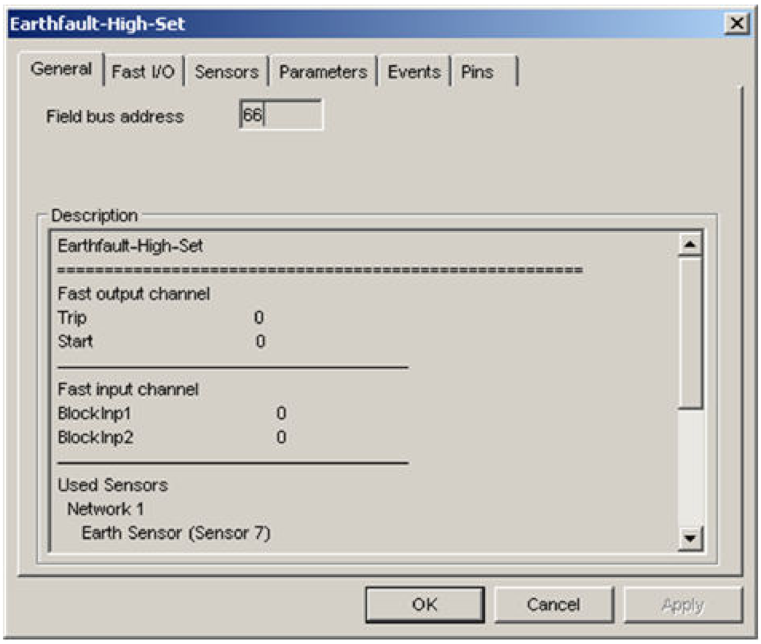


Figure 112: General

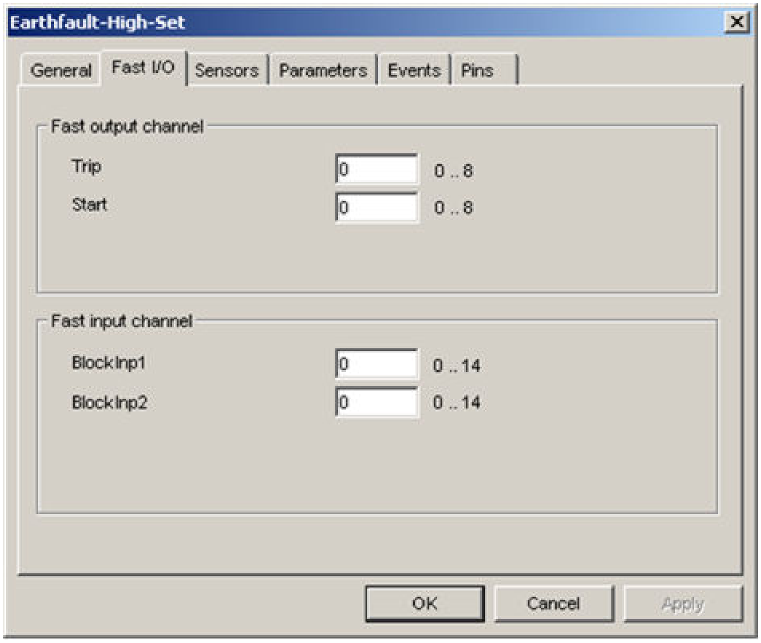


Figure 113: Fast I/O

Output Channel different from 0 means a direct execution of the trip or general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

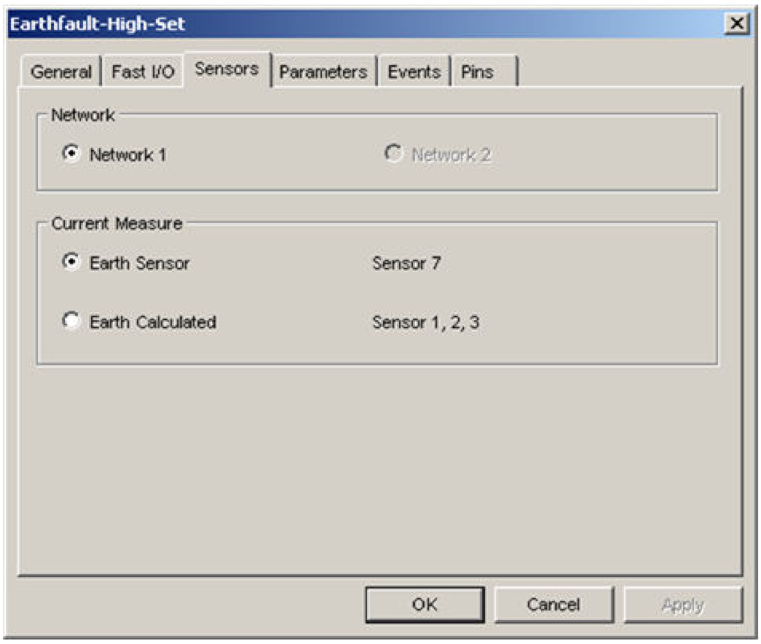


Figure 114: Sensors

The protection functions can operate on measured or calculated (on any set of phase currents in a triple) neutral current.

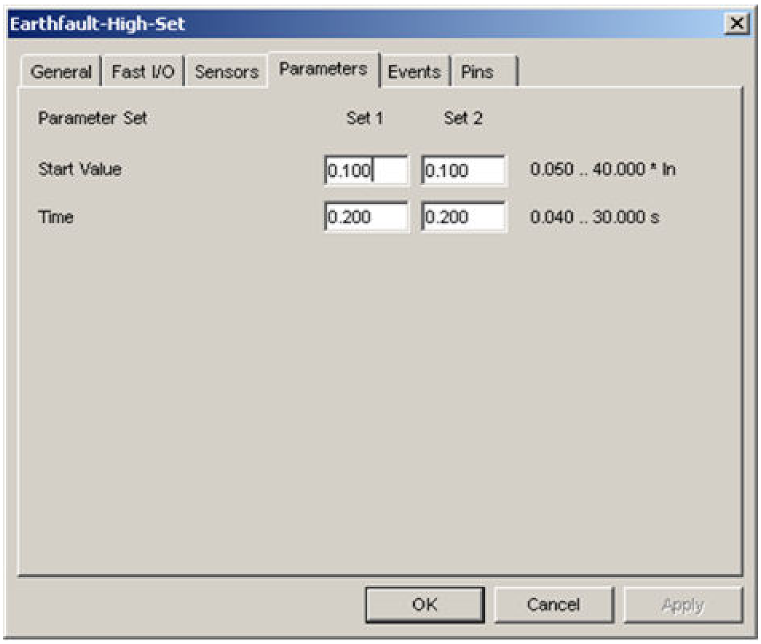


Figure 115: Parameters

Start Value	Current threshold for earth fault condition detection
Time	Time delay for earth fault Trip condition detection

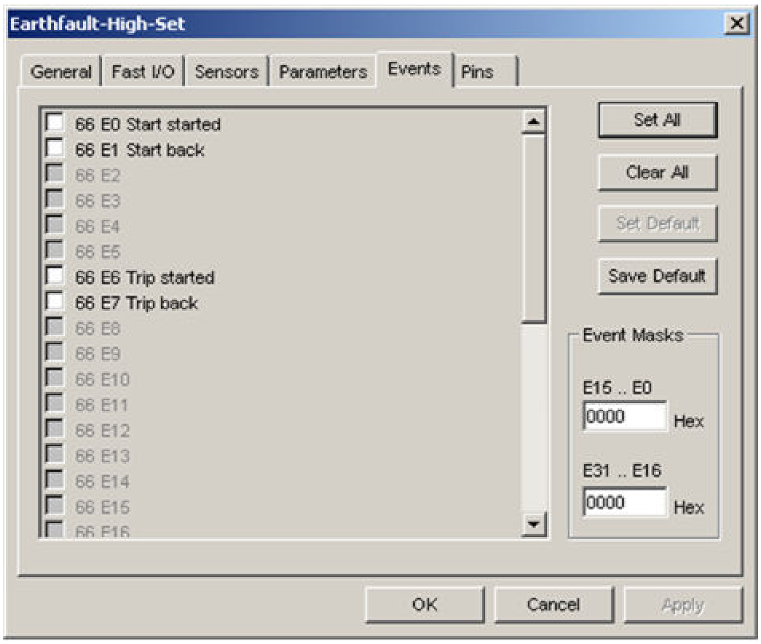


Figure 116: Events

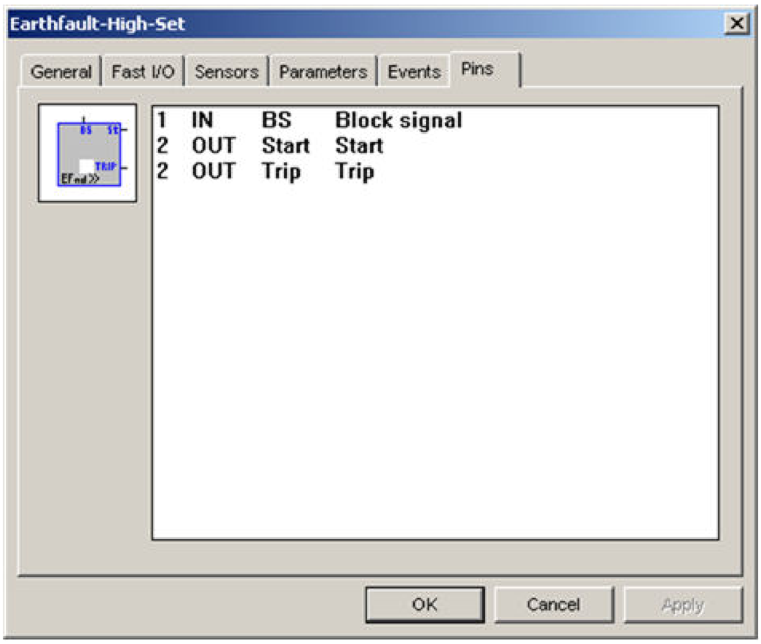


Figure 117: Pins

5.1.10.3 Measurement mode

All earth fault definite time protection functions evaluate the measured residual current or the calculated neutral current at the fundamental frequency.

5.1.10.4 Operation criteria

If the measured or calculated neutral current exceeds the setting threshold value (*Start Value*), the earth fault protection function is started.

The protection function will come back in passive status and the start signal will be cleared if the neutral current falls below 0.95 the setting threshold value.

After the protection has entered the start status and the preset operating time (*Time*) has elapsed, function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the neutral current value falls below 0.4 the setting threshold value.

5.1.10.5 Setting groups

Two parameter sets can be configured for each earth fault protection function.

5.1.10.6 Parameters and events

Table 48: Setting values

Parameter	Values	Unit	Default	Explanation
Start value	0.05...40.00	In	0.10	Current threshold for earth fault condition detection
Time	40...30000	ms	200	Time delay for earth fault Trip condition detection

Table 49: Events

Code	Event reason
E0	Start started
E1	Start back
E6	Trip started
E7	Trip back
E18	Protection block started
E19	Protection block back

By default all events are disabled.

5.1.11 Directional earth-fault protection (single stage)

REF 542plus has two directional earth-fault protection functions, each of which can be independently activated and configured, see the following figures.

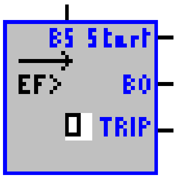


Figure 118: Directional earth fault low

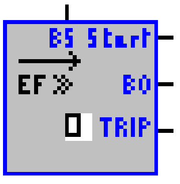


Figure 119: Directional earth fault high

5.1.11.1 Input/output description

Table 50: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 51: Output

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal
BO	Digital signal (active high)	Block output signal

The START signal will be activated when the measured or calculated neutral current exceeds the setting threshold value (*Start Value*) and the fault is in the specified direction.

The TRIP signal will be activated when the start conditions are true and the operating time (*Time*) has elapsed.

The Block Output (BO) signal becomes active when the protection function detects a current exceeds the preset value and the fault direction opposite to the specified direction.

5.1.11.2 Configuration

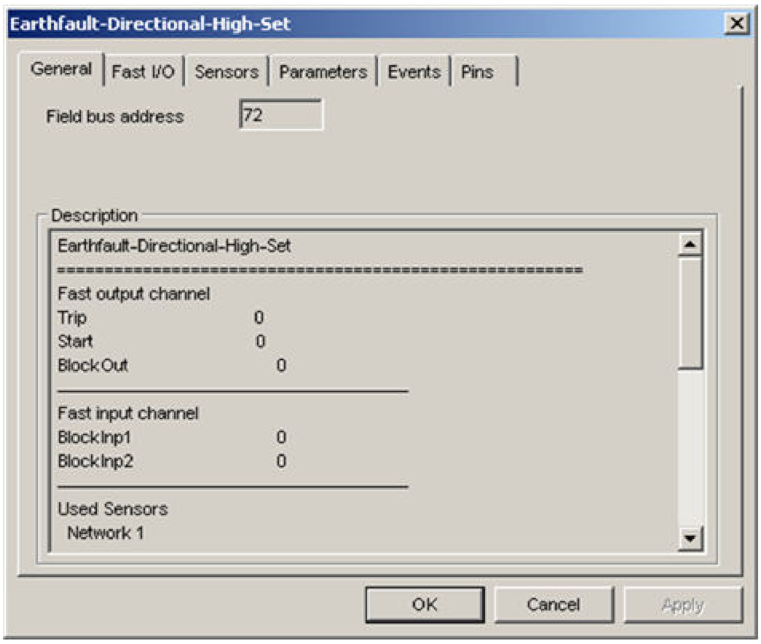


Figure 120: General

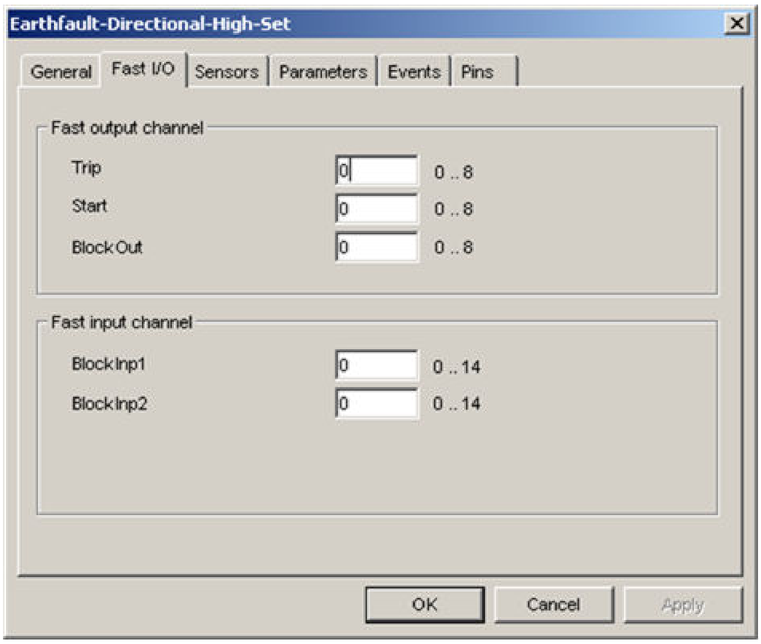


Figure 121: Fast I/O

Output Channel different from 0 means a direct execution of the trip or general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

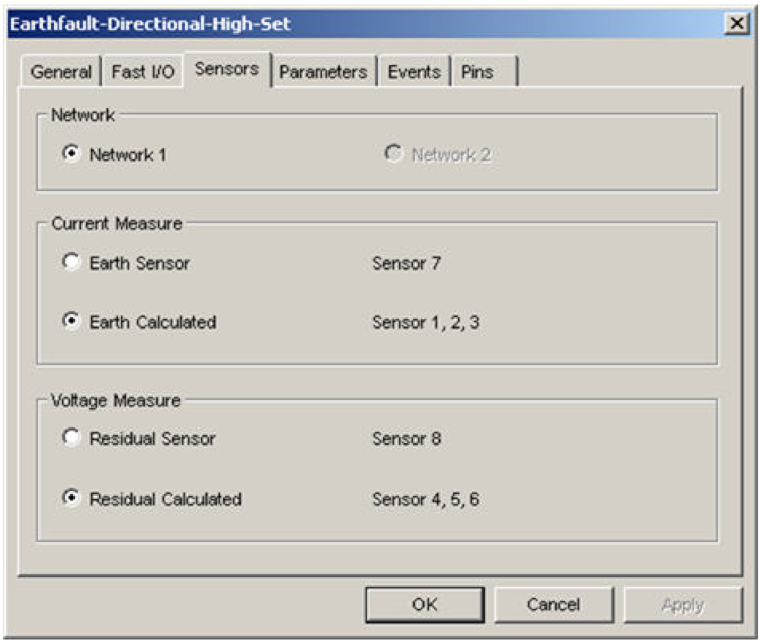


Figure 122: Sensors

The protection functions can operate on neutral current and residual voltage quantities measured through dedicated sensor(s) or calculated from the current and voltage phase components in a triple.

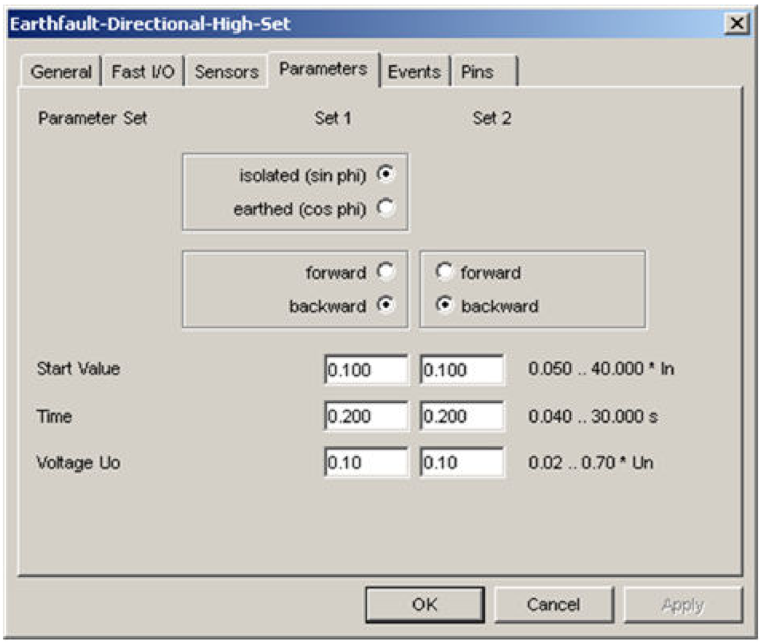


Figure 123: Parameters

Net type	Parameter defining the connection to ground network typology
Direction	Directional criteria to be assessed together to earth fault condition for START detection
Start Value	Current threshold for earth fault condition detection
Time	Time delay for earth fault Trip condition detection
Voltage U0	Residual or neutral voltage threshold

(The convention used to define Trip or Block area with respect to residual voltage U0 vector is described in the following, based on the typical connection diagram of current and voltage transformers for a generic feeder.

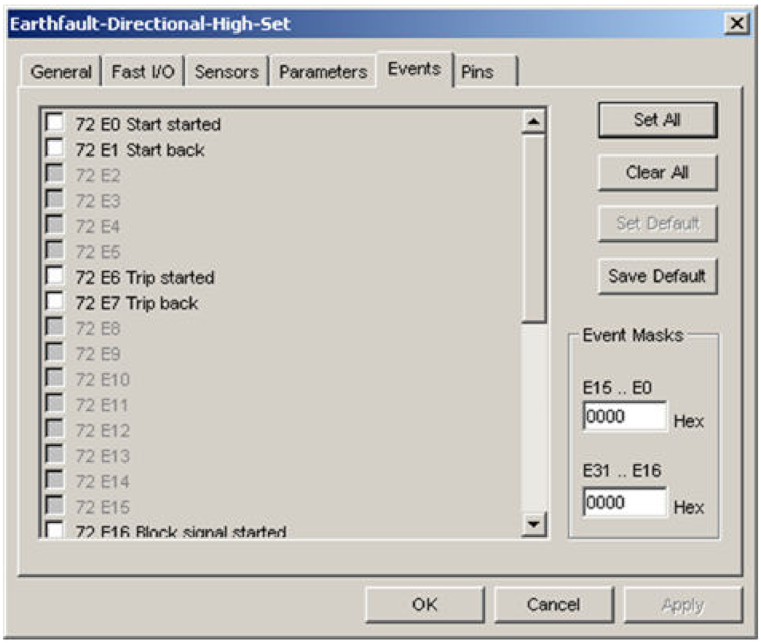


Figure 124: Events

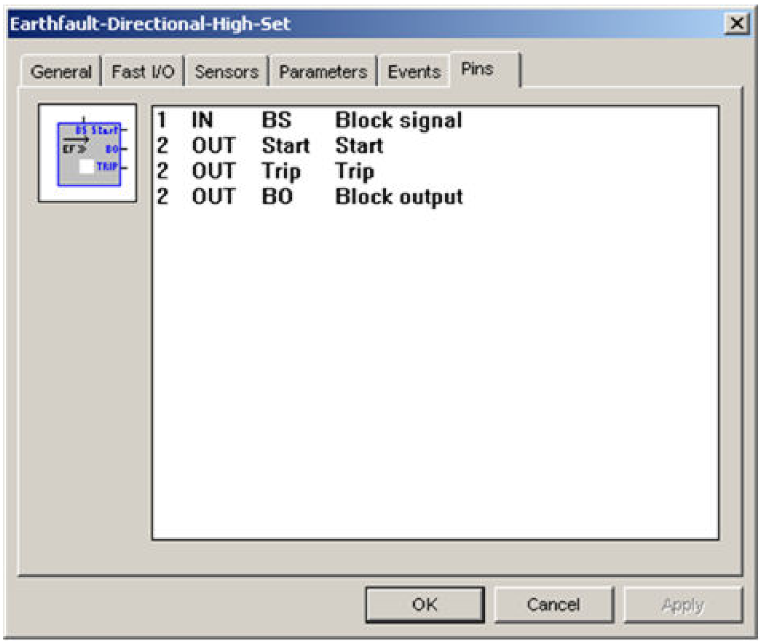


Figure 125: Pins

5.1.11.3 Measurement mode

All directional earth fault definite time protection functions evaluate the measured or calculated amount of neutral current I0 and voltage U0 at the fundamental frequency.

5.1.11.4 Operation criteria

The direction is determined (hence the protection function is active) only if the neutral voltage is above the preset threshold, that is, *Voltage U0*.

The way the direction is determined depends on the selected network type (“isolated”/”earthed”).

If parameter *Net type* is set to isolated, then the neutral current is of capacitive type. Then its main component is on an orthogonal projection with respect to the neutral voltage.

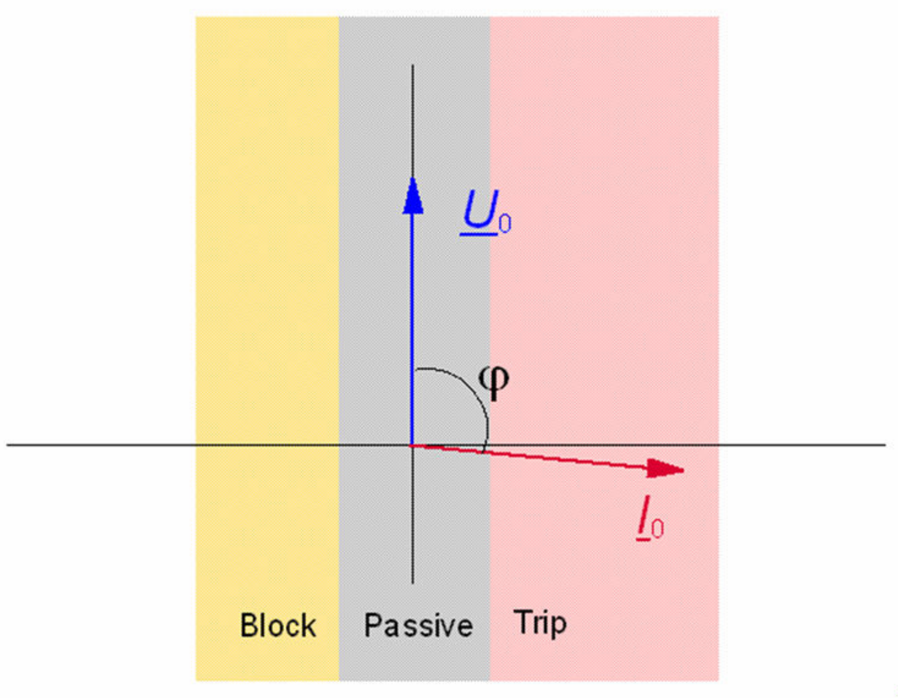


Figure 126: Operating characteristic of the earth fault directional protection (isolated network sin φ)

If parameter *Net type* is set to earthed, then the neutral current is of resistive type. Then its main component is on a projection parallel to the neutral voltage.

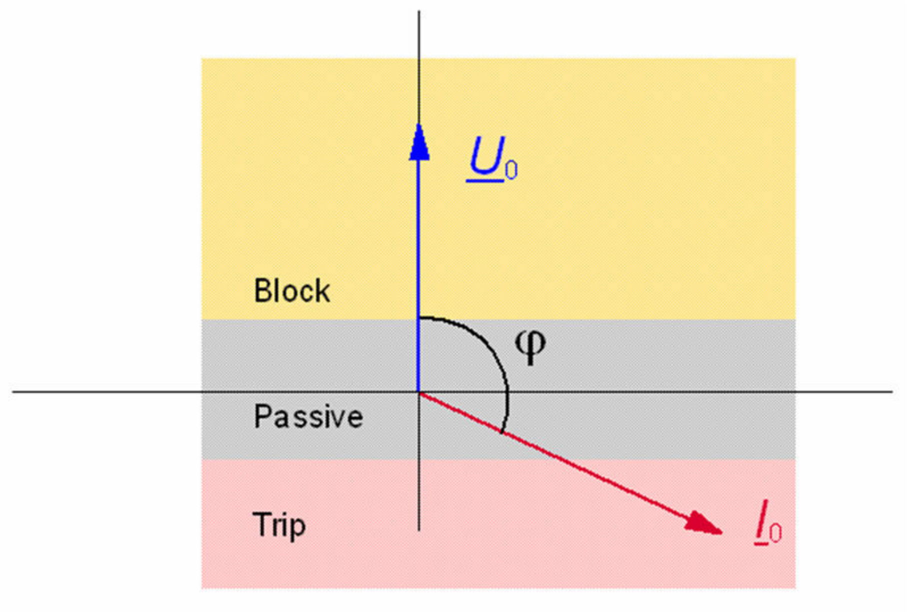


Figure 127: Operating characteristic of the earth fault directional protection (earthed network cos φ)

If all of the following conditions are true, the protection function is started.

- Neutral voltage value is above the preset threshold (that is, *Voltage U0*).
- “Significant” component of neutral current value exceeds the setting threshold value (*Start Value*).
- The direction is as selected, that is, “backward”/”forward”.

When the preset threshold values (*Start Value* and Uo) are exceeded and the first two conditions are true but the fault is in the opposite direction to the specified one, the Block Output signal becomes active.

The protection function will come back in passive status and the start signal will be cleared if the neutral current “significant” component value falls below 0.95 the setting threshold value OR if the conditions on Neutral voltage value OR direction are not true.

After the protection has entered the start status and the preset operating time (*Time*) has elapsed, function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the neutral current “significant” component value falls below 0.4 the setting threshold value.

5.1.11.5 Setting groups

Two parameter sets can be configured for each directional earthfault protection function.

5.1.11.6 Parameters and events

Table 52: Setting values

Parameter	Values	Unit	Default	Explanation
Net type	Isolated/ earthed	-	Isolated	Network grounding typology.
Direction	Forward/ backward	-	Backward	Directional criteria.
Start value	0.05...40.00	In	0.10	“Significant” component threshold
Time	40...30000	ms	200	Operating Time between start and trip.
Voltage U0	0.02...0.70	Un	0.10	Neutral or residual voltage threshold.

Table 53: Events

Code	Event reason
E0	Protection start
E1	Start is cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive
E16	Block output signal is active
E17	Block output signal is back to inactive
E18	Protection block started
E19	Protection block back

By default all events are disabled.

5.1.12 Earth fault IDMT (single stage)

The dependent earth-fault current timer protection, like IDMT, is a time-delay function with a set of hyperbolic current-time characteristics. An earth-fault IDMT function, in which four current-time characteristics may be selected, can be activated in REF542:

- Normal inverse
- Very inverse
- Extremely inverse and
- Long-term inverse

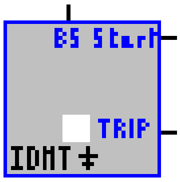


Figure 128: Earth fault IDMT

5.1.12.1 Input/output description

Table 54: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until BS signal goes low.

Table 55: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal

The START signal will be activated when the measured or calculated neutral current exceeds the setting threshold value (*Base current Ieb*) by a factor 1.2. The TRIP signal will be activated when the start conditions are true and the calculated operating time has elapsed.

5.1.12.2 Configuration

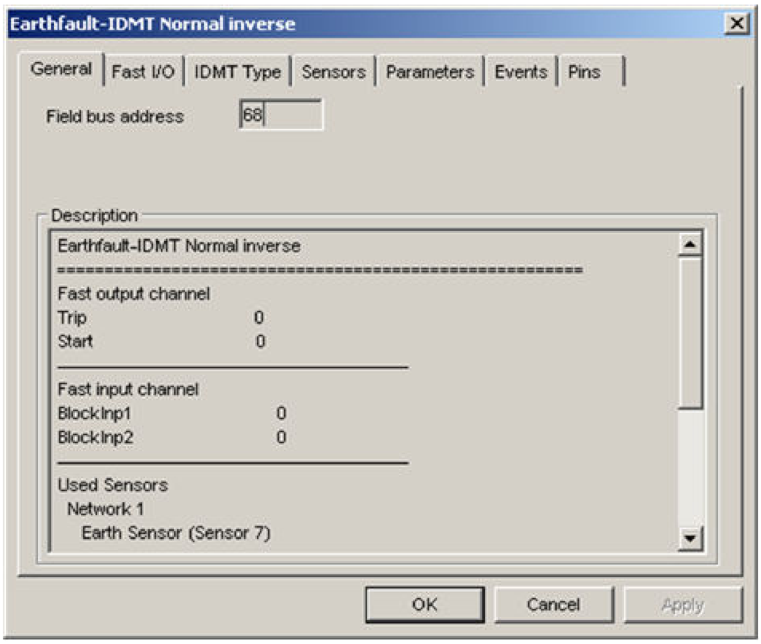


Figure 129: General

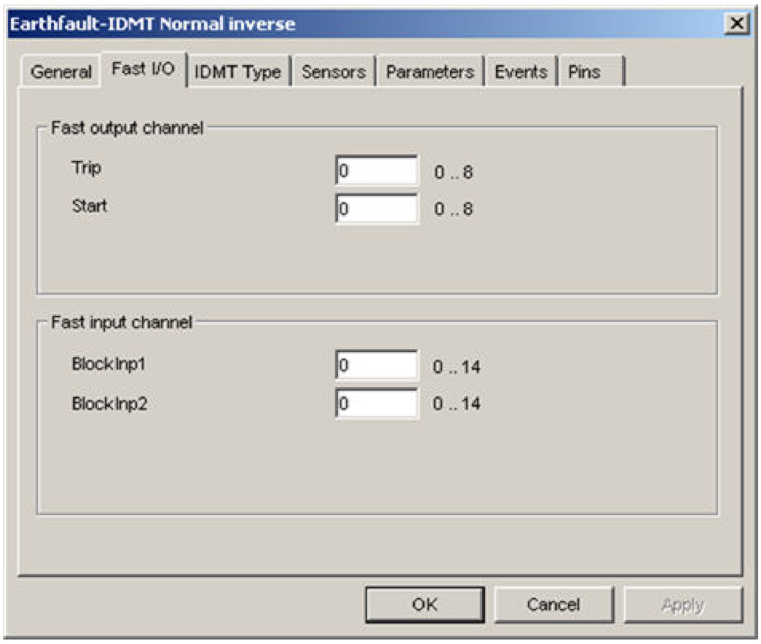


Figure 130: Fast I/O

From 0 means a direct execution of the trip or start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

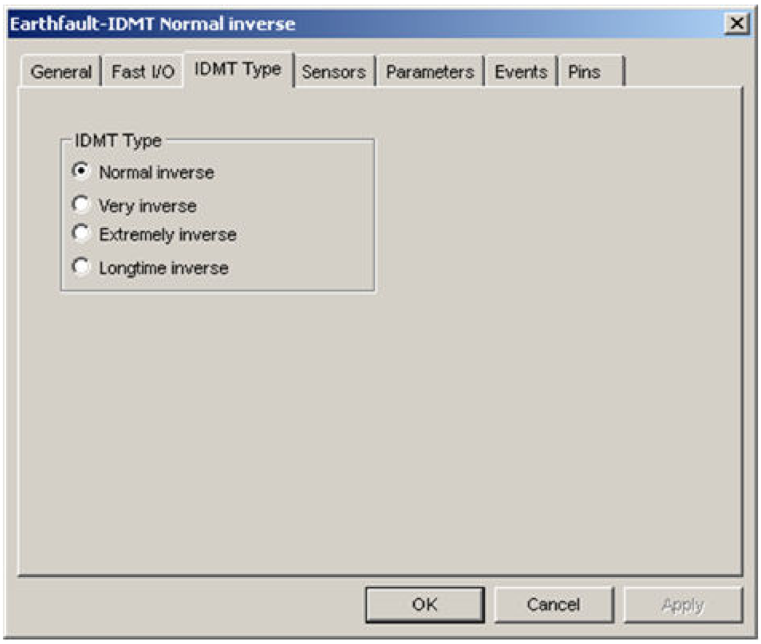


Figure 131: IDMT Type

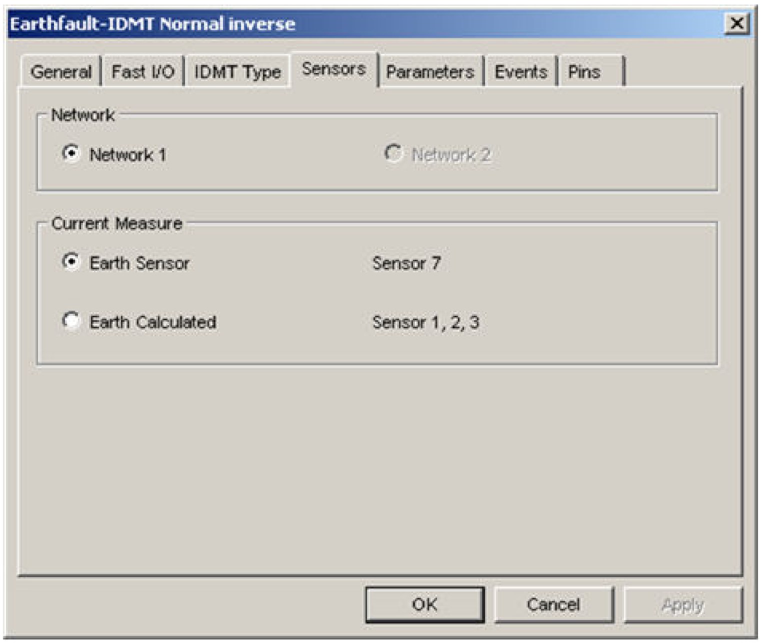


Figure 132: Sensors

The protection function can operate on measured or calculated (on any set of phase currents in a triple) neutral currents.

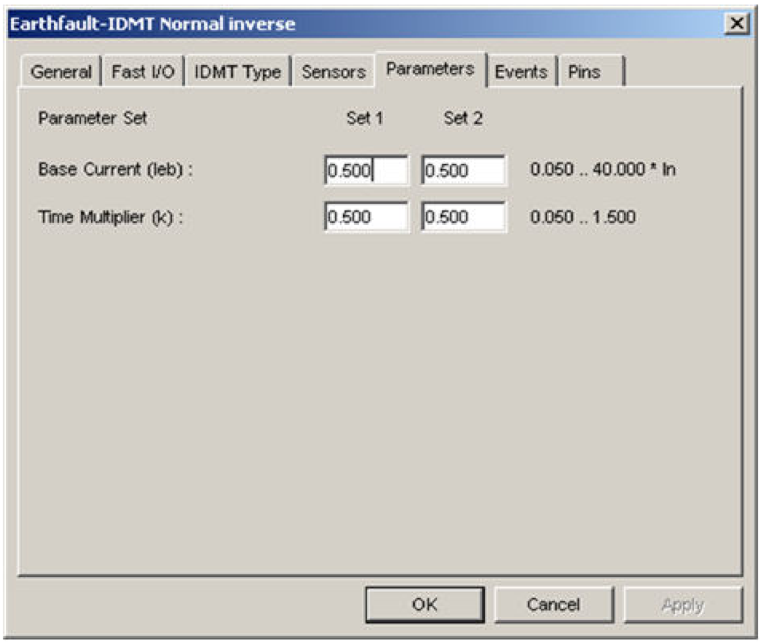


Figure 133: Parameters

Base current (Ieb)	Current threshold for overcurrent condition detection
Time multiplier (k)	Parameter to vary time delay for Trip condition

The trip time is calculated according to British Standard (BS 142) when the time multiplier k is used. When the time multiplier k is set to one (k=1) the IDMT curve is in accordance to IEC 60255-3.

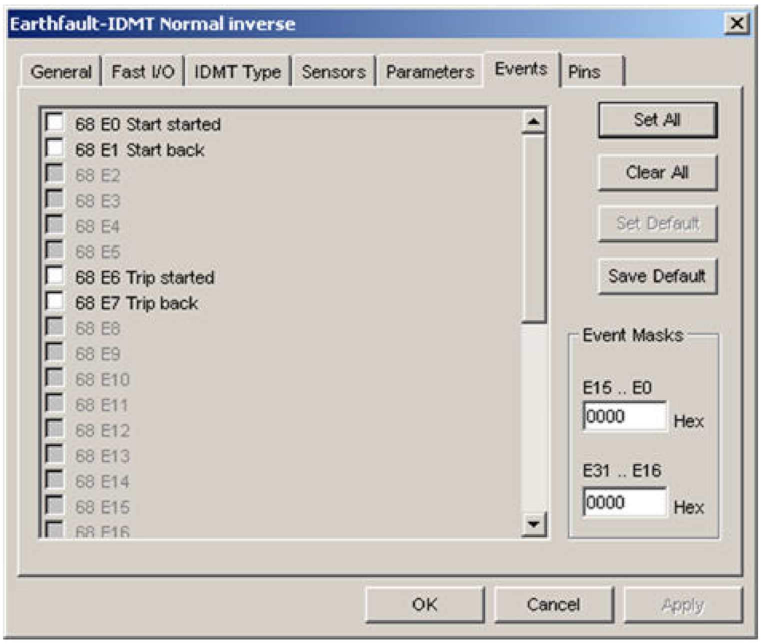


Figure 134: Events

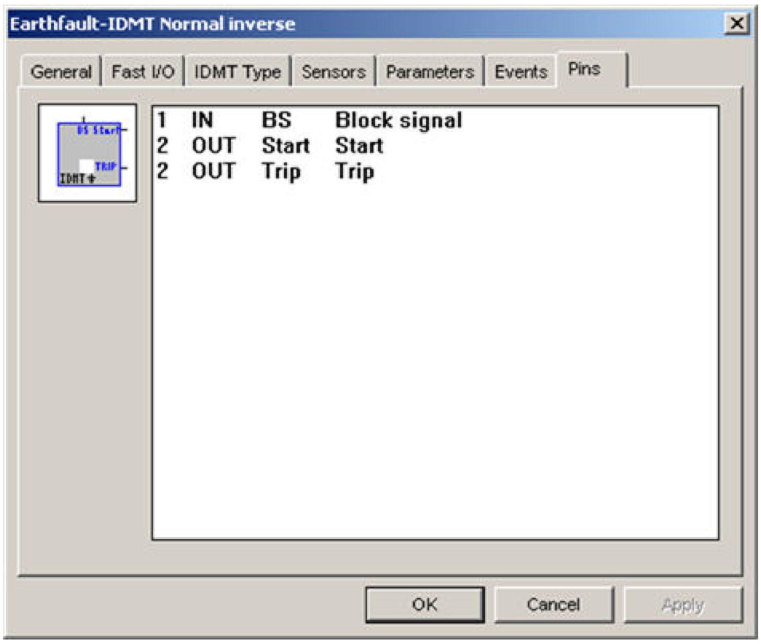


Figure 135: Pins

5.1.12.3 Measurement mode

Earth fault IDMT function evaluates the measured amount of residual current at the fundamental frequency.

5.1.12.4 Operation criteria

If the measured or calculated neutral current exceeds the setting threshold value (*Base current Ieb*) by a factor 1.2, the protection function is started.

The protection function will come back in passive status and the start signal will be cleared if the neutral current falls below 1.15 the setting threshold value.

When the protection enters the start status, the operating time is continuously recalculated according to the set parameters and measured current value. If the calculated operating time is exceeded, the function goes in TRIP status and the trip signal becomes active.

The operating time depends on the measured current and the selected current-time characteristic.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured or calculated neutral current value falls below 0.4 the setting threshold value.

5.1.12.5 Setting groups

Two parameter sets can be configured for the earth-fault IDMT protection function.

5.1.12.6 Parameters and events

Table 56: Setting values

Parameter	Values	Unit	Default	Explanation
Type	NI/VI/EI/LTI	-	NI	Tripping characteristic according to the IEC 60255-3 curve definition
Base current (Ieb)	0.05...40	-	0.5	Fault current factor threshold for start condition detection
Time multiplier (k)	0.05...1.50	-	0.50	Time multiplier to vary time delay for Trip condition according to BS 142

Table 57: Events

Code	Event reason
E0	Protection is start
E1	Start is cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive
E18	Protection block is active
E19	Protection block is back to inactive

By default all events are disabled.

5.1.13 Sensitive directional earth fault protection

REF 542plus has one sensitive directional earth fault protection function (67N Sensitive).

With respect to the two directional earth fault protection functions (67N), the 67N sensitive protection can be configured to set the maximum sensitivity direction at a user defined angle (*Angle delta*). The only additional requirement is to acquire the neutral current I0 through a dedicated earth transformer in order to have the proper precision.

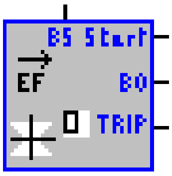


Figure 136: Sensitive directional earth fault protection

5.1.13.1 Input/output description

Table 58: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 59: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal
BO	Digital signal (active high)	Block output signal

The START signal will be activated when the measured residual voltage exceeds the setting threshold value (*Voltage Uo*) and the neutral current is in the specified Trip area.

The TRIP signal will be activated when the start conditions are true and the operating time (*Time*) has elapsed.

The Block Output (BO) signal becomes active when the protection function detects residual voltage and neutral current exceeds the preset values, but the fault (neutral current) is in the block area (opposite to the specified direction, *Angle delta*).

5.1.13.2 Configuration

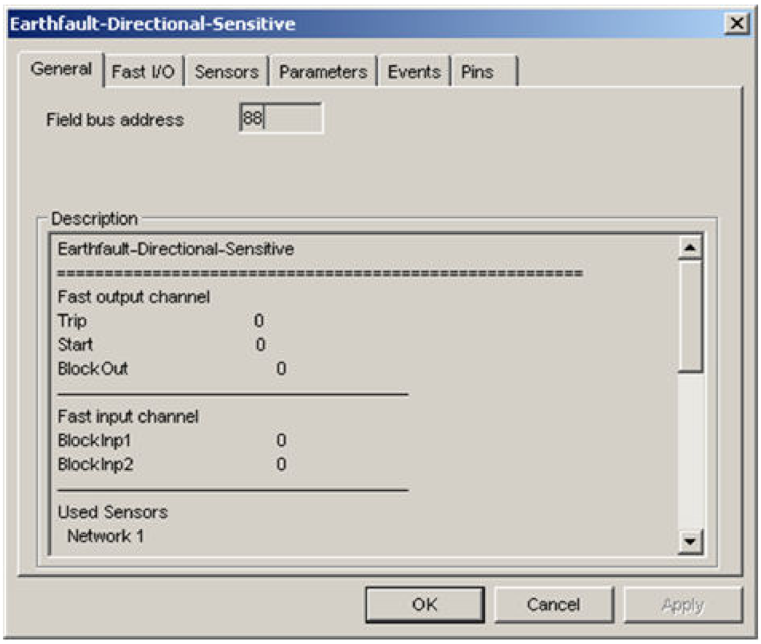


Figure 137: General

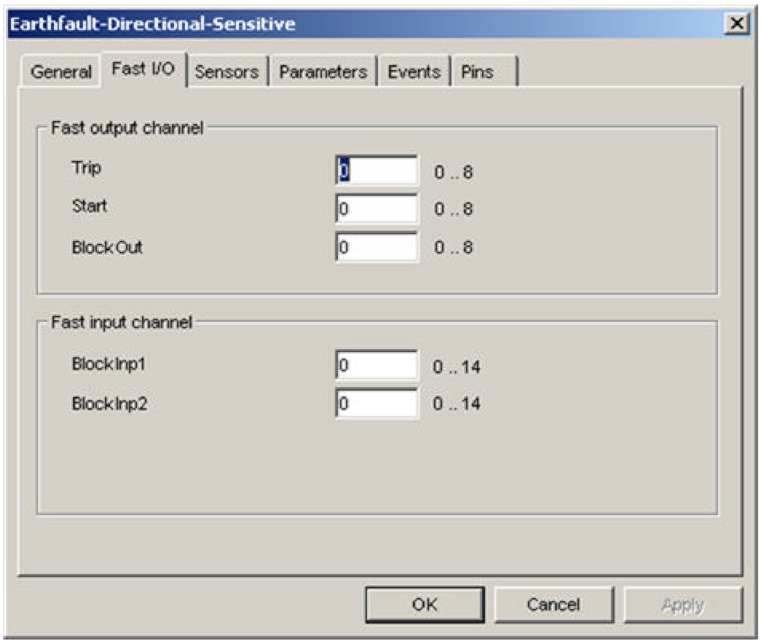


Figure 138: Fast I/O

Output Channel different from 0 means a direct execution of the trip, start or block output command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

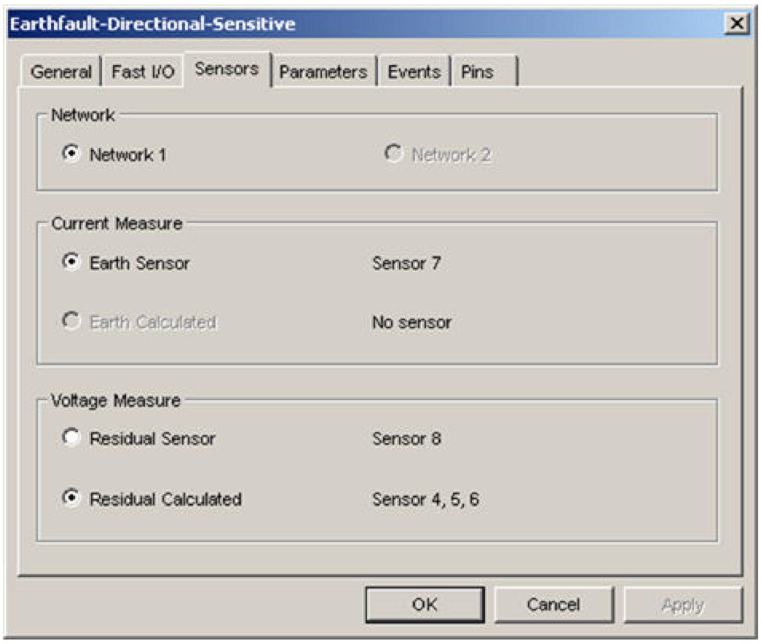


Figure 139: Sensors

The protection functions can operate on neutral current and residual voltage quantities.

The neutral current I0 is acquired through the dedicated transformer in order to have the proper precision. The residual voltage U0 can be either measured through a dedicated sensor or calculated from the voltage phase components in a triple.

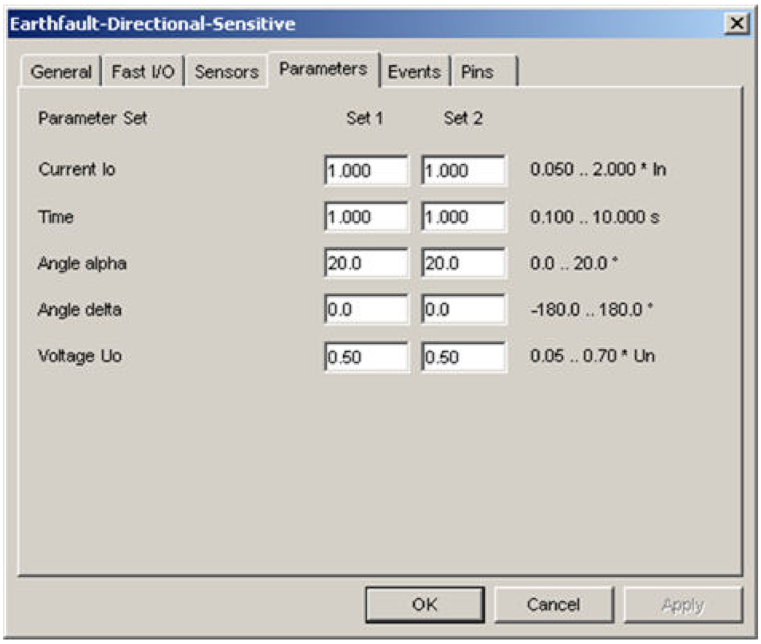


Figure 140: Parameters

Current I0	Current threshold for dir. earth fault condition detection
Time	Time delay for dir. earth fault Trip condition detection
Angle alpha	Parameter to improve the discrimination of the directional decision
Angle delta	Angle between U0 vector and the direction of maximum sensitivity
Voltage U0	Residual or neutral voltage threshold

The convention used to define Trip or Block area with respect to residual voltage U0 vector is described in the following, based on the typical connection diagram of current and voltage transformers for a generic feeder.

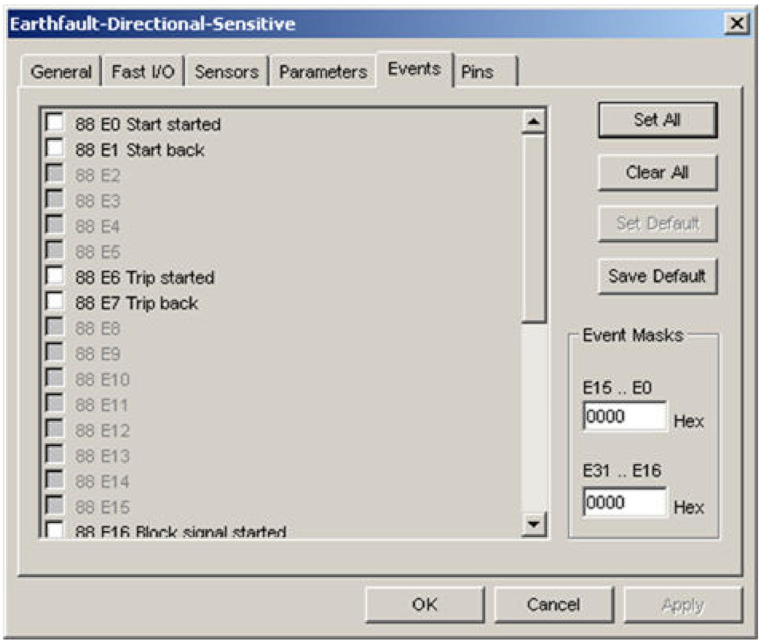


Figure 141: Events

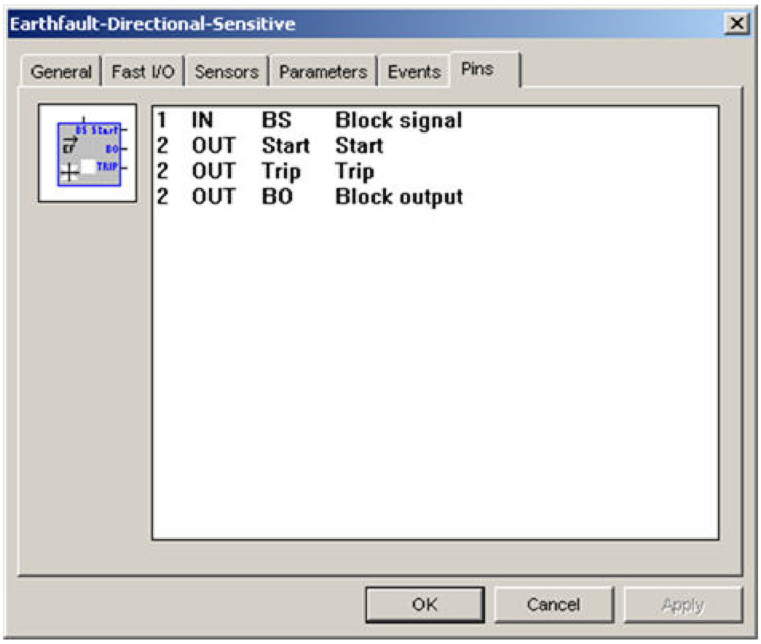


Figure 142: Pins

5.1.13.3 Measurement mode

Sensitive earth fault direction protection function evaluates the amount of residual current I_0 and voltage U_0 at the fundamental frequency. All sub harmonic disturbing signals down to 1/3 of the fundamental frequency is completely filtered out.

5.1.13.4 Operation criteria

If both the following conditions are true, the protection function is started.

- Residual voltage value is above the preset threshold (voltage U0).
- Neutral current value is in the trip area of the protection function.

If the condition of the voltage U0 is true, but the neutral current value is in the block area, the protection function remains idle and the Block Output signal becomes active. When the neutral current value is in the passive area both the Start and Block signals are inactive.

The protection function will come back in passive status and the start signal will be cleared if the neutral current OR residual voltage value fall below 0.95 the setting threshold value.

After the protection has entered the start status and the preset operating time (*Time*) has elapsed, function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the neutral current OR residual voltage value fall below 0.4 the setting threshold value. To ensure the required sensitivity and discrimination for the earth fault detection, in its implementation in REF 542plus the operating characteristic is formed with additional adjustability. The following diagram shows the shape of the operating characteristic.

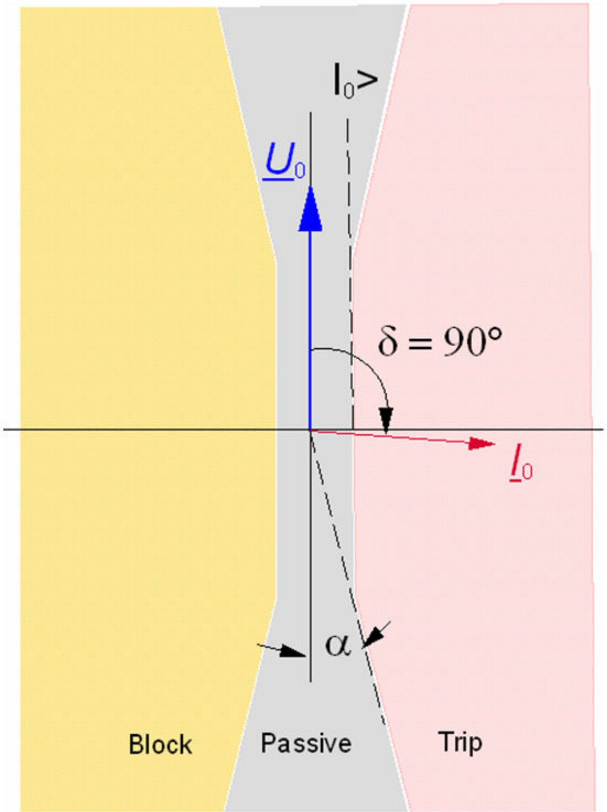


Figure 143: Operating characteristic of the earth fault directional sensitive protection for isolated network (φ = 90°)

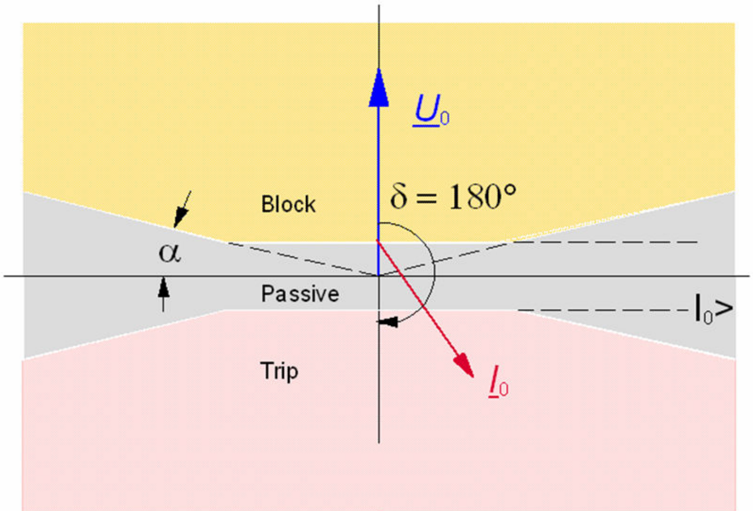


Figure 144: Operating characteristic of the earth fault directional sensitive protection for earthed network (φ = 180°)

The value of δ (that is Angle delta between U0 vector and the direction of maximum sensitivity) can be configured in the range from -180° to 180°. This provides the option of using the earth fault directional sensitive protection for every type of network grounding situation. Assuming that the connection is done according to the recommended connection diagram, the setting can be selected as follows:

- $\delta = 90°$ for isolated network
- $\delta = 180°$ for earth fault compensated or resistance earthed network.

The “significant” component of neutral current is its projection on the direction of maximum sensitivity. Neutral current value is in the trip or block area when the “significant” component exceeds the setting threshold value (*Current I0*).

The other parameter α, that is, *Angle alpha*, is used to improve the discrimination of the directional decision.

5.1.13.5 Setting groups

Two parameter sets can be configured for the sensitive directional earth-fault protection function.

5.1.13.6 Parameters and events

Table 60: Setting values

Parameter	Values	Unit	Default	Explanation
Current I0	0.05...2.00	In	1.00	Earth fault current threshold
Time	115...10000	ms	1000	Operating Time between start and trip
Angle alpha	0.0...20.0	°	20.0	Discrimination of the directional decision
Angle delta	-180.0...180.0	°	0.0	Angle between U0 and maximum sensitivity direction
Voltage U0	0.05...0.70	Un	0.50	Neutral or residual voltage threshold

Table 61: Events

Code	Event reason
E0	Protection is start
E1	Start is cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive
E16	Block output is active
E17	Block output is back to inactive
E18	Protection block is active
E19	Protection block is back to inactive

By default all events are disabled.

5.1.14 Sector directional earth fault protection

REF 542plus can install up to 10 sector directional earth fault protection functions (67N Sector). The value of *Sector Angular Width* (that is Angle $\Delta\varphi$ between U0 vector and the direction of maximum sensitivity) can be configured in the range from -180° to 180°. This provides the option of using the sector directional earth fault protection for every type of network grounding situation (isolated, earthed or compensated).

With respect to the sensitive directional earth fault protection function (67N Sensitive), the 67N Sector protection enables:

- Multiple instances (1…10 different stages)
- Fully configurable sensor interface, enabling I0 and U0 quantities to be directly acquired through dedicated transformers or calculated from the current/voltage phase components
- Direction enable/disable configuration, it can be used as earth fault (non-directional) protection
- Start criteria based on neutral current Magnitude or Basic Angle to set the maximum sensitivity direction at a user defined angle *Sector Basic Angle*.
- Angular sector Trip area configurable by a user defined angle. *Sector Angular Width*.
- Neutral current and residual voltage configurable *Start Drop-off delays* to enable stable protection operation during transients, as in the presence of intermittent arcing phenomena.

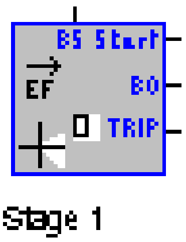


Figure 145: Sector directional earth fault protection

5.1.14.1 Input/output description

Table 62: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 63: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal
BO	Digital signal (active high)	Block output signal

The START signal will be activated when the measured residual voltage exceeds the setting threshold value (*Voltage Uo*) and the neutral current is in the specified Trip sector.

The TRIP signal will be activated when the start conditions are true and the operating time (*Time*) has elapsed.

The Block Output (BO) signal becomes active when the protection function detects residual voltage and neutral current exceeding the preset values, but the fault (neutral current) is in the block area (opposite to the specified direction, *Sector Basic Angle*).

5.1.14.2 Configuration

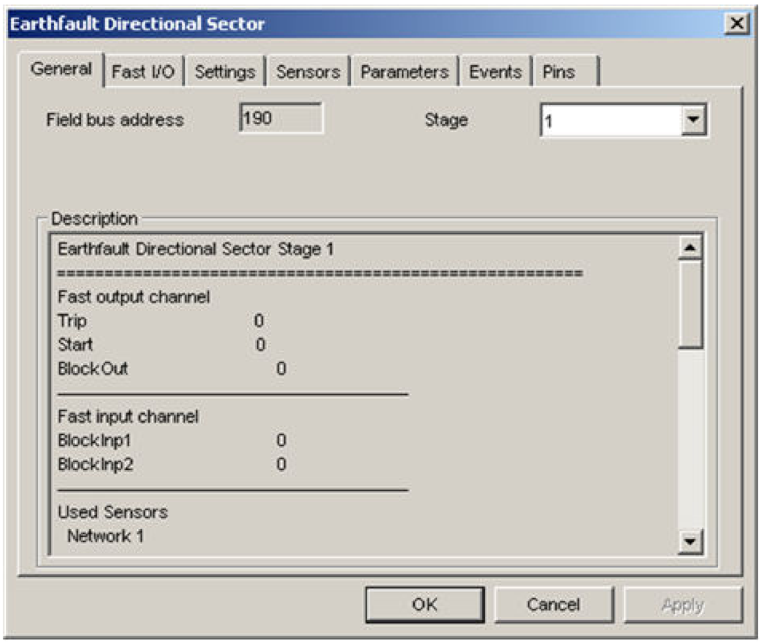


Figure 146: General

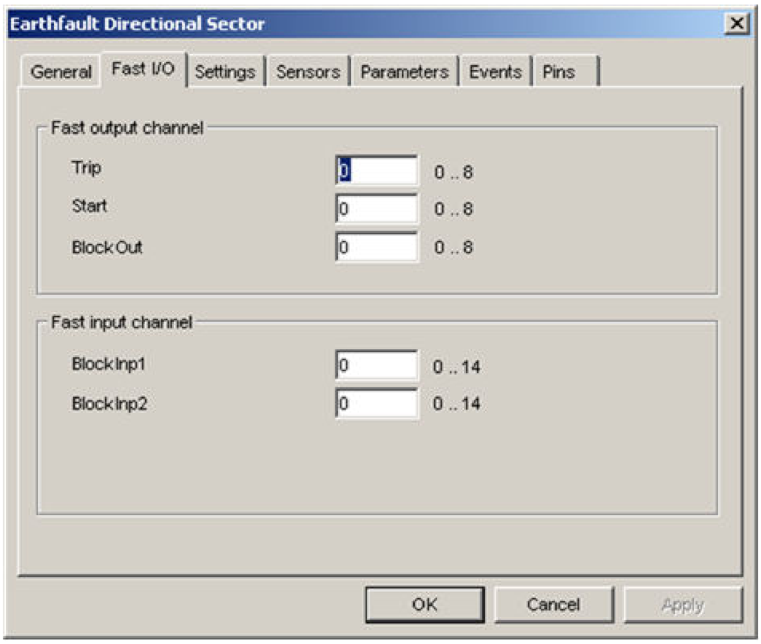


Figure 147: Fast I/O

Output channel different from 0 means a direct execution of the trip, start or block output command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

Stage order can be reassigned with the Stage drop-down list in the General tab.

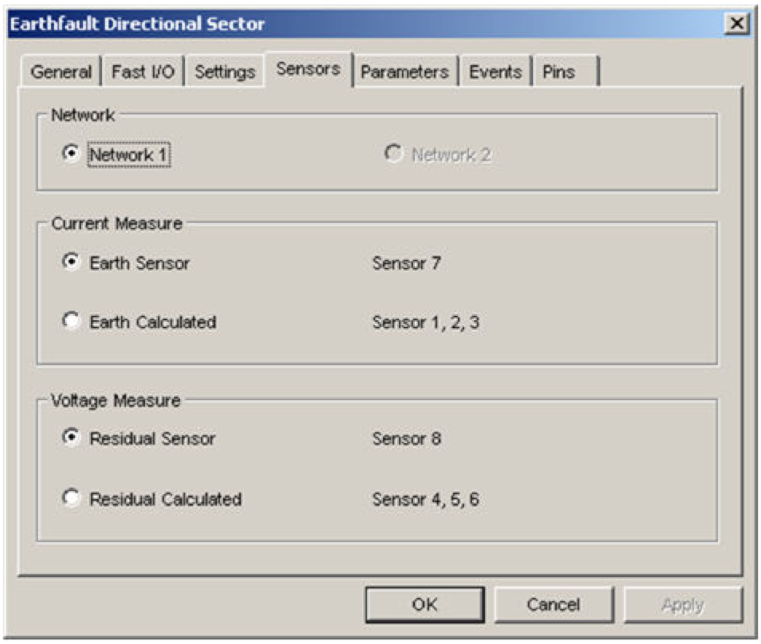


Figure 148: Sensors

The protection functions can operate on neutral current and residual voltage quantities.

The neutral current I0 and the residual voltage U0 can be either measured through a dedicated sensor or calculated from the current and voltage phase components in a triple.

In order to assure the proper precision the Start values settings are evaluated in the in the Parameters tab taking into account the whole analog input acquisition chain. A warning is issued if the preset threshold does not satisfy this check.

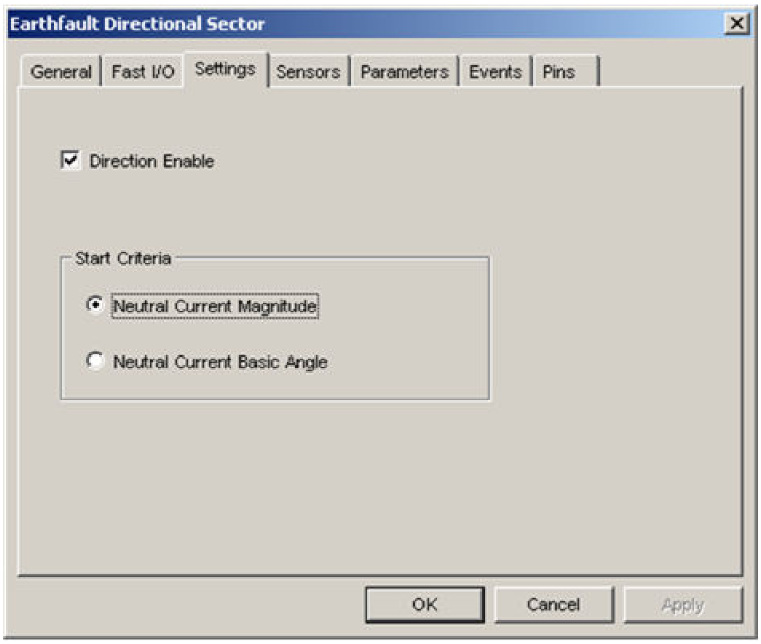


Figure 149: Settings

The Settings tab provides the main options for the operation of the protection:

- The Direction Enable checkbox provides the option of deactivating the directional criteria. When it is not checked, the protection behaves as earth fault (non-directional) protection and all the parameters relevant to the sector are disabled. Only the Current Start Drop-off option is still available.
- The Start Criteria options enable to select between two different criterion on how to monitor the neutral current I0. The diagrams below show how this feature works:
    - *Neutral Current magnitude*, when selected, the measured magnitude of the neutral current phasor is compared to the preset threshold I_{0s} (*Neutral Current Start Value*).
    - *Neutral Current Basic Angle*, when selected, the component I_{0b} of the measured neutral current phasor in the direction of the Basic Angle φ_b

(direction of maximum sensitivity) is compared to the preset threshold I_{0s} (*Neutral Current Start Value*).

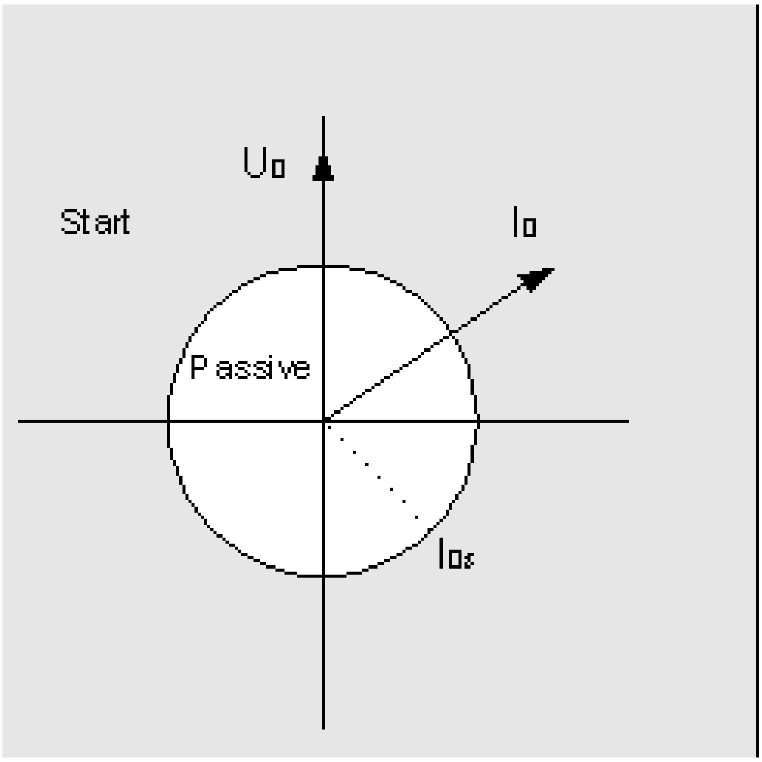


Figure 150: Neutral Current Magnitude

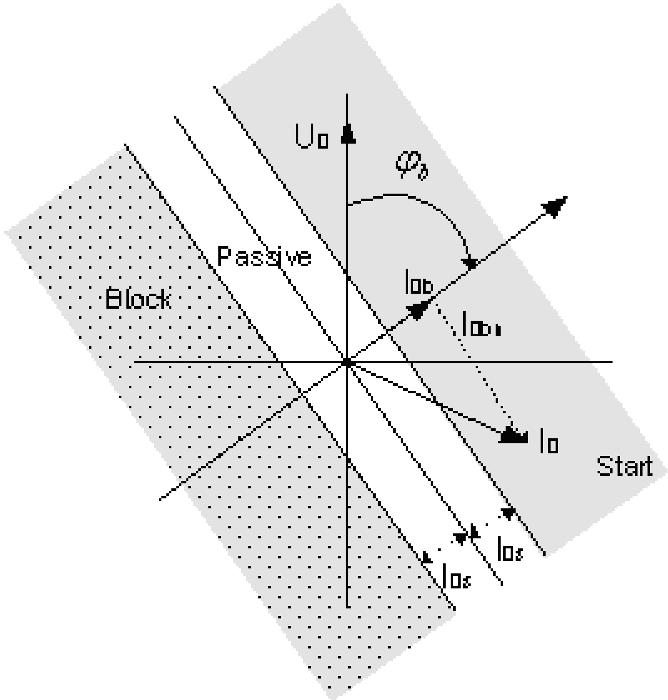


Figure 151: Neutral Current Basic Angle behavior

The “significant” component of neutral current is its projection I_{0b} on the direction of maximum sensitivity φ_b. Neutral current value may enter the trip or block area when the “significant” component exceeds the setting threshold value (*Neutral Current Start Value*).

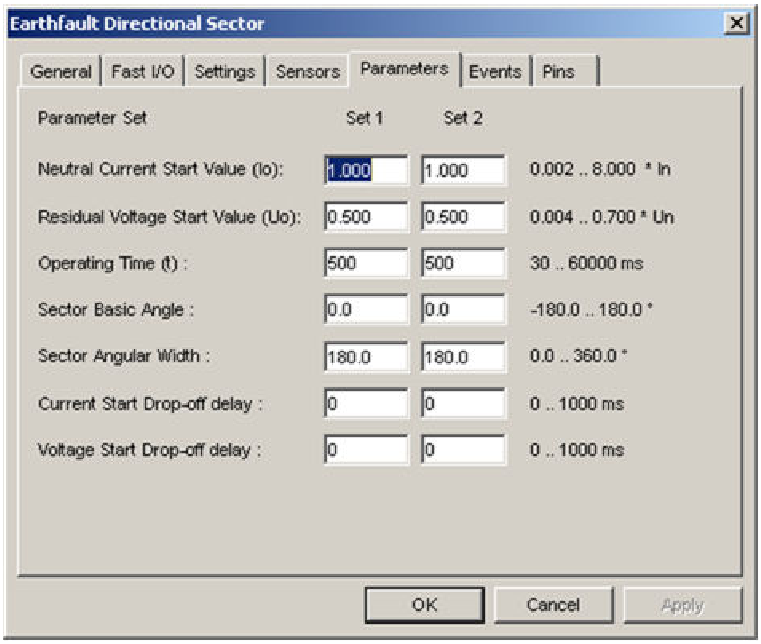


Figure 152: Parameters

Neutral Current Start Value (I0)	Current threshold for directional earth-fault condition detection
Residual Voltage Start Value (U0)	Voltage threshold for directional earth-fault condition detection
Operating Time (t)	Time delay for dir. earth-fault Trip condition detection
Sector Basic Angle	Angle φ_b between U0 vector and the bisector (direction of maximum sensitivity)
Sector Angular Width	Angle defining the angular Trip area (sector)
Current Start Drop-off delay	Delay to the reset of Start condition with intermittent earth-fault current
Voltage Start Drop-off delay	Delay to the reset of Start condition with intermittent residual voltage

Angles are referenced to the voltage phasor U_0 in a clockwise convention.

The convention used to define Trip or Block area with respect to residual voltage U0 vector is described in the following, based on the typical connection diagram of current and voltage transformers for a generic feeder.

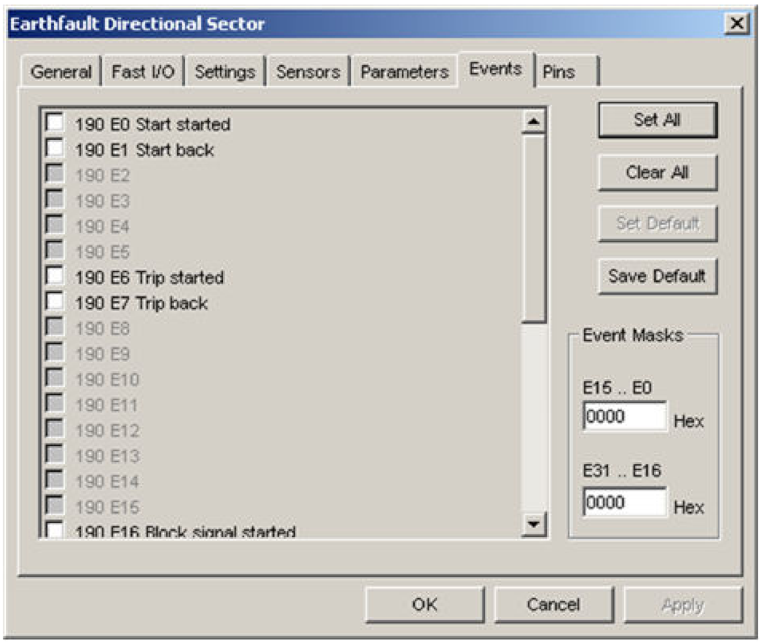


Figure 153: Events

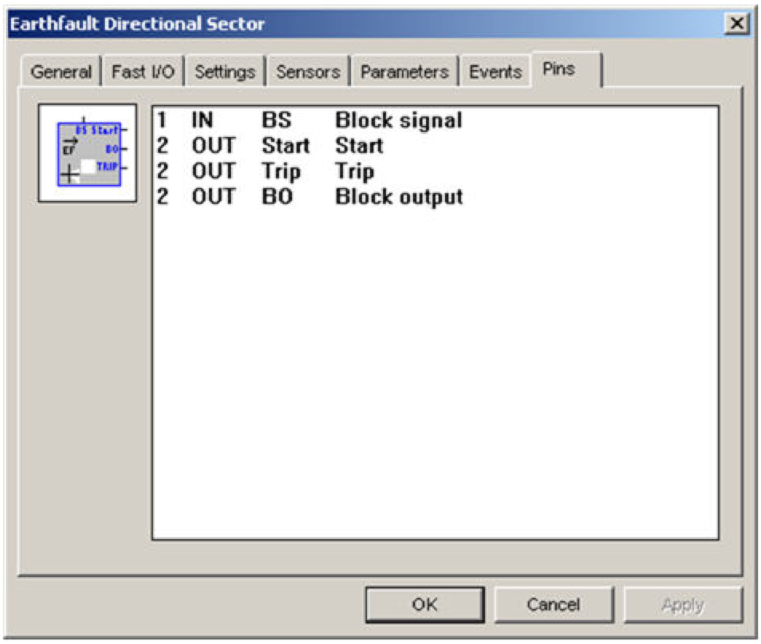


Figure 154: Pins

5.1.14.3 Measurement mode

Sector directional earth fault protection function evaluates the amount of residual current I_0 and voltage U_0 at the fundamental frequency.

5.1.14.4 Operation criteria

When the directional criteria is not active (*Direction Enable*; checkbox NOT checked) in the following description only the condition on neutral current value magnitude is evaluated (that is, compared with setting threshold value *Neutral Current Start Value*).

If both the following conditions are true, the protection function is started.

- Residual voltage value is above the preset threshold (that is, Residual Voltage Start Value U0).
- Neutral current phasor is in the trip area (sector) of the protection function.

If the condition of the voltage U0 is true but the neutral current phasor is in the block area, the protection function remains idle and the Block Output signal becomes active. When the neutral current phasor is in the passive area both the Start and Block signals are inactive.

The protection function will come back in passive status and the start signal will be cleared (when both Current Start Drop-off time and Voltage Start Drop-off time are zero and therefore inactive) if the neutral current or residual voltage value fall below 0.95 the setting threshold value or the neutral current phasor exits the activation area (Trip or Block area).

After the protection has entered the start status and the preset operating time (*Time*) has elapsed, function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the neutral current or residual voltage value fall below 0.4 the setting threshold value or the Neutral current phasor exits the activation area.

5.1.14.5 Trip and Block areas

To ensure the required sensitivity and discrimination for the earth fault detection, in its implementation in REF 542plus the operating characteristic is formed with additional adjustability.

The following diagrams show the shape of the operating characteristic. The protection behaves differently depending on the Neutral Current Start Criteria selected.

If *Neutral Current magnitude Start Criteria* is selected, the trip area and the block area are 360° complementary, the passive area is the circle of preset threshold radius (that is, *Neutral Current Start Value*).

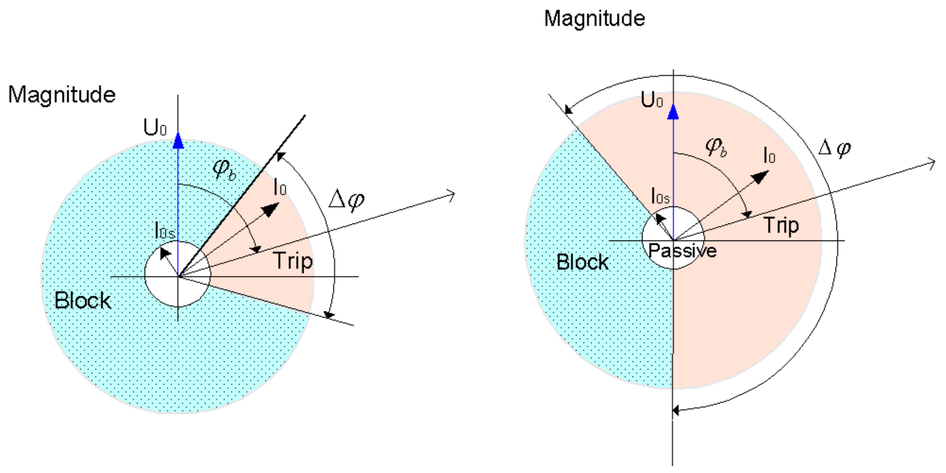


Figure 155: Operating characteristic of the sector directional earth fault protection function, Neutral Current Magnitude

If *Neutral Current Basic Angle Start Criteria* is selected, the behavior is dependent on the angle Δφ defining the angular Trip area (*Sector Angular Width*).

- Δφ < 180°, the block area corresponds to the semiplane opposite to the trip area.
- Δφ < 180°, the trip area is limited to 180°, the block area is 360° complementary to the preset Sector Angular Width Δφ, the passive area around includes parts of the Sector Angular Width in the plane opposite to the trip area.

Due to directionality of the criterion, no Neutral current phasor even if exceeding preset threshold value with component I_{0b}, "significant" component of neutral current projected on the direction of maximum sensitivity φ_b, opposite to φ_b can start the protection function.

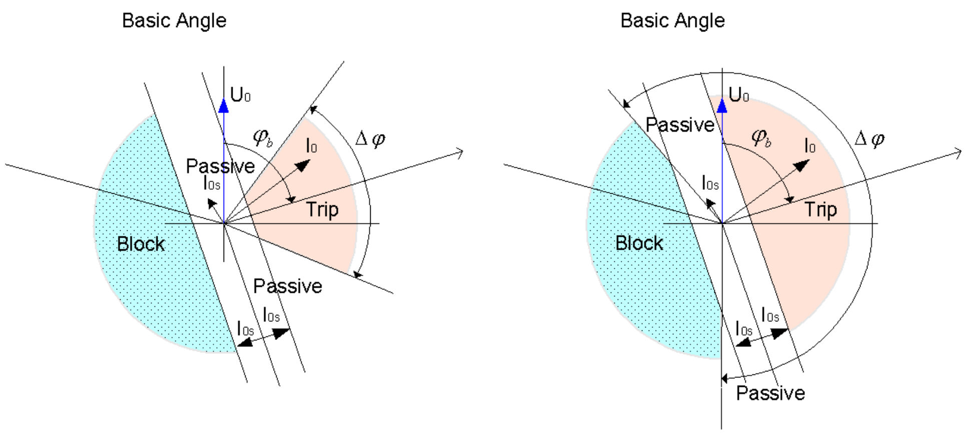


Figure 156: Operating characteristic of the sector directional earth fault protection function, Neutral Current Basic Angle

The start criteria (Magnitude Vs. Basic Angle) changes significantly the shape of passive, block and trip areas.

5.1.14.6 Start drop-off delay function

To ensure the required sensitivity and discrimination for the earth fault in order to avoid flickering of the Start signal in case of intermittent currents and voltages two drop-off delay timers have been provided to delay the reset of the start status.

If the drop-off delay timer is active (t>0), the protection function will not come back in passive status and the start signal will not be cleared when the relevant Start condition falls below 0.95 the setting threshold.

Thus, after the protection has entered the start status the start status is sustained. After the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated if the start status is still sustained and the start conditions are again verified.

If the voltage Start drop-off time is set to a value different from zero when the residual voltage drops-off (Uo falls below 0.95 the setting threshold value) the start status will be reset after the voltage start drop-off time is elapsed. If voltage is lacking for a time interval shorter than voltage start drop-off time the start output will not be affected by the voltage shortage.

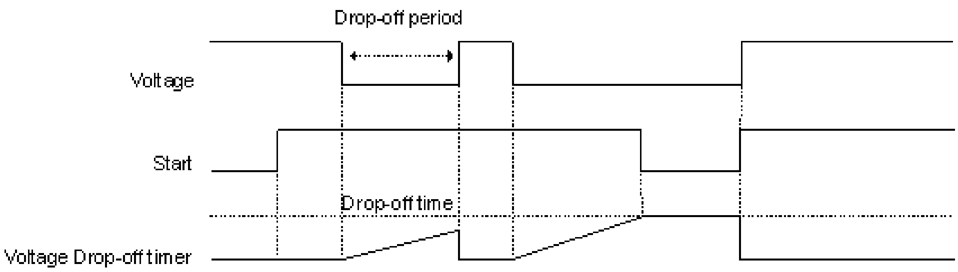


Figure 157: Voltage Delayed Start Drop-Off

Similarly, if the current start drop-off time is set to a value different from zero when the neutral current phasor drops-off (exit the trip area) the start status will be reset after the current start drop-off time is elapsed. If the neutral current phasor stays out of the activation area for a time shorter than current start drop-off time the Start output won’t be affected.

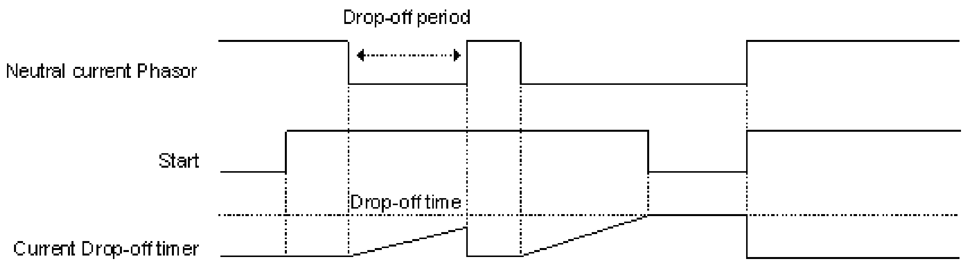


Figure 158: Current delayed start drop-off

5.1.14.7 Setting groups

Two parameter sets can be configured for the sector directional earth fault protection function.

5.1.14.8 Parameters and events

Table 64: Setting values

Parameter	Values	Unit	Default	Explanation
Neutral current start value I0	0.002...8.00	In	1.000	Earth fault current threshold
Residual voltage start value U0	0.004...0.700	Un	0.500	Residual voltage threshold
Operating time t	30...60000	ms	500	Operating time between start and trip
Sector basic angle	-180.0...180.0	°	0.0	Angle between U0 and maximum sensitivity direction
Sector angular width	0.0...360.0	°	360.0	Angle defining the angular Trip area
Current start drop/off delay	0…1000	ms	0	Start reset delay for intermittent current I0
Voltage start drop/off delay	0…1000	ms	0	Start reset delay for intermittent voltage U0

Table 65: Events

Code	Event reason
E0	Protection is start
E1	Start is cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive
E16	Block output is active
E17	Block output is back to inactive
E18	Protection block is active
E19	Protection block is back to inactive

By default all events are disabled.

5.2 Voltage protection

5.2.1 Overvoltage protection

There are three overvoltage definite time protection functions in REF 542plus, which can be independently activated and parameterized. See the following figures.

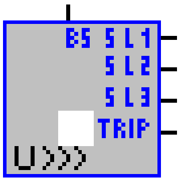


Figure 159: Overvoltage instantaneous

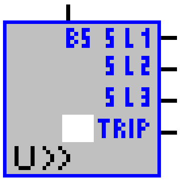


Figure 160: Overvoltage high

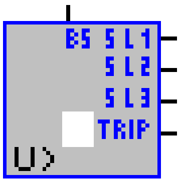


Figure 161: Overvoltage low

5.2.1.1 Input/output description

Table 66: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 67: Outputs

Name	Type	Description
S L1	Digital signal (active high)	Start signal of IL1
S L2	Digital signal (active high)	Start signal of IL2
S L3	Digital signal (active high)	Start signal of IL3
TRIP	Digital signal (active high)	Trip signal

S L1, S L2 and S L3 are the phase selective start signals. The phase starting signal will be activated when the respective phase (line) voltage start conditions are true (voltage exceeds the setting threshold value).

The TRIP signal will be activated when at least for a phase voltage the start conditions are true and the operating time has elapsed.

5.2.1.2 Configuration

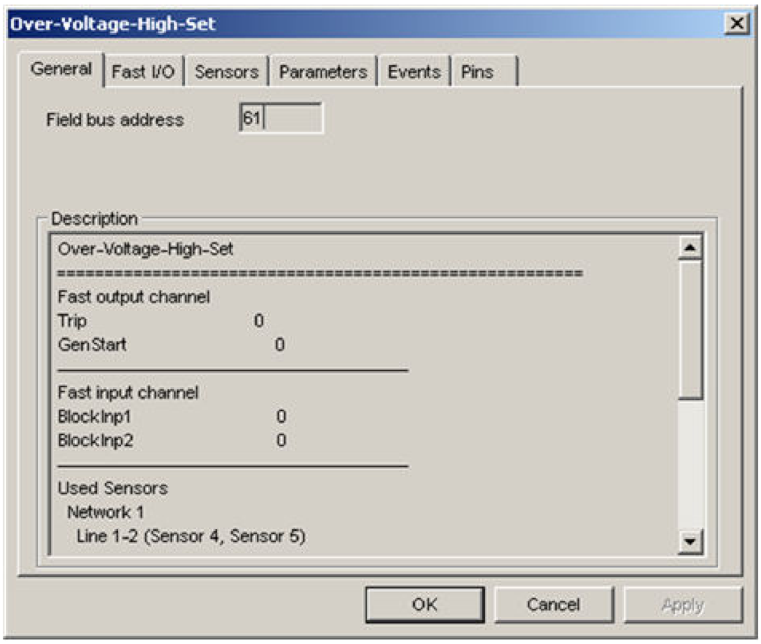


Figure 162: General

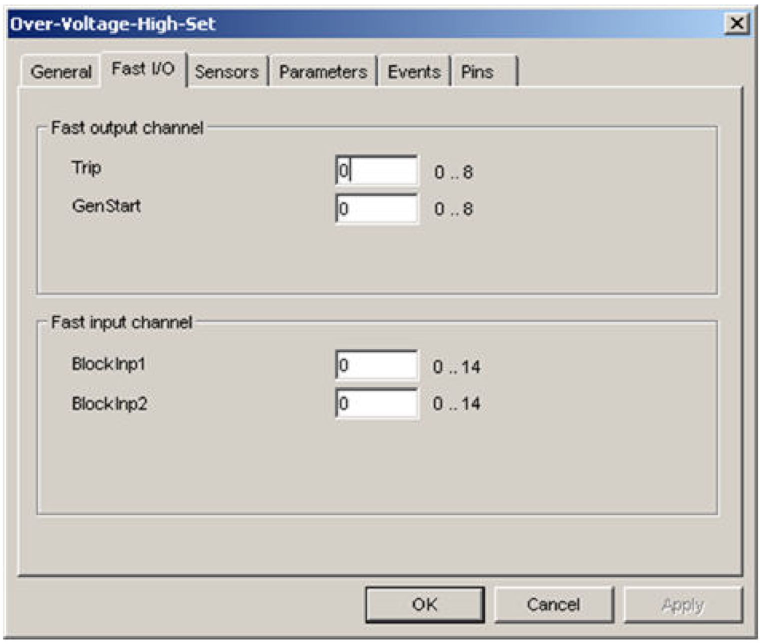


Figure 163: Fast I/O

Output Channel different from 0 means a direct execution of the trip or start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

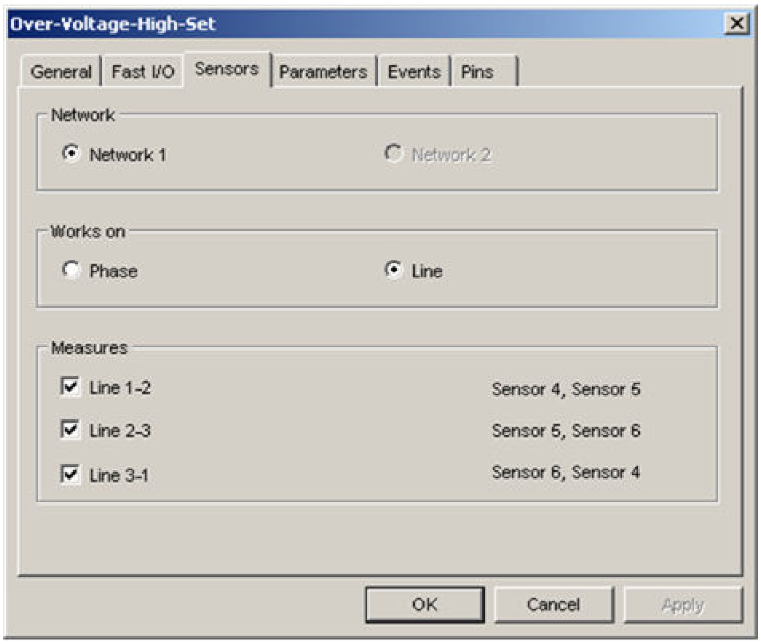


Figure 164: Sensors

The protection functions can operate on any combination of phase (or line) voltages in a triple, for example, it can operate as single phase or double phase, three-phase protection on voltages belonging to the same system.

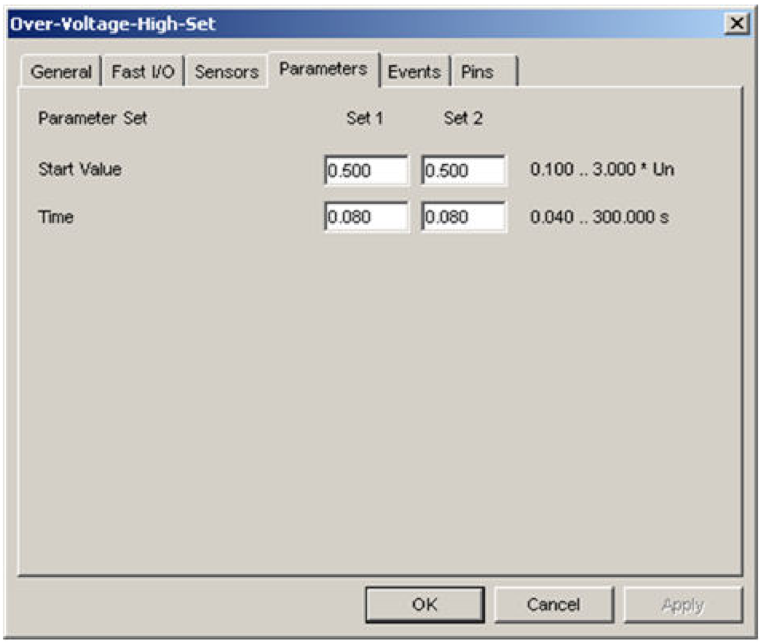


Figure 165: Parameters

Start Value	Voltage threshold for overvoltage condition detection
Time	Time delay for overvoltage Trip condition detection

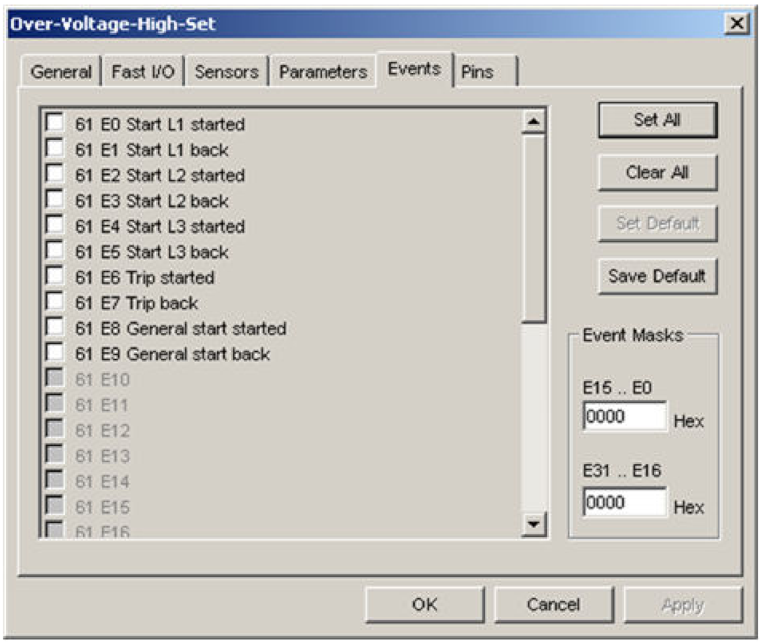


Figure 166: Events

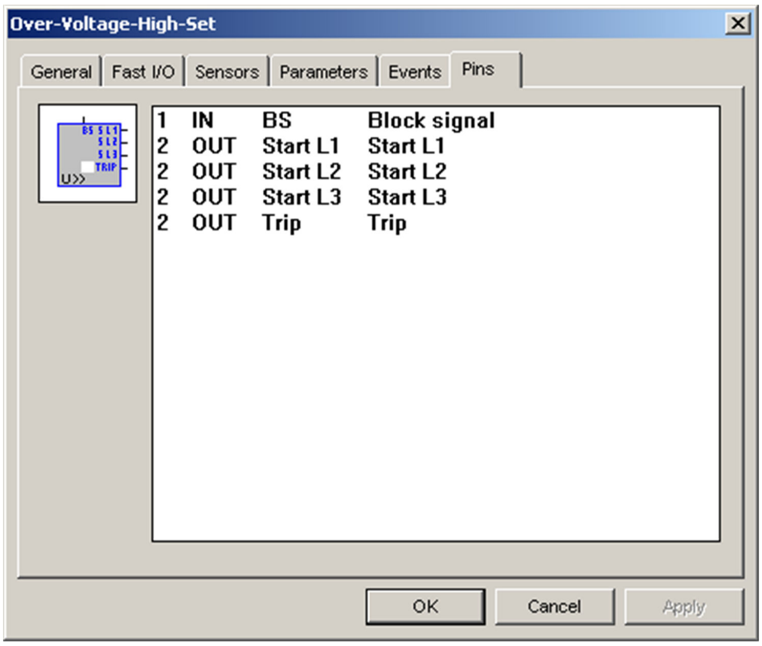


Figure 167: Pins

5.2.1.3 Measurement mode

Overvoltage protection functions evaluate the phase or line voltage RMS value at the fundamental frequency.

5.2.1.4 Operation criteria

If the measured voltage exceeds the setting threshold value (*Start Value*), the overvoltage protection function is started. The start signal is phase selective. It means that when at least the value of one phase voltage is above the setting threshold value the relevant start signal will be activated.

The protection function will remain in START status until there is at least one phase started. It will come back in passive status and the start signal will be cleared if for all the phases the voltage falls below 0.95 the setting threshold value. After the protection has entered the start status and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured voltage value falls below 0.4 the setting threshold value.

The overvoltage protective functions, like the overcurrent protective functions, are used in a time graded coordination. An example of grading is shown in the following diagram.

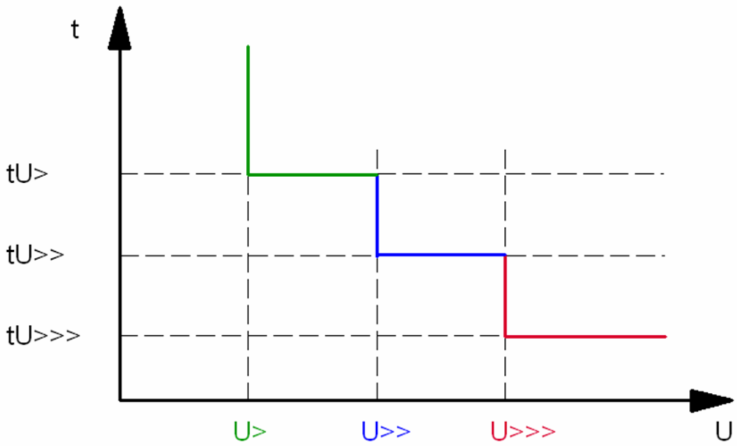


Figure 168: Overvoltage response grading.

5.2.1.5 Setting groups

Two parameter sets can be configured for each of the overvoltage protection functions.

5.2.1.6 Parameters and events

Table 68: Setting values

Parameter	Values	Unit	Default	Explanation
Start Value U>, U>>	0.1...3.00	Un	0.50	Voltage threshold for Start condition detection
Time	40...300000	ms	80	Time delay for Trip condition
Start Value U>>>	0.1...3.00	Un	0.50	Voltage threshold for Start condition detection
Time	15...300000	ms	80	Time delay for Trip condition

Table 69: Events

Code	Event reason
E0	Protection start on phase L1
E1	Start on phase L1 cancelled
E2	Protection starton phase L2
E3	Start on phase L2 cancelled
E4	Protection start on phase L3
E5	Start on phase L3 cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E18	Block signal is active
E19	Block signal is back to inactive state

By default all events are disabled.

5.2.2 Undervoltage protection

There are three undervoltage protection functions in REF 542plus, which can be activated and parameters set independently of one another. See the following figures.

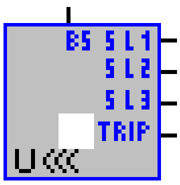


Figure 169: Undervoltage instantaneous

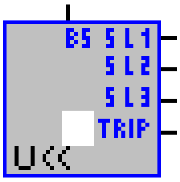


Figure 170: Undervoltage high

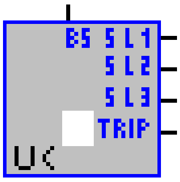


Figure 171: Undervoltage low

5.2.2.1 Input/output description

Table 70: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the `BS` signal becomes active, the protection function is reset no matter its state. It means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the `BS` signal goes low.

Table 71: Outputs

Name	Type	Description
S L1	Digital signal (active high)	Start signal of IL1
S L2	Digital signal (active high)	Start signal of IL2
S L3	Digital signal (active high)	Start signal of IL3
TRIP	Digital signal (active high)	Trip signal

`S L1`, `S L2` and `S L3` are the phase selective start signals. The phase starting signal will be activated when respective phase (line) voltage start conditions are true (voltage falls below the setting threshold value).

The `TRIP` signal will be activated when at least for a phase voltage the start conditions are true and the operating time has elapsed.

5.2.2.2 Configuration

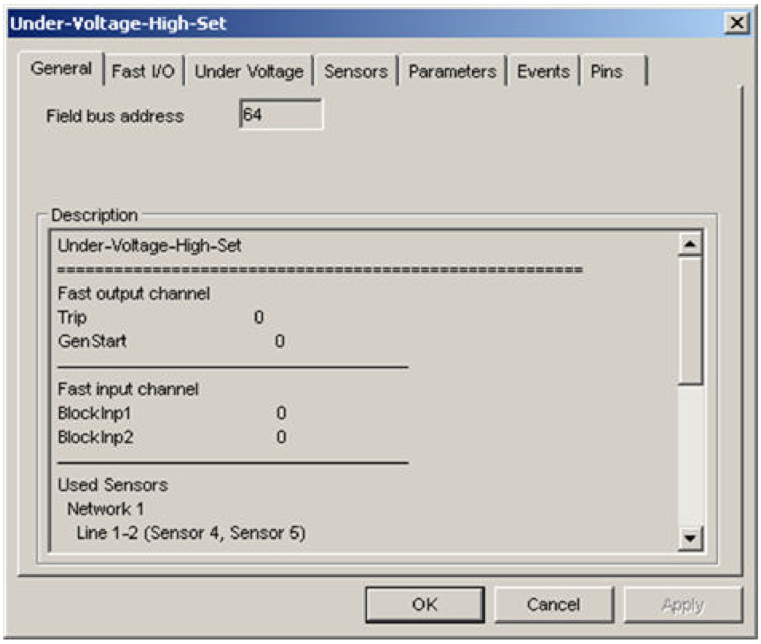


Figure 172: General

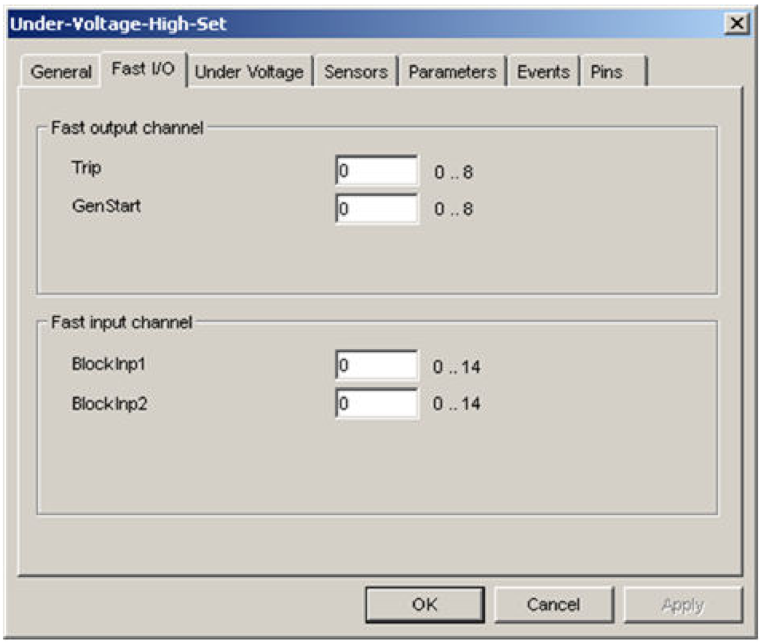


Figure 173: Fast I/O

Output Channel different from 0 means a direct execution of the trip or start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

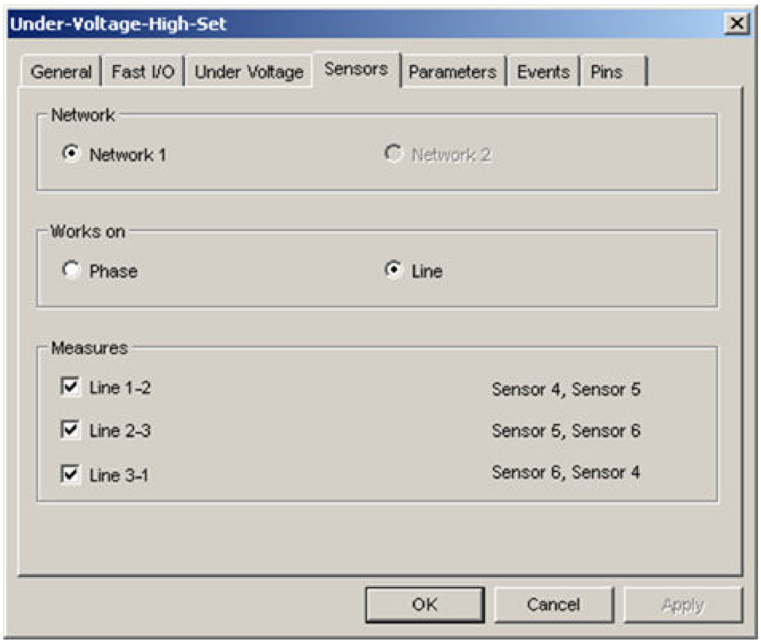


Figure 174: Sensors

The protection functions can operate on any combination of phase (or line) voltages in a triple, for example, it can operate as single phase, double phase or three-phase protection on voltages belonging to the same system.

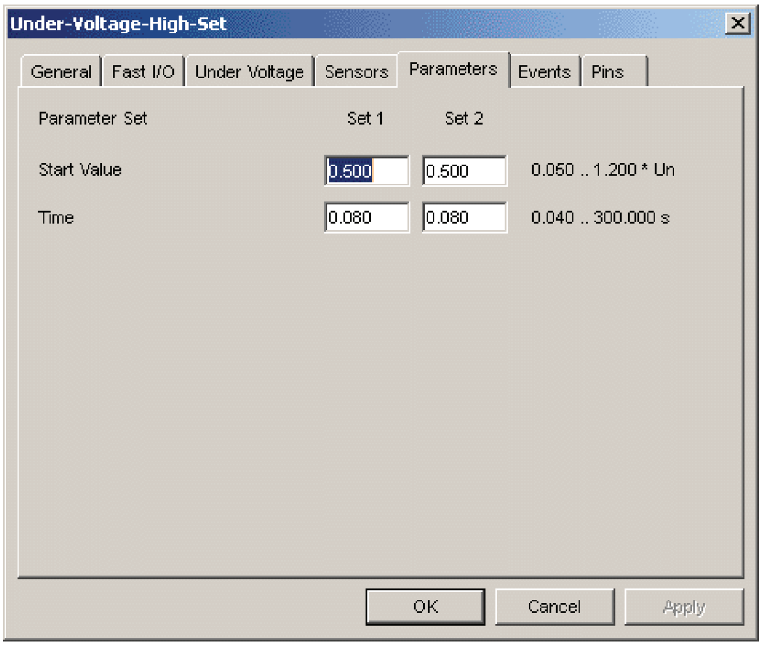


Figure 175: Parameters

Start Value	Voltage threshold for undervoltage condition detection
Time	Time delay for undervoltage Trip condition detection

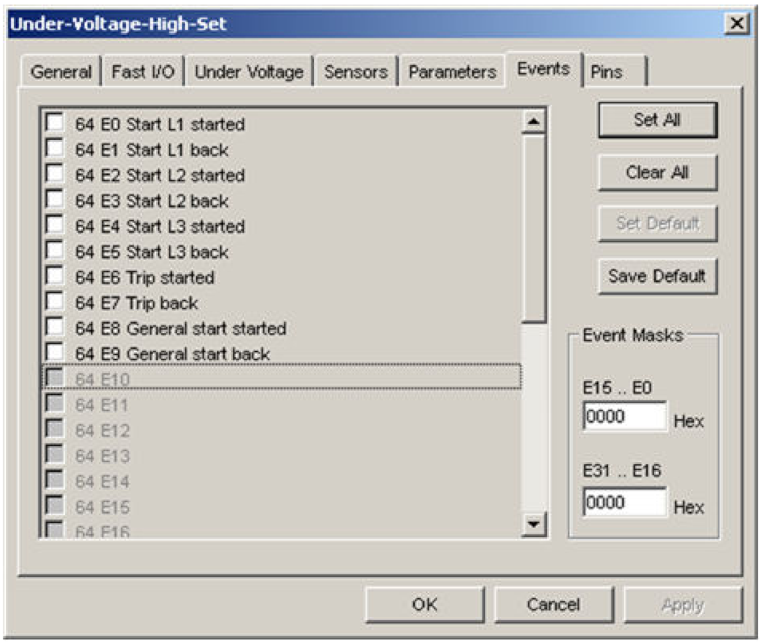


Figure 176: Events

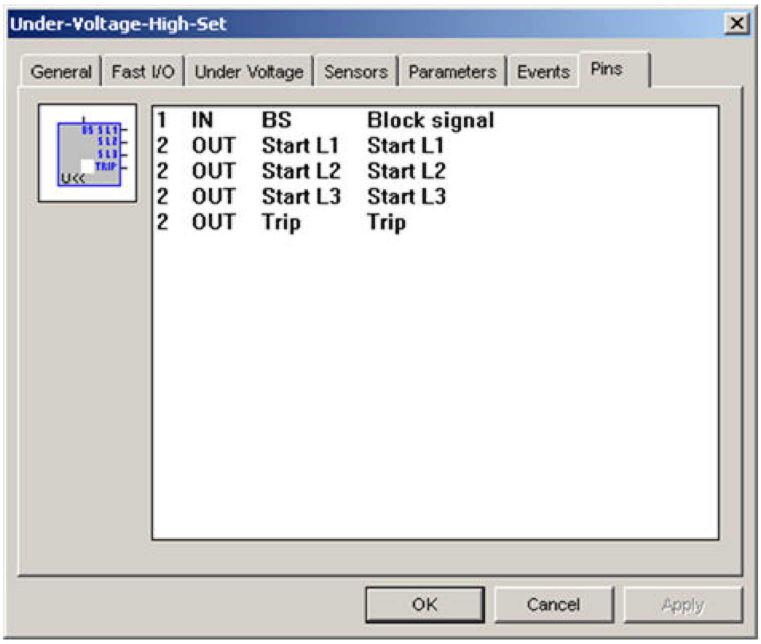


Figure 177: Pins

5.2.2.3 Measurement mode

Undervoltage protection functions evaluate the phase or line voltage RMS value at the fundamental frequency.

5.2.2.4 Operation criteria

If the measured voltage falls below the setting threshold value (*Start Value*), the undervoltage protection function is started. The start signal is phase selective. It means that when at least the value of one phase voltage is below the setting threshold value the relevant start signal will be activated.

The protection function will remain in START status until there is at least one phase started. It will come back in passive status and the start signal will be cleared, if for all the phases the voltage raises above 1.05 the setting threshold value. After the protection has entered the start status and the preset operating time (*Time*) has elapsed, function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured voltage value falls below 0.4 the setting threshold value.

The undervoltage protection functions are used in a graded coordination. An example of staging is shown in the following diagram.

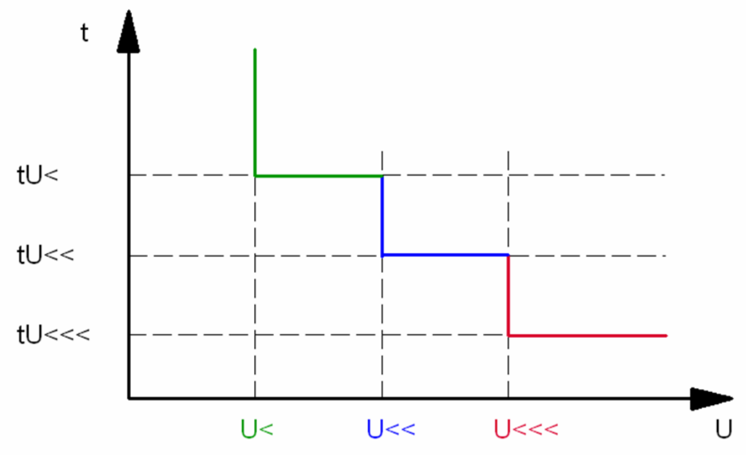


Figure 178: Undervoltage protection response stages

5.2.2.5 Behavior at low voltage values

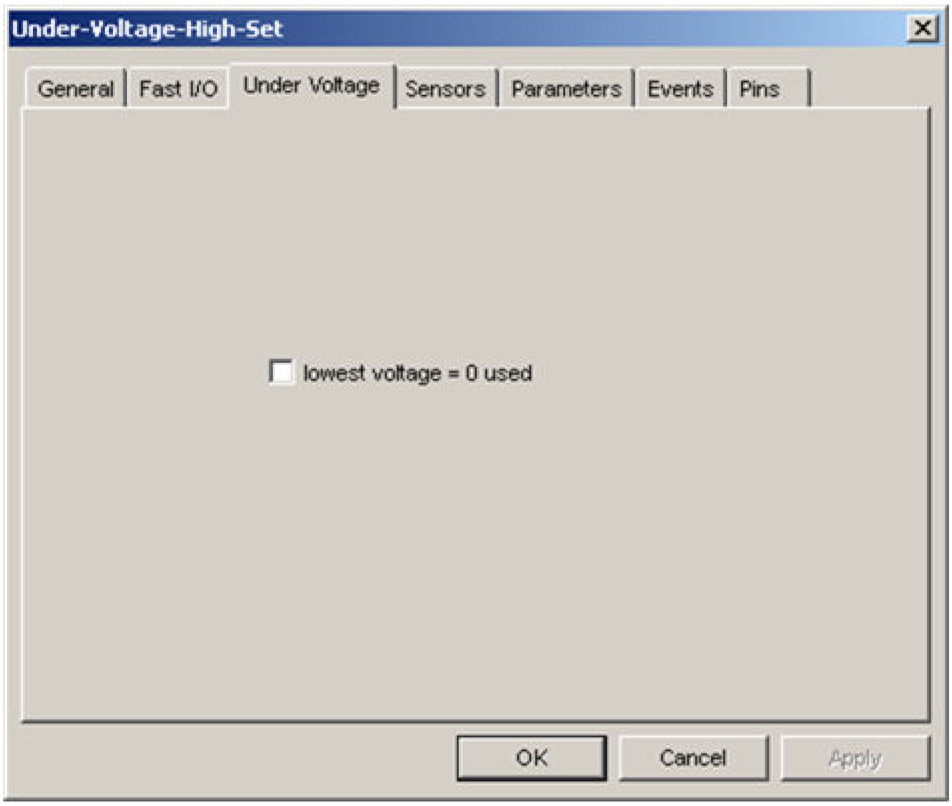


Figure 179: Under Voltage

Because a de-energized feeder has no voltage, an undervoltage protection function remains activated. It is not be possible then to switch the feeder on again.

Therefore, the Under Voltage tab provides the option of deactivating the undervoltage protection functions when the voltage is in the range 0 to 40% of the setting voltage threshold (*Start Value*).

The diagrams below shows how this feature works when the “lowest voltage = 0” flag is checked:

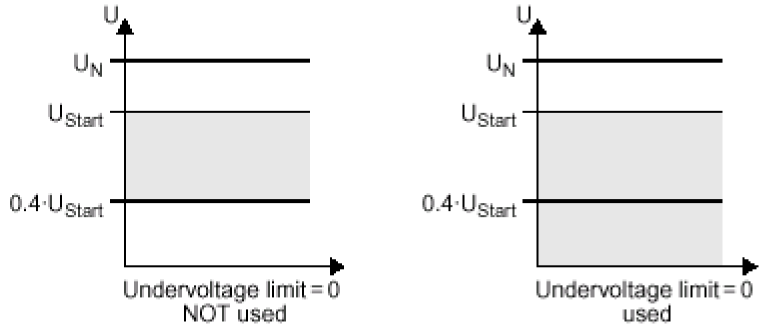


Figure 180: Configuration of the undervoltage limit = 0

If 40% is considered too high, the undervoltage function can also be blocked, for example, through the circuit-breaker auxiliary contact by connecting a signal (high at CB open) to the `BS` input pin inside FUPLA.

5.2.2.6 Setting groups

Two parameter sets can be configured for each of the undervoltage protection functions.

5.2.2.7 Parameters and events

Table 72: Setting values

Parameter	Values	Unit	Default	Explanation
lowest voltage = 0 used	used/not used	-	not used	When “used” the U< functions are active below the 0.4 Start Value
Start Value U<, U<<	0.05...1.20	Un	0.50	Voltage threshold for Start condition detection
Time	40...300000	ms	80	Time delay for Trip condition
Start Value U<<<	0.05...1.20	Un	0.50	Voltage threshold for Start condition detection
Time	15...300000	ms	80	Time delay for Trip condition

Table 73: Events

Code	Event reason
E0	Protection start on phase L1
E1	Start on phase L1 cancelled
E2	Protection start on phase L2
E3	Start on phase L2 cancelled
E4	Protection start on phase L3
E5	Start on phase L3 cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E18	Protection block signal is active state
E19	Protection block signal is back to inactive state

By default all events are disabled.

5.2.3 Residual overvoltage protection

There are two residual overvoltage protection functions in REF 542plus, which can be independently activated and parameterized. See the following figures.

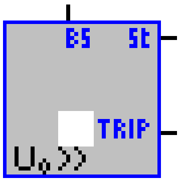


Figure 181: Residual overvoltage high

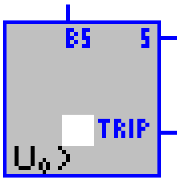


Figure 182: Residual overvoltage low

5.2.3.1 Input/output description

Table 74: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that, all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 75: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal

The START signal will be activated when the measured or calculated residual voltage exceeds the setting threshold value (*Start Value*).

The TRIP signal will be activated when the start condition is true and the operating time (*Time*) has elapsed.

5.2.3.2 Configuration

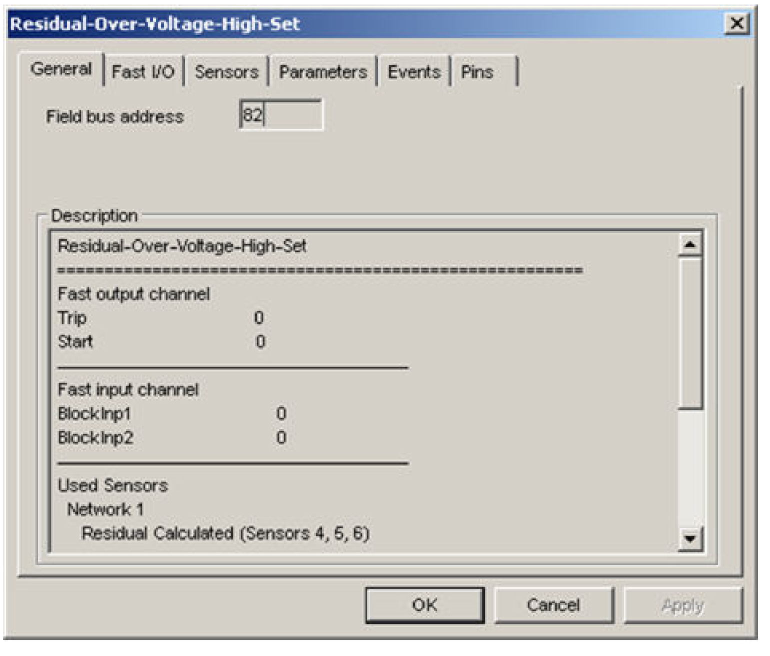


Figure 183: General

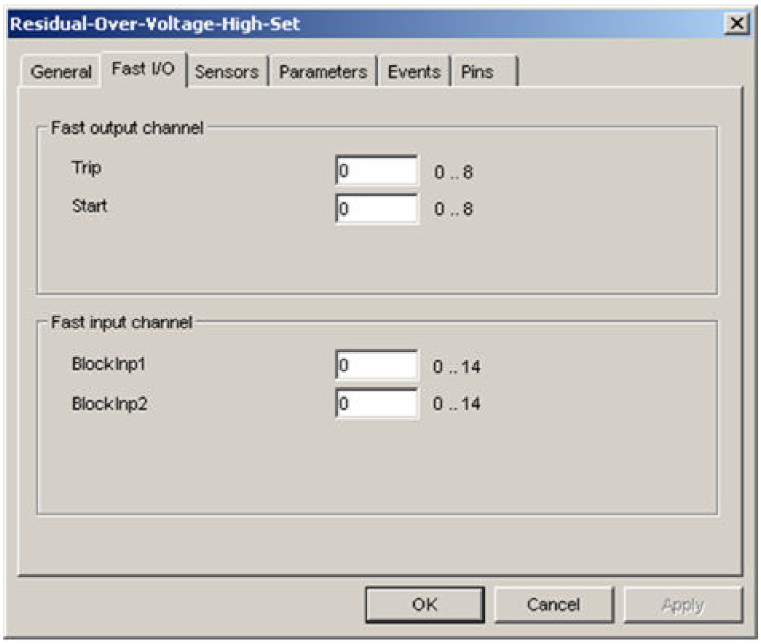


Figure 184: Fast I/O

Output Channel different from 0 means direct a execution of the trip or start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

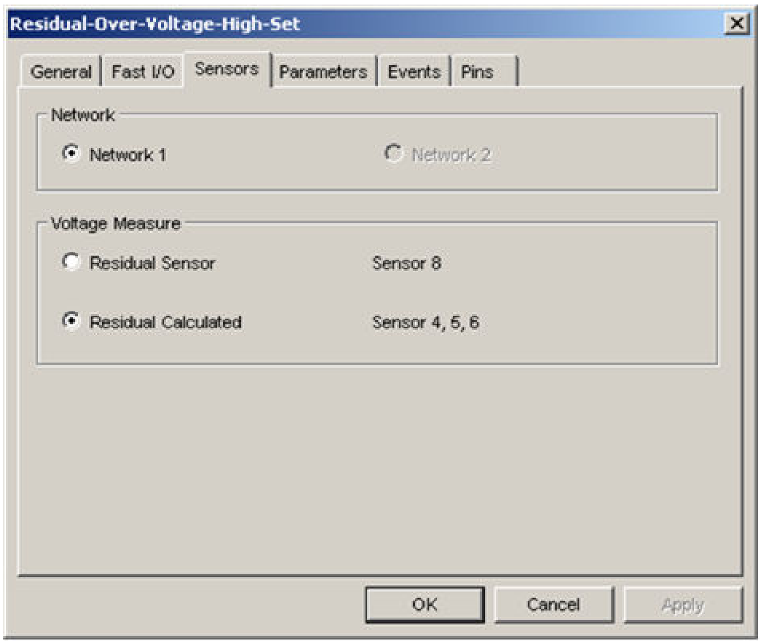


Figure 185: Sensors

The protection functions can operate on residual voltage measured through a dedicated sensor (for example, open delta connected voltage transformers) or calculated from the voltage phase (line) components in a triple.

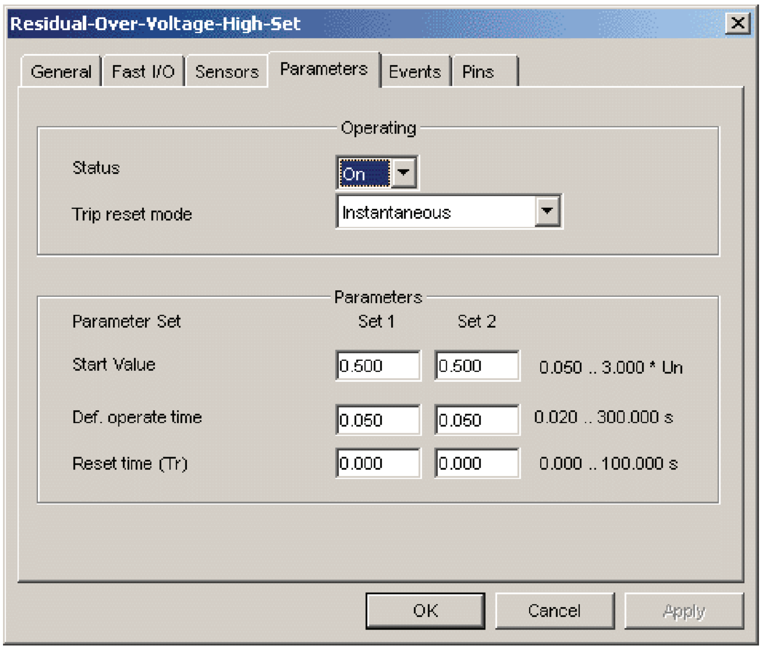


Figure 186: Parameters

Status	Setting for enabling/disabling the function
Trip reset mode	“Instantaneous” = The reset time is applied only to the `START` signal and the `TRIP` signal drops off instantaneously when the fault disappears, that is, the fault clearance resets the function. “Delayed” = The reset time is applied also to the `TRIP` signal. The `TRIP` drop off is delayed by applying the DT reset time characteristic.
Start Value	Voltage threshold for residual overvoltage condition detection
Def. operate time	Time delay for residual overvoltage Trip condition detection
Reset time (Tr)	Reset time delay for the residual overvoltage drop-off condition (“0” means no reset time delay to be applied)

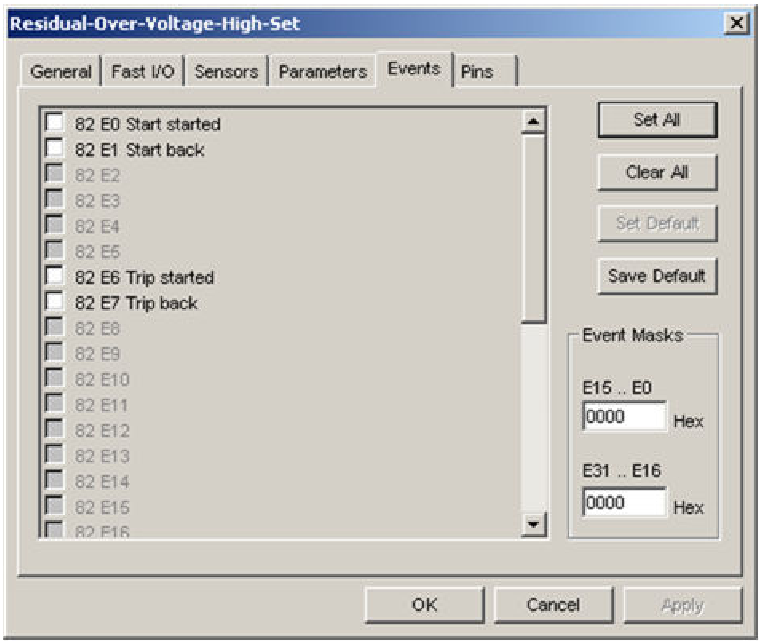


Figure 187: Events

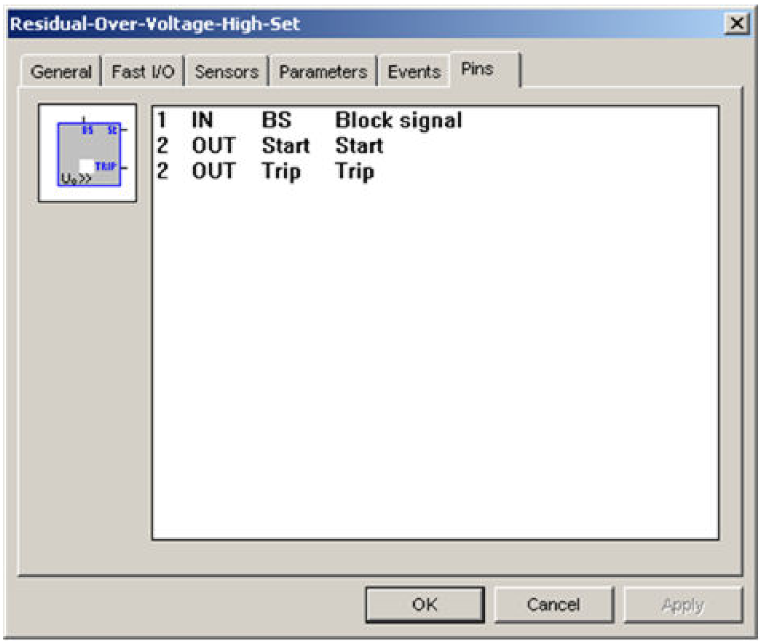


Figure 188: Pins

5.2.3.3 Measurement mode

Residual overvoltage protection functions evaluate the residual voltage at the fundamental frequency.

5.2.3.4 Operation criteria

If the measured voltage exceeds the setting threshold value (*UNe*), the residual overvoltage protection function is started.

The protection function will come back in passive status and the start signal will be cleared if the voltage falls below 0.95 the setting threshold value.

After the protection has entered the start status and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured voltage value falls below 0.4 the setting threshold value.

5.2.3.5 Setting groups

Two parameter sets can be configured for each of the residual overvoltage protection functions.

5.2.3.6 Parameters and events

Table 76: Setting values

Parameter	Values	Unit	Default	Explanation
Start Value	0.10...3.00	Un	0.50	Voltage threshold for Start condition detection
Def. operate time	20...300000	ms	50	Time delay for Trip condition
Reset time (Tr)	0...100000	ms	0	Reset time delay for the residual overvoltage drop-off condition

Table 77: Events

Code	Event reason
E0	Start started
E1	Start back
E6	Trip started
E7	Trip back
E18	Protection block started
E19	Protection block back

By default all events are disabled.

5.2.4 Overvoltage average protection

There are two overvoltage average protection functions in REF 542plus, one instance for each configured network. They can be independently activated and parameterized. See the following figures.

Figure 189: Net 1

Figure 190: Net 2

5.2.4.1 Input/output description

Table 78: Inputs

Name	Type	Description
BS	Digital signal (active high)	Blocking signal
RST	Digital signal (active low-to-high)	Reset average values signal
INIT	Digital signal (active low-to-high)	Init average values signal

When the `BS` signal becomes active, the protection function is reset regardless of its state. This means that all the output pins go low, generating the required events, if any, and all the internal registers and timers are cleared. The protection function remains in the idle state until the `BS` signal goes low.

When the `RST` signal is triggered, the protection function resets the voltage average measurement values.

When the `INIT` signal is triggered, the protection function initializes the voltage average measurement values with the actual $RMS_{10/12cycles}$ voltage values. This input could be used either after the start-up or during the protection testing to instantaneously set the initial condition of test without waiting that the measurement reaches the requested initial value.

The RST/INIT command is not performed when protection is blocked.

Table 79: Outputs

Name	Type	Description
START L1	Digital signal (active high)	Start signal U_L1E/ U_L12
START L2	Digital signal (active high)	Start signal U_L2E/ U_L23
START L3	Digital signal (active high)	Start signal U_L3E/ U_L31
GEN.START	Digital signal (active high)	General start signal (logical OR combination of all start signals)
TRIP	Digital signal (active high)	Trip signal

`START L1`, `START L2` and `START L3` are the phase selective start signals. The phase starting signal is activated when the respective phase (line) average voltage start conditions are true, that is, voltage exceeds the setting threshold value.

The `TRIP` signal is activated when the start conditions are true at least for a phase voltage and the trip delay time has elapsed.

5.2.4.2 Configuration

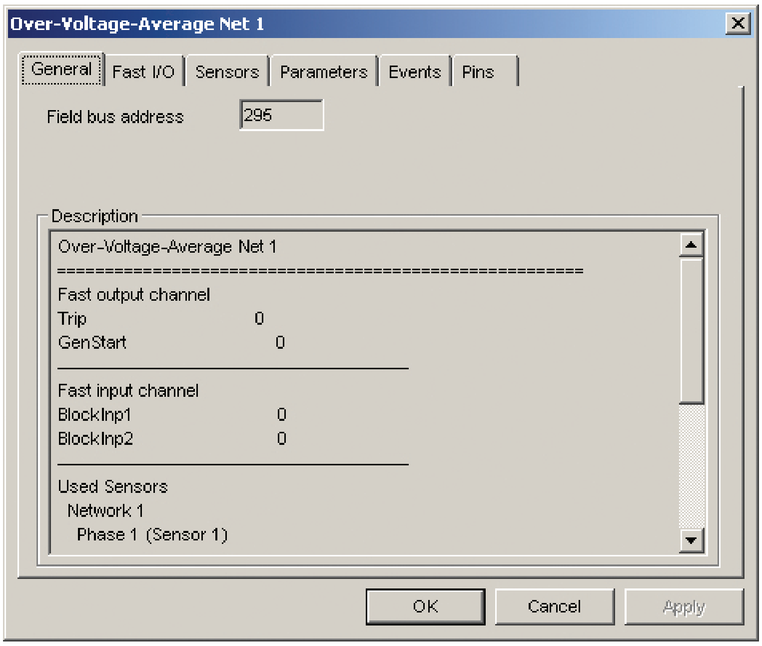


Figure 191: General

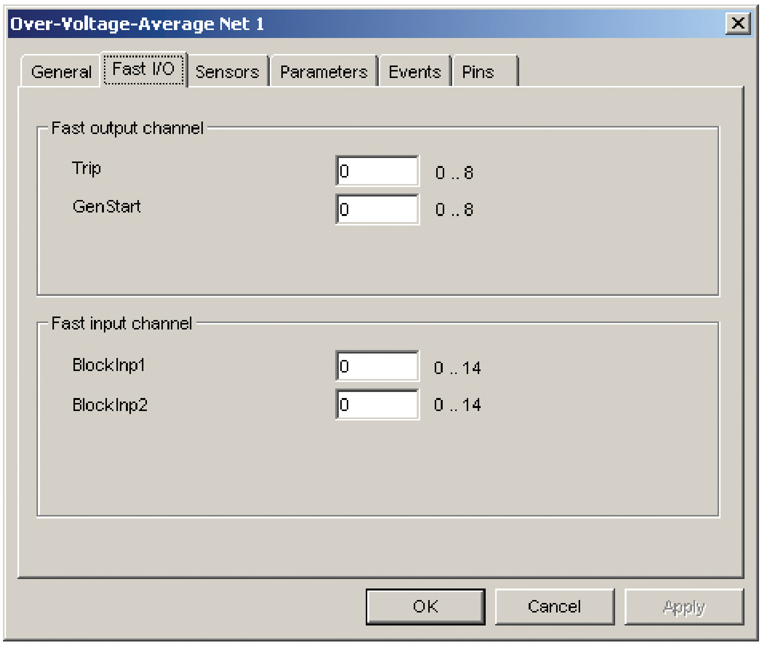


Figure 192: Fast I/O

Output Channel different from 0 means a direct execution of the trip or start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

Although the Fast I/Os are not significant for this protection, they are configurable to be compliant with all the other protections.

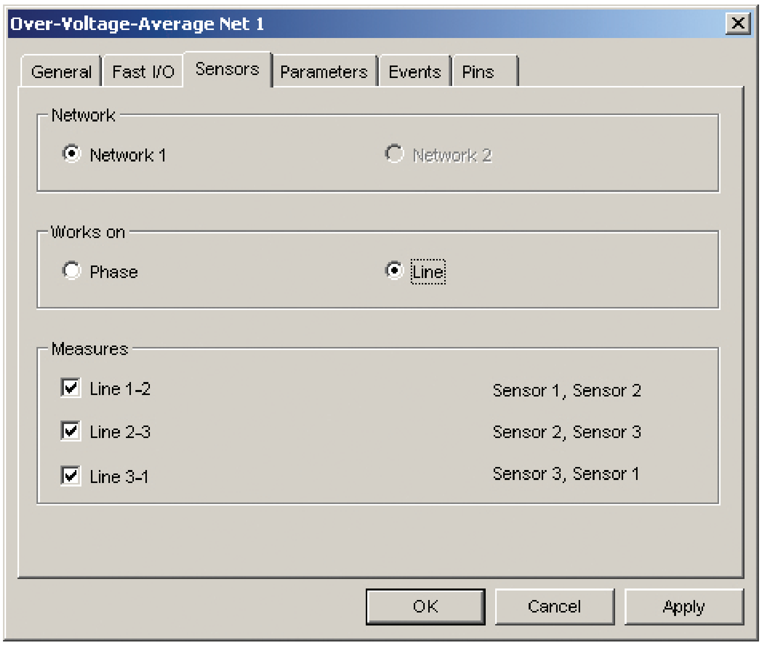


Figure 193: Sensors

The protection functions can operate on any combination of phase (or line) voltages in a triple, for example, as a single phase, double phase or three-phase protection on voltages belonging to the same network.

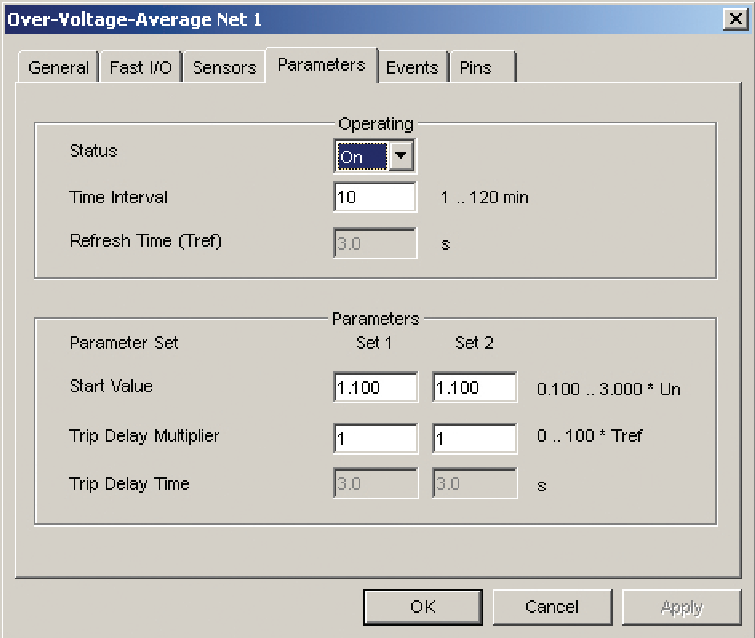


Figure 194: Parameters

Status	Operating status
Time Interval	Time interval for average voltage calculation
Refresh Time (Tref)	The refresh time depends on the time interval setting (see Calculation of $RMS_{Refresh}$ voltages) and it is shown to make the parameter setting more user-friendly.
Start Value	Voltage threshold for overvoltage condition detection
Trip Delay Multiplier	The trip delay setting is expressed as a multiplier of the refresh time to ensure that it is a multiple of this time.
Trip Delay Time	This value, *Refresh Time (Tref)* multiplied by *Trip Delay Multiplier*, is shown to provide user-friendly feedback on the trip delay setting.

Changing of the *Time Interval* by a parameter session (HMI, remote, and so on) does not affect the average voltage values, that is, it is assumed that they are valid also for the new time interval.

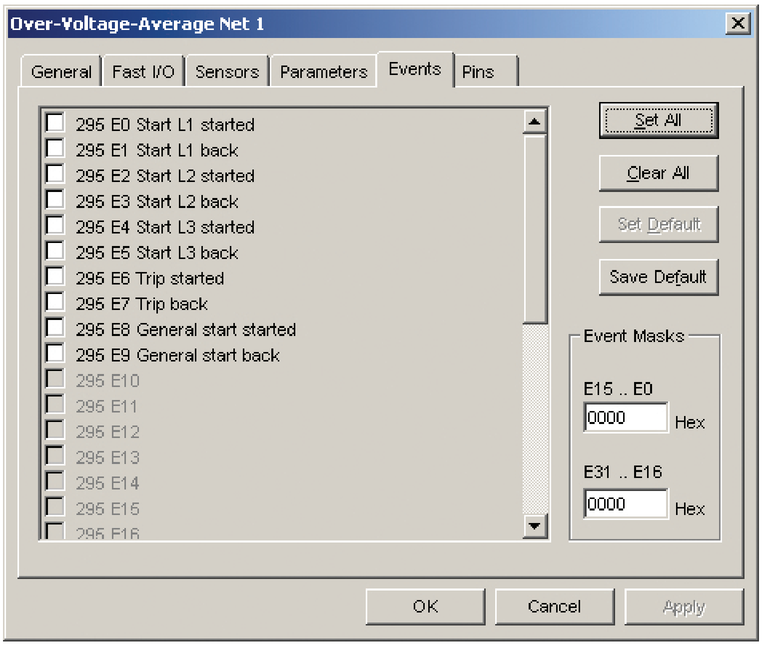


Figure 195: Events

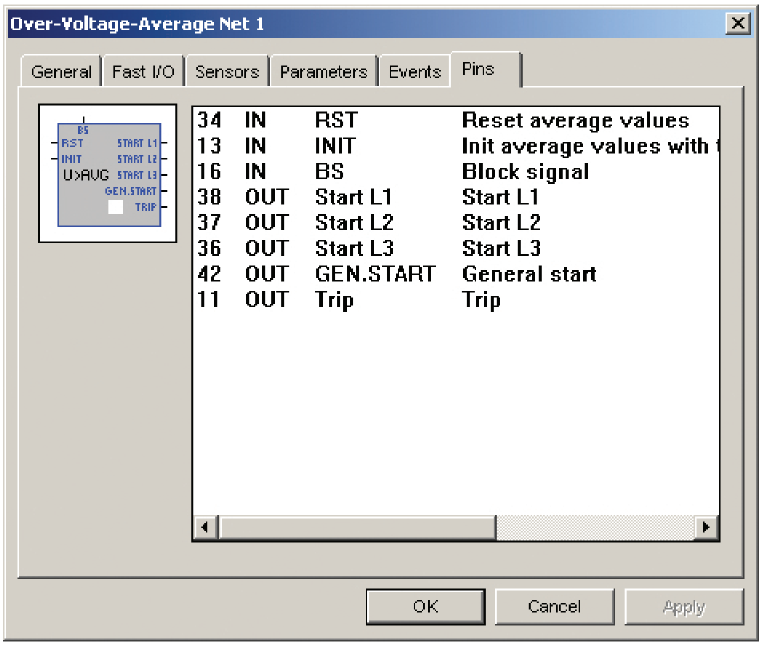


Figure 196: Pins

5.2.4.3 Measurement mode

The method of calculating average voltage measurement values is based on standard IEC 61000-4-30 and is performed by three successive aggregations.

1. The voltage input samples are aggregated to calculate the $RMS_{10/12cycles}$ voltages.
2. The $RMS_{10/12cycles}$ voltages are aggregated to get an intermediate value ($RMS_{Refresh}$) used to refresh the final average value.
3. The $RMS_{Refresh}$ values are aggregated to obtain the final average value ($RMS_{Average}$).

The calculated $RMS_{Average}$ voltage values can be selected as LED bar measurements and into the Analog Threshold FUPLA function. They have also been added to the CB trip context measurements set.

Calculation of $RMS_{10/12cycles}$ voltages

The $RMS_{10/12cycles}$ voltages are calculated by applying the standard RMS formula using the voltage samples at 1200 Hz (10/12 cycles = 200 ms = 240 samples at 1200 Hz).

Case A

Protection works on phase-to-earth voltages or on phase-to-phase voltages directly connected to the relay.

$$RMS_{10/12cycles} = \sqrt{\frac{\sum_{i=1}^{240} S^2(i)}{240}}$$

(Equation 19)

S Sample value at 1200 Hz relative to the input voltage

Case B

Protection works on phase-to-phase voltages calculated from the two connected phase-to-earth input voltages.

$$RMS_{10/12cycles} = \sqrt{\frac{\sum_{i=1}^{240} (S_x - S_y)^2}{240}}$$

(Equation 20)

Sx, Sy Sample values at 1200 Hz relative to the two phase-to-earth input voltages used for phase-to-phase voltage calculation

Calculation of $RMS_{Refresh}$ voltages

The $RMS_{Refresh}$ voltages are calculated by aggregating the $RMS_{10/12cycles}$ on an interval that depends on the *Time Interval* parameter ($T_{Average}$). This interval represents the refresh time of the final measurement ($T_{Refresh}$) and is given by:

$$T_{Refresh} = RoundUp\left(\frac{T_{Average}}{200}\right)$$

(Equation 21)

The RoundUp() function rounds up the result of the division to the nearest time multiple of $T_{10/12cycles}$ (0.2 s). This is necessary because the result of the division is not a multiple of 0.2 s in case of odd *Time Interval* settings (1, 3, 5, ..., 119). The $T_{Average}$ divisor (200) represents the maximum number of items reserved to the buffer for calculating the final measure. This number has been chosen to be compatible with the standard that provides a $T_{Average}$ of 10 minutes with a 3 second refresh time. Therefore, the number of elements to be reserved for the buffer is:

$$\frac{10min}{3s} = 200$$

(Equation 22)

The $RMS_{Refresh}$ voltages are calculated by applying the standard RMS formula using the $RMS_{10/12cycles}$.

$$RMS_{Refresh} = \sqrt{\frac{\sum_{i=1}^{N} RMS_{10/12cycles}^{2}(i)}{N}}$$

(Equation 23)

N is the number of elements to be aggregated given by:

$$N = \left(\frac{T_{Refresh}}{T_{10/12cycles}}\right)$$

(Equation 24)

Table 80 contains the relevant average voltage refresh time (rounded up, in case of odd time interval, to be a multiple of 0.2 s) for each configurable *Time Interval*.

Table 80: Average voltage refresh times and the corresponding configurable time intervals

Time Interval [min]	$T_{Refresh}$ [s]	Time Interval [min]	$T_{Refresh}$ [s]	Time Interval [min]	$T_{Refresh}$ [s]
1	0.4	41	12.4	81	24.4
2	0.6	42	12.6	82	24.6
3	1	43	13	83	25
4	1.2	44	13.2	84	25.2
5	1.6	45	13.6	85	25.6
Table continues on next page					

Time Interval [min]	$T_{Refresh}$ [s]	Time Interval [min]	$T_{Refresh}$ [s]	Time Interval [min]	$T_{Refresh}$ [s]
6	1.8	46	13.8	86	25.8
7	2.2	47	14.2	87	26.2
8	2.4	48	14.4	88	26.4
9	2.8	49	14.8	89	26.8
10	3	50	15	90	27
11	3.4	51	15.4	91	27.4
12	3.6	52	15.6	92	27.6
13	4	53	16	93	28
14	4.2	54	16.2	94	28.2
15	4.6	55	16.6	95	28.6
16	4.8	56	16.8	96	28.8
17	5.2	57	17.2	97	29.2
18	5.4	58	17.4	98	29.4
19	5.8	59	17.8	99	29.8
20	6	60	18	100	30
21	6.4	61	18.4	101	30.4
22	6.6	62	18.6	102	30.6
23	7	63	19	103	31
24	7.2	64	19.2	104	31.2
25	7.6	65	19.6	105	31.6
26	7.8	66	19.8	106	31.8
27	8.2	67	20.2	107	32.2
28	8.4	68	20.4	108	32.4
29	8.8	69	20.8	109	32.8
30	9	70	21	110	33
31	9.4	71	21.4	111	33.4
32	9.6	72	21.6	112	33.6
33	10	73	22	113	34
34	10.2	74	22.2	114	34.2
35	10.6	75	22.6	115	34.6
36	10.8	76	22.8	116	34.8
37	11.2	77	23.2	117	35.2
38	11.4	78	23.4	118	35.4
39	11.8	79	23.8	119	35.8
40	12	80	24	120	36

Calculation of $RMS_{Average}$ voltages

The $RMS_{Average}$ voltages are calculated by applying the standard RMS formula using $RMS_{Refresh}$.

$$RMS_{Average} = \sqrt{\frac{\sum_{i=1}^{N} RMS_{Refresh}^{2}(i)}{N}}$$

(Equation 25)

N is the number of elements to be aggregated given by:

$$N = Round\left(\frac{T_{Average}}{T_{Refresh}}\right)$$

(Equation 26)

The Round() function rounds the result of the division to the nearest integer if $T_{Average}$ is not a multiple of $T_{Refresh}$.

5.2.4.4 Operation criteria

If the measured average voltage exceeds the setting threshold value (*Start Value*), the overvoltage average protection function is started. The start signal is phase selective. It means that when at least one average voltage value is above the setting threshold value, the relevant start signal is activated.

The protection function remains in the START status until at least one phase is started. The status returns to PASSIVE and the start signal is cleared if, for all the phases, the voltage falls below the setting threshold value. After the protection has entered the START status and the preset trip delay time (multiple of) has elapsed, the function goes in TRIP status and the trip signal is generated. In TRIP status the start signals remain frozen to identify the fault phases at the instant of the trip.

The protection function exits the TRIP status and the trip/start signals are cleared when all the measured average voltages fall below 0.96 of the setting threshold value.

Considering the slow dynamic of the measurement, the protection may remain in the START status for a long time. This time period could exceed the maximum allowed duration of the latest START situation (ms). In this case, the START event is shown in the HMI events page with this value.

5.2.4.5 Setting groups

Two parameter sets can be configured for each of the overvoltage average protection functions.

5.2.4.6 Parameters and events

Table 81: Setting values

Parameter	Values	Unit	Default	Explanation
Status	On/Off		On	Operating status
Time Interval	1...120	Min.	10	Time interval for average voltage calculation
Start value U>avg	0.1...3.00	Un	1.1	Average voltage threshold for Start condition detection
Trip Delay Multiplier	0...100	Tref	1	Trip delay expressed as a multiple of refresh time

Table 82: Events

Code	Event reason
E0	Protection start on phase L1
E1	Start on phase L1 cancelled
E2	Protection start on phase L2
E3	Start on phase L2 cancelled
E4	Protection start on phase L3
E5	Start on phase L3 cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E8	Protection general start (logical OR combination of all start signals)
E9	General start is cancelled
E18	Block signal is active
E19	Block signal is back to inactive state
E20	Reset signal is active (set to 0)
E21	Reset signal is back to inactive state
E22	Initialization signal is active (set to actual)
E23	Initialization signal is back to inactive state

By default all events are disabled.

5.3 Motor protection

The protection functions described in the following subsections are provided for protection of the motor from overloads and faults.

5.3.1 Thermal overload protection

REF 542plus has one thermal overload protection function.

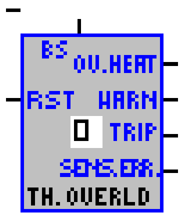


Figure 197: Thermal overload protection

5.3.1.1 Input/output description

Table 83: Inputs

Name	Type	Description
BS	Digital signal (active high)	Blocking signal
RST	Trigger signal (active low-to-high)	Reset signal

When the `BS` signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the `BS` signal goes low.

When the reset input pin (`RST`) is triggered, the estimated motor temperature is set to the parameter value Trst (*Reset Temperature Trst*).

Table 84: Outputs

Name	Type	Description
Warn	Digital signal (active high)	Warning signal
TRIP	Digital signal (active high)	Trip signal
Overheat	Digital signal (active high)	Overheat signal
Sensor Error	Digital signal (active high)	Error on RTD (used with 0...20 mA input)

The `WARN` signal will be activated when the calculated temperature exceeds the setting threshold value (Twarn).

The `TRIP` signal will be activated when the calculated temperature exceeds the setting threshold value (Ttrip).

The `Overheat` signal will be activated when the calculated temperature exceeds the setting threshold value *Nominal Motor Temperature (TMn)*.

The `Sensor Error` signal will be activated when the external *Environment Temperature (Tenv)* sensor use is set and its failure is detected.

5.3.1.2 Configuration

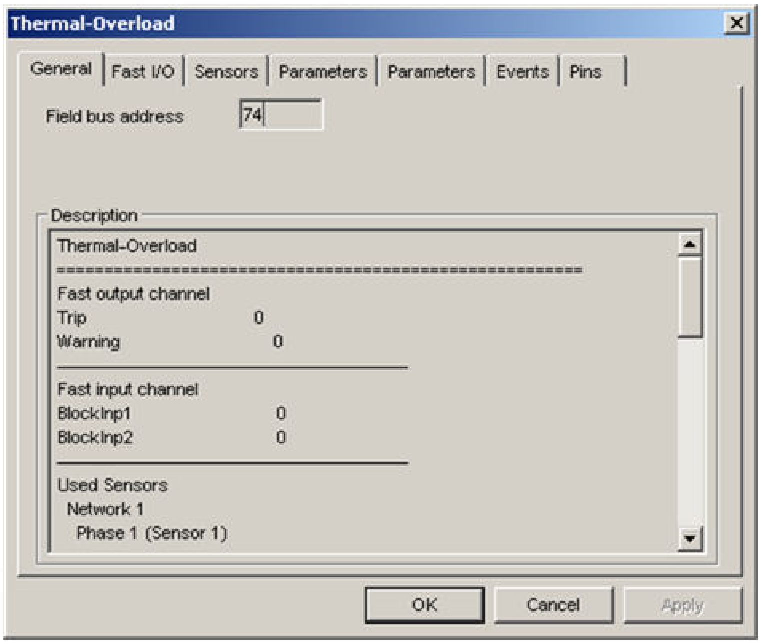


Figure 198: General

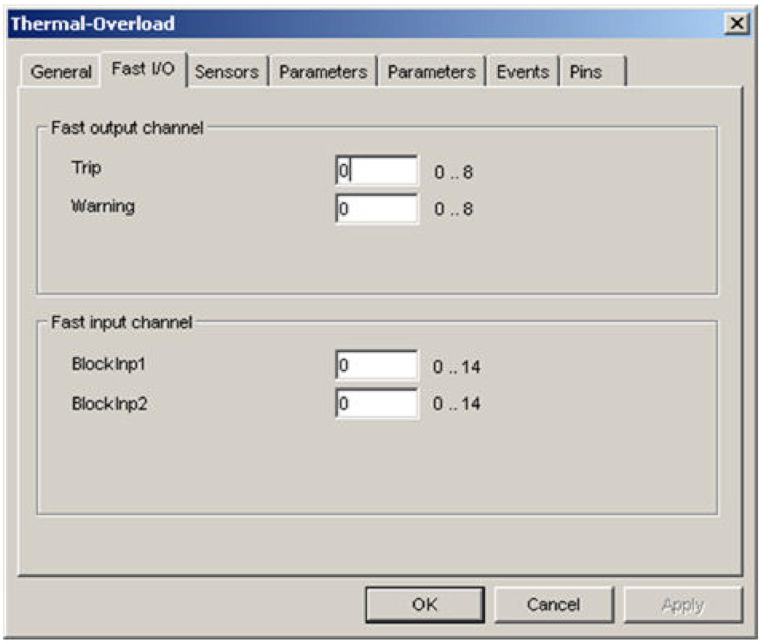


Figure 199: Fast I/O

Output Channel different from 0 means a direct execution of the trip command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

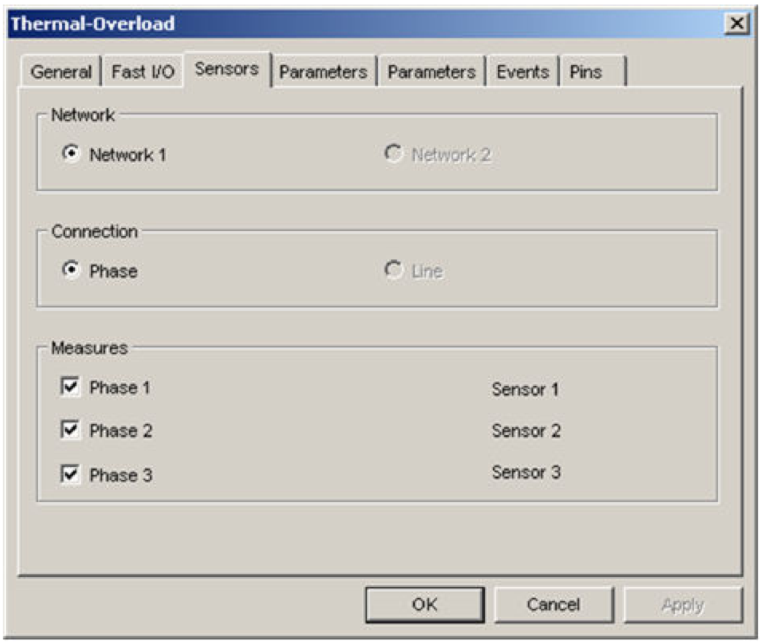


Figure 200: Sensors

The protection function operates on any combination of phase currents in a triple, for example, it can operate as single phase, double phase or three-phase protection on phase currents belonging to the same system.

An external sensor connected to the 4-20 mA Analog Input can directly measure the environment temperature. When it is used, it is automatically selected and displayed in the General tab.

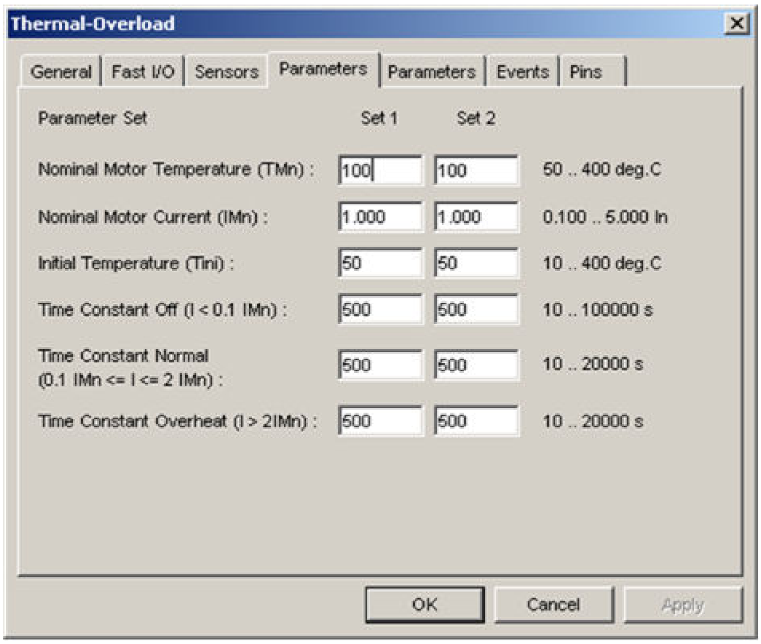


Figure 201: Parameters

Nominal Motor Temperature (TMn)	Nominal Motor Temperature, asymptotically reached at IMn with environment temperature Tenv
Nominal Motor Current (IMn)	Nominal Motor current for operational condition detection
Initial Temperature (Tini)	Initial motor temperature at protection initialasing
Time Constant Off	Time constant for cooling down
Time Constant Normal	Time constant for motor operational condition
Time Constant Overheat	Time constant for overload condition

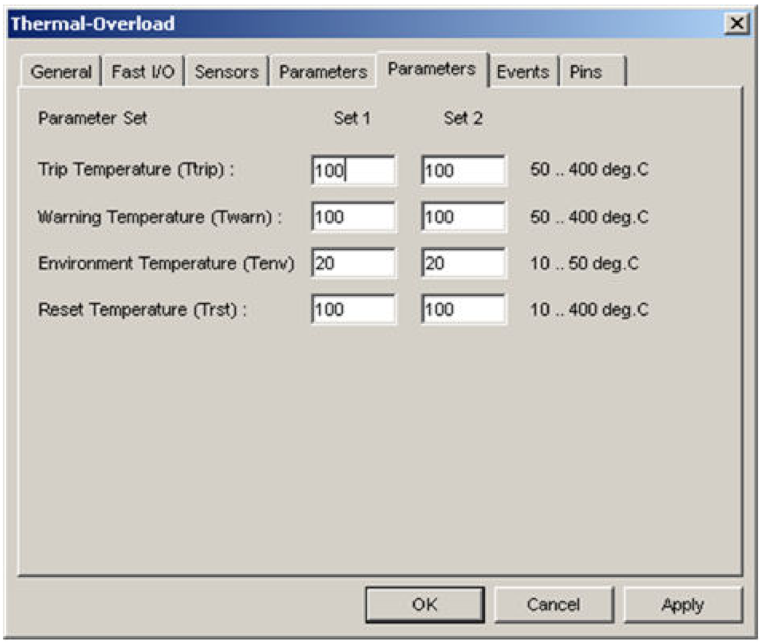


Figure 202: Parameters

Trip Temperature (Ttrip)	Temperature threshold for trip condition
Warning Temperature (Twarn)	Temperature threshold for warning condition
Environment Temperature (Tenv)	Ambient temperature
Reset Temperature (Trst)	Initial (i.e. after reset by RST input PIN) motor temperature

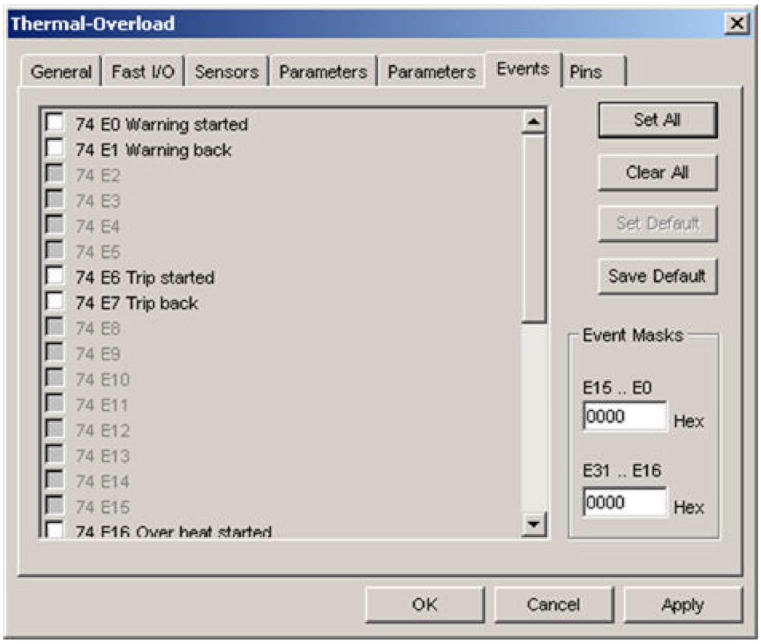


Figure 203: Events

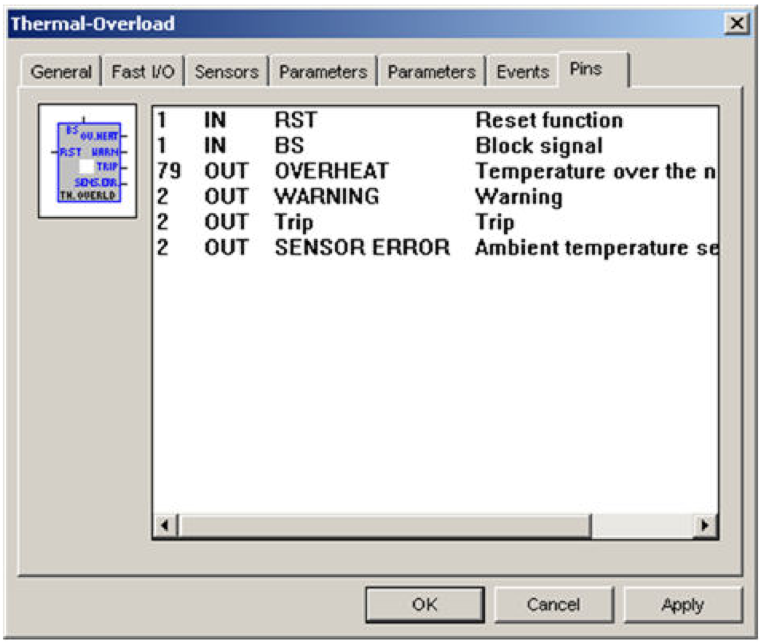


Figure 204: Pins

5.3.1.3 Measurement mode

Thermal overload protection function evaluates the square average of phase currents at the fundamental frequency. The instantaneous temperature estimation is based on the average of the phase currents monitored.

The environment temperature can either be set in the Parameter tab (Tenv) or measured through as external sensor and a 4-20 mA Analog Input. In case of an external measure failure the set parameter Tenv is used as backup.

5.3.1.4 Operation criteria

The thermal overload protection function estimates the instantaneous value of motor temperature.

If the estimated instantaneous temperature exceeds the first setting threshold value (Twarn), the protection function enters the START status and generates a WARNING signal.

If the estimated instantaneous temperature exceeds the second setting threshold value, the protection function generates a TRIP signal.

If the estimated instantaneous temperature exceeds the setting threshold value (*Nominal Motor Temperature TMn*), the protection function generates an overheat signal.

The protection function will exit the START status and come back in passive status. The start signal will be cleared if the estimated temperature falls below the setting threshold value Twarn.

The protection function will exit the TRIP status and the trip signal will be cleared when the estimated temperature falls below the setting threshold value Ttrip.

The protection function avoids also reconnection after a trip of overheated machines until the estimated motor temperature falls below the warning temperature Twarn (according to calculated motor cooling process, based on Time Constant OFF).

When the thermal overload protection is instantiated the motor temperature can be estimated. Therefore, after a trip for maximum number of starts, an overheated motor cannot be reconnected until its temperature has fallen below the warning temperature (Twarn). Therefore, the time to decrement the number of start counters will be the maximum between the setting time interval (Reset Time, t rst) and the motor cooling-down time estimation.

If the protection function is reset by means of the reset input pin (RST), the estimated motor temperature will be set to value Trst (*Reset Temperature*).

5.3.1.5 Thermal memory at power-down

At power-down, REF 542plus saves the estimated motor temperature (T) and at subsequent power-up is able to estimate the new motor temperature, under the hypothesis that the motor was cooling in the meantime (that is the timeconstant OFF is used).

5.3.1.6 Setting groups

Two parameter sets can be configured for the thermal overload protection function.

5.3.1.7 Parameters and events

Table 85: Setting values

Parameter	Values	Unit	Default	Explanation
Nominal Motor Temperature (TMn)	50...400	°C	100	Motor temperature at rated condition
Nominal Motor Current (IMn)	0.1...5.0	In	1.0	Current for operational mode (τ) detection
Initial Temperature (Tini)	10...400	°C	50	Initial temperature after Reset Signal at BS
Constant Off (I < 0.1 x IMn)	10...100000	s	500	Cooling time constant
Time Constant Normal	10...20000	s	500	Time constant under normal load condition
Time Constant Overheat (I > 2 x IMn)	10...20000	s	500	Time constant under overload condition
Trip Temperature (Ttrip)	50...400	°C	100	Temperature threshold for Trip condition
Warning Temperature (Twarn)	50...400	°C	100	Temperature threshold for warn condition
Environment Temperature (Tenv)	10...50	°C	20	Ambient Temperature
Reset Temperature (Trst)	10...400	°C	100	Initial (after reset by RSTPIN) motor temperature

Table 86: Events

Code	Event reason
E0	Warning signal is active
E1	Warning signal is back to inactive state
E6	Trip signal is active
E7	Trip signal is back to inactive state
E16	Overheat signal is active
E17	Overheat signal is back to inactive state
E18	Protection block signal is active
Table continues on next page	

Code	Event reason
E19	Protection block signal is back to inactive state
E20	Reset input signal is active
E21	Reset input signal is back to inactive state
E22	Sensor error is active
E23	Sensor error is back to inactive state

By default all events are disabled.

5.3.2 Motor start protection

REF 542plus has one motor start protection function.

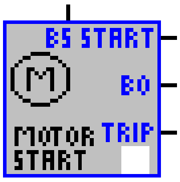


Figure 205: Motor start protection

5.3.2.1 Input/output description

Table 87: Inputs

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 88: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal
BO	Digital signal (active high)	Block output signal

The START signal will be activated when the current exceeds 10% motor nominal current value IMn and within 100 ms the setting threshold value (*Motor Start IMs*).

The TRIP signal will be activated when the start conditions are true and the calculated current-time integration (Is2 x *Time*) is exceed.

The Block Output (BO) signal becomes active at protection initialization until when the current exceeds 10% motor nominal current value IMn.

5.3.2.2 Configuration

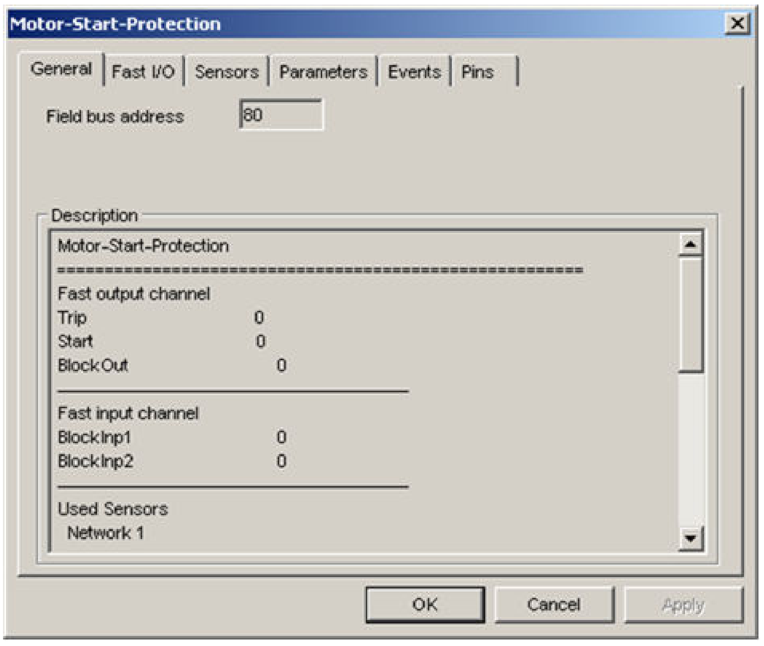


Figure 206: General

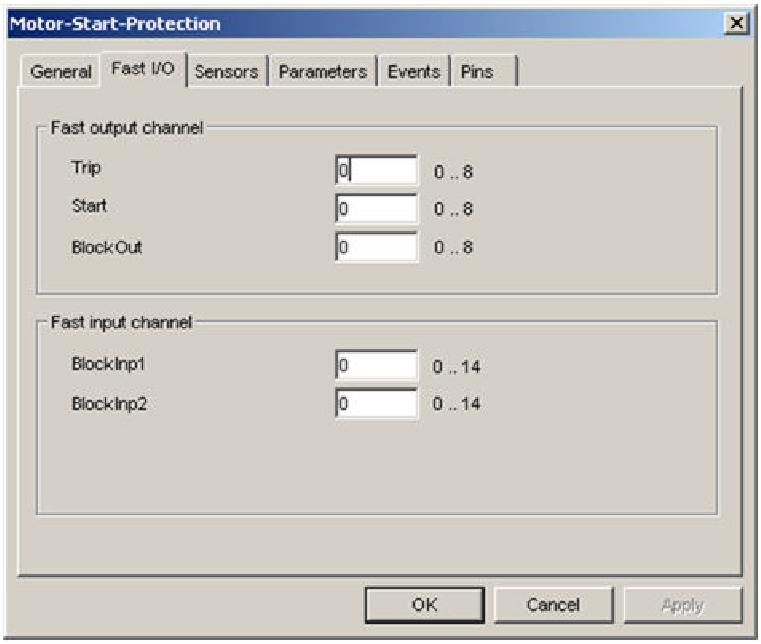


Figure 207: Fast I/O

Output Channel different from 0 means a direct execution of the trip command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

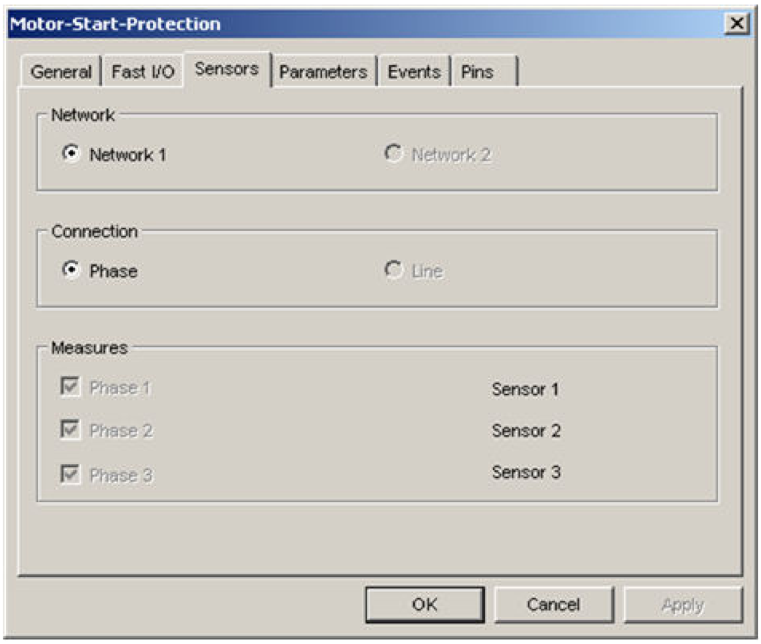


Figure 208: Sensors

The protection function operates on any set of phase currents in a triple.

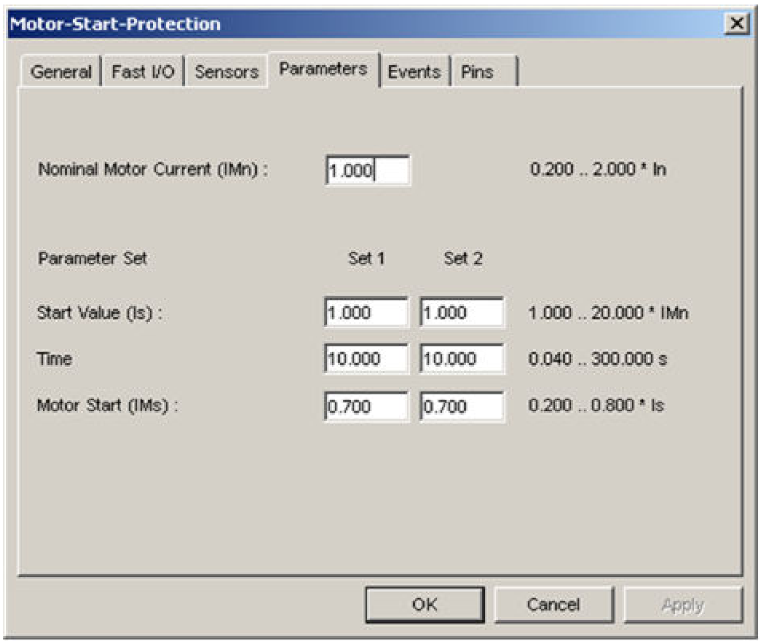


Figure 209: Parameters

Nominal Motor Current (IMn)	Nominal Motor current for operational condition detection
Start Value (Is)	Motor start current for Trip condition detection (start energy integral I^2t)
Time	Time for Trip condition detection
Motor Start (IMs)	Current threshold for motor start condition detection

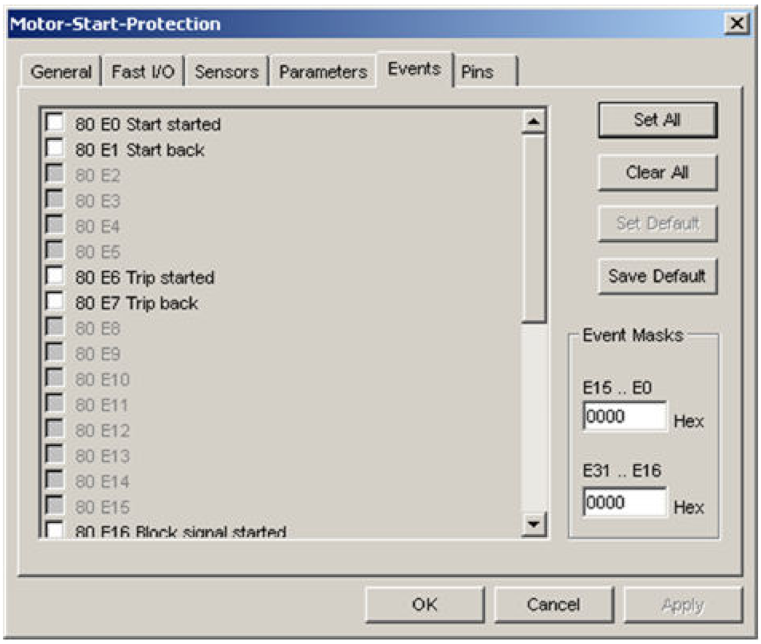


Figure 210: Events

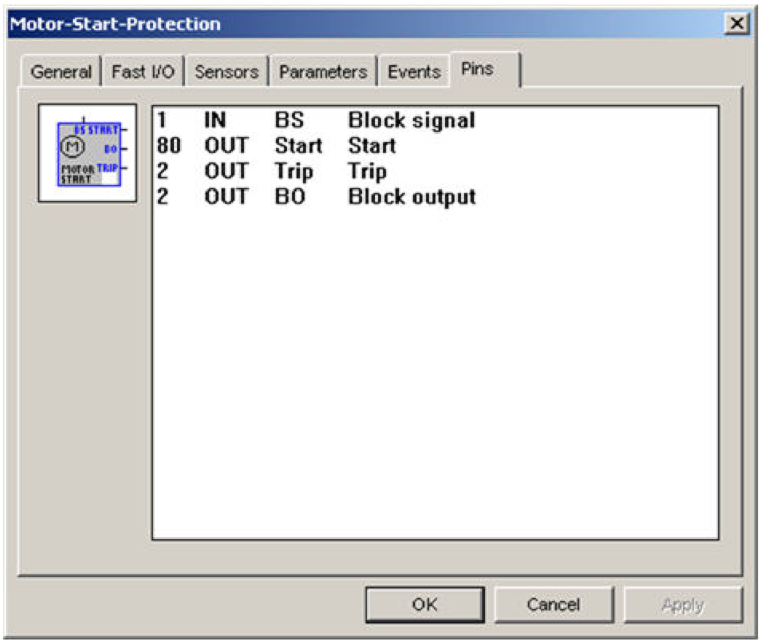


Figure 211: Pins

5.3.2.3 Measurement mode

Motor start protection function evaluates the current at the fundamental frequency.

The maximum measured motor current I_{RMS_max} is used to detect Start and Trip conditions.

The motor start behavior depends on the switching torque of the specific machine load. The manufacturer assigns an allowable current-time start integral I^2t for motors or, as an alternative, information on the maximum allowable start current and the maximum allowable start time is provided.

5.3.2.4 Operation criteria

A motor start is detected if:

- The maximum measured motor current exceeds 0.10 the setting threshold value nominal motor current (*Nominal Motor Current IMn*)
- Within 100 ms later the measured motor current exceeds the setting motor start detection (*Motor Start IMs*). When a motor start is detected the protection is started, the start signal is activated and the current-time integral

  $$\int i(t)^2 dt \qquad \text{(Equation 27)}$$

  is calculated.

The protection function will come back in passive status and the start signal will be cleared if the maximum motor current falls below 0.95 the setting motor start detection threshold value (IMs). At that time, calculation of current-time integral is stopped.

After the protection has entered the start status and the calculated current-time integration exceeds the default

$$I_s^2 \cdot T \qquad \text{(Equation 28)}$$

value, where:

- I_s is Start current parameter (*Start Value Is*)
- T is Time parameter (*Time*)

the function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured current value falls below 0.95 the setting motor start detection threshold value (IMs).

5.3.2.5 Setting groups

Two parameter sets can be configured for the motor start protection function.

5.3.2.6 Parameters and events

Table 89: Setting values

Parameter	Values	Unit	Default	Explanation
Nominal Motor Current (IMn)	0.20...2.00	In	1.00	Motor nominal current for Start condition
Start Value (Is)	1.00...20.00	IMn	1.00	Trip condition detection (integral I^2t)
Time	40...300000	ms	10000	Time for integral Trip condition
Motor Start (IMs)	0.20...0.80	Is	0.70	Current threshold for Start condition

Table 90: Events

Code	Event reason
E0	Protection start
E1	Start cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E16	Block signal is active
E17	Block signal is back to inactive state
E18	Protection block signal is active state
E19	Protection block signal is back to inactive state

By default all events are disabled.

5.3.3 Blocking rotor

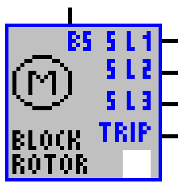


Figure 212: Blocking rotor

5.3.3.1 Input/output description

Table 91: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low. This input can be assigned to the speed indicator signal (tachometer generator or a speed switch).

Table 92: Outputs

Name	Type	Description
S L1	Digital signal (active high)	Start signal of IL1
S L2	Digital signal (active high)	Start signal of IL2
S L3	Digital signal (active high)	Start signal of IL3
TRIP	Digital signal (active high)	Trip signal

S L1, S L2 and S L3 are the phase selective start signals. The phase starting signal will be activated when respective phase current start conditions are true (one phase current exceeds *Start Value Is*).

The TRIP signal will be activated when at least for a phase current the start conditions are true and the operating time has elapsed.

5.3.3.2 Configuration

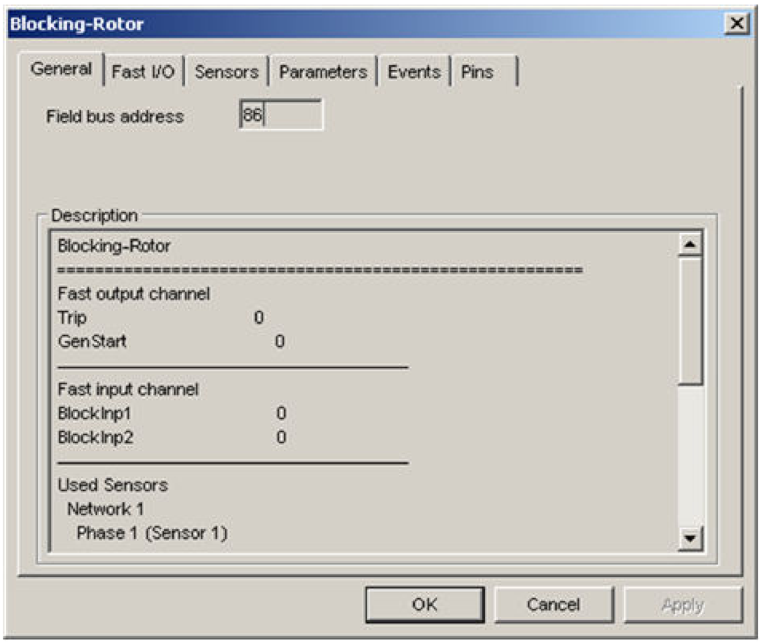


Figure 213: General

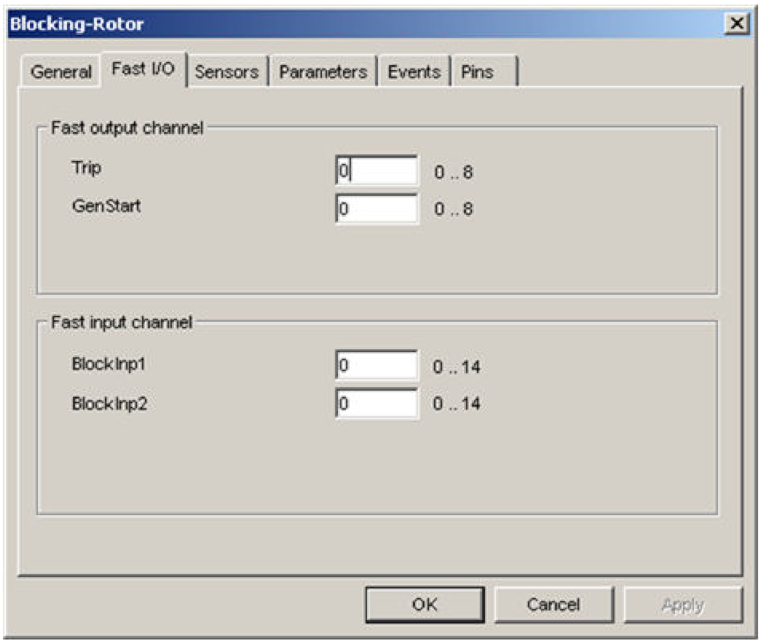


Figure 214: Fast I/O

Output Channel different from 0 means a direct execution of the trip or start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

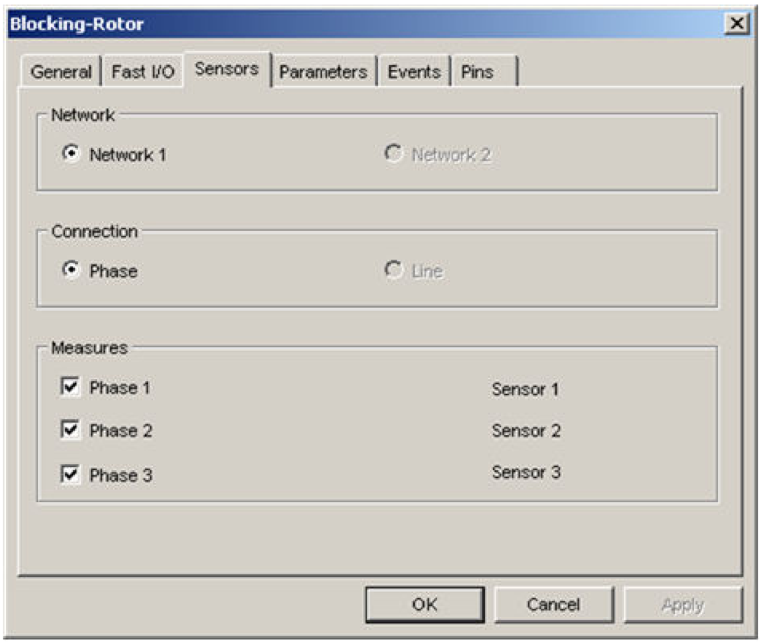


Figure 215: Sensors

The protection function operates on any combination of phase currents in a triple, for example, it can operate as single phase, double phase or three-phase protection on phase currents belonging to the same system.

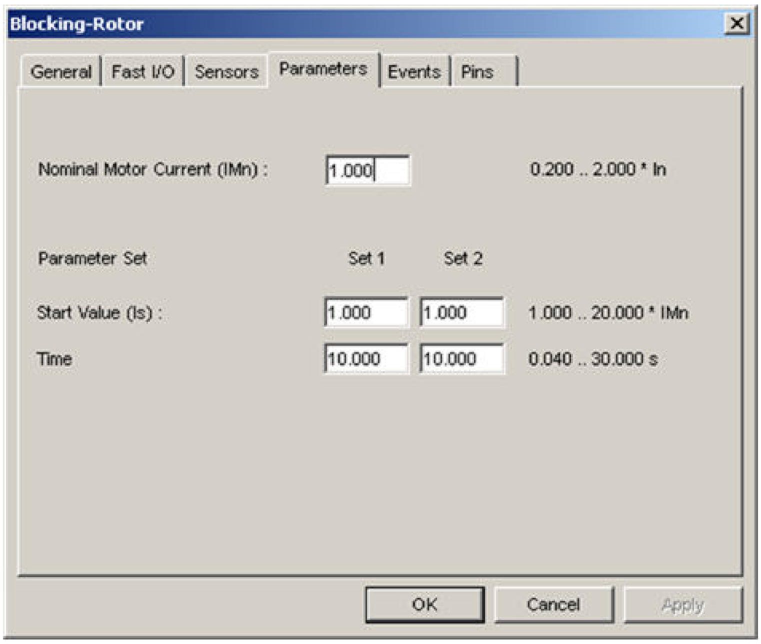


Figure 216: Parameters

Nominal Motor Current (IMn)	Nominal Motor current
Start Value (Is)	Current threshold for motor start condition detection
Time	Time delay for Trip condition detection

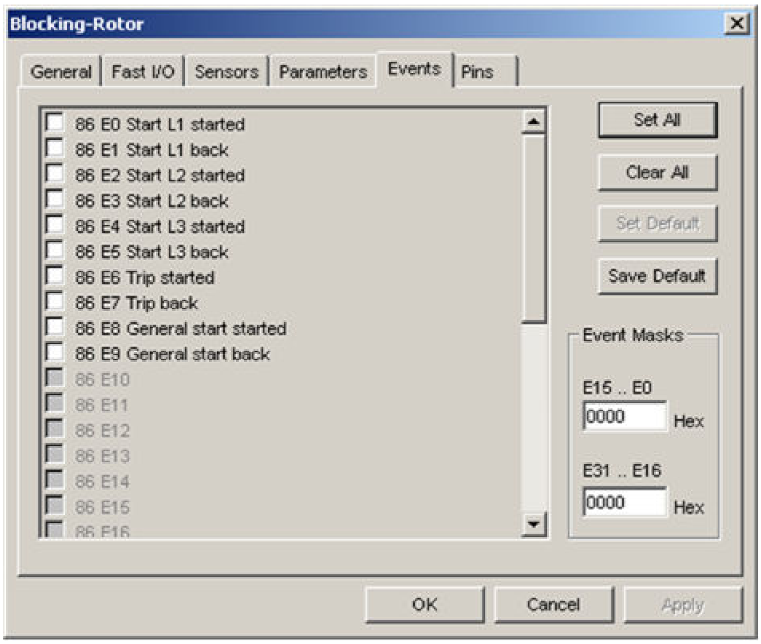


Figure 217: Events

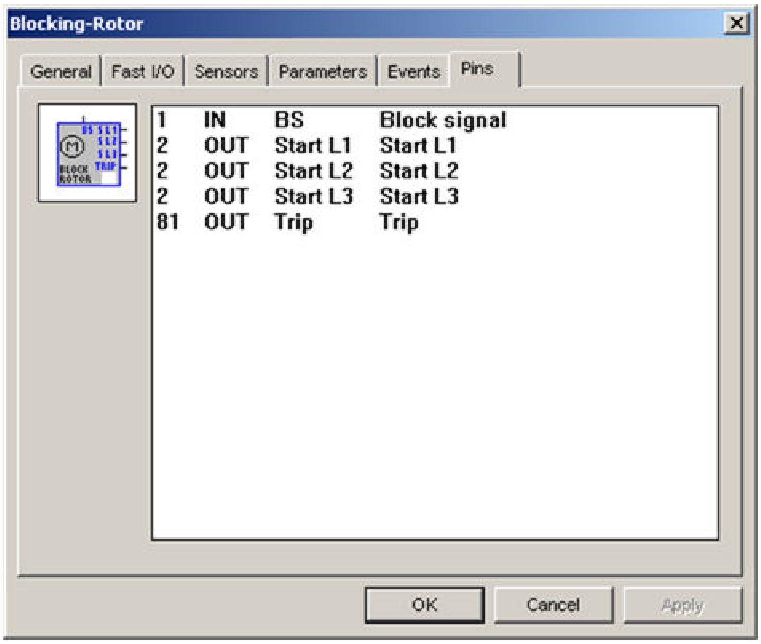


Figure 218: Pins

5.3.3.3 Measurement mode

Blocking rotor protection function evaluates the current at the fundamental frequency. It operates like an overcurrent protection function.

The blocking rotor protective function is used to detect a locked rotor condition by sensing the current increase arising from the loss of synchronism between the rotor revolving and phase voltages.

It can be used to monitor the starting characteristics of three-phase asynchronous motors to check whether the rotor braking is on and other conditions preventing the motor to speed up. If this malfunction occurs, the starting current would flow permanently and the motor would be thermally overloaded.

5.3.3.4 Operation criteria

The blocking rotor protection function can be blocked on the `BS` input. The blocking input can be provided by a speed switch or by the start signal output from the motor start protection function.

A tachometer generator or a speed switch is used to send a defined signal at a specified speed. If the rotor of the monitored motor is locked, the missing speed signal will ensure that the overcurrent function in the protective function will continue to remain active.

The protection function can also be used without a speed signal by using the start signal output from the motor start protection function to block it during the motor starting phase. When the motor start condition is detected the blocking rotor function is blocked by the BS input.

If the measured current exceeds the setting motor starting threshold value (*Start Value, Is*), the protection function is started. The start signal is phase selective It means that when at least the value of one phase current is above the setting threshold value the relevant start signal will be activated (`SL 1`, `SL 2` or `SL 3`).

The protection function will remain in START status until there is at least one phase started. It will come back in passive status and the start signal will be cleared if for all the phases the current falls below 0.95 the setting threshold value. After the protection has entered the start status and the preset operating time (*Time*) has elapsed, function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured current value falls below 0.4 the setting threshold value.

5.3.3.5 Setting groups

Two parameter sets can be configured for the blocking rotor protection functions.

5.3.3.6 Parameters and events

Table 93: Setting values

Parameter	Values	Unit	Default	Explanation
Nominal Motor Current IMn	0.20...2.00	In	1.00	Nominal Motor current
Start Value Is	1.00...20.00	Imn	1.00	Current threshold for motor start condition detection
Time	40...30000	ms	10000	Time delay for Trip condition detection

Table 94: Events

Code	Event reason
E0	Protection start on phase L1
E1	Start on phase L1 cancelled
E2	Protection start on phase L2
E3	Start on phase L2 cancelled
E4	Protection start on phase L3
E5	Start on phase L3 cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state

By default all events are disabled.

5.3.4 Number of starts

REF 542plus has an additional motor protection function that supervises the number of motor starts. It distinguishes between the cold and warm starts, the allowable number which is generally provided by the motor manufacturer. The starting signal (`START` output) of the motor start protection function is used to count the starts.

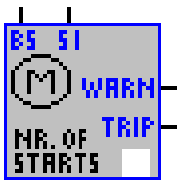


Figure 219: Number of starts

5.3.4.1 Input/output description

Table 95: Inputs

Name	Type	Description
BS	Digital signal (active high)	Blocking signal
SI	Trigger signal (active high)	Motor start signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

The SI signal is used to provide to the number of start function the start signal output from the motor start protection function by wiring the connection in FUPLA. It is used to count the motor number of starts.

Table 96: Outputs

Name	Type	Description
Warn	Digital signal (active high)	Warning signal
TRIP	Digital signal (active high)	Trip signal

The WARN signal will be activated when the cold (or warm) starts counter reaches the setting threshold value maximum number of starts (Ncs and Nws respectively).

The TRIP signal will be activated when the cold (or warm) starts counter exceeds the setting threshold value maximum number of starts (Ncs and Nws respectively).

5.3.4.2 Configuration

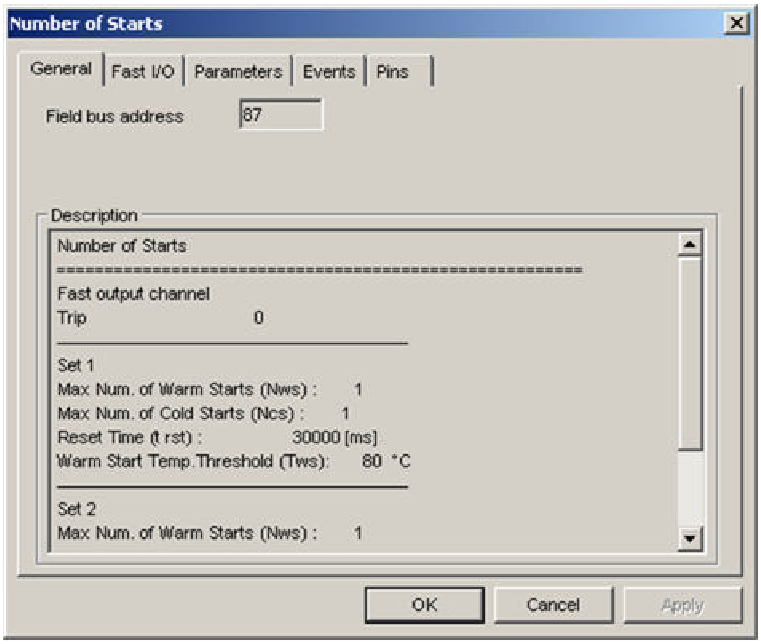


Figure 220: General

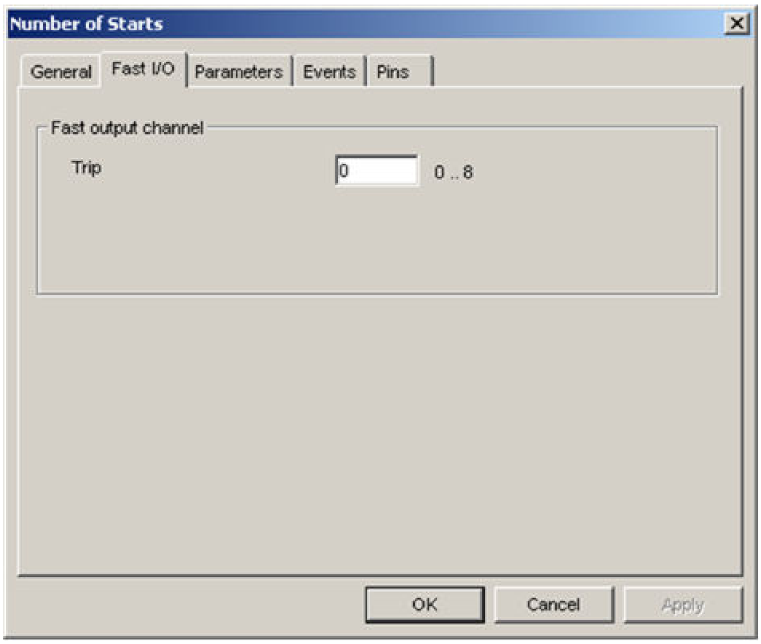


Figure 221: Fast I/O

Output Channel different from 0 means a direct execution of the trip or start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

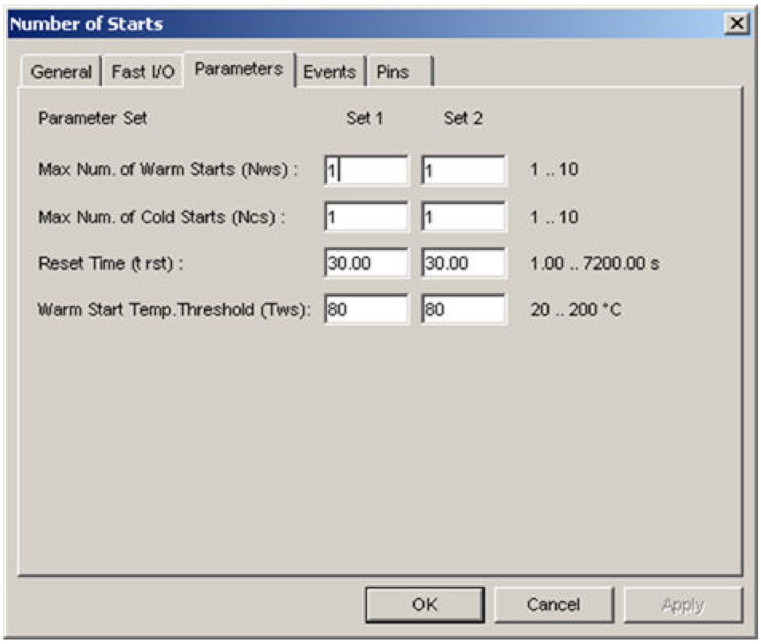


Figure 222: Parameters

Max Num. of Warm Starts (Nws)	Motor manufacturer declared N° of starts above temperature threshold Tws
Max Num. of Cold Starts (Ncs)	Motor manufacturer declared N° of starts below temperature threshold Tws
Reset Time (t rst)	Cooling down motor time; time to dissipate the heat of a motor start
Warm Start Temp. Threshold (Tws)	Above Tws temperature threshold a start is assumed to be warm

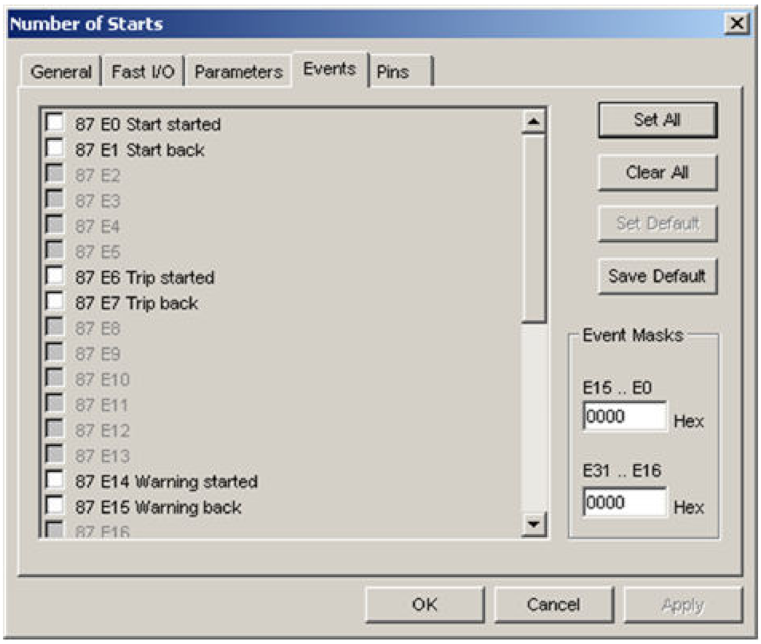


Figure 223: Events

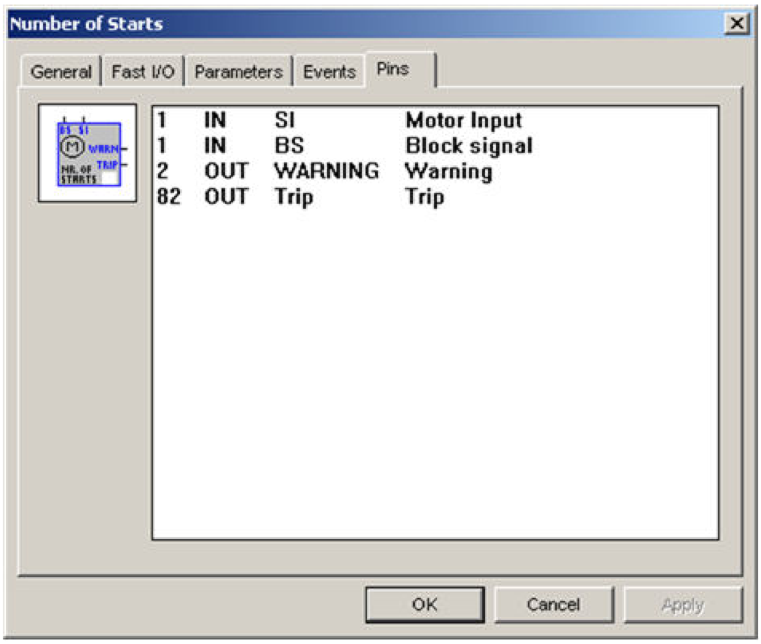


Figure 224: Pins

5.3.4.3 Measurement mode

Number of starts protection function supervises the motor number of starts. The starting signal of motor start protection function is used to count starts.

It is also important to distinguish between the cold and warm starts, the allowable number of which is generally provided by the motor manufacturer.

Motor temperature estimated by the thermal overload function is used to determine whether a start is cold or a warm. When the thermal overload function is not instantiated, a cold start is assumed.

5.3.4.4 Operation criteria

If thermal overload protection is not enabled, the estimated machine temperature is not available and the warm counter is not increased (the warm counter is frozen to zero). In this case, all the counted starts are classified as cold.

When the thermal overload protection is enabled the estimated motor temperature is compared with the setting temperature threshold (*Warm Start Temp. Threshold Tws*). Above Tws temperature thereshold a start is assumed to be warm, below it is assumed to be a cold start.

At every motor start (detected by the motor start protection function), depending on the type of start (warm or cold start) the related counter is incremented by one unit. At every warm start, both the warm counter and the cold counter are incremented. Cold starts to increment only the cold counter.

If no start has occurred after the setting time interval (*Reset Time, t rst*) it is assumed that the motor had time to cool down and both the cold and warm start counters are decremented by one unit.

If the preset number of warm (*Max Num. of Warm Starts, Nws*) or respectively of cold starts (*Max Num. of Cold Starts, Ncs*) is reached, the protection function is started and the relevant warning signal will be activated. If there is another start, the protection function will enter the TRIP status and the trip signal will be activated.

If the protection function is in TRIP status and the above condition is satisfied, the protection function will exit the trip status and the trip signal will be cleared. The protection function is in TRIP status and the trip signal remains active until the reset period t rst has expired. Then both cold and warm start counters are decremented and the trip signal will be cleared.

The protection function will exit START status, come back in passive status and the start signal will be cleared, if the cold and warm counters fall below the respective maximum setting values Ncs and Nws, that is after the reset period t rst has expired.

5.3.4.5 Setting groups

Two parameter sets can be configured for the number of starts protection functions.

5.3.4.6 Parameters and events

Table 97: Setting values

Parameter	Values	Unit	Default	Explanation
Max num. of warm starts (Nws)	1...10	-	1	Number of starts above Tws
Max num. of cold starts (Ncs)	1...10	-	1	Number of starts below Tws
Reset time (t rst)	1.00...7200.0 0	s	30.00	Time to cool down after a start
Warm start temp. threshold (Tws)	20...200	°C	80	Temperature threshold to define a warm start

Table 98: Events

Code	Event reason
E0	Protection start
E1	Start cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E14	Warning signal is active
E15	Warning signal is back to inactive state
E18	Block signal is active
E19	Block signal is back to inactive state

By default all events are disabled.

5.4 Distance protection

5.4.1 Distance protection V1

Distance protection V1 is dedicated to protect a meshed medium-voltage system or a simple high-voltage system. Version V1 is compatible with the distance protection of the previous releases.

Figure 225: Distance protection

5.4.1.1 Input/output description

Table 99: Inputs

Name	Type	Description
BL	Digital signal (active high)	Blocking signal
SIGNAL COMP	Digital signal (active high)	Signal comparison scheme

When the `BL` signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function will then remain in idle state until the `BL` signal goes low.

Table 100: Outputs

Name	Type	Description
< Z1	Digital signal (active high)	Z1 signal used for signal comparison
START L1	Digital signal (active high)	Start signal in L1
START L2	Digital signal (active high)	Start signal in L2
START L3	Digital signal (active high)	Start signal in L3
EARTH START	Digital signal (active high)	Start Earth signal
GENERAL START	Digital signal (active high)	General start signal
TRIP	Digital signal (active high)	Trip signal

5.4.1.2 Configuration

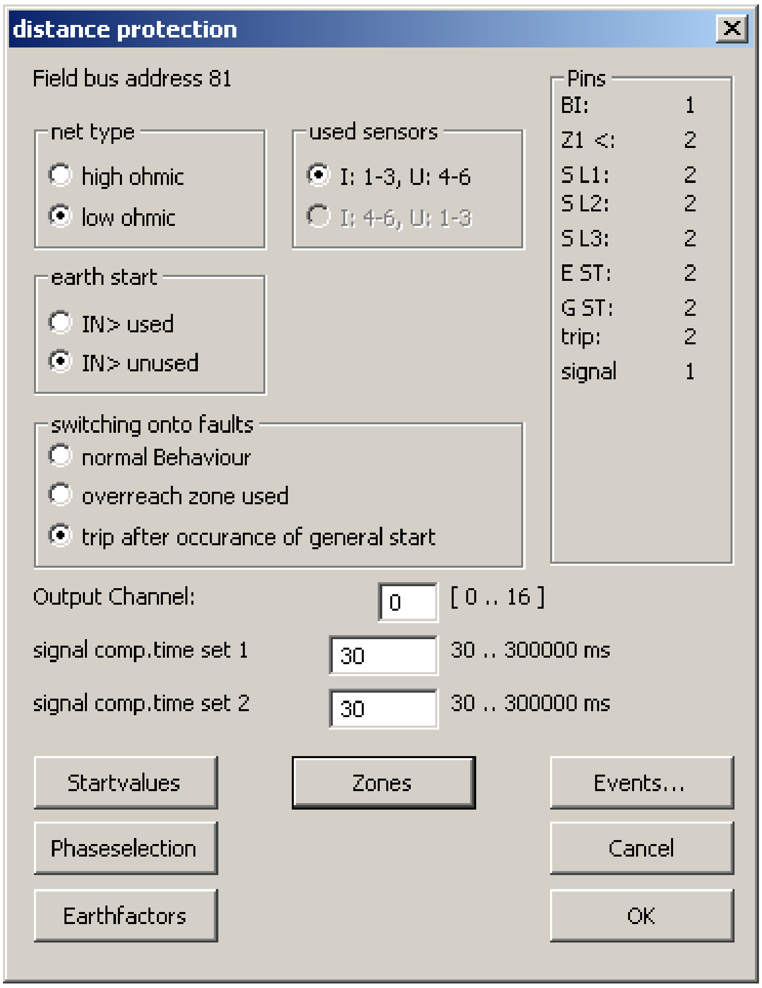


Figure 226: General

Output Channel different from 0 means direct execution of the trip command, that is skipping FUPLA cycle evaluation.

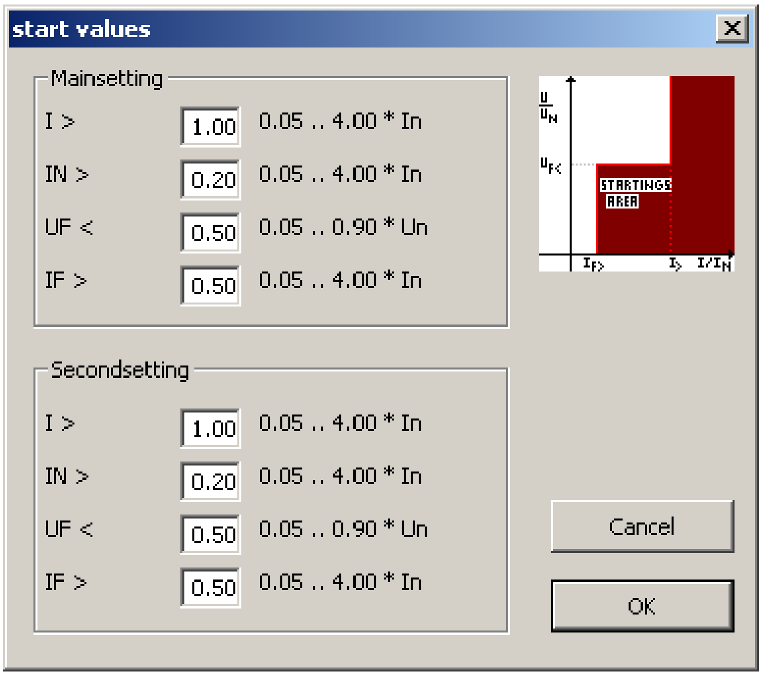


Figure 227: Start values

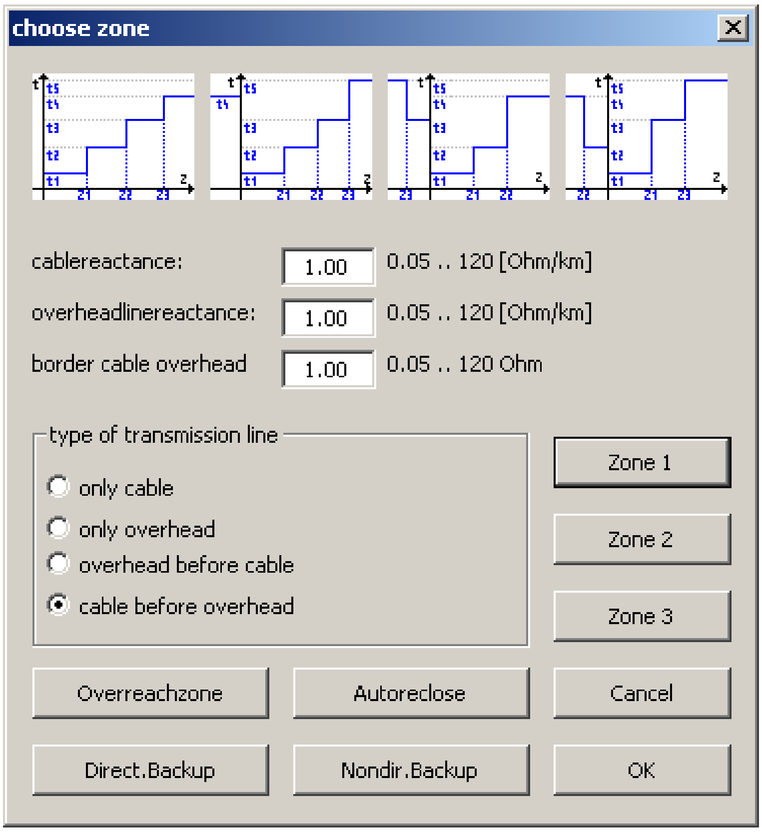


Figure 228: Zones

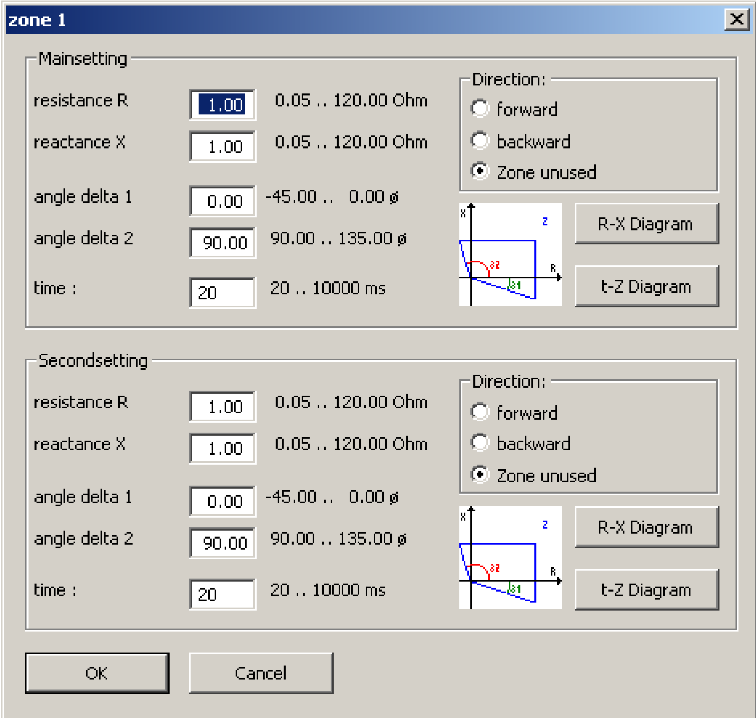


Figure 229: Zone 1

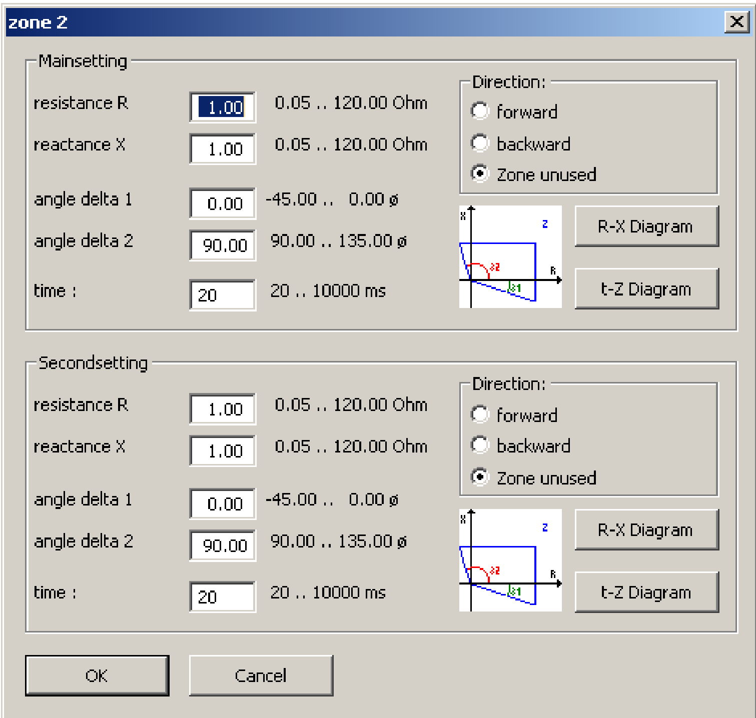


Figure 230: Zone 2

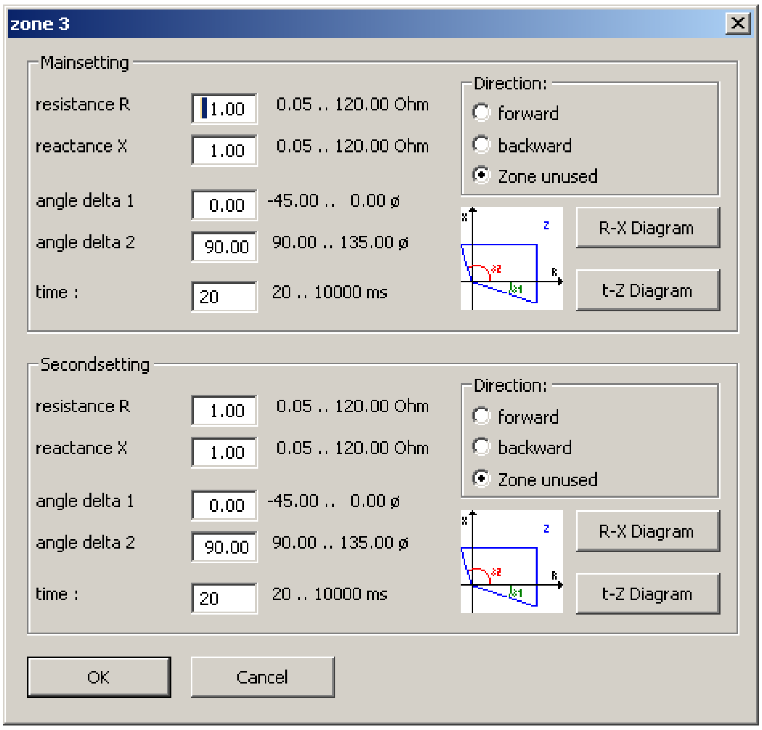


Figure 231: *Zone 3*

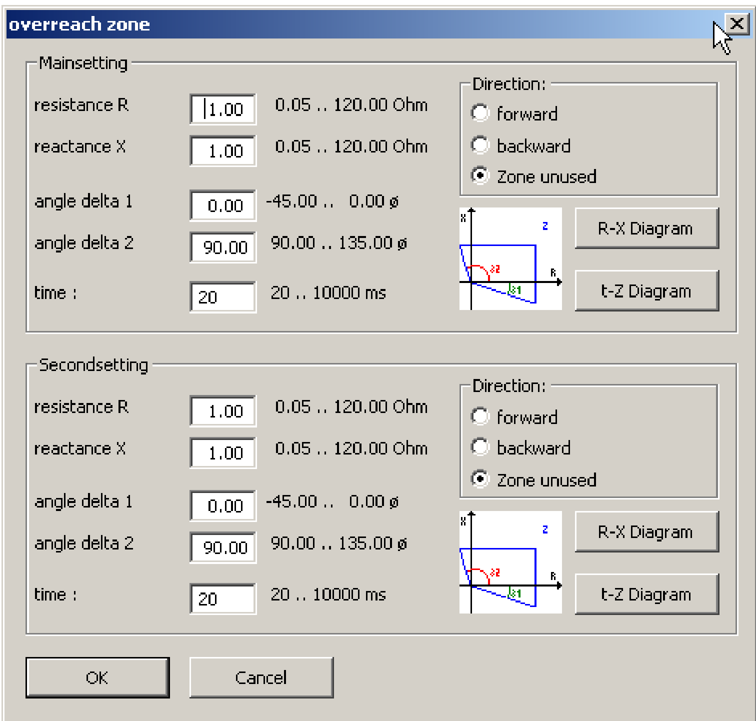


Figure 232: *Zone overreach*

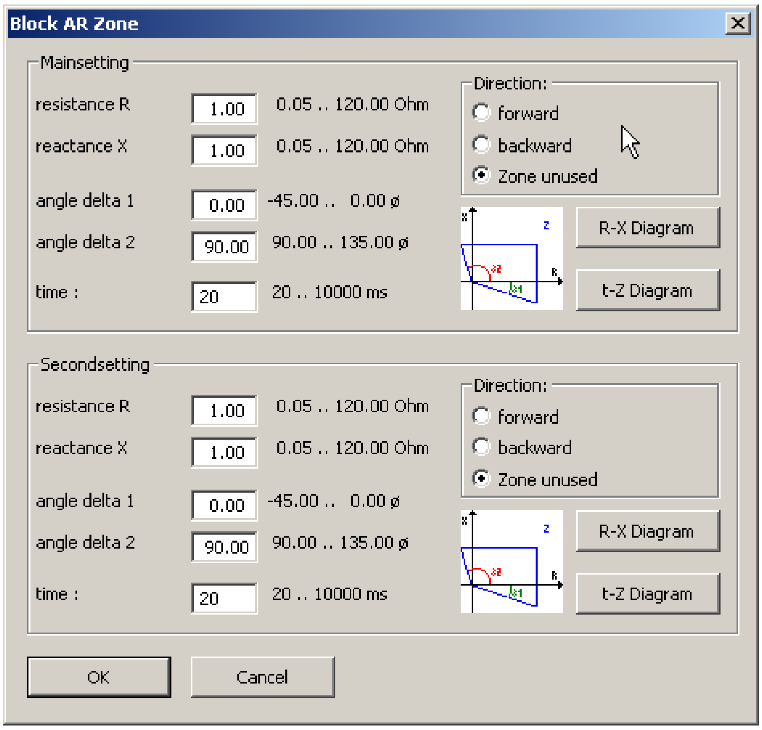


Figure 233: Zone autoreclose (control)

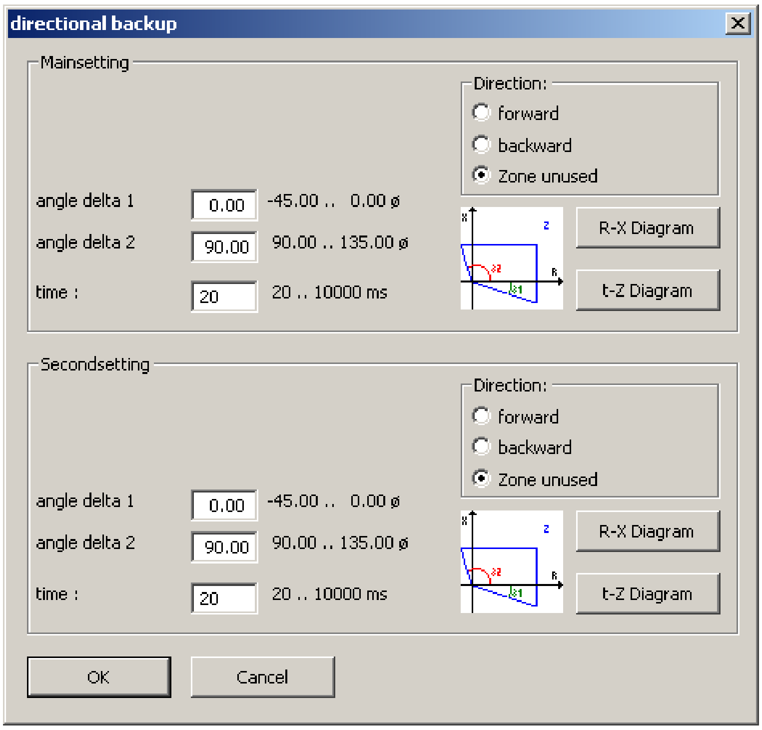


Figure 234: Directional backup

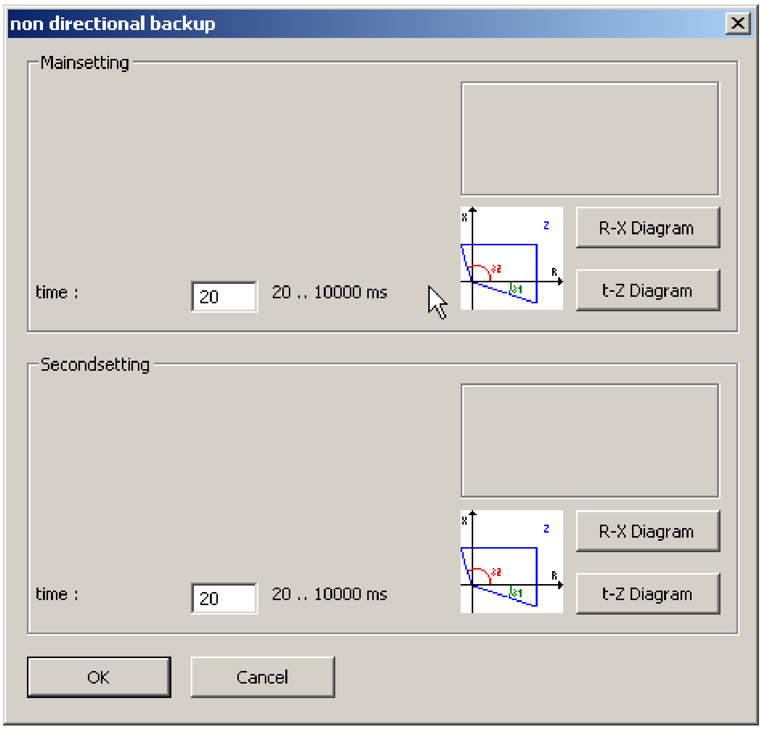


Figure 235: Non-directional backup

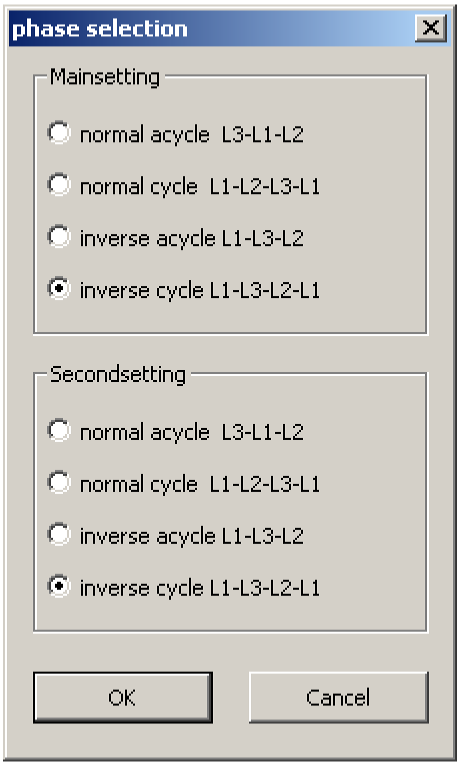


Figure 236: Phase selection

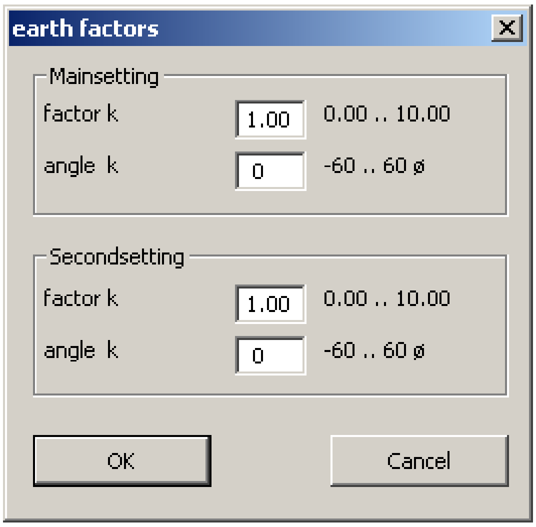


Figure 237: Parameters earth factors

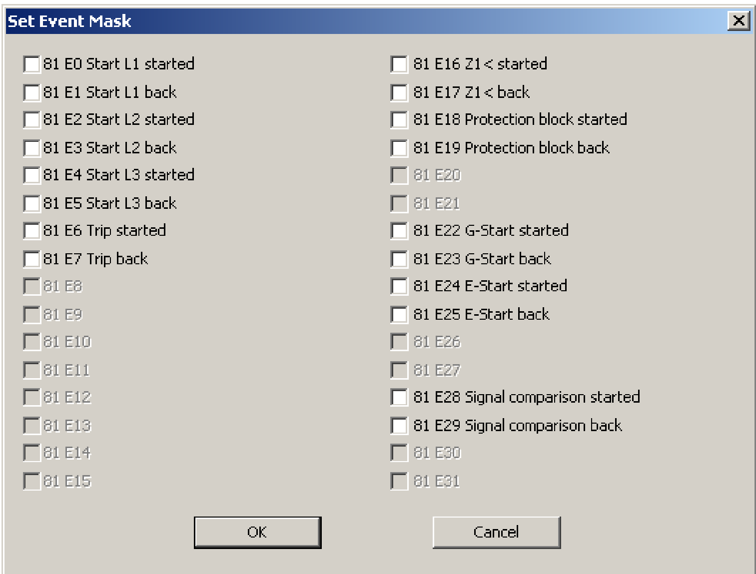


Figure 238: Events

5.4.1.3 Operation mode

The distance protection comprises the following subordinate functions:

- Start
- Impedance determination
- Directional memory
- Tripping logic

To run the protection function, the phase currents and the phase voltages measurement quantities are required. The phase currents and the phase voltages are arranged in consecutive groups of three. The following combinations can be configured:

- Measuring input 1,2,3: current signals; measuring input 4,5,6: voltage signals in phase L1, L2, L3
- Measuring input 1,2,3: voltage signals; measuring input 4,5,6: current signals in phase L1, L2, L3

The start function is intended to check for the presence of a system failure and to detect the type of the fault. The appropriate measured quantities for determining the impedance and the directional decision are selected depending on the type of system fault. Once the direction and the zone of the system fault have been determined, the tripping logic is used to determine the trip time in accordance with the set impedance time characteristic.

A signal comparison protection scheme, which enables to protect a very short line selectively, is also integrated. This requires pilot wires for signal exchange.

For the network operation, it is important to localize the fault as soon as possible after the system fault has been switched off in order to repair the damage. Because the medium-voltage networks are usually spread over wide areas, fault-tracking information in km or in reactive ohm is desirable for network operation after the system fault has been tripped. For this reason, the fault locator, which can derive the fault distance from the measured fault impedance, is also implemented in the distance protection. It calculates the distance in km to the fault from the nominal value of the cable reactance.

The requirement of current transformers for distance protection must be fulfilled. Otherwise the proper function behavior can not be assure. Besides, the fault locator would not be in position to display the correct value.

Once the system fault has been switched off, it may also be of interest for the system operator to carry out a fault analysis from a disturbance recorder and the sequences of the appearance of the signaling events. The fault recorder function can be started either by an external signal (via a binary input) or by a signal from the distance protection. The general start or the trip signal can be used for this purpose.

If the fault recorder is started by the general start signal, the system quantities will be recorded. However, a correct fault reactance can only be detected if the fault is in the first protection zone. Therefore, it is recommended to start the fault recorder by a trip signal.

The option of switching the distance protection over to the overcurrent protection shall normally be provided. This procedure is generally referred to the so-called emergency overcurrent protection and is required if the voltage measurement quantities do not exist anymore, for example due to an MCB failure. Detailed information regarding to the operation principle and the calculation of the setting parameter can be found in the related application note.

5.4.1.4 Setting groups

Two parameter sets can be configured for the thermal overload protection function.

5.4.1.5 Parameters and events

Table 101: General parameter

Net type:	high ohmic, **low ohmic**
Used sensors:	**I: 1-3; U: 4-6** or I: 4-6; U: 1-3
Earth start:	IE> used or IE> unused (residual current)
Switching onto faults:	normal behavior, overreach zone used or **trip after occurrence of general start signal**
Signal Comp. Time:	30…30,000 ms (set 1/set 2), default 30 ms

Table 102: Start values

Parameter	Values	Unit	Default	Explanation
I>	0.05...4.00	In	1.00	Phase current high set
IN>	0.05...4.00	In	0.20	Residual current
UF	0.05...0.90	Un	0.50	Phase or line voltage (net type)
IF>	0.05...4	In	0.50	Phase current low set

Table 103: Choose zone

Parameter	Values	Unit	Default	Explanation
Cable reactance	0.05...120	Ohm/km	1	
OH line reactance	0.05...120	Ohm/km	1	
Border OH/cable	0.05...120	Ohm	1	

Type of transmission line	only cable, only OH line, OH line before cable **or cable before OH line**

Table 104: Zone 1, 2, 3, Zone Overreach, Autoreclose (border)

Parameter	Values	Unit	Default	Explanation
Resistance R	0.05...120	Ohm	1	
Reactance X	0.05...120	Ohm	1	
Angle delta 1	-45...0	°	0	
Angle delta 2	90...135	°	90	
Time	20...10000	ms	20	
Direction	forward, backward or zone unused	-	zone un-used	

Table 105: Directional backup

Parameter	Values	Unit	Default	Explanation
Angle delta 1	-45...0	°	0	
Angle delta 2	90...135	°	90	
Time	20...10000	ms	20	
Direction	forward, backward or zone unused	-	zone un-used	

Table 106: Non-directional backup

Parameter	Values	Unit	Default	Explanation
Time	20...10000	ms	20	

Table 107: Phase selection

Parameter	Trip Selection
Normal acycle	L3 - L1 - L2
Normal cycle	L3 - L1 - L2 - L3
Inverse acycle	L1 - L3 - L2
Inverse cycle	L3 - L2 - L1 - L3

Table 108: Earth factor

Parameter	Values	Unit	Default	Explanation
Factor k	0...10			
Angle k	-60...60	°		

Table 109: Events

Code	Event reason
E0	Start L1 started
E1	Start L1 back
E2	Start L2 started
E3	Start L2 back
E4	Start L3 started
E5	Start L3 back
E6	Trip started
E7	Trip back
E16	Z1< started
E17	Z1< back
E18	Protection block started
E19	Protection block back
E22	General start started
E23	General start back
E24	Earth start started
E25	Earth start back
E28	Signal comparison started
E29	Signal comparison back

By default all events are disabled.

5.4.2 Distance protection V2

Distance protection V2 is introduced in Release 3.0, starting from version V4F08x, and dedicated to protect a three-phase meshed medium-voltage system or a simple high-voltage system. It is designed so that it can also be used to protect a single-phase as well as a two-phase railway system. In that case, two separate networks can be protected simultaneously.

The first function block is used for the common fault detection. The second function block can be configured for the related zones as needed by the protection scheme.

Figure 239: Distance protection common fault detection function

Figure 240: Distance protection zone (configurable for up to eight distance zones)

5.4.2.1 Input/output description

Table 110: Inputs, common fault detection

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset regardless of its state. This means that all the output pins go low, generating the required events, if any, and all the internal registers and timers are cleared. The protection function remains idle until the BL signal goes low.

Table 111: Outputs, common fault detection

Name	Type	Description
START L1	Digital signal (active high)	Start signal in L1
START L2	Digital signal (active high)	Start signal in L2
START L3	Digital signal (active high)	Start signal in L3
EARTH START	Digital signal (active high)	Start Earth signal
GENERAL START	Digital signal (active high)	General start signal
TRIP	Digital signal (active high)	Trip signal

START L1, START L2 and START L3 are the phase-selective start signals. The phase-starting signal is activated when the respective phase current start conditions are true (current exceeds the setting threshold value and the fault is in the specified direction).

GENERAL START is a logical OR combination of the start signals START L1, START L2 and START L3 and remains active until the reset time, if used, has expired.

EARTH START is activated when the residual current value exceeds the threshold value.

The TRIP signal is activated when at least for the start conditions are true and the operating time has elapsed.

Table 112: Inputs, distance zone

Name	Type	Description
BS	Digital signal (active high)	Blocking signal
PTT	Digital signal (active high)	Transfer trip signal

When the BS signal becomes active, the protection function is reset regardless of its state. This means that all the output pins go low, generating the required evens, if any, and all the internal registers and timers are cleared. The protection function remains idle until the BS signal goes low.

PTT is activated by an incoming transfer trip signal and can control the trip signal of the zone.

Table 113: Outputs, distance zone

Name	Type	Description
START L1	Digital signal (active high)	Start signal in L1
START L2	Digital signal (active high)	Start signal in L2
START L3	Digital signal (active high)	Start signal in L3
EARTH START	Digital signal (active high)	Start Earth signal
GENERAL START	Digital signal (active high)	General start signal
TRIP	Digital signal (active high)	Trip signal

START L1, START L2 and START L3 are the phase-selective start signals. The phase-starting signal is activated when the respective phase current start conditions are true (current exceeds the setting threshold value and the fault is in the specified direction).

GENERAL START is a logical OR combination of the start signals START L1, START L2 and START L3 and remains active until the reset time, if used, has expired.

EARTH START is activated when the residual current value exceeds the threshold value.

The TRIP signal is activated when at least for the start conditions are true and the operating time has elapsed.

5.4.2.2 Configuration

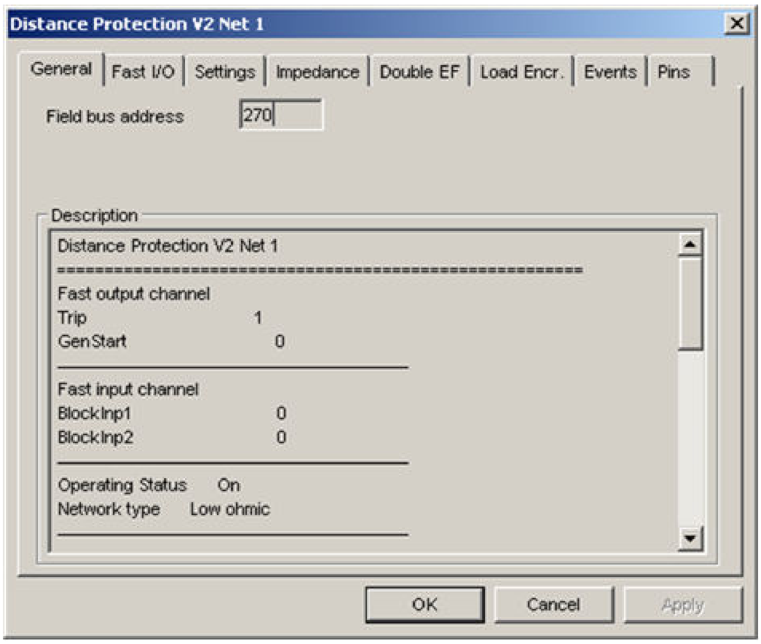


Figure 241: Common fault detection, general

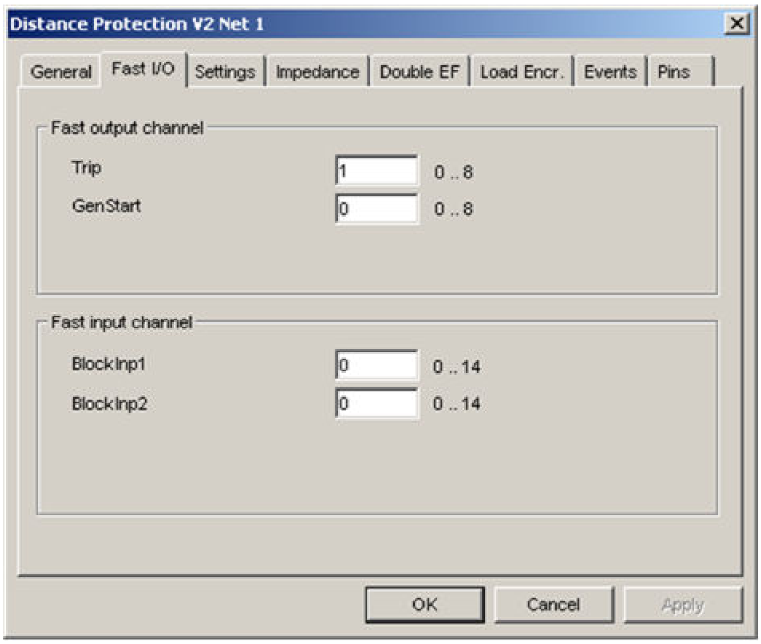


Figure 242: Common fault detection, Fast I/O

Trip	Generate trip signal from the subsequent zones
GenStart	Generate general start signal from the subsequent zones
BlockInp1	Block the operation of all zones
BlockInp2	Block the operation of all zones

Fast input/output channel other than 0 means a direct execution of the trip command, that is, skipping the FUPLA cyclic evaluation.

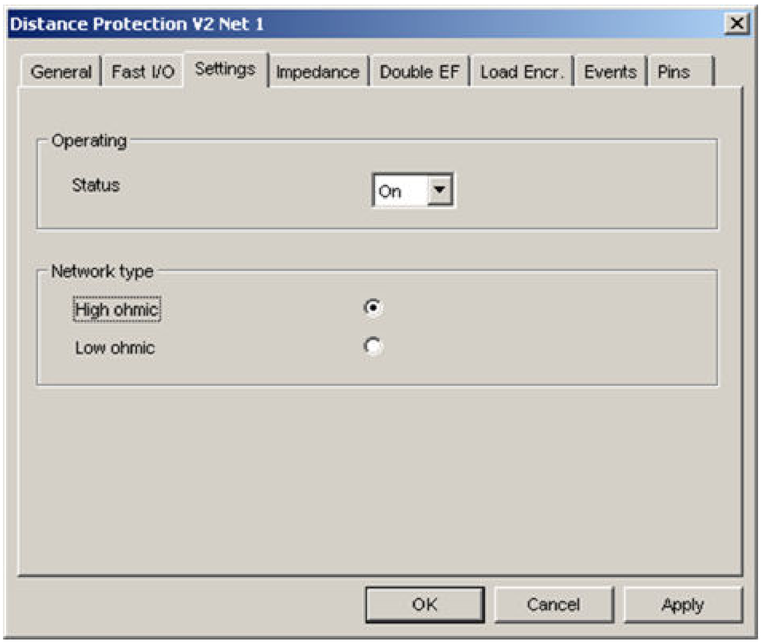


Figure 243: Common fault detection, settings

The operating status for the entire distance protection can be set to “On” or “Off.” In case it is set to “Off,” all subsequent distance zones are off too.

Distance protection can be used either in a network type with a high- or low-ohmic earthing. The high-ohmic earthing describes an electrical system with an isolated neutral or earth fault compensation. In the low-ohmic system the neutral is connected to earth via resistance or reactance.

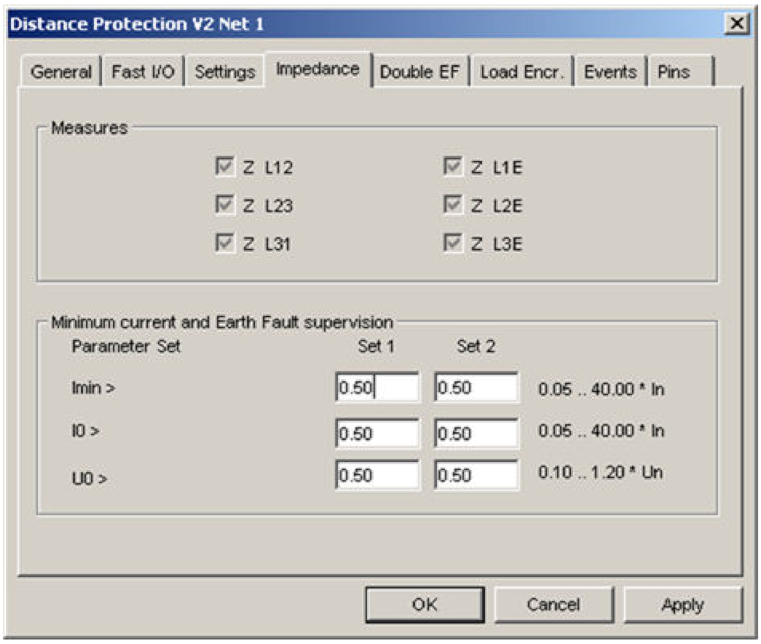


Figure 244: Common fault detection, impedance

Imin> Minimum phase current to release the impedance calculation

I0> Threshold value for the residual current

U0> Threshold value for the residual voltage

All the impedance loops to be calculated are listed in the property sheet. In a three-phase system there are six impedance loops in total to be considered. For single or two-phase applications, for example for the protection of a railway system, the calculated impedance loops, depending on the selected current and voltage sensor configuration, are shown accordingly.

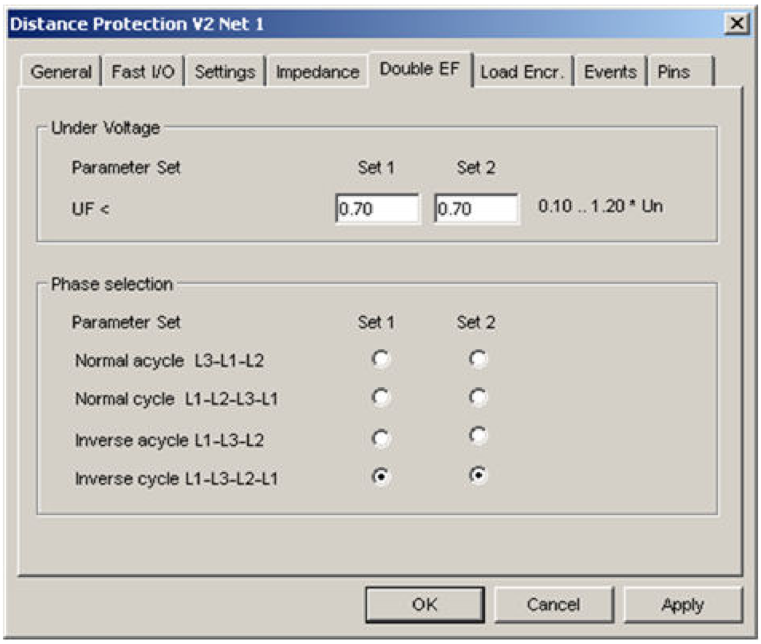


Figure 245: Common fault detection, double-earth fault

UF<	Undervoltage supervision of the line voltages to detect the involved phases
Phase selection	Clearance of one earth fault during a double-earth fault in the high-ohmic net type. For example, for the setting normal acycle L3-L1-L2, the earth fault in phase L3 is switched off during a double-earth fault in phases L2 and L3.

The double-earth fault parameters are only available and released for the high-ohmic net type. The aim is to switch off only one of the two earth faults which occur on different locations in the network according to a specific phase selection scheme.

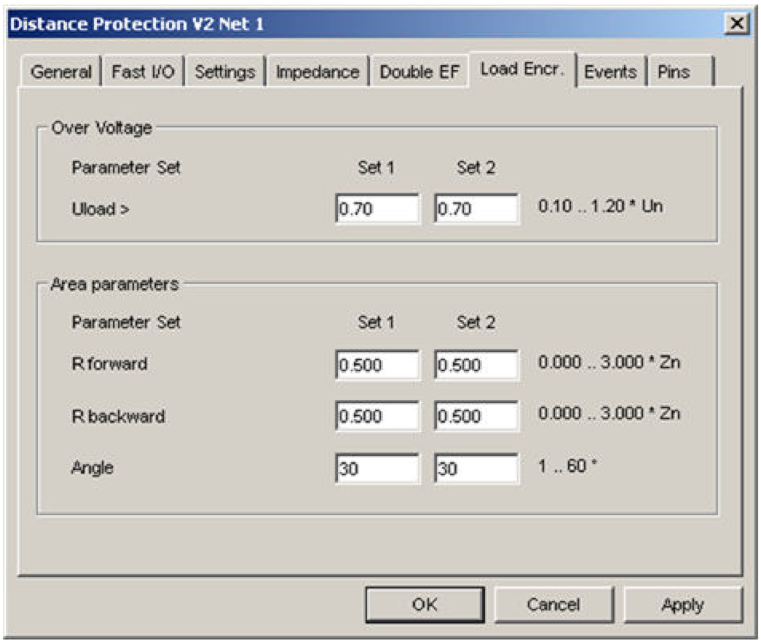


Figure 246: Common fault detection, load encroachment

Uload>	Overvoltage supervision of all line voltages to indicate normal operation
R forward	Reach for the start of the load encroachment area in forward direction
R backward	Reach for the start of the load encroachment area in backward direction
Angle	Angle for limitation of the load encroachment area in both directions

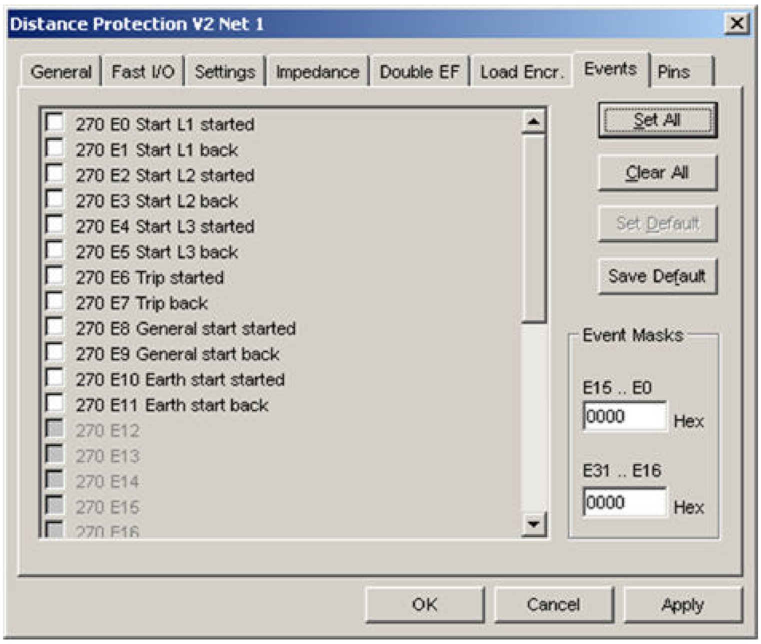


Figure 247: Common fault detection, events

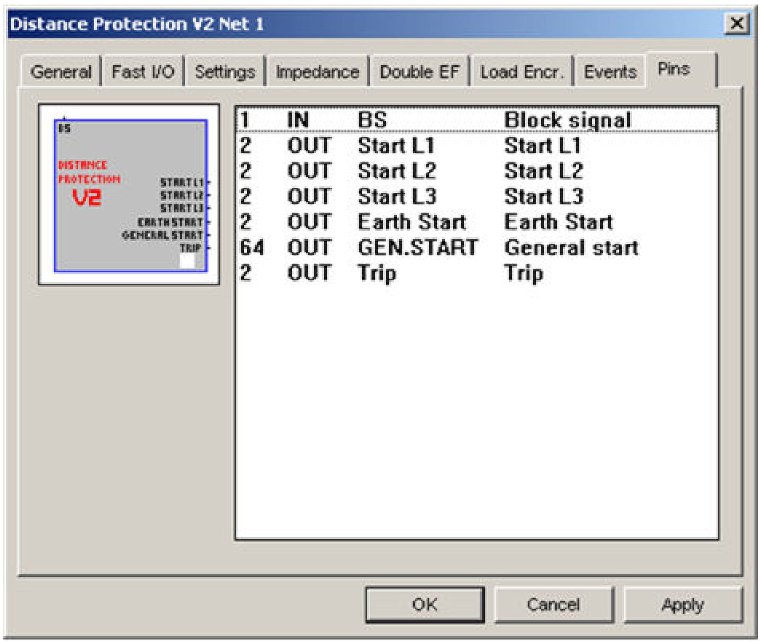


Figure 248: Common fault detection, pins

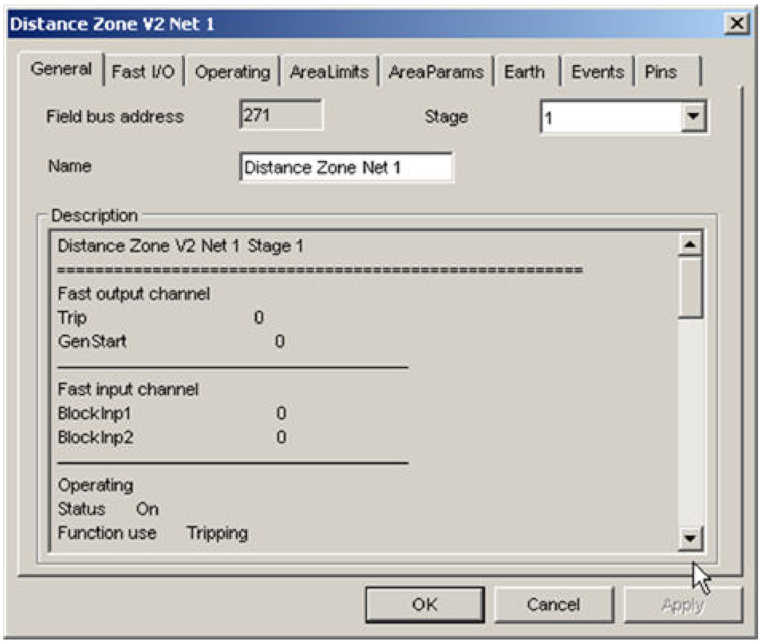


Figure 249: Zone, general

Stage	Number of zones for the required protection scheme (8 in total)
Name	Free selectable naming of the zone, eg overreach zone

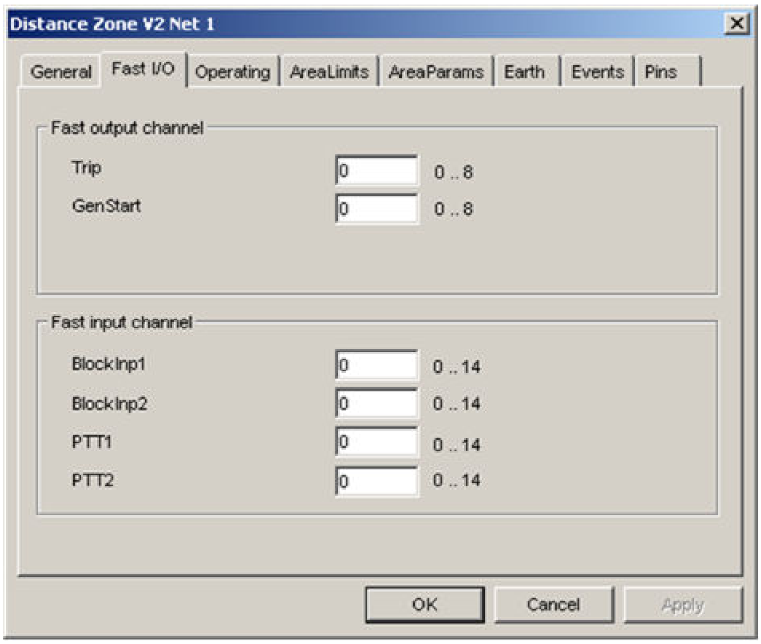


Figure 250: Zone, fast I/O

Trip	Generate trip signal
GenStart	Generate general start signal
GenStart	Generate general start signal
BlockInp1	Block the operation of the zone
BlockInp2	Block the operation of the zone
PTT1	Transfer trip signal for the signal comparison scheme
PTT2	Transfer trip signal for the signal comparison scheme

Fast input/output channel other than 0 means a direct execution of the trip command, that is, skipping the FUPLA cyclic evaluation.

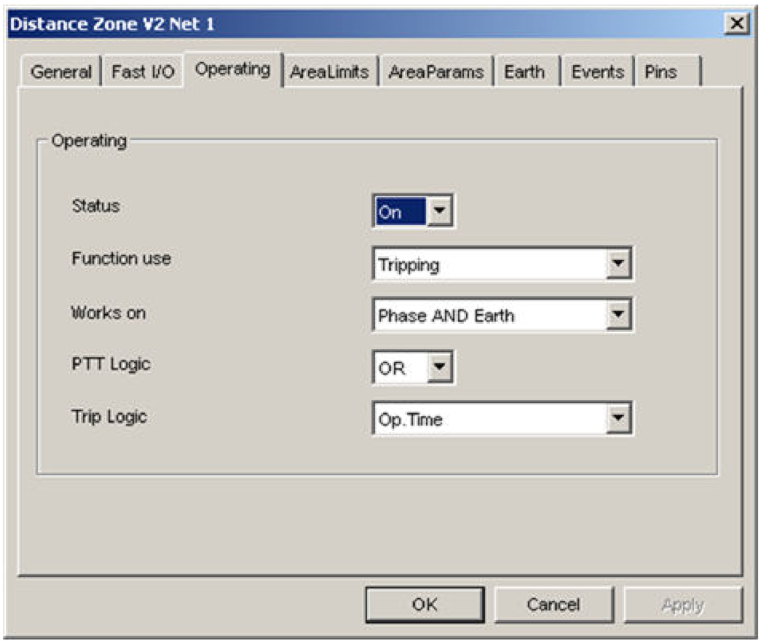


Figure 251: Zone, operating

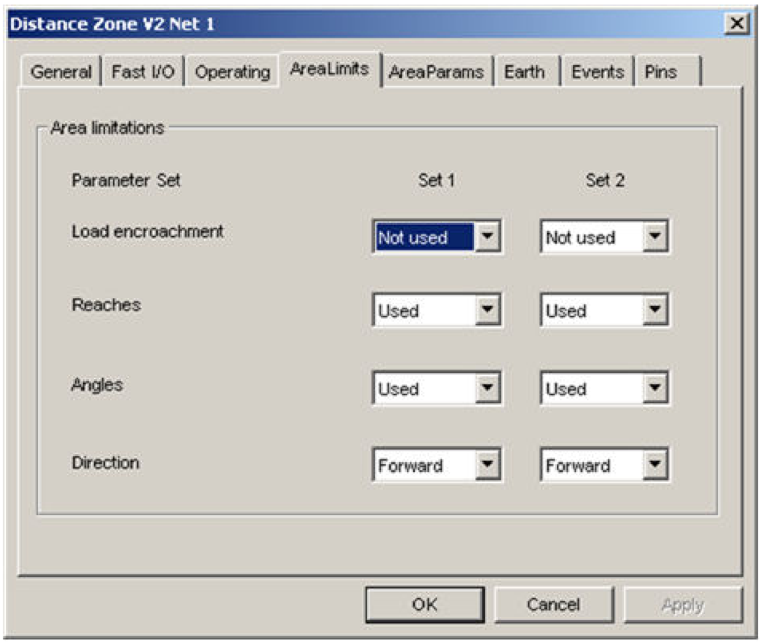


Figure 252: Zone, area limits

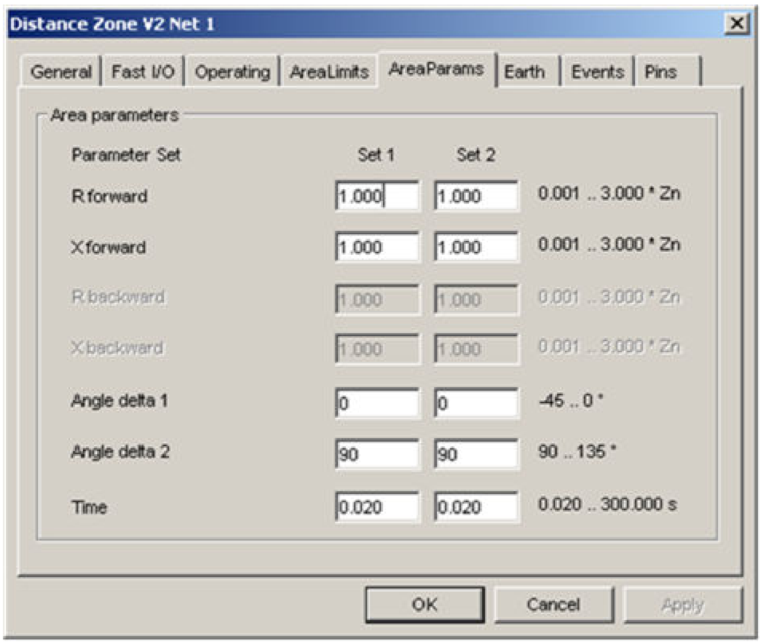


Figure 253: Zone, area parameters

R forward	Zone limitation in forward direction
X forward	Zone limitation in forward direction
R backward	Zone limitation in backward direction
X backward	Zone limitation in backward direction
Angle delta1	Directional angle limitation
Angle delta2	Directional angle limitation

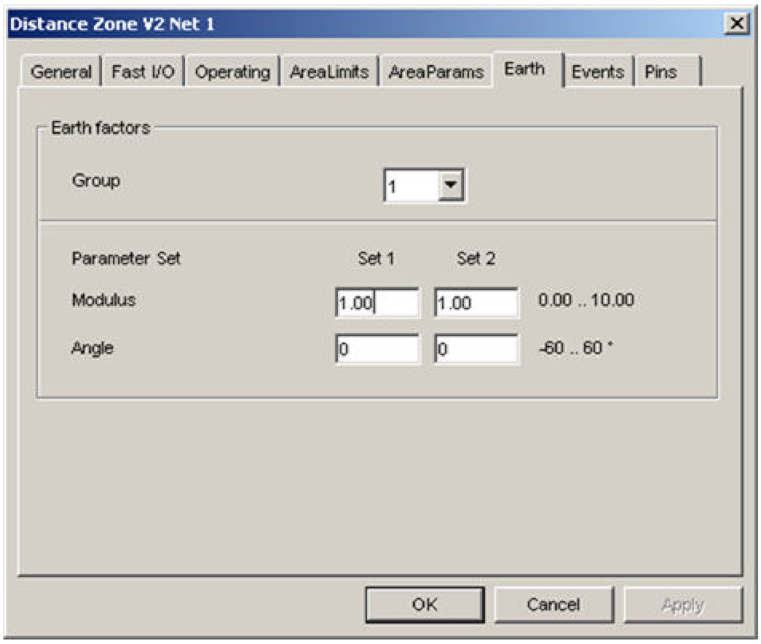


Figure 254: Zone, earth

Earth factor group	Setting group of the earth factor for the zones
Modulus	Modulus of the complex earth factor
Angle	Angle of the complex earth factor

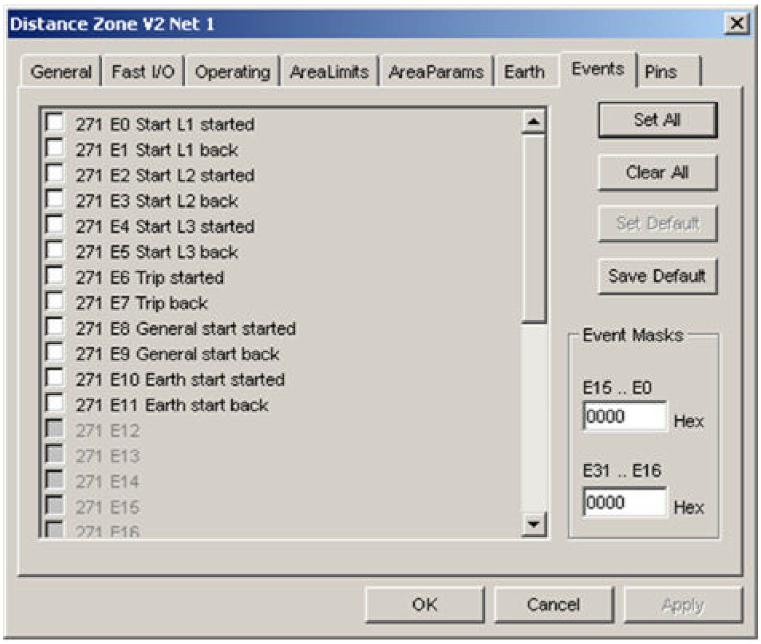


Figure 255: Zone, events

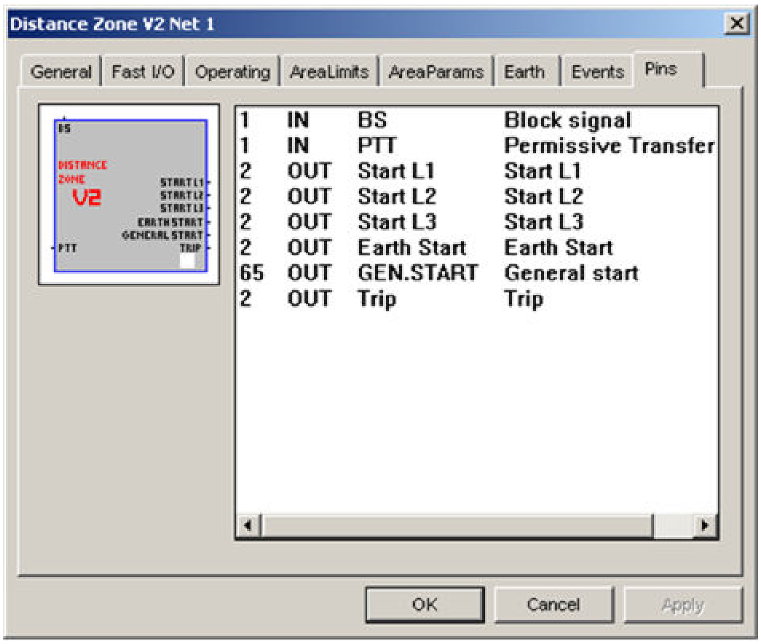


Figure 256: Zone, pins

5.4.2.3 Operation mode

The distance protection comprises of one common fault detection function and the zones. The number of required zones can be freely configured.

Please refer to the related application notes for more detailed information.

To run the protection function, the measurement quantities for the phase currents and phase voltages are required. For the application in a three-phase system, the phase currents and phase voltages are arranged in consecutive groups of three. In a single phase or two-phase system the corresponding input shall be used. The following combinations can be configured:

- Measuring input 1,2,3: current signals; measuring input 4,5,6: voltage signals in phase L1, L2, L3
- Measuring input 1,2,3: voltage signals; measuring input 4,5,6: current signals in phase L1, L2, L3

The common fault detection function is intended to check for the presence of a system failure and to detect the type of the fault, a system fault with or without the earth involvement. The appropriate measured quantities for determining the fault impedance and the directional decision are selected, depending on the type of system fault. Once the direction and the zone of the system fault have been determined, trip condition, operation time and transfer trip scheme, if applied, are checked.

For the network operation, it is important to localize the fault as soon as possible after the system fault has been switched off in order to repair the damage. Because the medium-voltage networks are usually spread over wide areas, fault-tracking information in the primary value of the reactive ohm is available. An optional fault locator function is provided too.

The requirement of current transformers for distance protection must be fulfilled. Otherwise the proper function behavior cannot be assured. Besides, the fault locator would not be in position to display the correct value.

Once the system fault has been switched off, a fault analysis can be carried out from a disturbance recorder and the sequences of the appearance of the signaling events. The fault recorder function can be started either by an external signal (via a binary input) or by a signal from the distance protection. The general start or trip signal can be used for this purpose.

If the fault recorder is started by the general start signal, the system quantities are recorded. However, a correct fault reactance can only be detected if the fault is in the first protection zone. Therefore, it is recommended to start the fault recorder by a trip signal.

The option of switching the distance protection to the overcurrent protection is normally provided. This procedure is generally referred to as the so-called emergency overcurrent protection and is required if the voltage measurement quantities do not exist anymore, for example due to an MCB failure. Detailed information regarding to the operation principle and the calculation of the setting parameter can be found in the related application note.

5.4.2.4 Setting groups

Two parameter groups can be configured for the distance protection V2 function. A switch-over between the parameter sets can be performed, depending on the network configuration. If this is not required, set 1 and set 2 can be parameterized identically to avoid a wrong setting if the switch-over of parameters has happened accidentally.

5.4.2.5 Parameters and events

Table 114: Common fault detection, setting values

Parameters	Values	Unit	Default	Explanation
Trip	0...8/16/24		0	Fast output channel
Gen Start	0...8/16/24		0	Fast output channel
BlockInp1	0...14/28/42		0	Fast input channel
BlockInp2	0...14/28/42		0	Fast input channel
Table continues on next page				

Parameters	Values	Unit	Default	Explanation
Status	On/off		On	Operating status
Network type	High ohmic/low ohmic		Low	Earthing of the system neutral
Imin >	0.05...40.00	In	0.50	Current for starting the calculation
I0>	0.05...40.00	In	0.50	Residual current
U0>	0.05...40.00	Un	0.50	Residual voltage
UF<	0.10...1.20	Un	0.70	Low line voltage during double earth fault
Phase selection	L3-L1-L2 L1-L2-L3-L1 L1-L3-L2 L1-L3-L2-L1		L1-L3-L2-L1	Phase selection to switch off an earth fault location during a double-earth fault condition
Uload >	0.10...1.20	Un	0.70	All line voltages high for load encroachment
R forward	0.000...3.000	Zn[1)]	0.500	Forward area for load encroachment
R backward	0.000...3.000	Zn[1)]	0.500	Backward area for load encroachment
Angle	1...60	°	30	Limitation of the area for load encroachment

1) Zn Reference-rated impedance value for setting of the reaches defined by Un divided by In

Table 115: Common fault detection events

Code	Events
E0	Protection start on phase L1
E1	Start on phase L1 canceled
E2	Protection start on phase L2
E3	Start on phase L2 canceled
E4	Protection start on phase L3
E5	Start on phase L3 canceled
E6	Trip signal active
E7	Trip signal back to inactive status
E8	General protection start (logical OR combination of starts)
E9	General start canceled
E10	Protection start on earth
E11	Start on earth canceled
E18	Protection block signal active
Table continues on next page	

Code	Events
E19	Protection block signal back to inactive status
E28	Operation on fault direction forward
E29	Operation on fault direction backward
E30	Operation on fault direction unknown
E31	Operation on fault direction both

Table 116: Zone

Parameters	Values	Unit	Default	Explanation
Trip	0...8/16/24		0	Fast output channel
Gen Start	0...8/16/24		0	Fast output channel
BlockInp1	0...14/28/42		0	Fast input channel
BlockInp2	0...14/28/42		0	Fast input channel
PTT1	0...14/28/42		0	Fast input channel (transfer trip scheme)
PTT2	0...14/28/42		0	Fast input channel (transfer trip scheme)
Status	On/off		On	Operating status
Function use	Tripping/signaling		Tripping	Zone used for tripping or only for indication
Works on	Phase Earth Phase AND Earth		Phase AND Earth	Calculation of the impedance loops
PTT logic	OR/AND		OR	Trip control by transfer trip scheme
Trip logic	Op. Time/Op. Time AND PTT/Op. Time OR PTT/PTT		Op. Time	Trip initiated by operation time and/or by transfer trip scheme
Load encroachment	Used/Not used		Not used	Used/Not used of load encroachment
Reaches	Used/Not used		Used	Used/Not used of the impedance limitation
Angles	Used/Not used		Used	Used/Not used of the directional limitation
Direction	Forward/ Backward/Both		Forward	Zone directional

Table continues on next page

Parameters	Values	Unit	Default	Explanation
R forward	0.000...3.000	Zn[1)]	0.500	Forward area for the impedance zone
X forward	0.000...3.000	Zn[1)]	0.500	Forward area for the impedance zone
R backward	0.000...3.000	Zn[1)]	0.500	Backward area for the impedance zone
X backward	0.000...3.000	Zn[1)]	0.500	Backward area for the impedance zone
Angle delta1	-45...0	°	0	Limitation of the area by directional angle
Angle delta2	90...135	°	90	Limitation of the area by directional angle
Time	0.020...300.000	s	0.0200	Operation time
Group	0...4		1	Group setting for the impedance calculation
Modulus	0.00...10.00		1.00	Modulus of the complex earth factor
Angle	-60...60	°	0	Angle of the complex earth factor

1) Zn Reference-rated impedance value for setting of the reaches defined by Un divided by In

Table 117: Zone

Code	Events
E0	Protection start on phase L1
E1	Start on phase L1 canceled
E2	Protection start on phase L2
E3	Start on phase L2 canceled
E4	Protection start on phase L3
E5	Start on phase L3 canceled
E6	Trip signal active
E7	Trip signal back to inactive status
E8	General protection start (logical OR combination of starts)
E9	General start canceled
E10	Protection start on earth
E11	Start on earth canceled
E18	Protection block signal active
E19	Protection block signal back to inactive status
Table continues on next page	

Code	Events
E20	Transfer trip scheme start
E21	Transfer trip scheme canceled
E28	Operation on fault direction forward
E29	Operation on fault direction backward
E30	Operation on fault direction unknown
E31	Operation on fault direction both

5.4.3 Fault locator

The fault locator is introduced in release 3.0, starting from version V4F08x. It is designed as a separate and autonomous function block to calculate the location of the system fault. By applying the calculated fault reactance and the necessary input data, reactance per km of the related line section, the fault location in km within the line section is derived. The fault locator is in position to cover up to four line sections.

Figure 257: Fault locator

5.4.3.1 Input/output description

Table 118: Inputs, common fault detection

Name	Type	Description
BS	Digital signal (active high)	Blocking signal
EX. TRIG	Digital signal (active high)	External trigger signal

When the BS signal becomes active, the fault locator function is reset, no matter its state. This means that all the output pins go low, generating the required events, if any, and all the internal registers and timers are cleared. The fault locator function remains in the idle state until the BS signal goes low.

EX. TRIG is an external trigger signal through a binary input which can be used to start the fault locator to calculate the fault location in km within the related line section.

Table 119: Outputs, common fault detection

Name	Type	Description
START	Digital signal (active high)	Start signal
OUT. TRIG.	Digital signal (active high)	Output trigger indication

The START signal is activated when the fault locator is triggered.

The TRIP signal is activated when at least for the start conditions are true and the operating time has elapsed.

5.4.3.2 Configuration

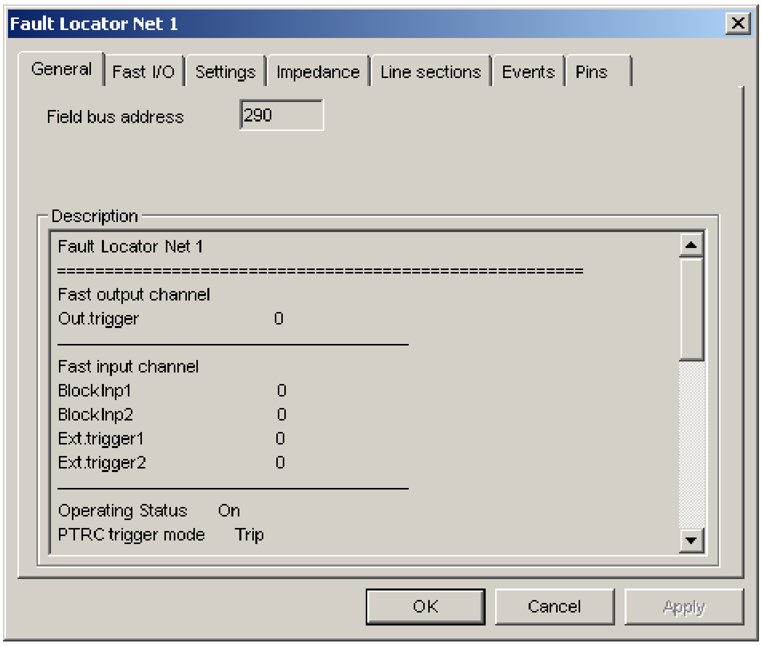


Figure 258: General

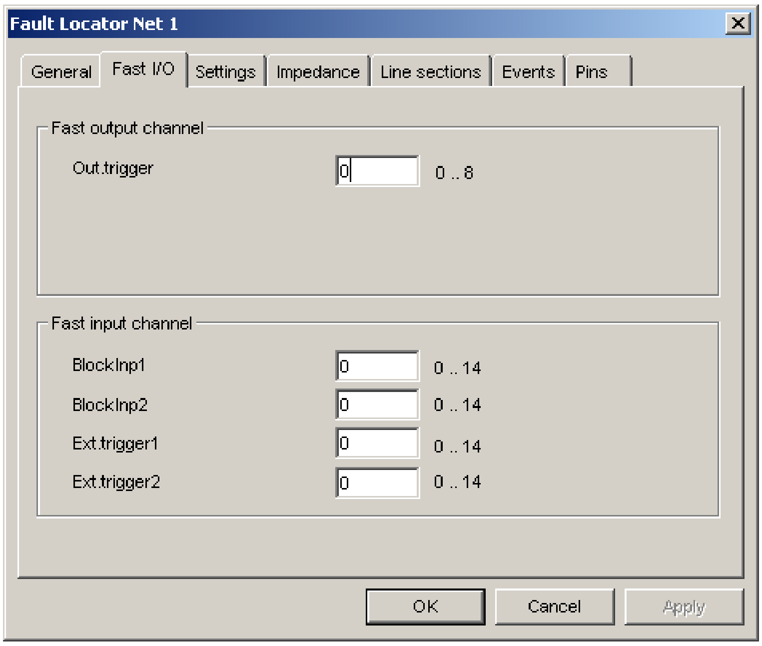


Figure 259: Fast I/O

BlockInp1	Block signal
BlockInp2	Block signal
Ext.trigger1	Trigger signal
Ext.trigger2	Trigger signal

Fast input/output channel different from 0 means a direct execution of the trip command, that is, skipping the FUPLA cyclic evaluation.

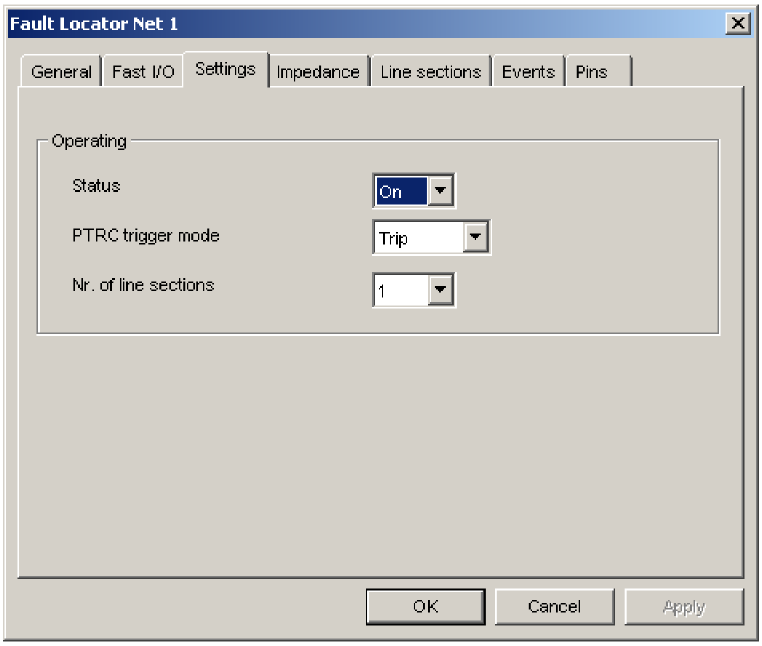


Figure 260: Settings

Status	Operating status
PTRC trigger mode	Triggering of the fault locator by internal protection functions
Nr. of line sections	Number of different line sections to be covered by the fault locator

The fault locator function operates on any combination of the phase current and phase voltages in a triple. For example, it can operate as a single-phase, double-phase or three-phase fault locator on the phase currents and the corresponding phase voltages belonging to the same network.

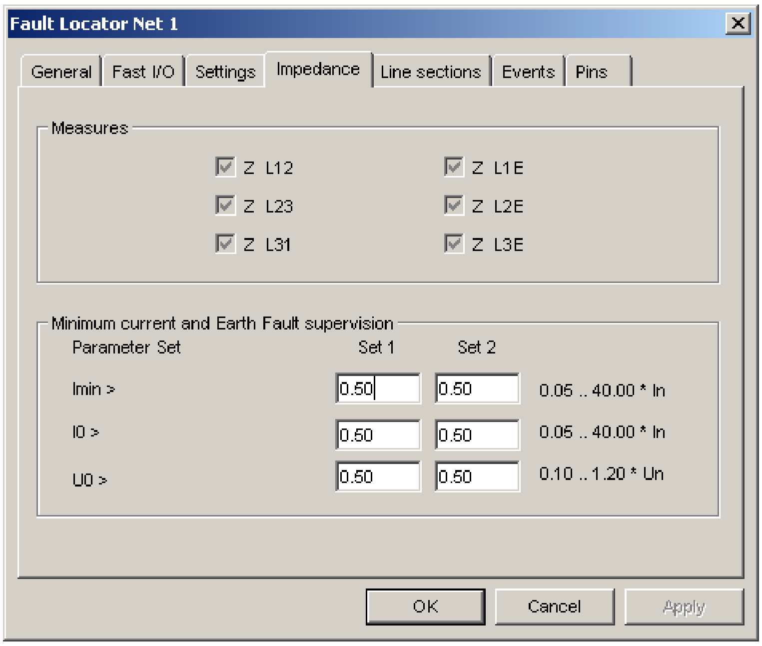


Figure 261: Impedance

Imin> Minimum phase current to release the fault calculation

Io> Residual current for earth fault supervision

Uo> Residual voltage for earth fault supervision

The "Measures" section shows the calculated fault loops for deriving the fault location from the fault reactance. It can operate on any combination of the phase currents and voltages in a triple, for example, and in the single-phase and double-phase systems by applying the related phase currents and phase voltages belonging to the same network.

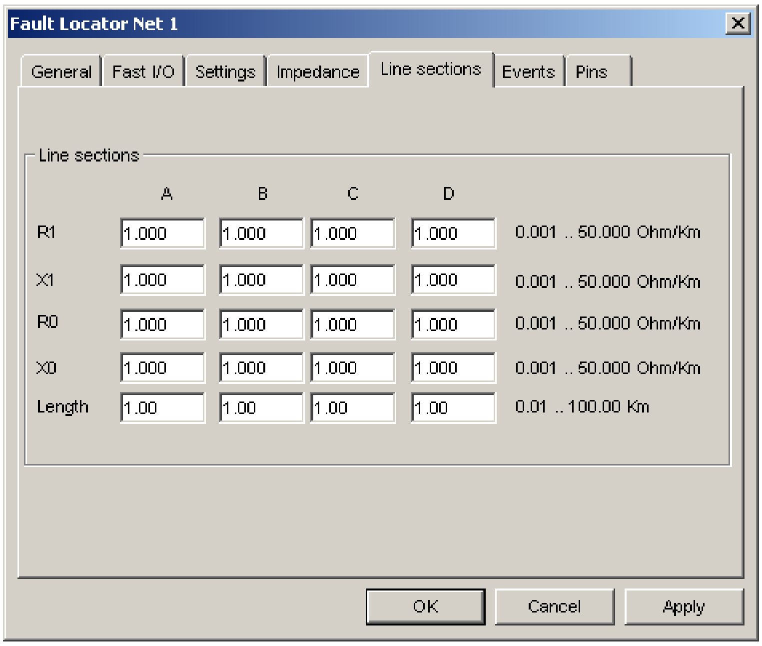


Figure 262: Line sections

R1	Line resistance (positive sequence value) in Ohm per km
X1	Line reactance (positive sequence value) in Ohm per km
R0	Line resistance (zero sequence value) in Ohm per km
X0	Line reactance (zero sequence value) in Ohm per km
Length	Line length in km
A	1st Line section A
B	2nd Line section B
C	3rd Line section C
D	4th Line section D

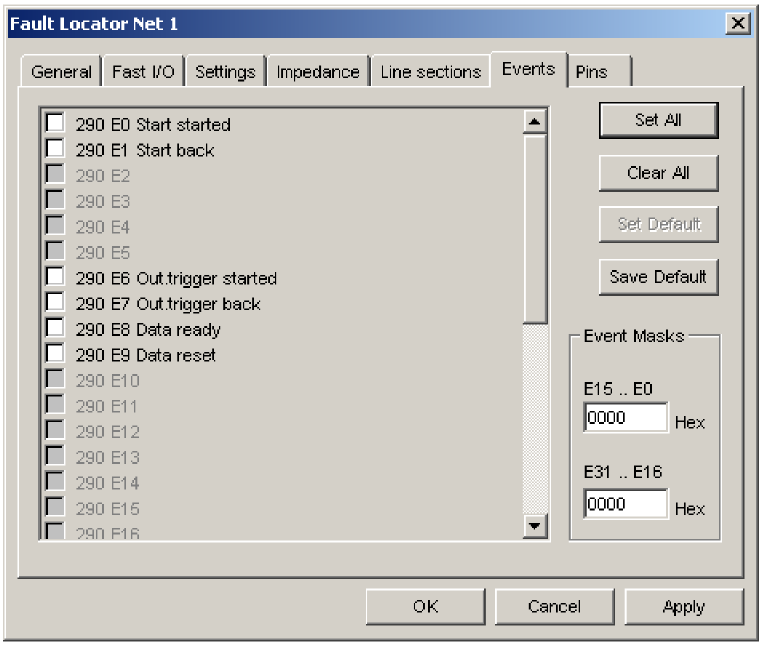


Figure 263: Events

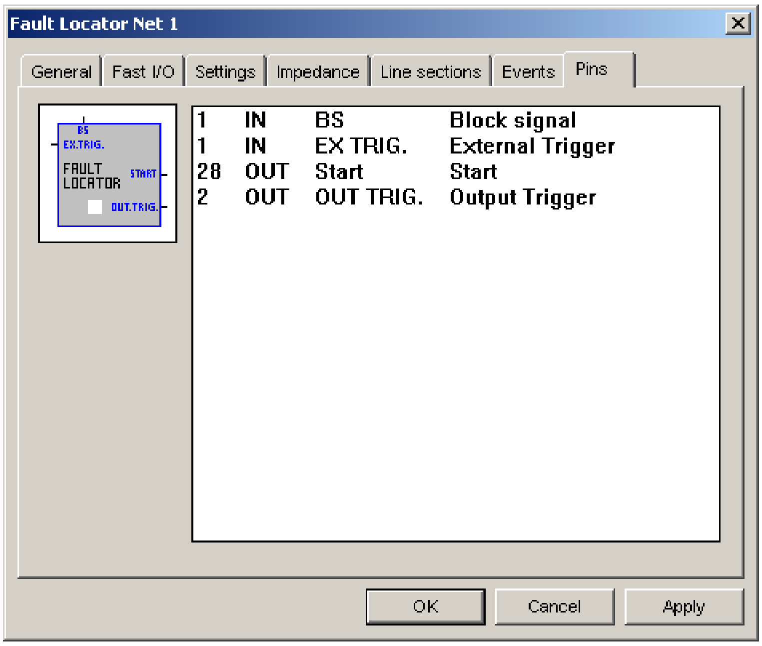


Figure 264: Pins

5.4.3.3 Operation mode

After the fault locator has been triggered, the calculation of the fault locator is started, provided that the corresponding phase currents for the related fault loops exceed the threshold value Imin>. To detect the earth fault condition, the residual voltage Uo> and the residual current Io> are supervised. Depending on the fault condition, the fault impedance is calculated. The fault location is derived from the value of the fault reactance and the input data of the line section. The line can comprise up to four different line sections.

5.4.3.4 Setting groups

Two parameter sets can be configured for the fault locator. A switch-over between the parameter sets can be performed depending on the network configuration. If this is not required, set 1 and set 2 can be parameterized identically to avoid a wrong setting if the switch-over of parameters has happened accidentally.

5.4.3.5 Parameters and events

Table 120: Setting values

Parameters	Values	Unit	Default	Explanation
Out.trigger	0...8		0	Fast output channel
BlockInp1	0...14		0	Fast input channel
BlockInp2	0...14		0	Fast input channel
Ext.trigger1	0...14		0	Fast input channel (external trigger)
Ext.trigger2	0...14		0	Fast input channel (external trigger)
Status	On/Off		On	Operating status
PTRC trigger mode	Not used/Start/ Trip		Trip	Trigger by internal protection functions
Nr. of line sections	1/2/3/4		4	Number of the different line sections to be covered
Imin>	0.05...40.00	In	0.50	Overcurrent condition
Io>	0.05...40.00	In	0.50	Residual overcurrent condition
Uo>	0.10...1.20	Un	0.50	Residual overvoltage condition
R1	0.001...50.000	Ohm/km	1.000	Resistance (positive sequence) per km
X1	0.001...50.000	Ohm/km	1.000	Reactance (positive sequence) per km
Ro	0.001...50.000	Ohm/km	1.000	Resistance (zero sequence) per km
Xo	0.001...50.000	Ohm/km	1.000	Reactance (zero sequence) per km
Length	0.01...100.00	km	1.00	Length of the related line section
A				1st line section
Table continues on next page				

Parameters	Values	Unit	Default	Explanation
B				2nd line section
C				3rd line section
D				4th line section

Table 121: Events

Code	Events
E0	Protection start on phase L1
E1	Start on phase L1 canceled
E6	Trip signal active
E7	Trip signal back to inactive status

5.5 Differential protection

5.5.1 Transformer Differential Protection

Differential protection can be used to protect power transformers, motors and generators. The protection function has the following properties:

- Differential protection of two windings power transformer
- Amplitude and vector group adaptation
- Zero sequence current compensation
- Three-fold tripping characteristic
- Inrush stabilization by 2nd and 5th harmonics
- Stabilization during through-faults also in case of current transformers (CT) saturation

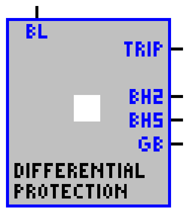


Figure 265: Transformer Differential Protection

5.5.1.1 Input/output description

Table 122: Inputs

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function will then remain in idle state until BS signal goes low.

Table 123: Outputs

Name	Type	Description
TRIP	Digital signal (active high)	Trip signal
BH2	Digital signal (active high)	Block by 2^{nd} harmonic signal
BH5	Digital signal (active high)	Block by 5^{th} harmonic signal
GB	Digital signal (active high)	General Block output signal

The TRIP signal will be activated when at least one of the calculated differential currents Id exceeds the bias-dependent setting threshold value AND if the harmonic stabilization is enabled, the harmonic content of differential current is below the set thresholds (2^{nd} ,5^{th}*Threshold*).

When the harmonic stabilization is enabled, the Block Output (BH2, BH5) signals become active if the protection function detects a differential current exceeding the preset threshold and the harmonic content of differential current is above the set thresholds (2^{nd} ,5^{th}*Threshold*).

5.5.1.2 Configuration

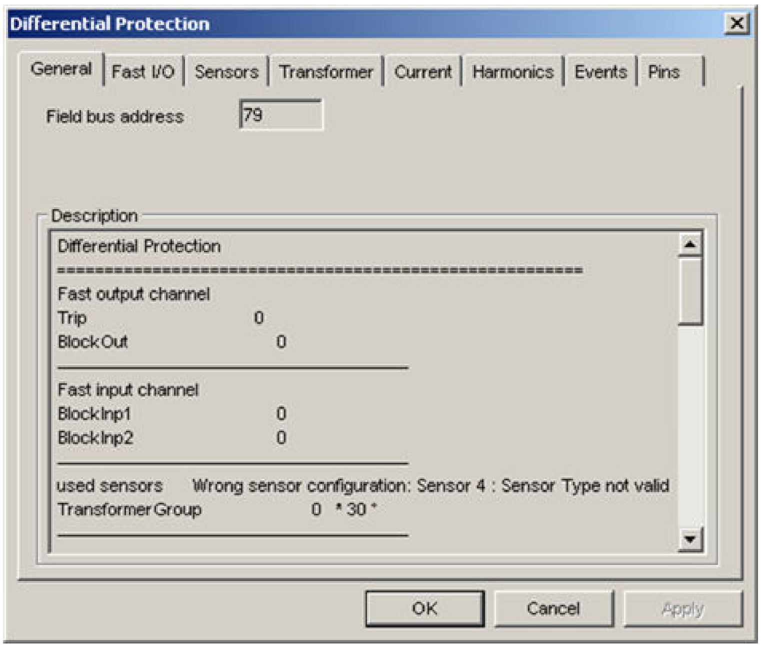


Figure 266: General

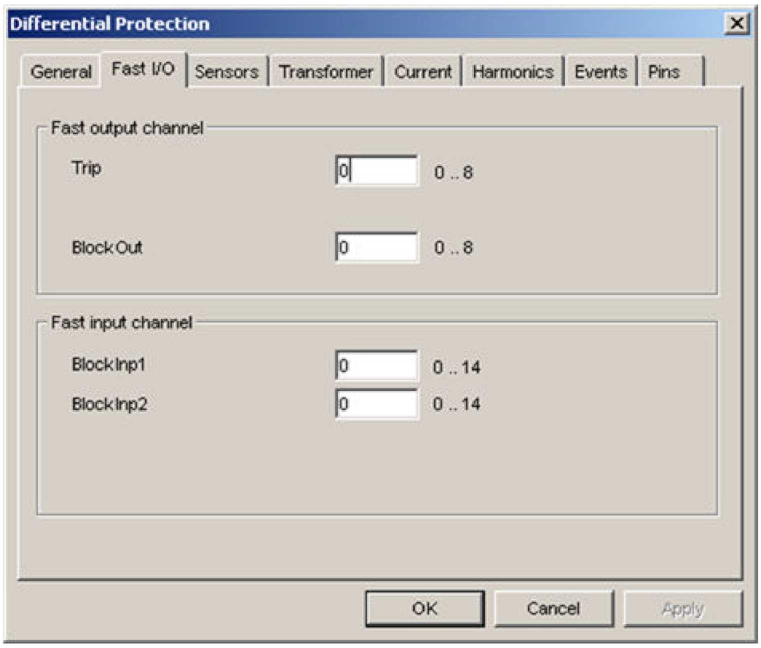


Figure 267: Fast I/O

Output Channel different from 0 means a direct execution of the trip command, that is, skipping FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

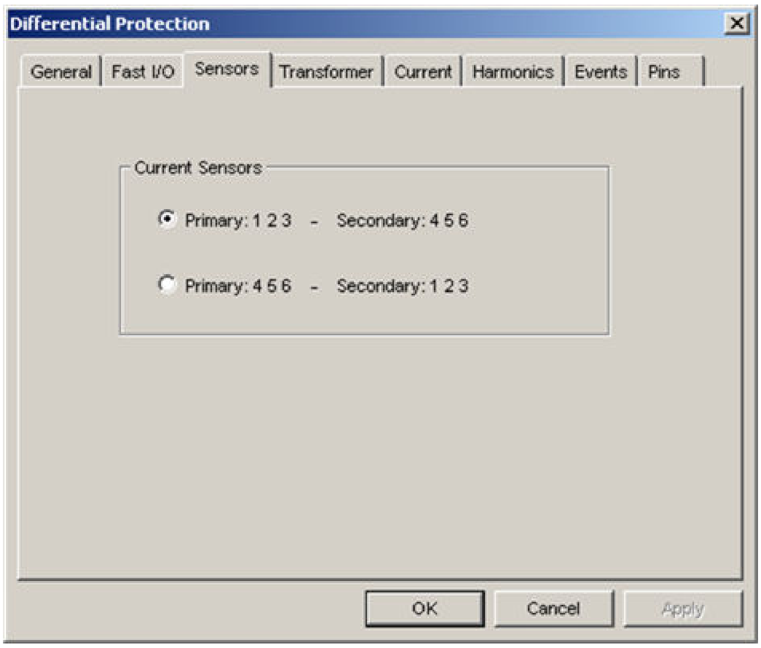


Figure 268: Sensors

Transformer differential protection requires 6 current sensors; it operates on two sets of phase currents in a triple on primary and secondary side of the transformer.

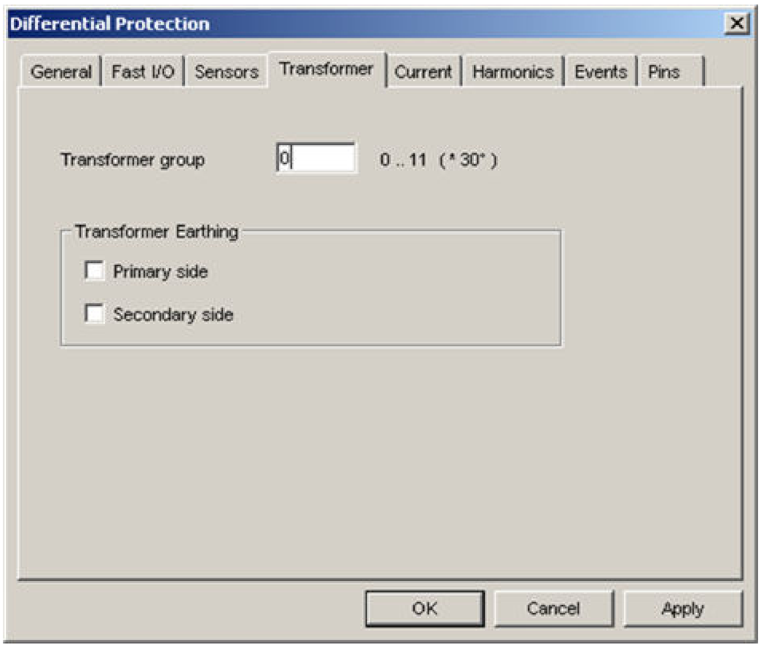


Figure 269: Transformer

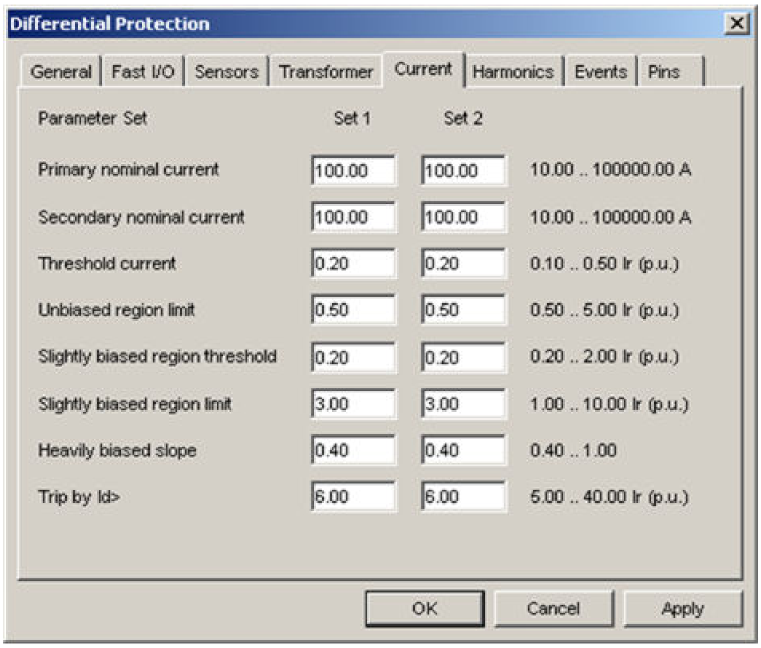


Figure 270: Current

Primary nominal current	Nominal transformer current on primary side
Secondary nominal current	Nominal transformer current on secondary side, to be used for power transformer ratio compensation
Threshold current	First region Id threshold
Unbiased region limit	First region Ib threshold
Slightly biased region threshold	Second region Id threshold
Slightly biased region limit	Second region Ib threshold
Heavily biased slope	Third region slope
Trip by Id	Upper Id threshold for Trip condition detection

All the Differential protection thresholds are referred the Rated power transformer current Ir (p.u) in per unit; i.e. normalized on the primary or secondary nominal power transformer current (**Primary, Secondary nominal current**). In this way all differences due to CT ratios and board transformer analog input are automatically normalized.

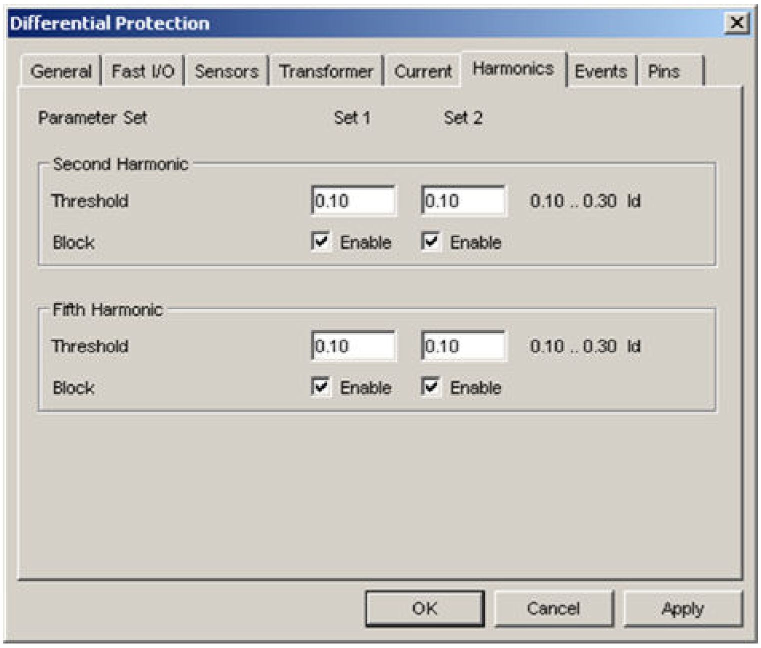


Figure 271: Harmonics

Threshold	Threshold value for 2nd, 5th harmonic content detection
Block	Flag enabling the harmonic content detection. When threshold value is exceeded it blocks the protection function and generates a blocking signal

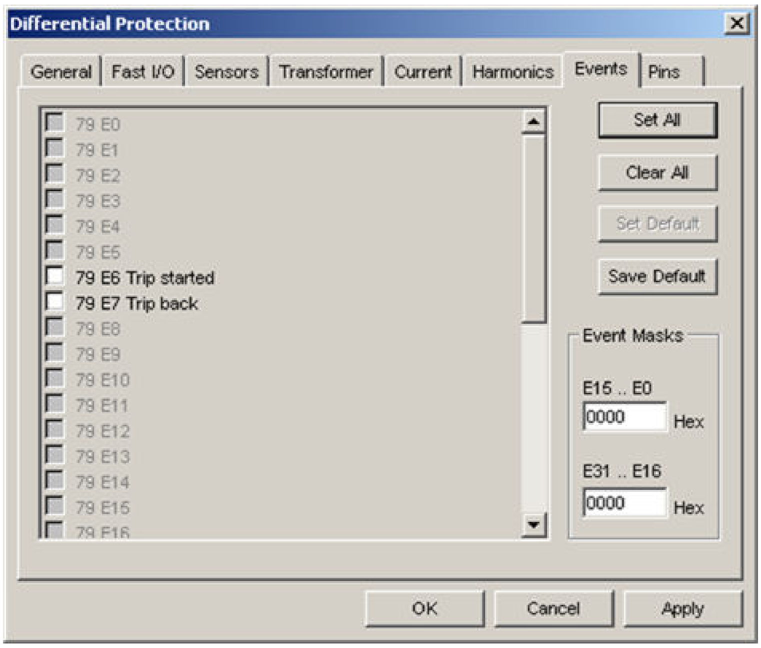


Figure 272: Events

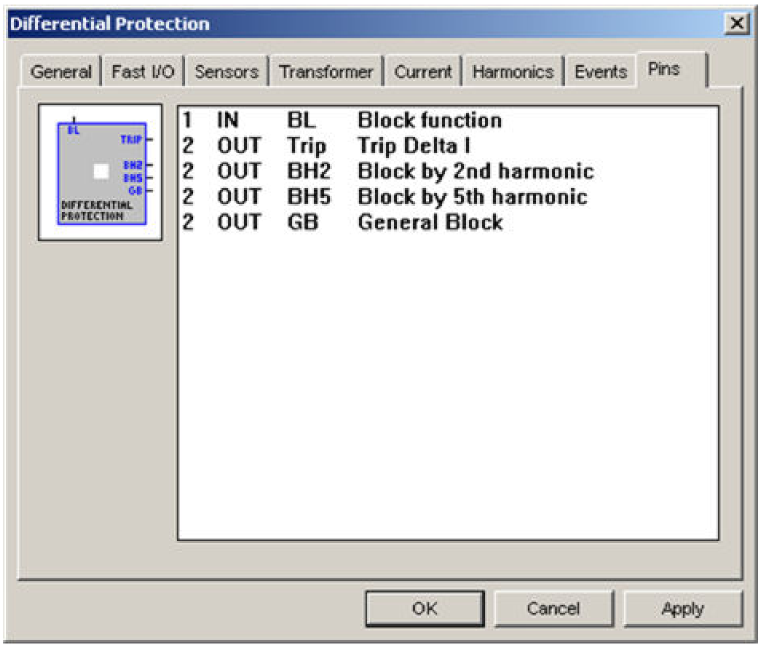


Figure 273: Pins

5.5.1.3 Measurement mode

Differential protection function evaluates the measured amount of differential current at the fundamental, 2nd and 5th harmonic frequencies.

5.5.1.4 Operation criteria

Transformer differential protection is a current comparison scheme for the protection of a component with two sides, like for example two windings power transformer, therefore the incoming and outgoing currents through the component to be protected are compared with each other.

If no fault exists in the protection zone, the incoming current and the outgoing current are identical.

Therefore the difference between those currents, the differential current Id, is used as criteria for fault detection. The protection zone of transformer differential protection is limited by the place where the current transformers or current sensors are installed.

The signals path and the measurement processing to obtain the differential current Id sed as criteria for fault detection are described in the following flowchart:

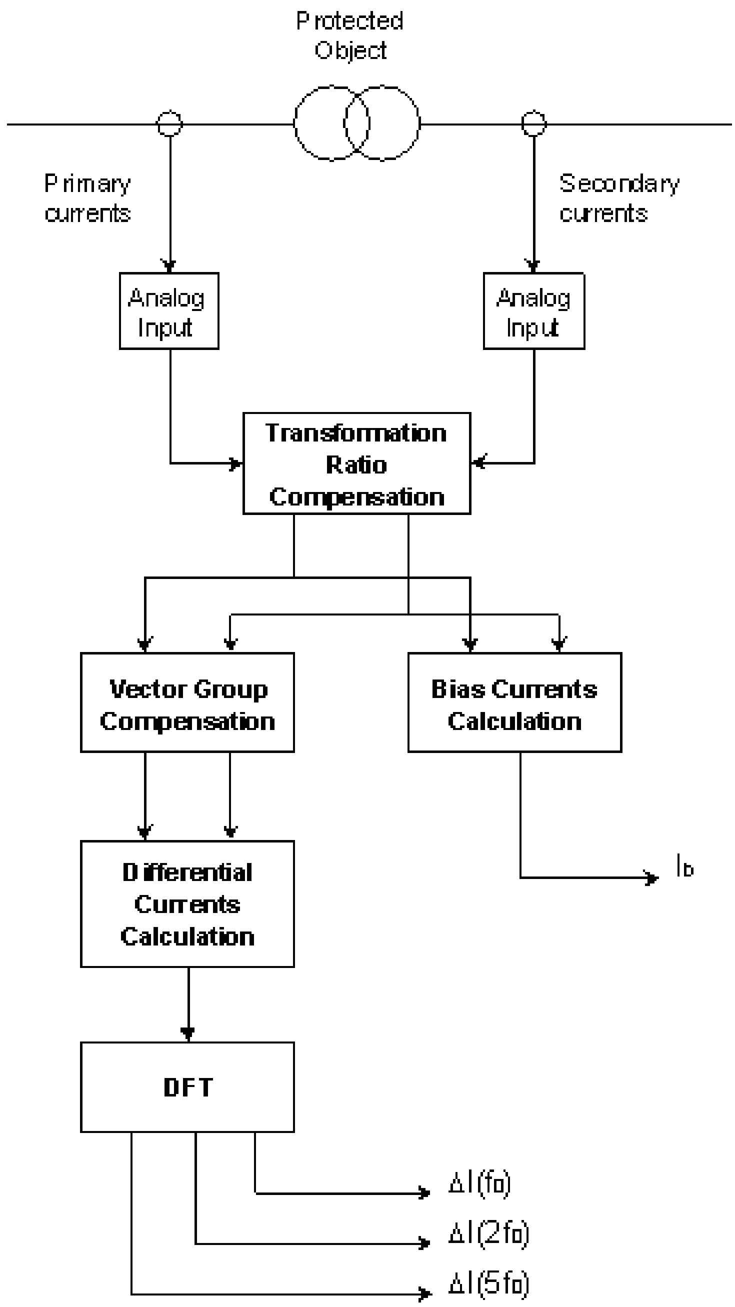


Figure 274: The signals path and the measurement processing

After transformer ratio compensation and vector group adaptation the bias and differential currents are calculated on the three phases.

If harmonic stabilization is enabled (in “Harmonic” dialog window), 2^{nd} and/or 5^{th} harmonic contents of differential currents are calculated.

If at least one of the calculated differential currents Id is above the bias (of the considered phase) dependent setting threshold (given by the tripping characteristic, *Threshold current*, *Slightly biased region threshold*, *Heavily biased region slope* or *Trip by Id>*), then (if required) the check for harmonic stabilization is performed.

If harmonic content of differential current Id is above the set threshold (2^{nd} , 5^{th}*Threshold*), then the protection function will be blocked and the relevant Block signal will be activated, else it goes in TRIP status and the trip signal is generated. The Block of the protection function with the corresponding signal generation will appear, if the Id harmonic content exceeds the setting threshold value for the 2^{nd} and the 5^{th}. harmonics.

The protection function will remain in TRIP status if there is at least one differential current above the threshold. It will come back in passive status and the Trip signal will be cleared if for all the phases the differential current falls below 0.4 the setting threshold value. To perform the current comparison, it is necessary to correct the amplitude of the currents to compensate the transformer ratio. The amplitude correction is done by software. In the case of power transformer protection for example, the current measurement quantities on the primary and the secondary side are corrected by taking into account the different nominal values of the sensors and primary/secondary nominal current parameters.

5.5.1.5 Tripping characteristic

The tripping characteristic of the transformer differential protection function is a three-fold characteristic. In the following figure the characteristic is shown.

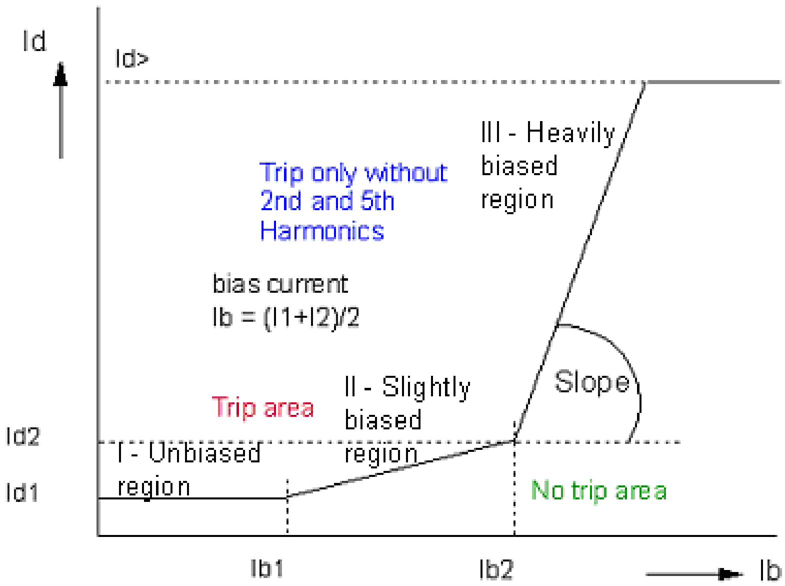


Figure 275: Tripping characteristic of the transformer differential protection function

The tripping characteristic is drawn on p.u. basis after normalization of I1 and I2 currents on on the primary or secondary nominal power transformer current (*Primary nominal current*, *Secondary nominal current*). Therefore Id and Ib currents are expressed in p.u. as multiples of the Rated power transformer current Ir (p.u).

The bias currents are defined as the average values (in p.u.) between primary and secondary currents obtained after transformation ratio compensation and vector group adaptation.

Due to the measurement error of the current quantities on both sides of the object to be protected, a small differential current Id will occur during normal operation condition.

The first fold of the characteristic curve is given by the settable threshold value of the differential current (*Threshold current*) and the bias current limit (*Unbiased region limit*).

The second fold of the characteristic curve is defined by the threshold value of the differential current (*Slightly biased region threshold*) and the bias current limit (*Slightly biased region limit*).

Afterwards a line with a selectable slope (*Heavily biased slope*) continues the characteristic.

In case of the occurrence of a high differential current, a direct tripping can also be generated by the threshold value (*Trip by Id*>) as the third fold of the tripping characteristic. The setting value should be selected in such a way, that no tripping could happen during the energizing of the power transformer.

5.5.1.6 Inrush stabilization

When switching on a power transformer without the connected loads, a high inrush current might occur. As consequence, there could be some unwanted tripping

To stabilize this condition of the power transformer the presence of the 2^{nd} harmonic in the differential current can be used as criteria. Therefore the ratio of the 2^{nd} harmonic current to the current at fundamental frequency is important. As soon as the threshold value (*threshold*) is exceeded, the protection function is blocked and a blocking signal is activated.

In case of switching on a power transformer in parallel without the connected loads, the inrush current can also be generated in the transformer which is already in operation. In this case, it is necessary to detect the 5^{th} harmonic in the differential current to avoid the undesired tripping.

For that reason, the differential protection in REF 542plus is foreseen with the 2^{nd} and the 5^{th} harmonic blocking possibilities, which can be set separately from each other.

5.5.1.7 Setting groups

Two parameter sets can be configured for the transformer differential protection function.

5.5.1.8 Parameters and events

Table 124: Setting values

Parameter	Values	Unit	Default	Explanation
Transformer group	0...11	-	0	Parameters for vector group adaptation and transformation ratio compensation between primary - secondary currents.
Transformer earthing: Primary side Secondary side	 Yes/No Yes/No	 - -	 No No	
Primary nominal current	10...100000	A	100	
Secondary nominal current	10...100000	A	100	
Threshold current	0.10...0.50	Ir (p.u.)	0.20	First region Id threshold.
Unbiased region limit	0.50...5.00	Ir (p.u.)	0.50	First region Ib threshold.
Slightly biased region threshold	0.20...2.00	Ir (p.u.)	0.20	Second region Id threshold.
Slightly biased region limit	1.00...10.00	Ir (p.u.)	3.00	Second region Ib threshold.
Heavily biased region slope	0.40...1.00	-	0.40	Third region slope.
Trip by Id>	5.00...40.00	Ir (p.u.)	6.00	Upper Id threshold for Trip.
Second harmonic: Threshold block	 0.10...0.30 Enabled/ Disabled	 Id -	 0.30 Enabled	Stabilization against no load transformer inrush current
Fifth harmonic: Threshold block	 0.10...0.30 Enabled/ Disabled	 Id -	 0.30 Enabled	Stabilization against transformer overexitation current

Table 125: Events

Code	Event reason
E6	Trip signal is active
E7	Trip signal is back to inactive state
E18	Protection block signal is in active state
E19	Protection block signal is back to inactive
E20	Block signal due to the 2nd harmonic is active
E21	Block signal due to the 2nd harmonic back to inactive
E24	Block signal due to the 5th harmonic is active
Table continues on next page	

Code	Event reason
E25	Block signal due to the 5th harmonic is back to inactive
E26	General block harmonic start
E27	General block harmonic back

By default all events are disabled.

5.5.2 Restricted differential protection

Restricted differential protection can be used as restricted earth fault protection to detect and disconnect a fault in the grounding system of the transformer.

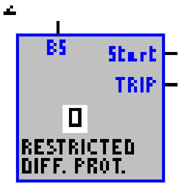


Figure 276: Restricted differential protection

5.5.2.1 Input/output description

Table 126: Inputs

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the `BS` signal becomes active, the protection function is reset no matter its state, this means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the `BS` signal goes low.

Table 127: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal

The `START` signal will be activated when the differential current Id exceeds the setting threshold value.

The `TRIP` signal will be activated when the start and trip conditions are true and the operating time (*Time*) has elapsed.

5.5.2.2 Configuration

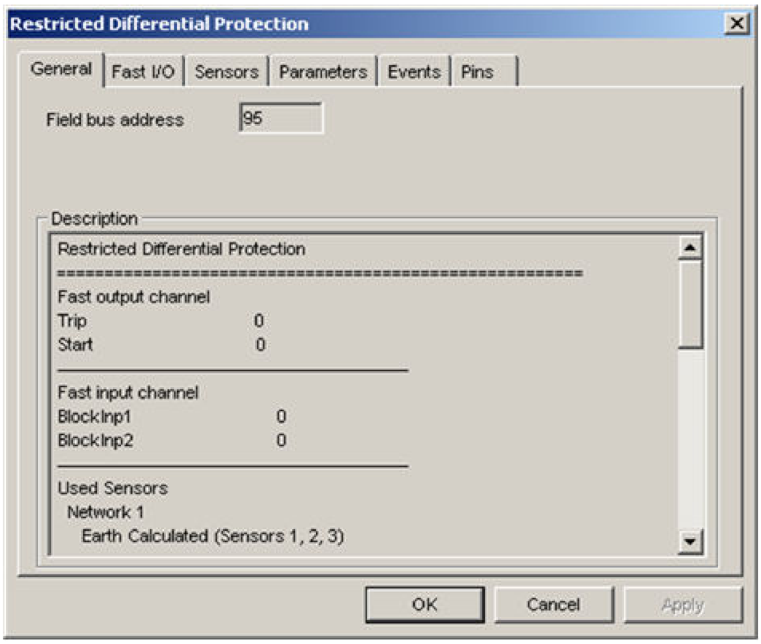


Figure 277: General

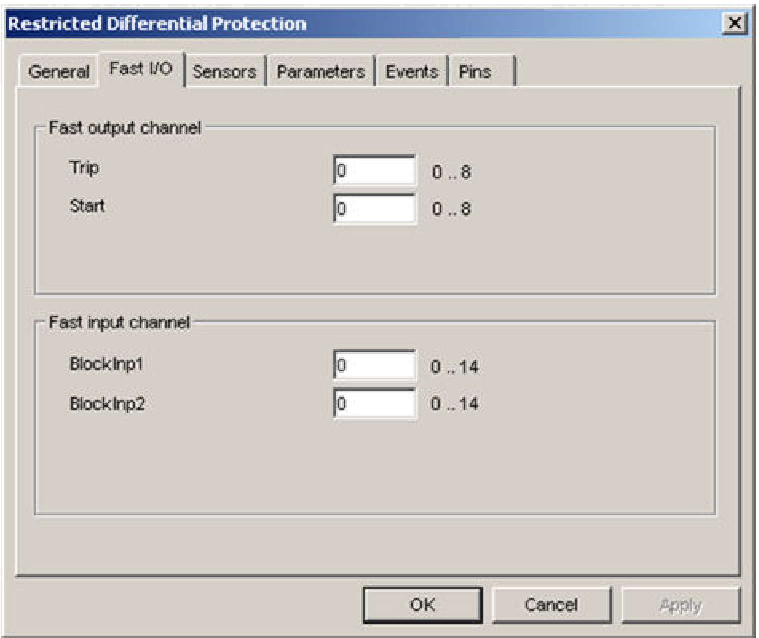


Figure 278: Fast I/O

Output Channel different from 0 means a direct execution of the trip command, that is, skipping FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

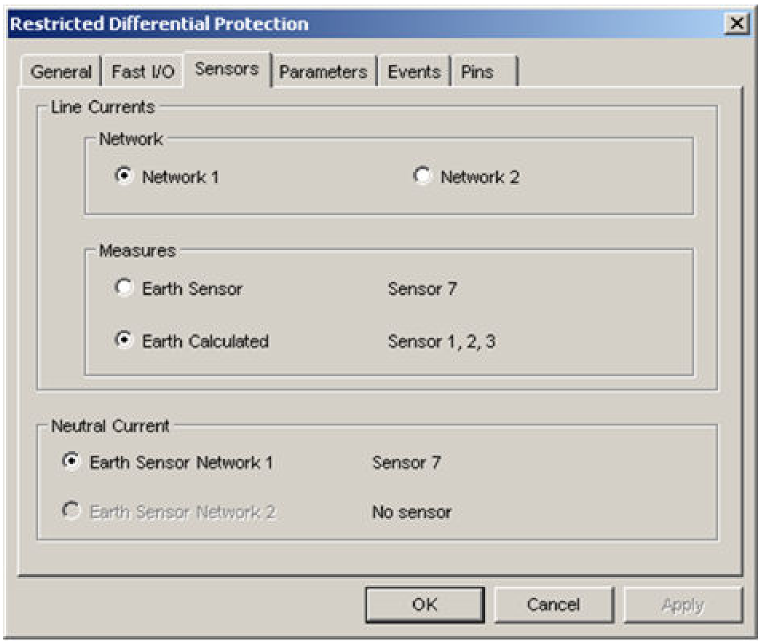


Figure 279: Sensors

The protection function operates on the comparison of two neutral currents; the zero-sequence current calculated by means of current measures acquired from the lines (on any set of phase currents in a triple), and the measured earth-fault current flowing through the neutral conductor towards the ground. The protection is used in case of star windings with earthed neutral transformers.

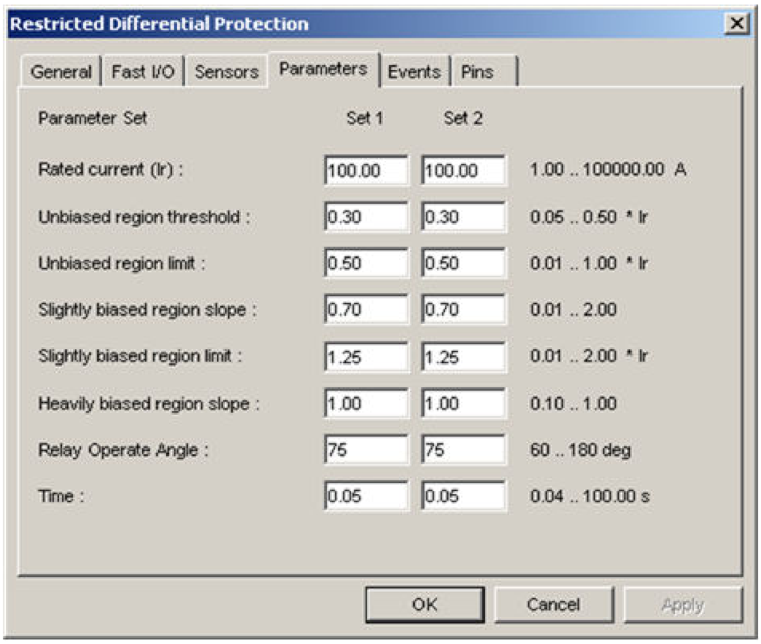


Figure 280: Parameters

Rated current	Rated current for CT ratio compensation and currents normalization
Unbiased region limitUnbiased region threshold	First region Id threshold
Slightly biased region threshold	First region Ib threshold
Slightly biased region limit	Second region Id threshold
Heavily biased slope	Second region Ib threshold
Relay Operate Angle	Third region slope
Time	Directional criteria

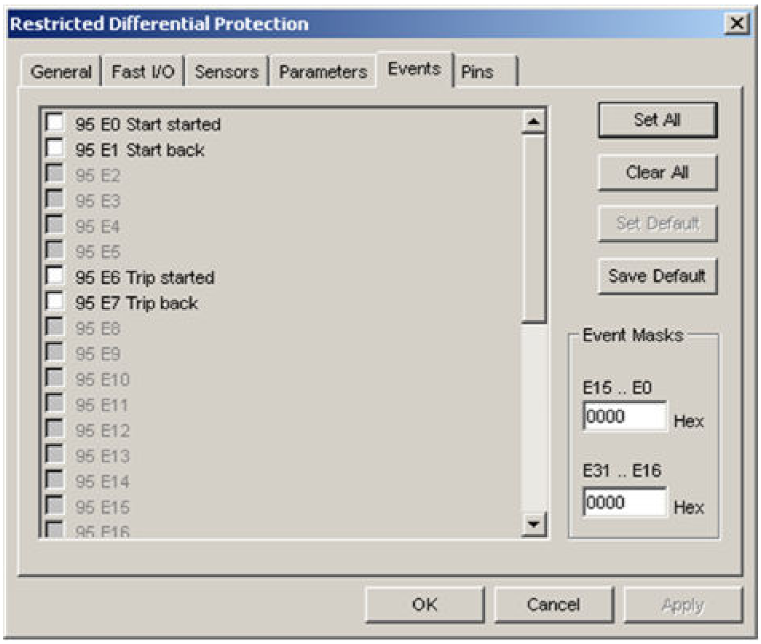


Figure 281: Events

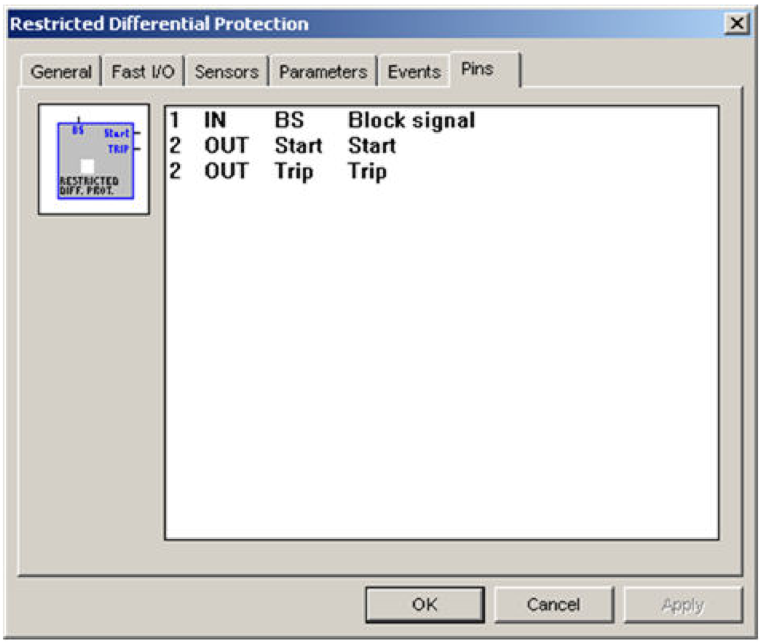


Figure 282: Pins

5.5.2.3 Measurement mode

The restricted differential protection function evaluates the differential current between two neutral currents at the fundamental frequency.

The two currents can be the calculated or measured residual current I0 from the phase currents compared with the neutral current IG in the transformer restricted earth-fault application, in case of line differential protection, the neutral currents of each end of the line (I1.and I2).

5.5.2.4 Operation criteria

The restricted differential protection is a current comparison scheme. Therefore, the incoming and outgoing currents, through the object to be protected, are compared with each other. If no fault exists in the protection zone, the incoming current and the outgoing current are identical. That is why the difference between those currents, the differential current $Id_d = I_0 - IG_G = I_2 - I_1$, is used as criteria for fault detection.

The protection zone of the restricted differential protection is limited by the place where the current transformers or current sensors are installed.

If the calculated differential current Id is above the bias-dependent setting threshold (given by the tripping characteristic, *Unbiased region threshold*, *Slightly biased region threshold* or *Heavily biased slope*), protection function is started and the Start signal will be activated.

The protection function will come back in passive status and the start signal will be cleared, if the differential current Id falls below 0.95 the setting threshold value.

If the start conditions are true then the following conditions are checked:

Direction. The directional check is made only if I0 is more than 3% of the rated current (*Rated current Ir*). If the result of the check means “external fault”, the trip is not issued. If the directional check cannot be executed, then direction is no longer a condition for a trip.

External fault. For as long as the external fault persists (flag enabled in passive condition only, for Id< 0.5 the lower setting threshold and IG> 0.5 the *Rated current Ir*), an additional temporary condition is introduced, which requires that IG has to be higher than 0.5 Ir for protection temporarily desensitization.

Bias. The bias current Ib is above 0.5 the maximum bias current calculated during the start condition period. Ibtrip > 0.5 Ibmax (start period).

When the protection has entered the start status and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated if all the above conditions are true.

The protection function will exit TRIP status to come back in passive status and the Trip signal will be cleared, if the differential current Id falls below 0.4 the setting threshold value.

5.5.2.5 Tripping characteristic

The tripping characteristic of the restricted differential protection function is a three-fold characteristic.

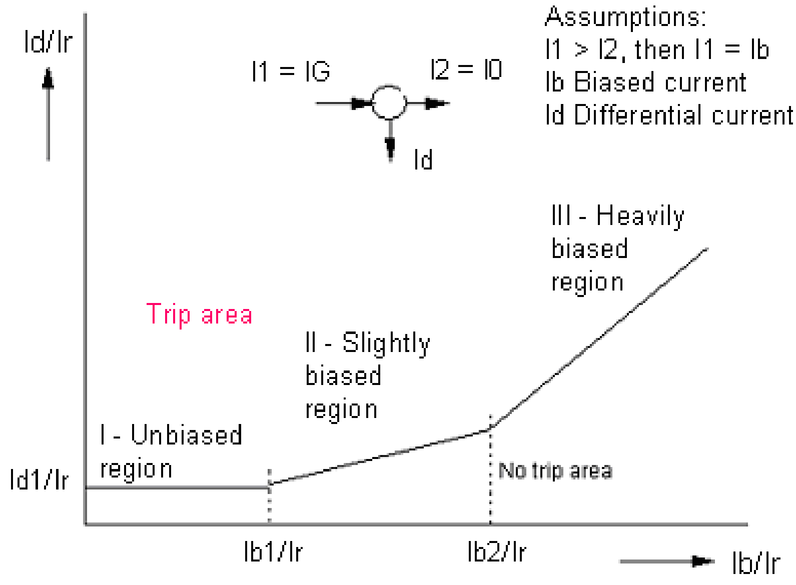


Figure 283: Tripping characteristic

The tripping characteristic is drawn on p.u. basis after normalization of I1 and I2 currents on power transformer rated current (*Rated current Ir*).

The bias current is per definition always the one with the higher magnitude, Ib = max (IG, I0) or Ib = max (I1, I2).

After the compensation of different sensor nominal values, the differential current Id and the bias current Ib are calculated.

The first fold of the characteristic curve is given by the settable threshold value of the differential current (*Unbiased region threshold*) and the bias current limit (*Unbiased region limit*).

The second fold of the characteristic curve is defined by the threshold value of the differential current (*Slightly biased region threshold*) and the bias current limit (*Slightly biased region limit*).

Afterwards a line with a selectable slope (Heavily biased slope) continues the characteristic.

In case of an external fault characterized from a high fault current, it could happen that the different CTs do not transform the primary current the same way (even if they have the same characteristics), allowing the circulation of a differential current through the protection.

The tripping characteristic allows facing CT introduced error (for example due to phase and ratio error, different CT load or magnetic properties), without decreasing the sensitivity of the differential protection. In fact, in case of high line currents and high ground current, the higher differential current threshold compensates such an error even if there are differences about the I0 and IG transformation.

5.5.2.6 Directional criterion for stabilization against CT saturation

Earth faults on lines connecting the power transformer occur much more often than earth faults on a power transformer winding. It is important therefore that the restricted earth fault protection should remain secure during an external fault and immediately after the fault has been cleared by some other protection.

The directional criterion is applied in order to distinguish between internal and external earth faults in case of CT saturation, to prevent misoperations at heavy external earth faults. This criterion is applicable is the residual current I0 is at least 3% Ir.

For an external earth fault with no CT saturation, the residual current in the lines I0 and the neutral current IG are equal in magnitude and phase. The current in the neutral IG is used as directional reference because it flows for all earth faults in the same direction.

To stabilize the behavior against CT saturation, a phase comparison scheme is introduced. In case of a heavy current fault with saturation of one or more CT, the measured currents IG and I0 may no more be equal, nor will their positions in the complex plane be the same, and a certain value of false differential current Id can appear.

If the fault is inside of the protection zone, the currents to be compared must have a phase shift to each other. That is why a so-called relay operate angle ROA (Relay Operating Angle) is introduced, like shown in Figure 5.5.2.6. The direction of neutral current is inside the ROA, if it is an internal fault. The direction of both current is outside the ROA for external faults.

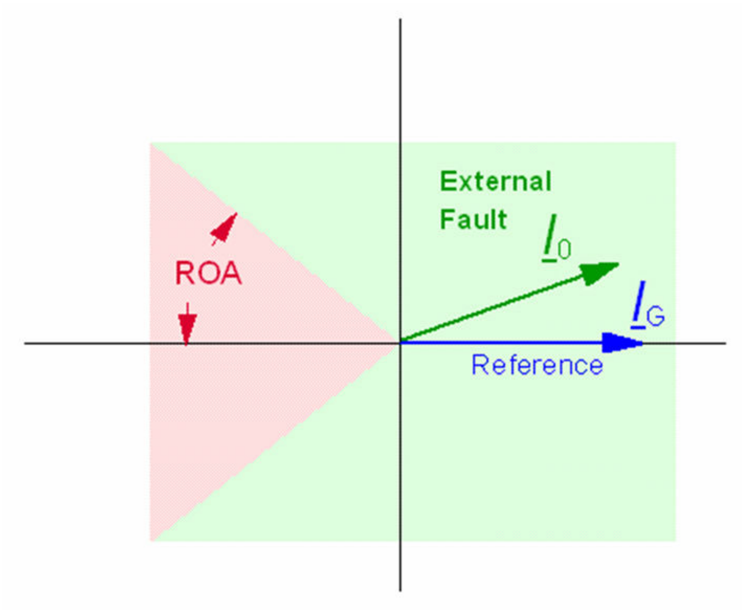


Figure 284: Currents at an external earth fault with CTs saturation

In case of an internal fault, the I0 lies into the operate area for internal fault and the protection is allowed to operate, see Figure 285.

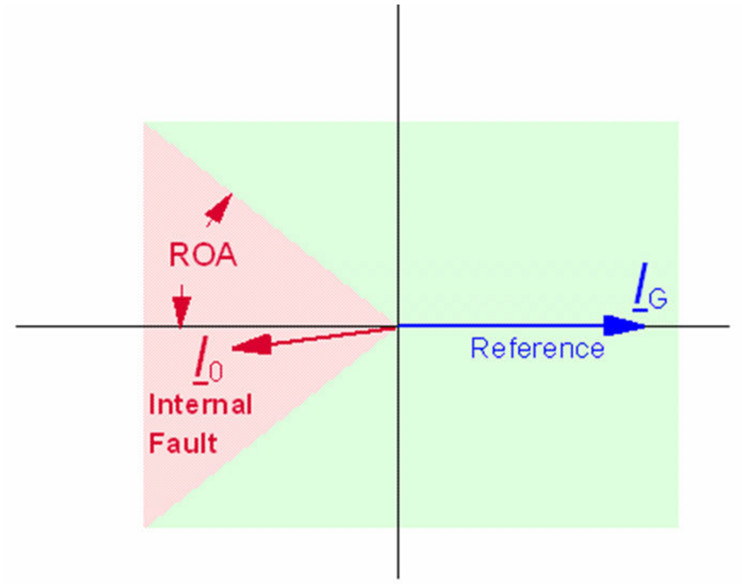


Figure 285: Currents at an internal earth fault

ROA can be taken out of operation by setting it to 180°, if no CT saturation has to be considered.

In case the restricted differential is used for the line application, the same considerations apply by using I1 and I2 neutral currents.

5.5.2.7 Setting groups

Two parameter sets can be configured for the restricted differential protection function.

5.5.2.8 Parameters and events

Table 128: Setting values

Parameter	Values	Unit	Default	Explanation
Reference nominal current	1...100000	A	100	Reference current for CT ratio compensation/ currents normalization.
Unbiased region threshold	0.05...0.50	Ir	0.30	First region Id threshold.
Unbiased region limit	0.01...1.00	Ir	0.50	First region Ib threshold.
Slightly biased region slope	0.01...2.00	-	0.70	Second region Id threshold.
Slightly biased region limit	0.01...2.00	Ir	1.25	Second region Ib threshold.
Heavily biased region slope	0.10...1.00	-	1.00	Third region slope.
Relay operate angle	60...180	°	75	Directional criteria.
Time	0.04...100.00	s	0.05	Time delay for trip condition detection.

Table 129: Events

Code	Event reason
E0	Protection start
E1	Start cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E16	Block signal is active state
E17	Block signal is back to inactive state
E18	Protection block signal is active state
E19	Protection block signal is back to inactive state

By default all events are disabled.

5.6 Other protections

5.6.1 Unbalanced load protection

REF 542plus has one unbalanced load protection function.

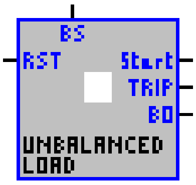


Figure 286: Unbalanced load protection

5.6.1.1 Input/output description

Table 130: Inputs

Name	Type	Description
BS	Digital signal (active high)	Blocking signal
RST	Trigger signal (active low-to-high)	Reset signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

When the reset input pin (RST) is triggered, the protection function is reset.

Table 131: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal
BO	Digital signal (active high)	Block output signal

The START signal will be activated when the calculated negative phase sequence current exceeds the setting threshold value (*Is*).

The TRIP signal will be activated when the start conditions are true and the operating time has elapsed.

The Block Output (BO) signal becomes active when the protection function exit TRIP status and remains active for the setting delay time (*Reset Time*).

5.6.1.2 Configuration

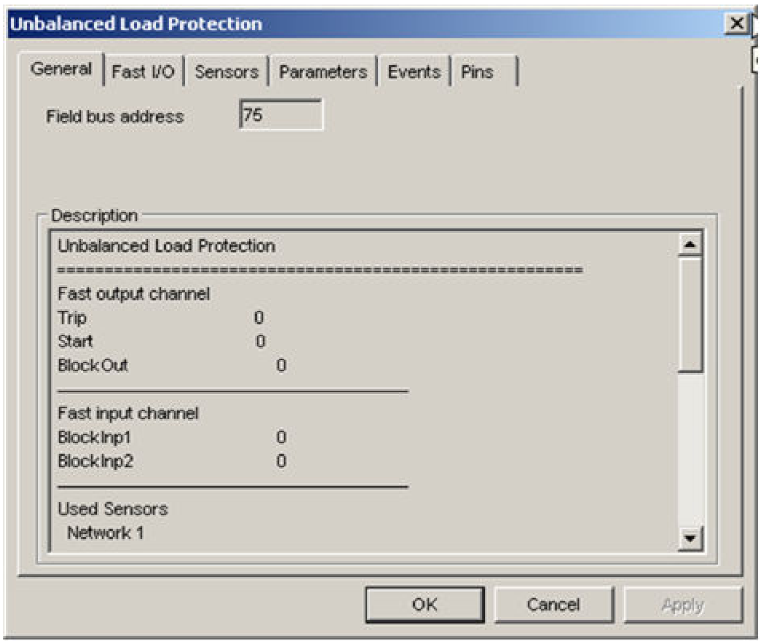


Figure 287: General

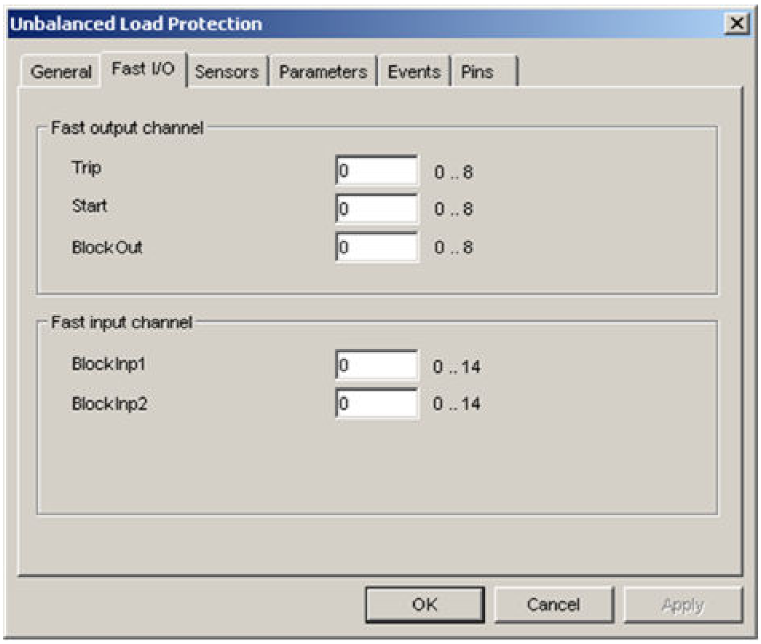


Figure 288: Fast I/O

Output Channel different from 0 means a direct execution of the trip, start or block output command (skipping FUPLA cyclic evaluation).

Input Channel different from 0 means a different execution of the block command, that is, skipping the FUPLA cyclic evaluation.

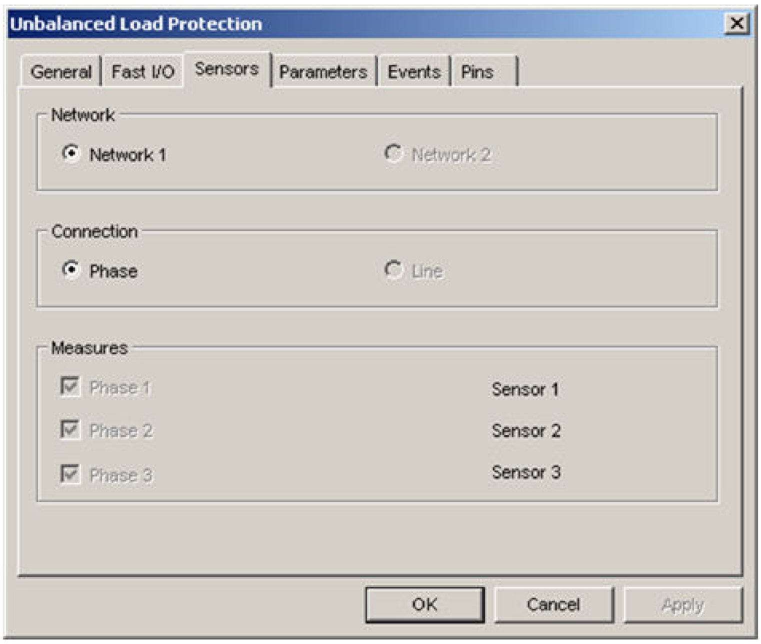


Figure 289: Sensors

The protection function operates on any set of phase currents in a triple.

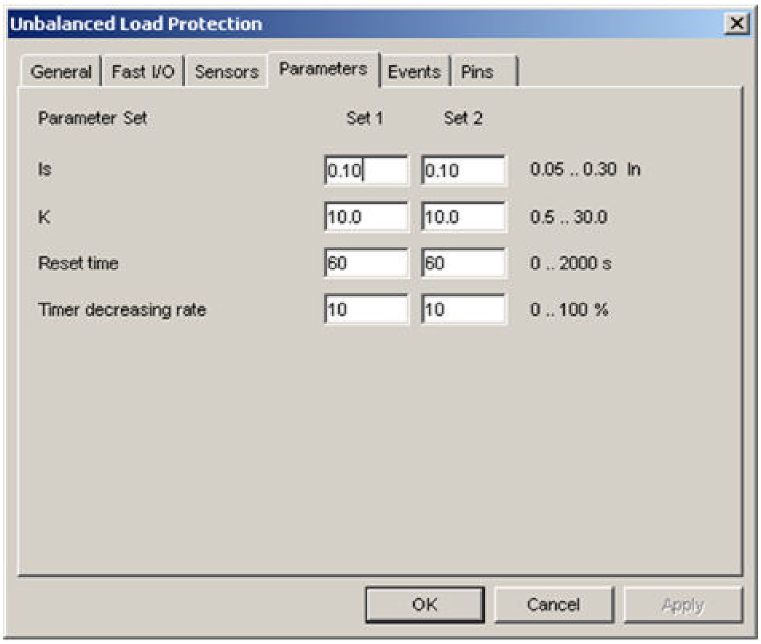


Figure 290: *Parameters*

Is	Current threshold for negative sequence condition detection
K	Heating parameter to vary time delay for trip condition
Reset Time	Time BO output is high (for example to block the re-closing possibility of a motor)
Timer decreasing rate	Parameter to vary thermal memory effect

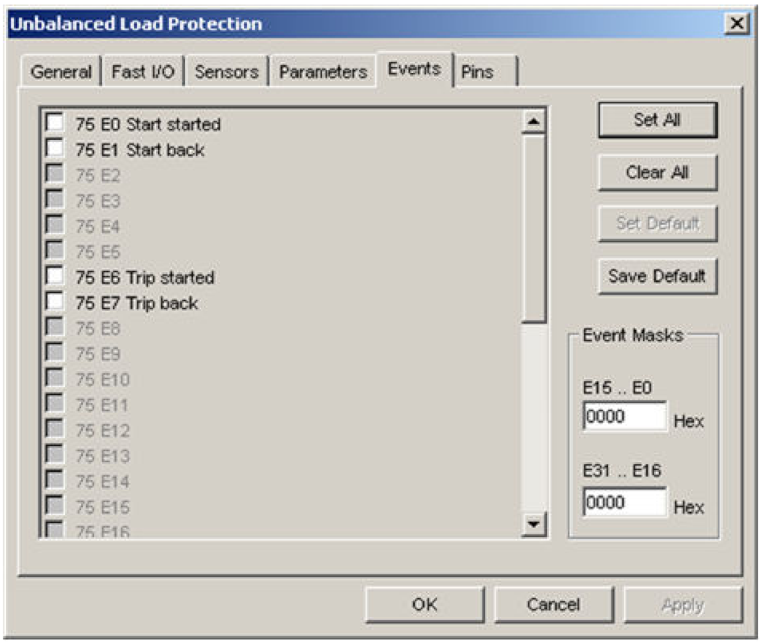


Figure 291: Events

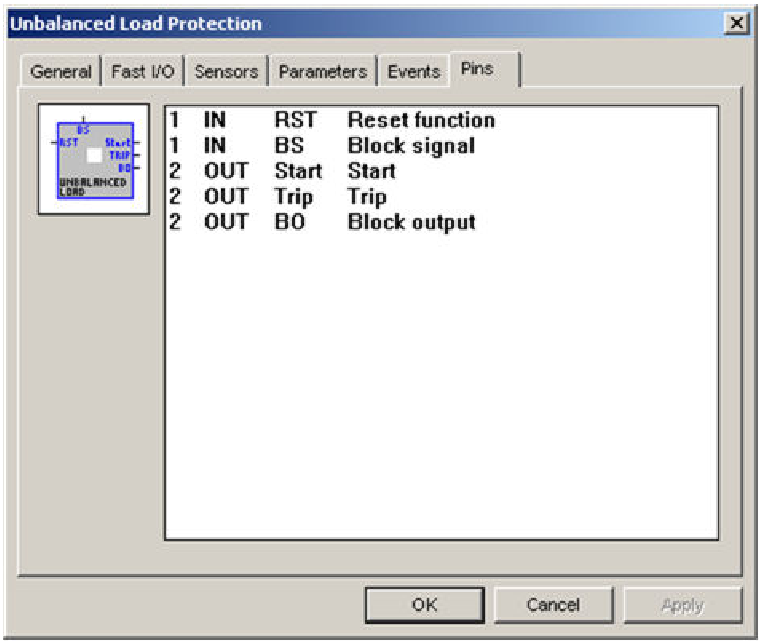


Figure 292: Pins

5.6.1.3 Measurement mode

Unbalanced load protection function evaluates the measured amount of negative phase sequence current at the fundamental frequency.

The negative-sequence three phase system L1 - L3 - L2 is superimposed on the three-phase system that corresponds to the standard phase sequence. This results in different field intensities in the magnetic laminated cores. The points with particularly high field intensities, the so-called hot spots, lead to the local overheating.

5.6.1.4 Operation criteria

If the calculated negative phase sequence current exceeds the setting threshold value (*Is*), then the protection function is started and the start signal will be activated.

When the protection enters the START status, the operating time is continuously recalculated according to the set parameters (*K*, *Is*) and the negative phase sequence current value.

If the calculated operating time is exceeded, the function goes in TRIP status and the trip signal becomes active.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured current value falls below 0.4 the setting threshold value. The operating time depends on the calculated negative phase sequence as follows:

$$t = \frac{K}{I_2^2 - I_S^2}$$

(Equation 29)

t Time until the protective function trips under sustained overcurrent

K Heating parameter of the component

I_2 Calculated negative phase sequence current expressed in In

I_S Start threshold expressed in In

According to the standard the characteristic is only defined for I_2/I_s in the range up to 20. If the values of the mentioned ratio are higher than 20, the operation time remains constant as the operation time calculated for I_s/I_2= 20.

If a trip is generated, for example in case of a motor protection, the motor should be blocked for reclosing. The `BO` signal is dedicated to block the reclosing possibility of the motor in this case. The `BO` signal remains active for the reset time after the functions exit TRIP status.

If the re-closing of the CB is not intended to be blocked, the *Reset Time* setting should be 0 or not used, because during the activation of `BO` signal the unbalanced load function is taken out of operation.

Thermal memory

To avoid machine overheating in case of an intermittent negative phase sequence current, the internal time counter is not cleared when the negative phase sequence current falls below the start threshold. Instead, it is linearly decremented with time, using a user-configurable slope (that is timer decreasing rate related to the setting of the Reset Time). 100% means full memory and 0% means no memory.

5.6.1.5 Setting groups

Two parameter sets can be configured for the unbalanced load protection function.

5.6.1.6 Parameters and events

Table 132: Setting values

Parameter	Values	Unit	Default	Explanation
Is	0.05...0.30	In	0.10	Current threshold for negative sequence detection
K	0.5...30.0	-	10.0	Heating parameter
Reset time	0...2000	s	60	Time to reset BO after a trip
Timer decreasing rate	0...100	%	10	Parameter to vary thermal memory effect

Table 133: Events

Code	Event reason
E0	Protection start on phase L3
E1	Start on phase L3 cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E16	Block signal is active
E17	Block signal is back to inactive state
E18	Protection block is back to inactive state
E19	Protection block is back to inactive state
E20	Reset input is active
E21	Reset input is back to inactive state

By default all events are disabled.

5.6.2 Directional power protection

Directional power protection function can be added as a supervision function with generators, transformers and three-phase asynchronous motors.

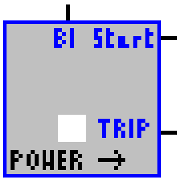


Figure 293: Directional power protection

5.6.2.1 Input/output description

Table 134: Inputs

Name	Type	Description
BI	Digital signal (active high)	Blocking signal

When the BI signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BI signal goes low.

Table 135: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	TRIP signal

The START signal will be activated when the calculated active power exceeds the setting threshold value (*Max Reverse Load*) and the power flow is in the opposite direction to the specified one.

The TRIP signal will be activated when the start conditions are true and the operating time has elapsed.

5.6.2.2 Configuration

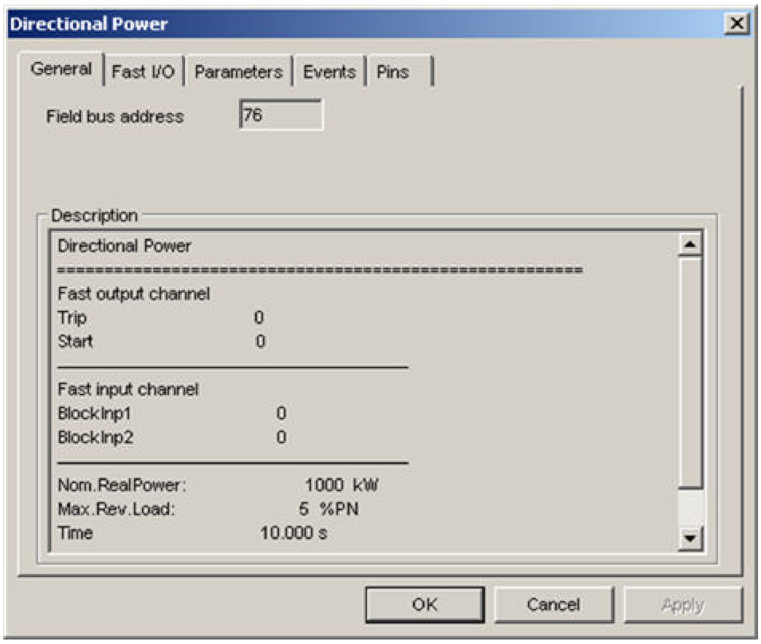


Figure 294: General

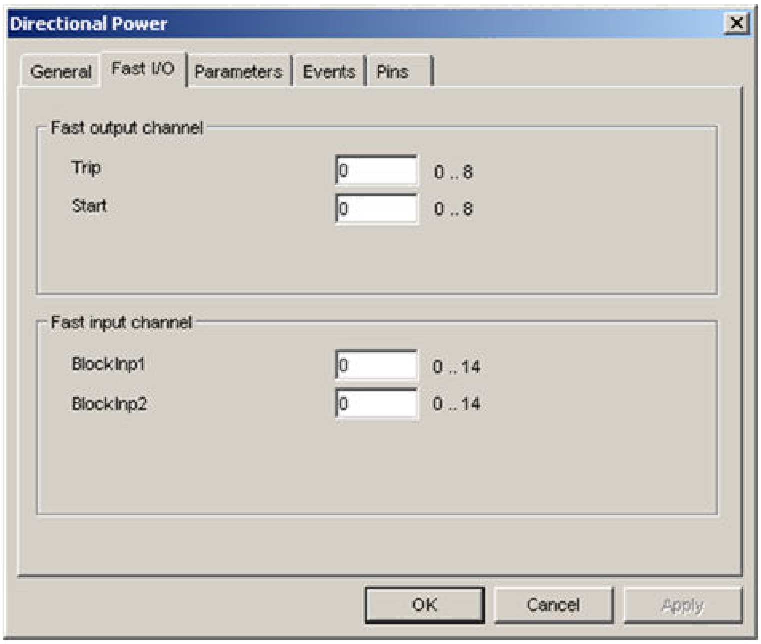


Figure 295: Fast I/O

Output Channel different from 0 means a direct execution of the trip or start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

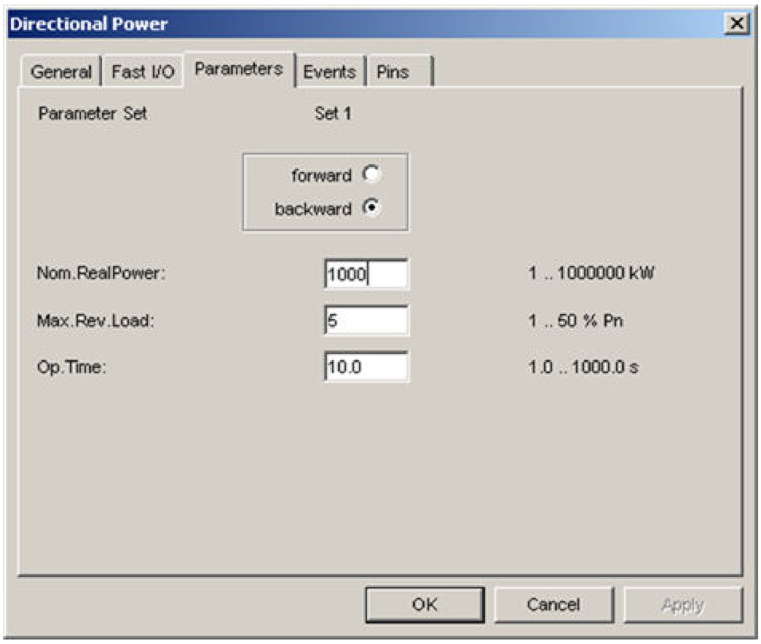


Figure 296: Parameters

Direction	Directional criteria to be assessed with Power flow for START detection
Nominal Real Power	Power reference Pn for quantities normalization
Max Reverse Load	Power threshold in opposition to set direction for start detection
Operating Time	Time delay for trip condition detection

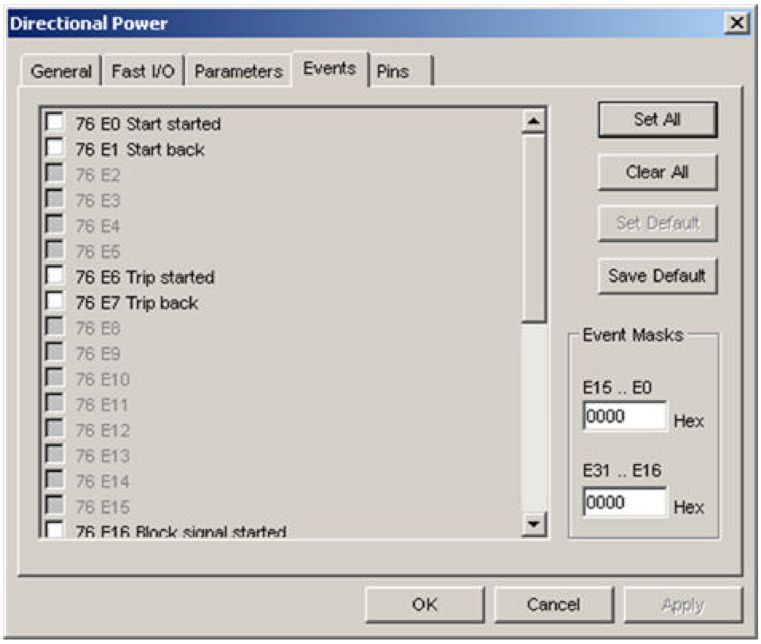


Figure 297: Events

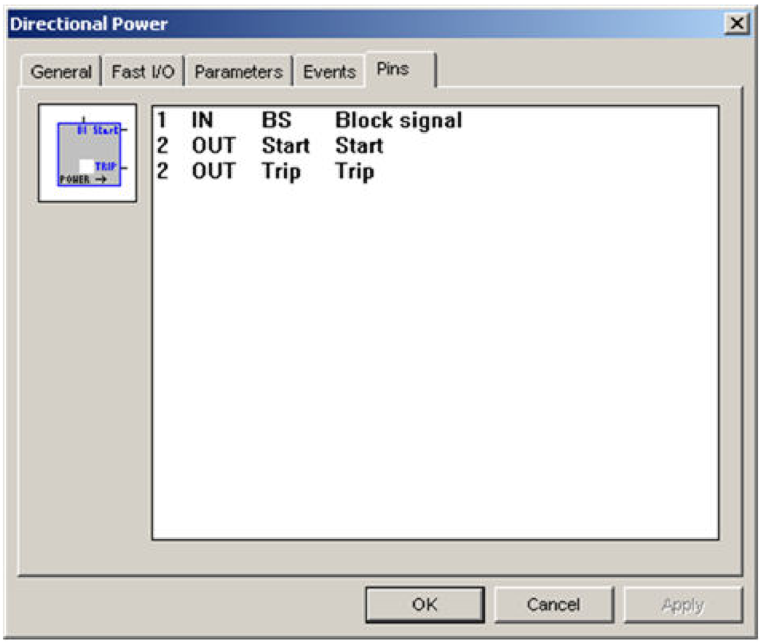


Figure 298: Pins

5.6.2.3 Measurement mode

The directional power protection function evaluates the active power at the fundamental frequency.

5.6.2.4 Operation criteria

The directional power supervision compares the calculated active power with a preset nominal value (Pn, *Nominal Real Power*) and a set power flow direction (*Direction*).

If the calculated active power exceeds the setting threshold value (*Max Reverse Load*), and the power flow is in the opposite direction to the specified one (“backward”/”forward”), the protection function is started and the start signal is generated.

The protection function will come back in passive status and the start signal will be cleared if the calculated active power falls below 0.95 the setting threshold value, or the power flow changes direction.

When the protection has entered the start status and the preset operating time (*Operating Time*) has elapsed, the function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured current value falls below 0.4 the setting threshold value.

5.6.2.5 Setting groups

Two parameter sets can be configured for the directional power protection function.

5.6.2.6 Parameters and events

Table 136: Setting values

Parameter	Values	Unit	Default	Explanation
Direction	Forward / Backward		Backward	Directional criteria for START detection
Nom. active power	1...1000000	kW	1000	Power reference for normalization
Max reverse load	1...50	% Pn	5	Power threshold for START detection
Operating time	1.0...1000	s	10	Time delay for trip condition

Table 137: Events

Code	Event reason
E0	Protection start
E1	Start cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E18	Protection block signal is active state
E19	Protection block signal is back to inactive state

By default all events are disabled.

5.6.3 Low load protection

REF 542plus has one low load protection function.

Three-phase asynchronous motors are subject to load variations. The low load monitoring function is provided to supervise the motor operational conditions for operation below the required load.

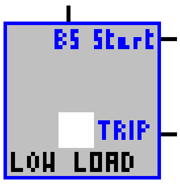


Figure 299: Low load protection

5.6.3.1 Input/output description

Table 138: Inputs

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the `BS` signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the `BS` signal goes low.

Table 139: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal

The `START` signal will be activated when the function is enabled (maximum phase current above *Min. Current*) and the calculated active power falls below 0.95 the setting threshold value (*Min. Load*).

The `TRIP` signal will be activated when the start conditions are true and the operating time (Operating *Time*) has elapsed.

5.6.3.2 Configuration

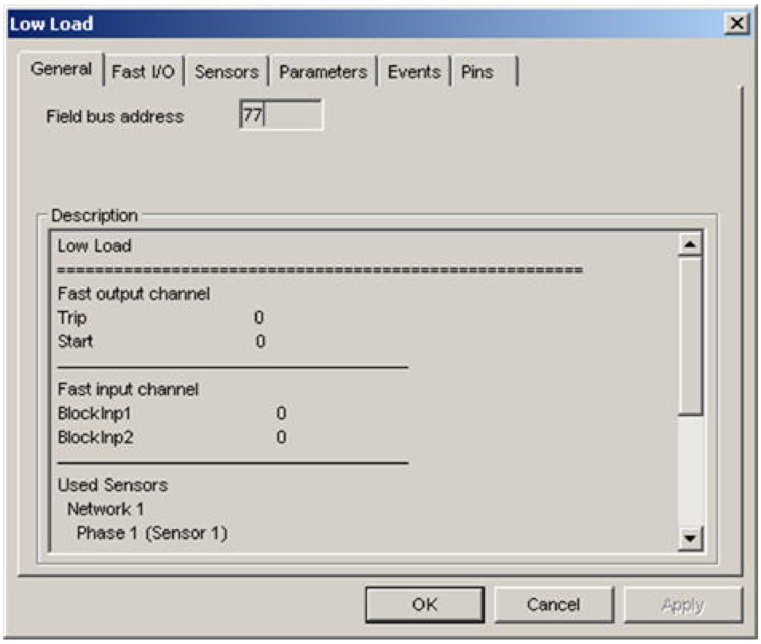


Figure 300: General

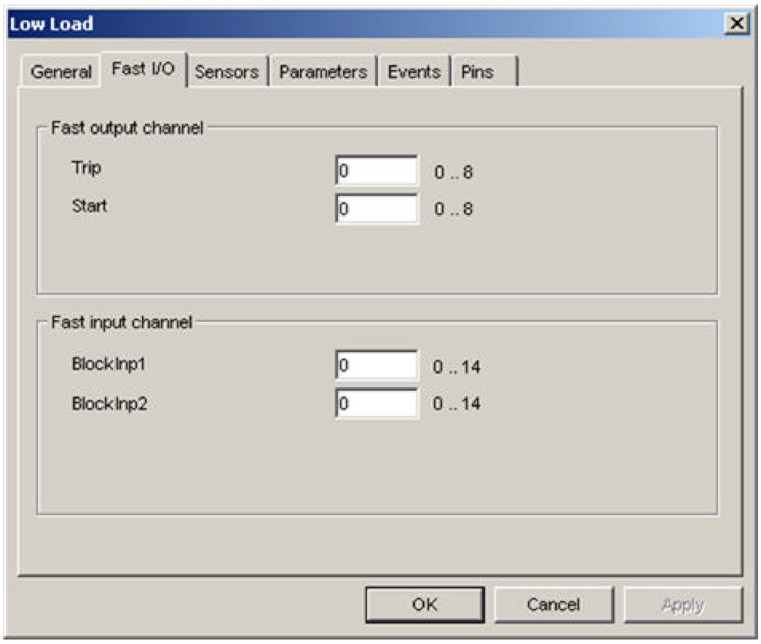


Figure 301: Fast I/O

Output Channel different from 0 means a direct execution of the trip or start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

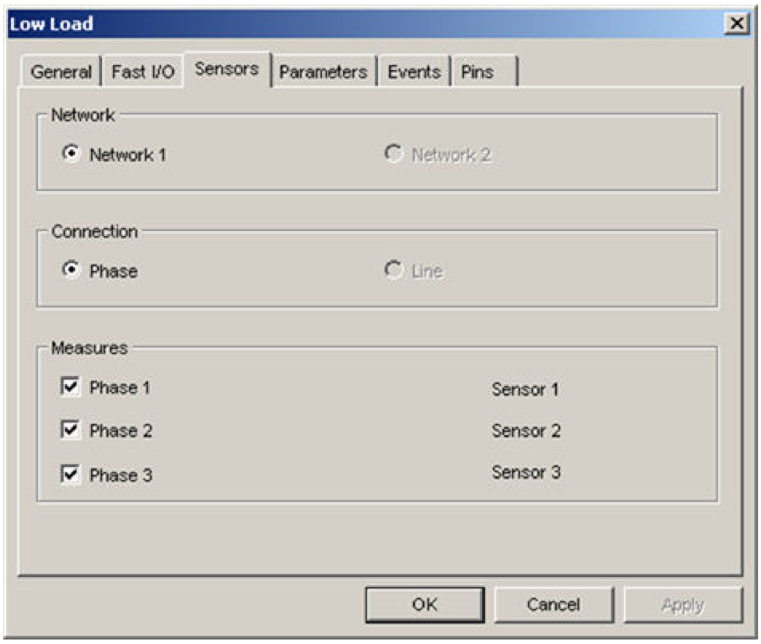


Figure 302: Sensors

The protection functions operate on any combination of phase currents in a triple, for example, it can operate as single-phase, double-phase or three-phase protection on phase currents belonging to the same system.

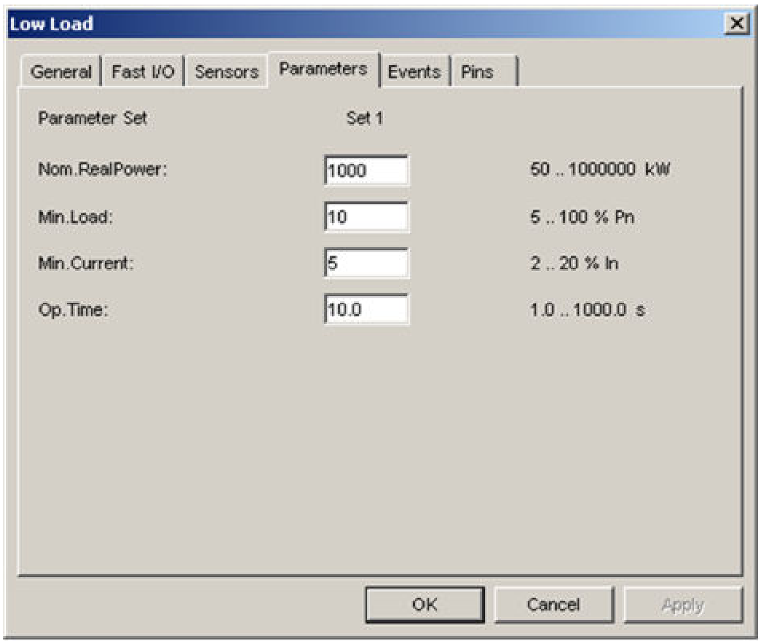


Figure 303: Parameters

Nominal Real Power	Power reference Pn for quantities normalization
Min. Load	Power threshold for start detection
Min. Current	Current threshold for start detection
Operating Time	Time delay for Trip condition detection

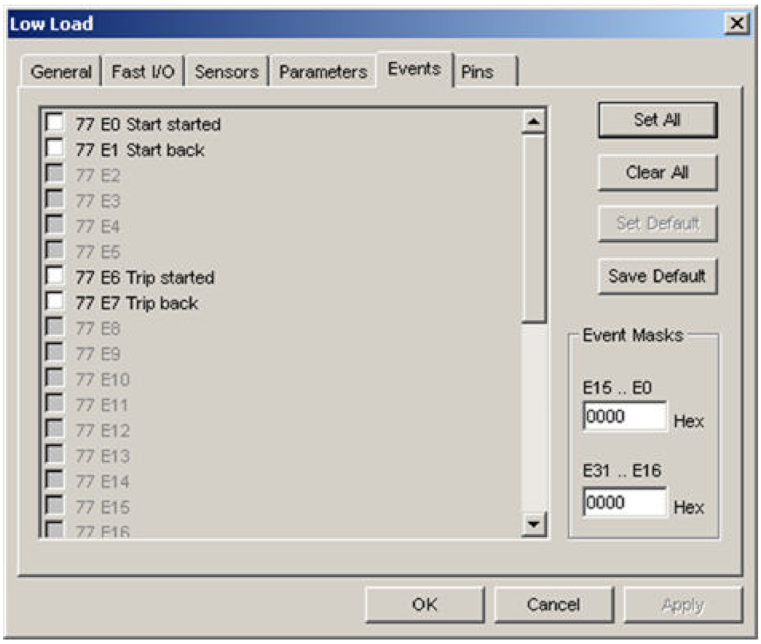


Figure 304: Events

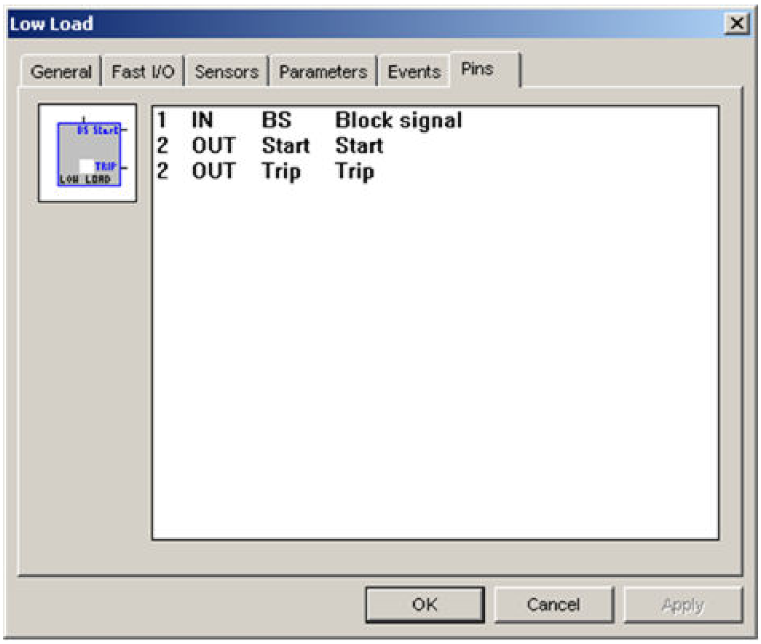


Figure 305: Pins

5.6.3.3 Measurement mode

The low load protection function evaluates the measured amount of current and of active power at the fundamental frequency.

5.6.3.4 Operation criteria

Low load protection function is enabled only if the maximum phase current of the configured sensors is above the preset threshold value (*Min Current*). It then normalizes the active power on a preset nominal value (Pn, *Nominal Real Power*).

When enabled, if the calculated active power falls below 0.95 the preset threshold value (*Min. Load*) the protection function is started and the Start signal is generated.

The protection function will come back in passive status and the start signal will be cleared if the calculated active power exceeds the setting threshold value.

After the protection has entered the start status and the preset operating time (*Operating Time*) has elapsed, function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the calculated active power exceeds 1.05 the setting threshold value.

5.6.3.5 Setting groups

Two parameter sets can be configured for low load protection function.

5.6.3.6 Parameters and events

Table 140: Setting values

Parameter	Values	Unit	Default	Explanation
Nom. real power	1...1000000	kW	1000	Power reference for normalization
Min load	5...100	% Pn	10	Power threshold for start detection
Min current	2...20	% In	5	Current threshold for start detection
Operating time	1.0...1000	s	10	Time delay for trip condition detection

Table 141: Events

Code	Event reason
E0	Start started
E1	Start back
E6	Trip started
E7	Trip back
E18	Protection block started
E19	Protection block back

By default all events are disabled.

5.6.4 Frequency supervision

REF 542plus has one frequency supervision function.

It is worth checking the network frequency for it to remain within the set limits when time and frequency-dependent processes are involved. Frequency changes influence, for example, the power dissipation, the speed (motors) and the firing characteristics (converters) of equipment. The frequency supervision function is used to report frequency variations in a configurable frequency range.

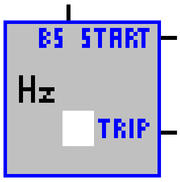


Figure 306: Frequency supervision

5.6.4.1 Input/output description

Table 142: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 143: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal

The START signal will be activated when the frequency exceeds the setting threshold value (*Start Value*).

The TRIP signal will be activated when the start conditions are true and the operating time (*Time*) has elapsed.

5.6.4.2 Configuration

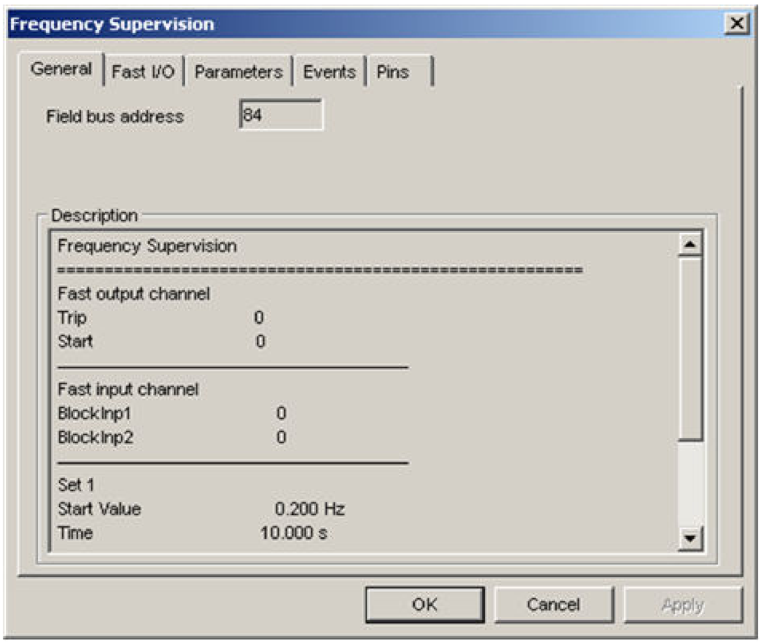


Figure 307: General

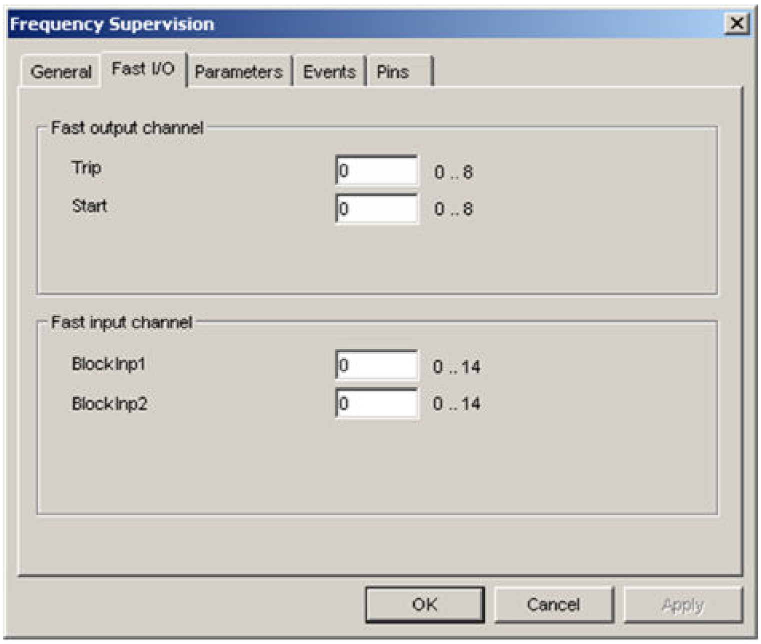


Figure 308: Fast I/O

Output Channel different from 0 means a direct execution of the trip command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

Sensors:

The supervision function selects automatically the best sensor. The function operates preferably on a voltage sensor, but it can work also on a current sensor.

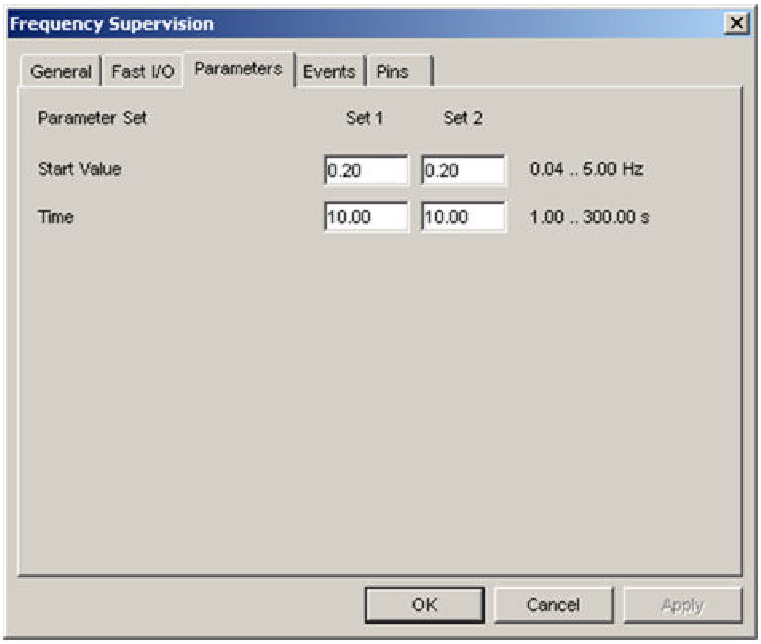


Figure 309: Parameters

Start Value	Frequency threshold for start condition detection
Time	Time delay for trip condition detection

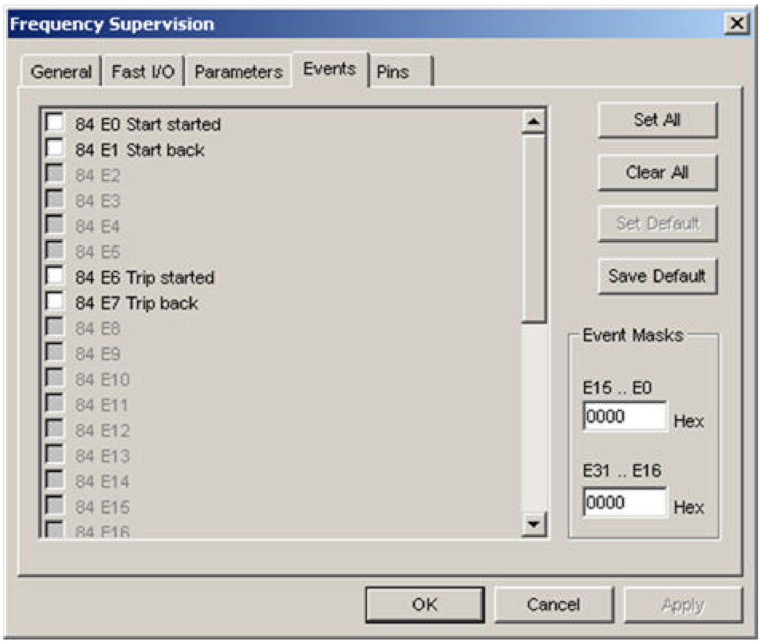


Figure 310: Events

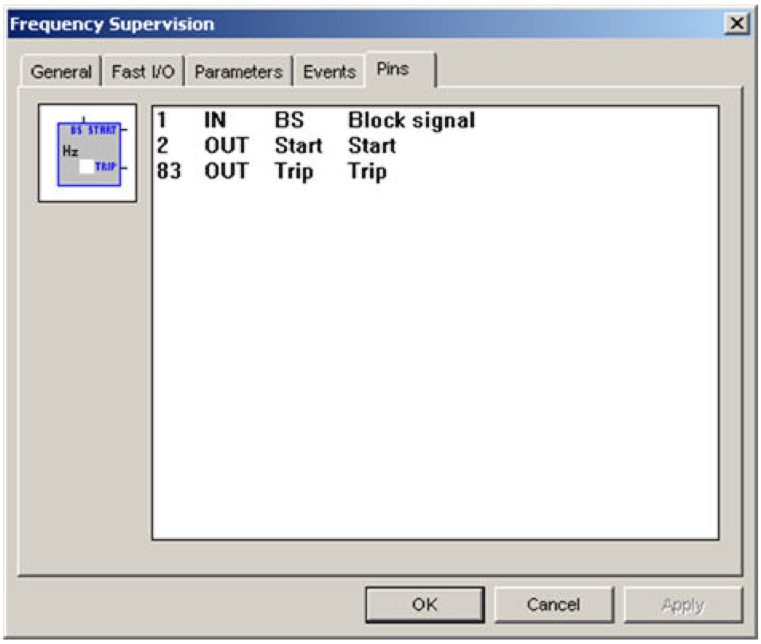


Figure 311: Pins

5.6.4.3 Measurement mode

The frequency supervision function evaluates network frequency on the measured value of the first available (voltage or current) sensor.

5.6.4.4 Operation criteria

If the measured network frequency is outside the allowed range, the supervision function is started.

If the measured network frequency remains outside the allowed range for at least operating time setting, a trip signal becomes active.

If the measured network frequency falls outside the allowed range, that is the network nominal frequency plus/minus the setting threshold value (*Start Value*), the frequency supervision function is started and the Start signal is generated.

The frequency supervision function will come back in passive status and the start signal will be cleared, if the frequency difference to the nominal network frequency falls below 0.95 the setting threshold value.

When the protection has entered the start status and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the Trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when the measured frequency value falls back within the allowed range, that is the network nominal frequency plus/minus 0.95 the setting threshold value.

5.6.4.5 Setting groups

Two parameter sets can be configured for frequency supervision function.

5.6.4.6 Parameters and events

Table 144: Setting values

Parameter	Values	Unit	Default	Explanation
Start value	0.04...5.0	Hz	0.20	Frequency threshold for start condition detection
Time	1.0...300.00	s	10.00	Time delay for Trip condition detection

Table 145: Events

Code	Event reason
E0	Start started
E1	Start back
E6	Trip started
E7	Trip back
E18	Protection block started
E19	Protection block back

By default all events are disabled.

5.6.5 Synchronism check

REF 542plus has one synchronism check protection function.

Paralleling monitoring is required if two networks are interconnected whose voltages may differ in quantity, phase angle and frequency as a result of different power supplies (SYN). The switching operation for coupling the separate systems can be enabled by the Synchronism Check SYN signal.

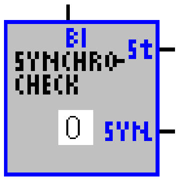


Figure 312: Synchronism check

5.6.5.1 Input/output description

Table 146: Input

Name	Type	Description
BI	Digital signal (active high)	Blocking signal

When the BI signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BI signal goes low.

Table 147: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
SYN	Digital signal (active high)	Sync signal

The START signal will be activated when both the differential voltage ΔU and phase difference ΔΦ between corresponding line voltages of two networks fall below the setting threshold values (*Delta Voltage* AND *Delta Phase* respectively).

The SYN signal to parallel networks will be activated when the start conditions are true and the operating time (*Time*) has elapsed.

5.6.5.2 Configuration

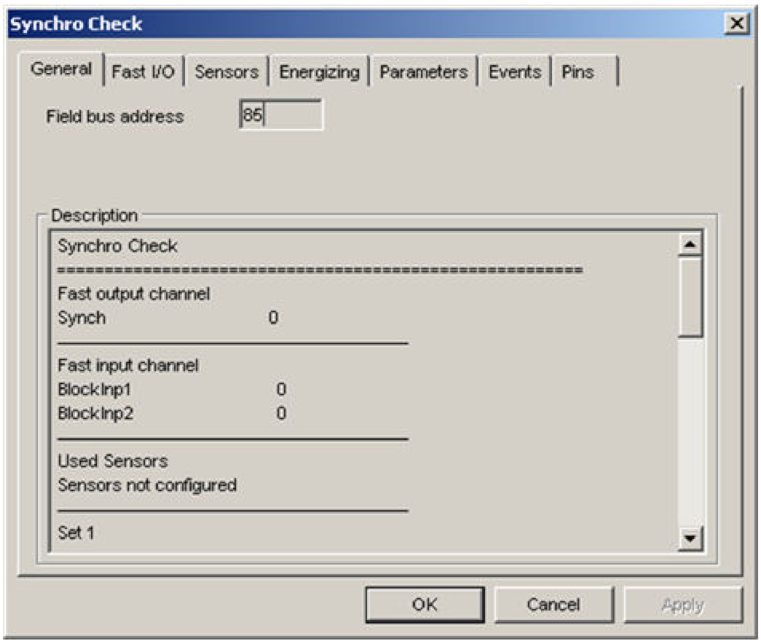


Figure 313: General

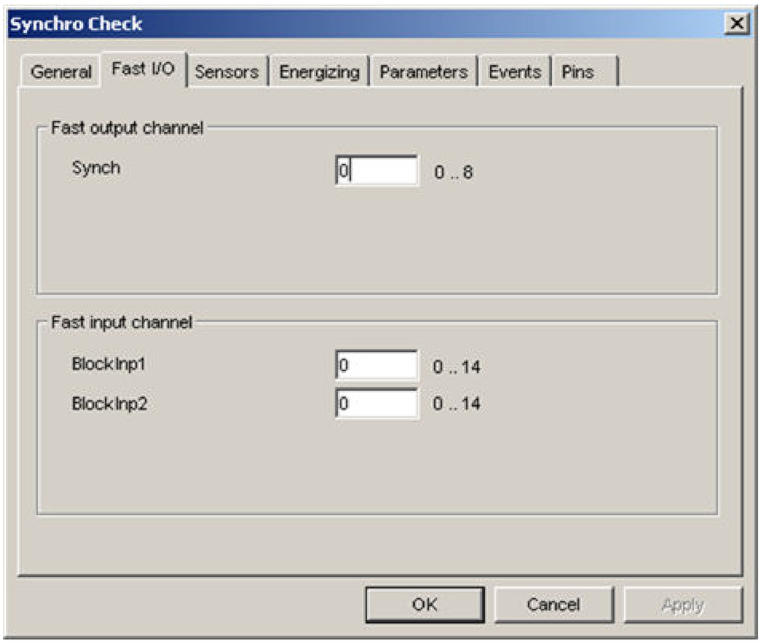


Figure 314: Fast I/O

Output Channel different from 0 means a direct execution of the synchronization command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

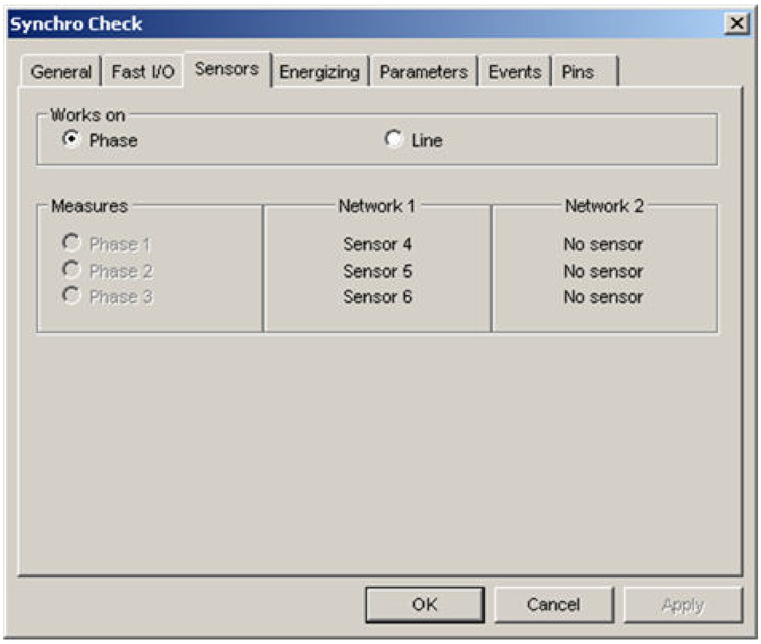


Figure 315: Sensors

The protection function operates on the combinations of phase (or line) voltages reported in the following table. The two phase voltages belonging to the two networks or a line voltage belonging to the second network are needed.

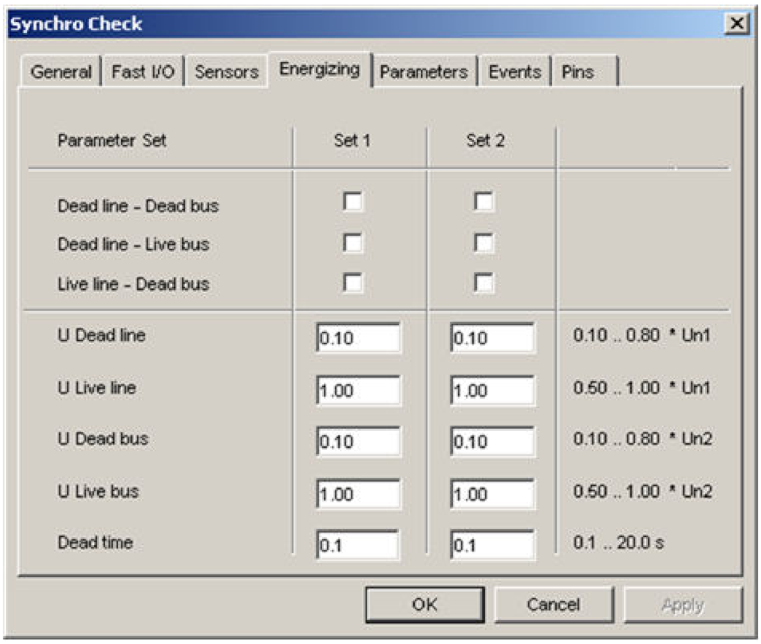


Figure 316: Energizing

Dead line – Dead bus	Maximum allowed amplitude difference between two synchronous networks
Dead line – Live bus	Maximum allowed phase difference between two synchronous networks
Live line – Dead bus	
U Dead line	Voltage setting to detect dead line condition
U Live line	Voltage setting to detect live line condition
U Dead bus	Voltage setting to detect dead bus condition
U Live bus	Voltage setting to detect live bus condition
Dead Time	Time delay for detection of synchronism condition

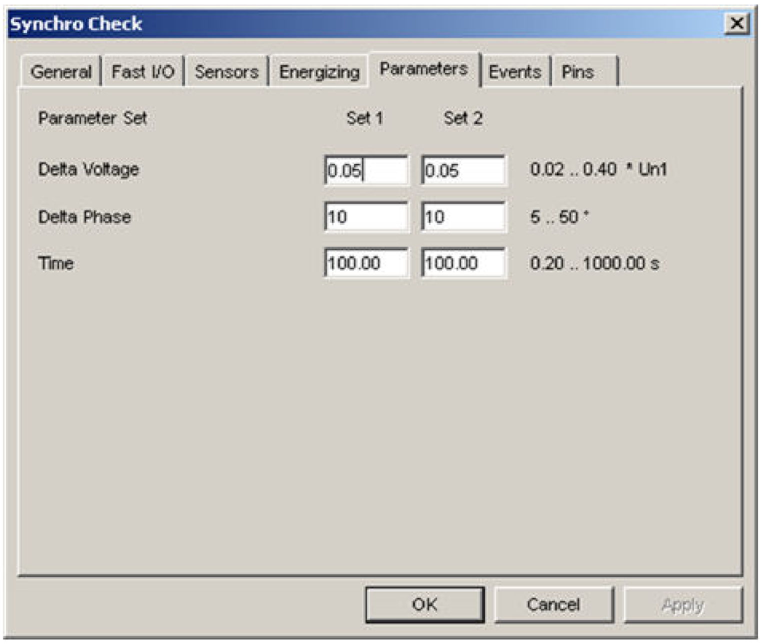


Figure 317: Parameters

Delta Voltage	Maximum allowed amplitude difference between two synchronous networks
Delta Phase	Maximum allowed phase difference between two synchronous networks
Time	Time delay for detection of synchronism condition

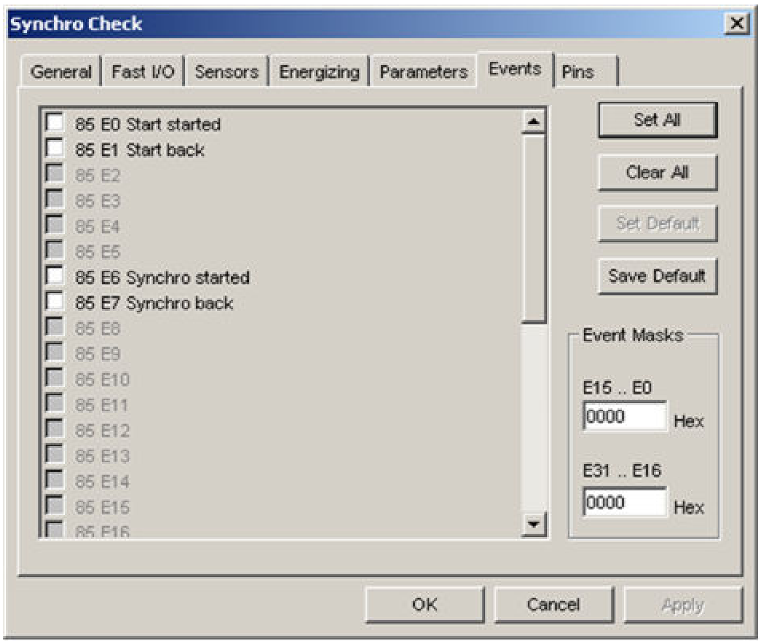


Figure 318: Events

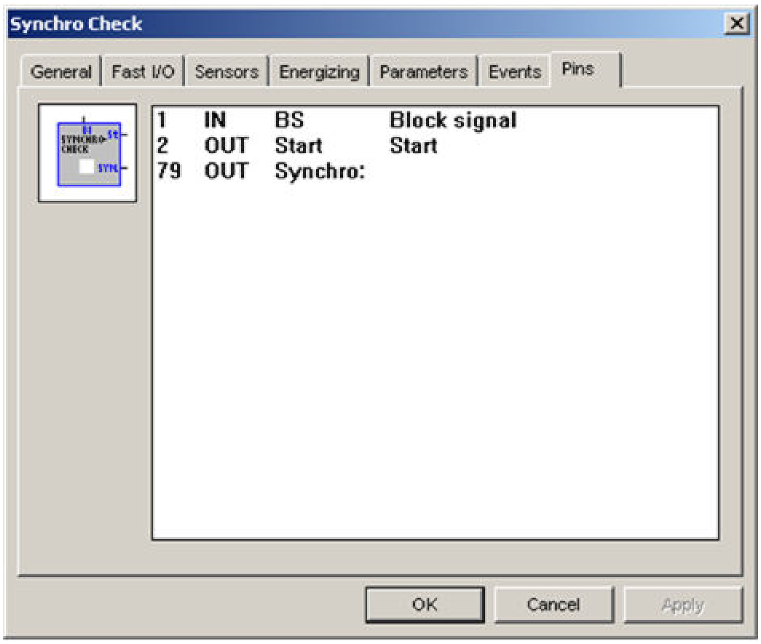


Figure 319: Pins

5.6.5.3 Measurement mode

Synchronism check protection function evaluates the measured amplitude and the rate of change of differential voltage between two networks corresponding the line voltages.

5.6.5.4 Operation criteria

The synchronism check protection function monitors the differential voltage ΔU between corresponding line and phase voltages of two networks and their phase difference ΔΦ.

If the measured differential voltage and phase difference fall below the setting threshold values (*Delta Voltage* AND *Delta Phase* respectively), the synchro check protection function is started.

The protection function will come back in passive status and the start signal will be cleared if differential voltage and phase difference exceed 1.05 the setting threshold value. After the protection has entered the start status and the preset operating time (*Time*) has elapsed, the signal for parallel switching of networks (SYN) is generated.

The protection function will exit the synchro status and the `SYN` signal will be cleared when the start conditions on differential voltage and phase difference values become false. *Delta Voltage* Maximum allowed amplitude difference between the two synchronous networks.

The determination of the setting of the synchronism check function is shown in an example below. If two networks must be switched in parallel, the voltage amplitudes in both networks must first be almost the same and should have approximately the value of the rated voltage.

As long as the frequencies in the networks are different, the two networks can naturally not be synchronized. A phase displacement will therefore occur between the two voltages that are compared.

As a result, a voltage difference occurs as a function of time. This voltage difference is the criteria for whether the two systems can be switched in parallel. The voltage condition are shown in an example in the following diagram.

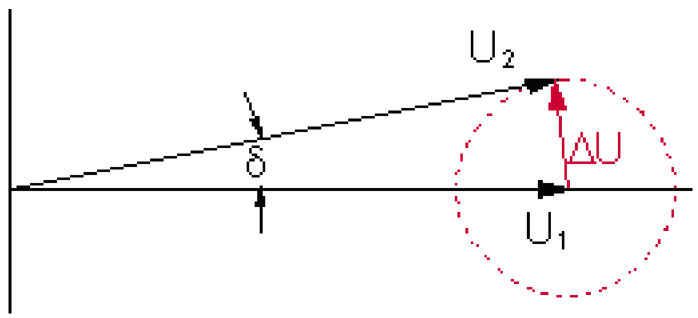


Figure 320: diagram of the voltage quantities with unequal frequencies.

As shown in the diagram, the phase difference that needs to be set depends on the setting of the differential voltage as follows:

$$\Delta\delta = \arctan\left(\frac{\Delta U}{U}\right)$$

(Equation 30)

$\Delta\delta$ Setting the phase difference

ΔU Setting the differential voltage as start value

U Rated voltage as reference quantity

The equation for the required voltage difference can be calculated as follows:

$$\Delta U = U \tan \Delta\delta$$

(Equation 31)

A time window t, which is equal to the time setting, can be used to check the frequency variation

$$t = \frac{2T_n\Delta\delta}{360^\circ}\frac{f_n}{\Delta f}$$

(Equation 32)

t	Time window to check frequency deviation
T_n	Period duration at rated frequency
f_n	Rated frequency
Δf	Frequency difference

As long as the frequency deviation remains within the allowable limit, the set time expires and generates the signal "SYN" to be formed for parallel switching of both networks.

An example of the calculation of the setting is as follows:

In a system with 50 Hz rated frequency the voltage deviation may be 20%. Consequently, the setting of the phase shift according to the above calculation is, at the maximum 11°. The minimum time setting can then be calculated according to the above equation to be 0.6 seconds.

5.6.5.5 Setting groups

Two parameter sets can be configured for the synchronism check protection function.

5.6.5.6 Parameters and events

Table 148: Setting values

Parameter	Values	Unit	Default	Explanation
Delta voltage	0.02...0.40	Un	0.05	Max amplitude difference
Delta phase	5...50	°	10	Max phase difference
Time	0.2...1000	s°	100.00	Time delay for synchro detection

Table 149: Events

Code	Event reason
E0	Protection start
E1	Start cancelled
E6	Synch is present
E7	Synch is not present
E18	Protection block is active
E19	Protection block is back to inactive

By default all events are disabled.

5.6.6 Switching resonance protection

REF 542plus has one switching resonance protection function, to be used together with the power factor controller and the high harmonic protection.

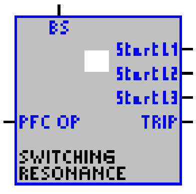


Figure 321: Switching resonance protection

5.6.6.1 Input/output description

Table 150: Inputs

Name	Type	Description
BS	Digital signal (active high)	Blocking signal
PFC OP	Trigger signal (active low-to-high)	PFC operation trigger

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

The PFC OP trigger is provided by the PFC function block to temporarily enable the resonance protection function at switching-in or switching-out of PFC controlled capacitor banks.

Table 151: Outputs

Name	Type	Description
Start L1	Digital signal (active high)	Start signal of IL1
Start L2	Digital signal (active high)	Start signal of IL2
Start L3	Digital signal (active high)	Start signal of IL3
TRIP	Digital signal (active high)	Trip signal

START L1, START L2 and START L3 are the phase selective start signals. The phase starting signal will be activated when respective phase current start conditions are true.

The TRIP signal will be activated when at least for one phase current the start conditions are true and the operating time has elapsed.

5.6.6.2 Configuration

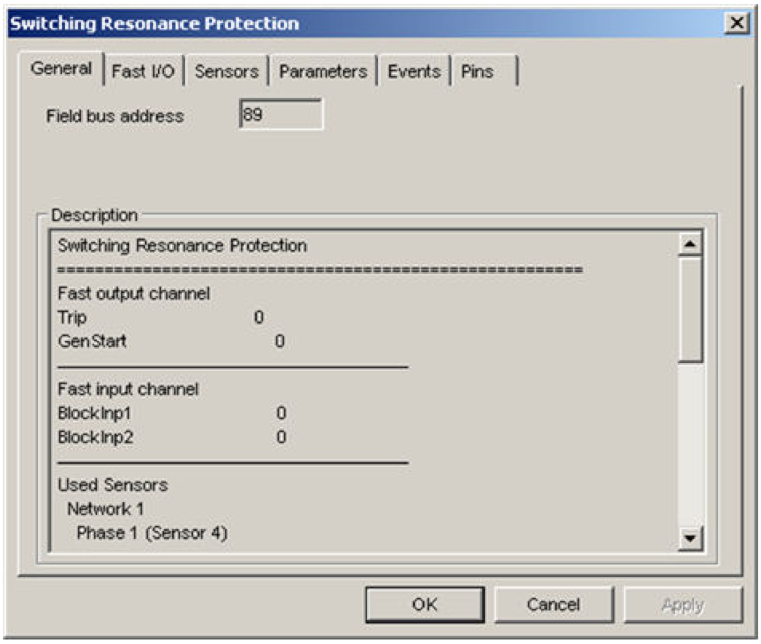


Figure 322: General

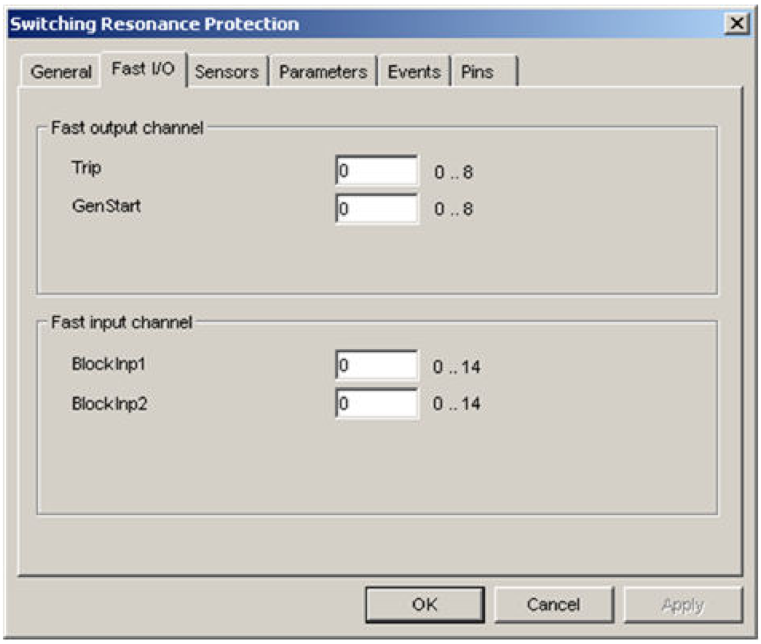


Figure 323: Fast I/O

Output Channel different from 0 means a direct execution of the trip or general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

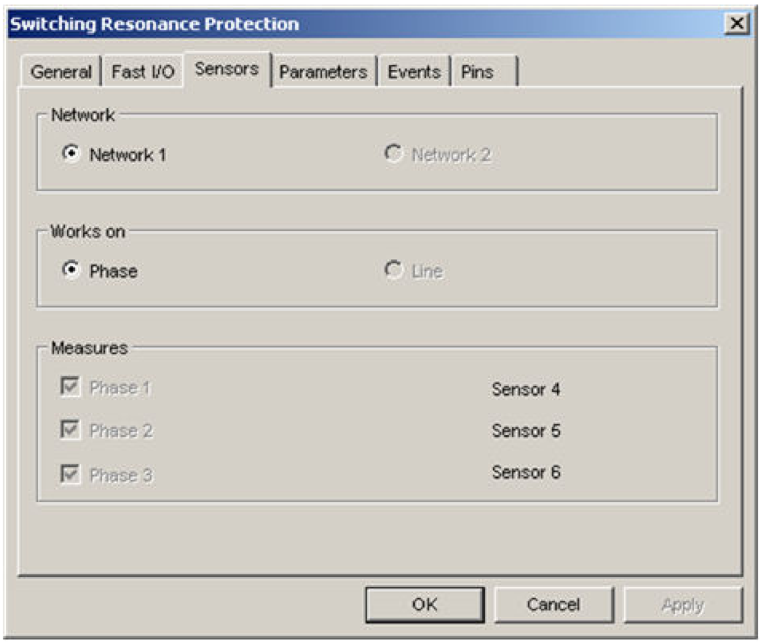


Figure 324: Sensors

The protection function operates on any combination of line or phase voltages in a triple, for example, it can operate as single-phase, double-phase or three-phase protection on voltages belonging to the same system.

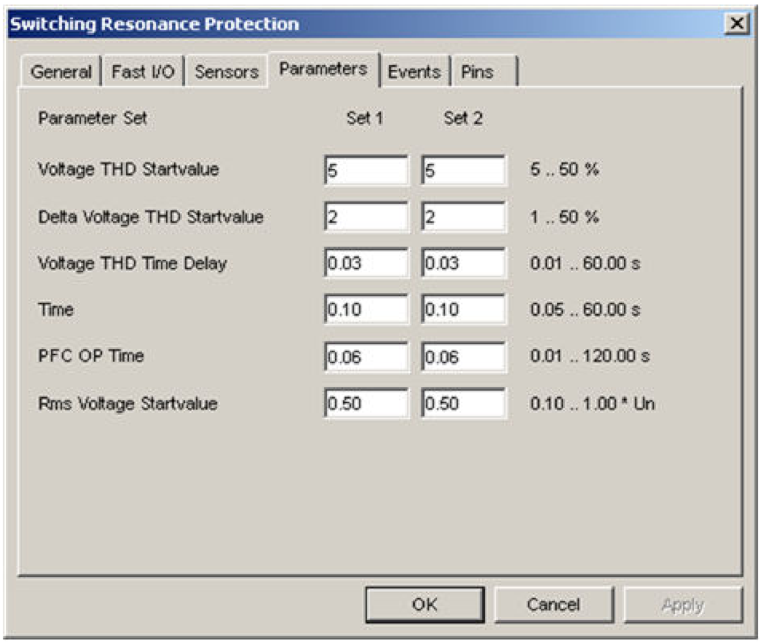


Figure 325: Parameters

Voltage THD Start value	THD amplitude threshold
Delta Voltage THD Start value	THD amplitude difference threshold
Voltage THD Time Delay	Time delay for THD detection
Time	Time delay for trip condition detection
PFC OP Time	Enabling time at PFC trigger
Rms Voltage Start value	Function enabling voltage threshold condition

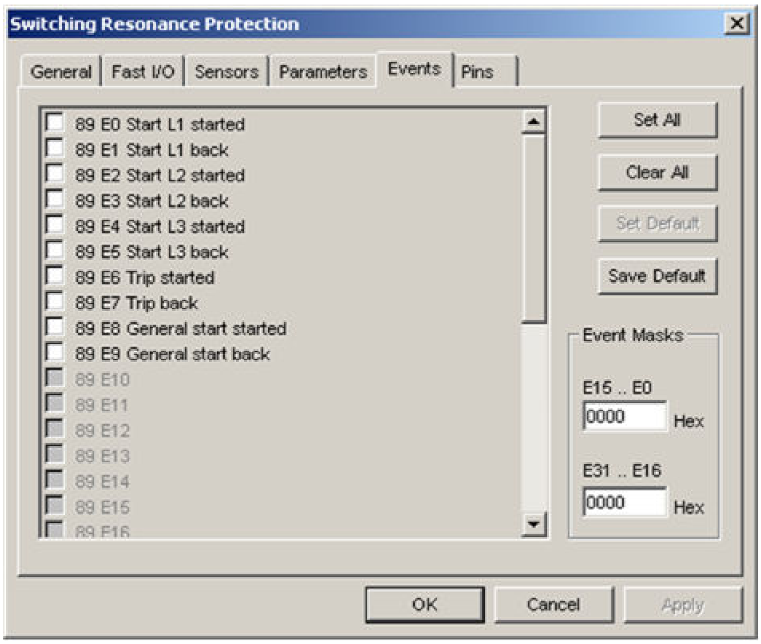


Figure 326: Events

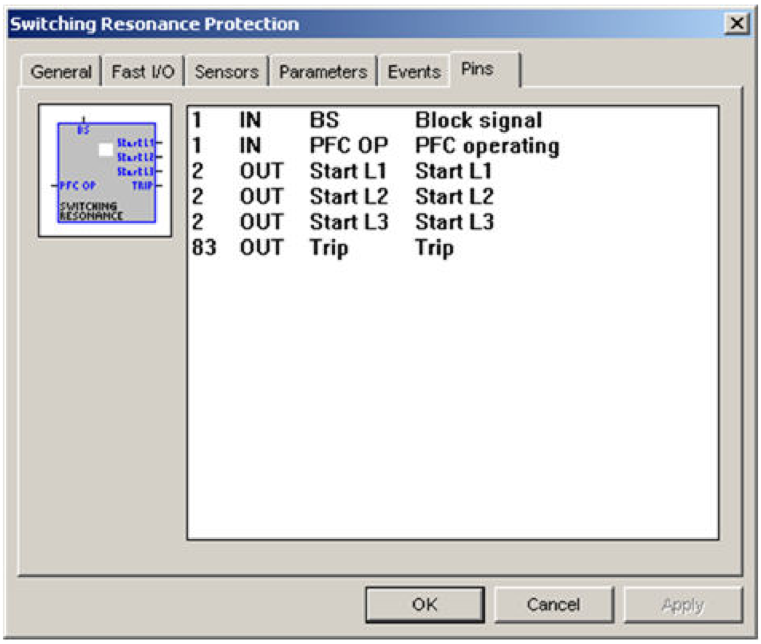


Figure 327: Pins

5.6.6.3 Measurement mode

Switching resonance protection function evaluates the amount of voltage RMS with harmonic content up to the 25th harmonic and THD (Total Harmonic Distortion).

5.6.6.4 Operation criteria

Operation of switching resonance protection function is triggered by an external signal connected to input pin `PFC OP` (provided by the PFC function switch ON/OFF output pins) and remains enabled for the preset time (*PFC OP Time*).

At `PFC OP` trigger instant, the voltage THD values are saved.

While enabled, if there is for at least one phase voltage (respectively line voltage, depending on the configuration):

- The RMS value is above the preset threshold (*Rms Voltage Start value*)
- The THD value is above the preset threshold (*Voltage THD Start value*) for at least the preset detection time (*Voltage THD Time Delay*)
- The variation of THD value with respect to the saved value (that is THD value at trigger time) is above the preset threshold (that is *Delta Voltage THD Start value*) for at least the preset detection time (that is *Voltage THD Time Delay*)

Then the protection function is started. The start signal is phase selective. When the above conditions are true at least the for one phase voltage, then the relevant start signal (`START L1`, `START L2` or `START L3`) will be activated.

The protection function will remain in START status until there is at least one phase started. It will come back in passive status and the start signal will be cleared if for all the phases the voltage falls below 0.95 one of the setting threshold values (*Rms voltage start value* OR *Voltage THD start value* OR *Delta Voltage THD start value*).

When the protection has entered the start status and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated.

5.6.6.5 Setting groups

Two parameter sets can be configured for the switching resonance protection function.

5.6.6.6 Parameters and events

Table 152: Setting values

Parameter	Values	Unit	Default	Explanation
Voltage THD start value	5...50	%	5	THD amplitude threshold
Delta Voltage THD start value	1...50	%	2	THD amplitude difference threshold
Voltage THD time delay	0.01...60.00	s	0.03	Stabilizing delay for THD detection
Time	0.05...60.00	s	0.10	Time delay for Trip condition detection
PFC OP time	0.01...120.00	s	0.06	Function enabling time at PFC trigger
Rms voltage start value	0.10...1.00	Un	0.50	Function enabling Voltage threshold condition

Table 153: Events

Code	Event reason
E0	Protection start on phase L1
E1	Start on phase L1 cancelled
E2	Protection started timing on phase L2
E3	Start on phase L2 cancelled
E4	Protection start on phase L3
E5	Start on phase L3 cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E16	Block output signal is active
E17	Block output signal is back to inactive
E18	Protection block signal is active state
E19	Protection block signal is back to inactive state
E20	PFC operation started
E21	PFC operation back

By default all events are disabled.

5.6.7 High harmonic protection

REF 542plus has one high harmonic protection function, to be used together with the power factor controller and the switching resonance protection.

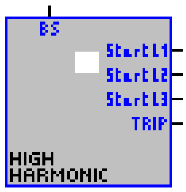


Figure 328: High harmonic protection

5.6.7.1 Input/output description

Table 154: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the `BS` signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function will then remain in idle state until BS signal goes low.

Table 155: Outputs

Name	Type	Description
Start L1	Digital signal (active high)	Start signal of IL1
Start L2	Digital signal (active high)	Start signal of IL2
Start L3	Digital signal (active high)	Start signal of IL3
TRIP	Digital signal (active high)	Trip signal

START L1, START L2 and START L3 are the phase selective start signals. The phase starting signal will be activated when respective phase current start conditions are true.

The TRIP signal will be activated when at least for a phase current the start conditions are true and the operating time has elapsed.

5.6.7.2 Configuration

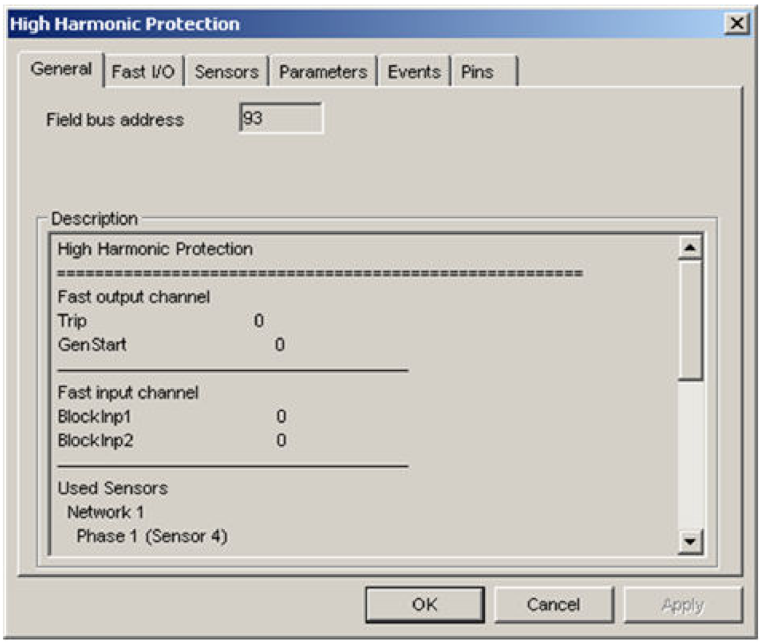


Figure 329: General

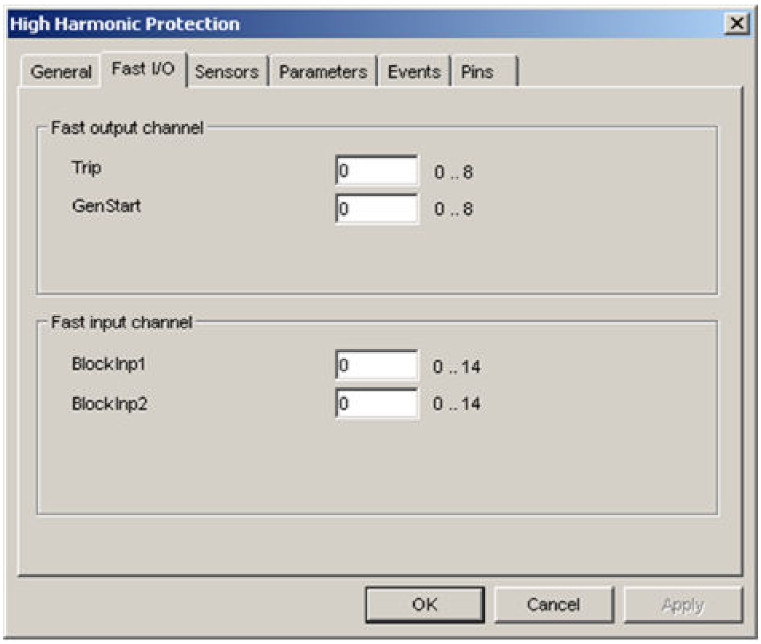


Figure 330: Fast I/O

Output Channel different from 0 means a direct execution of the trip or general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

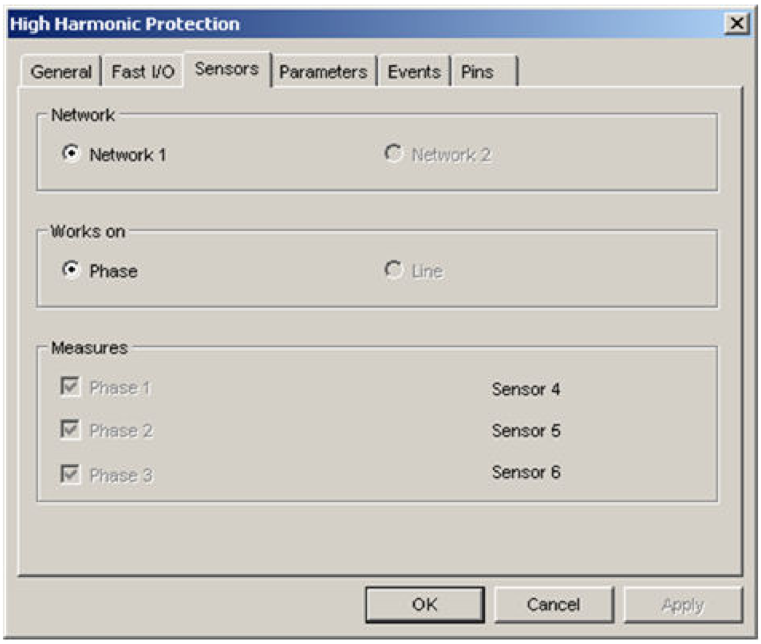


Figure 331: Sensors

The protection function operates on phase or line voltages in a triple.

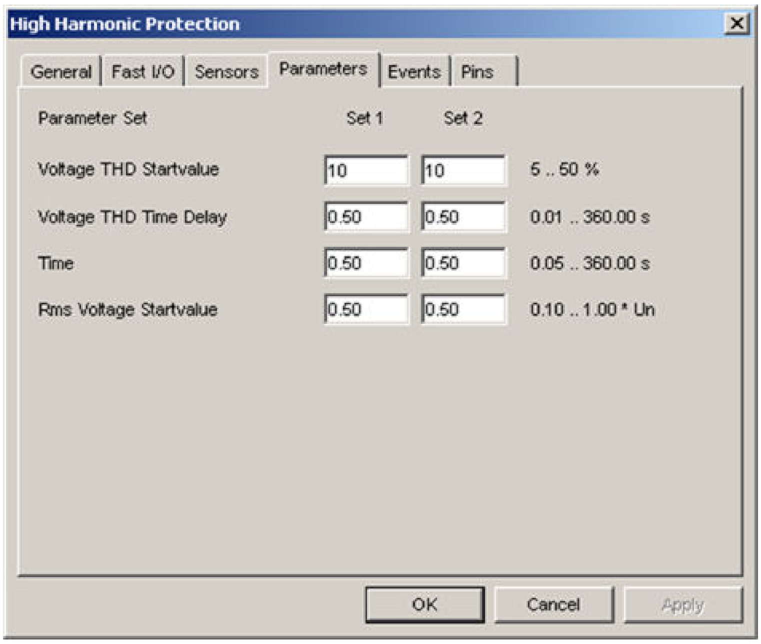


Figure 332: Parameters

Voltage THD Startvalue	THD amplitude threshold
Voltage THD Time Delay	Time delay for THD detection
Time	Time delay for Trip condition detection
Rms Voltage Startvalue	Function enabling Voltage threshold condition

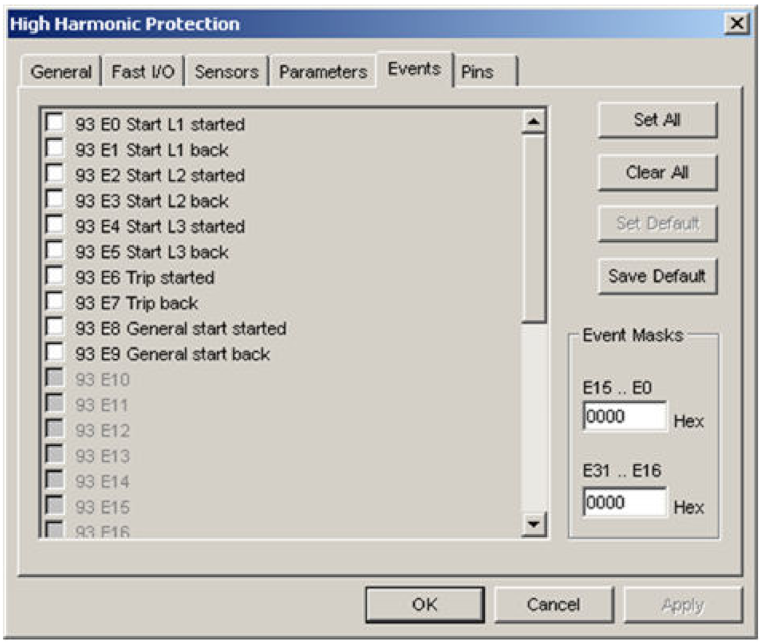


Figure 333: Events

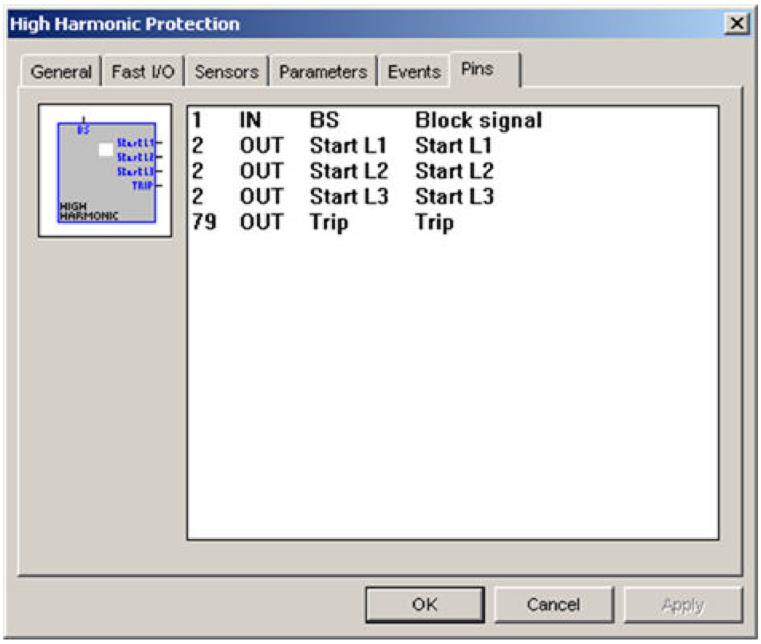


Figure 334: Pins

5.6.7.3 Measurement mode

High harmonic protection function evaluates the measured amount of voltage RMS and THD (Total Harmonic Distortion).

5.6.7.4 Operation criteria

If there is at least one phase voltage (respectively line voltage, depending on the configuration):

- The RMS value is above the preset threshold (*Rms Voltage Start value*)
- The THD value is above the preset threshold (*Voltage THD Start value*) for at least the preset detection time (*Voltage THD Time Delay*).

Then the protection function is started. The start signal is phase selective. It means that when the above conditions are true at least the for one phase voltage, then the relevant start signal (`START L1`, `START L2` or `START L3`) will be activated.

The protection function will remain in START status until there is at least one phase started. It will come back in passive status and the start signal will be cleared if for all the phases the voltage falls below 0.95 one of the setting threshold values (*Rms* OR *Voltage THD* OR *Delta Voltage THD*).

When the protection has entered the start status and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated.

5.6.7.5 Setting groups

Two parameter sets can be configured for the high harmonic protection function.

5.6.7.6 Parameters and events

Table 156: Setting values

Parameter	Values	Unit	Default	Explanation
Voltage THD start value	1...50	%	10	THD amplitude threshold
Voltage THD time delay	0.01...360	s	0.50	Stabilizing delay for THD detection
Time	0.05...360	s	0.50	Time delay for Trip condition detection
Rms voltage start value	0.10...1.00	Un	0.50	Function enabling Voltage threshold condition

Table 157: Events

Code	Event reason
E0	Start L1 started
E1	Start L1 back
E2	Start L2 started
E3	Start L2 back
E4	Start L3 started
E5	Start L3 back

Table continues on next page

Code	Event reason
E6	Trip started
E7	Trip back
E16	Block signal started
E17	Block signal back
E18	Protection block started
E19	Protection block back

By default all events are disabled.

5.6.8 Frequency protection

REF 542plus can install up to 6 frequency protection functions per protected net.

The frequency protection function is used to detect frequency variations in a configurable amplitude and rate of change frequency range.

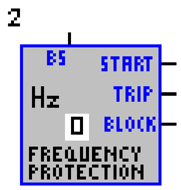


Figure 335: Frequency protection

5.6.8.1 Input/output description

Table 158: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function will then remain in idle state until the BS signal goes low.

Table 159: Outputs

Name	Type	Description
Start	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal
BLOCK	Digital signal (active high)	Block output signal

The START signal is activated if the start condition is fulfilled. If the setting value of the start signal is selected below the nominal frequency, the protection function operates as underfrequency protection. If the setting value is selected above the nominal frequency, the protection function operates as overfrequency protection. Also the rate rise of the frequency decrease or increase can be detected. The TRIP signal is generated according to the selected setting of the trip logic. The BLOCK output signal appears if the line voltage or the phase voltage depending on the setting parameter is below the setting value of the undervoltage threshold value.

5.6.8.2 Configuration

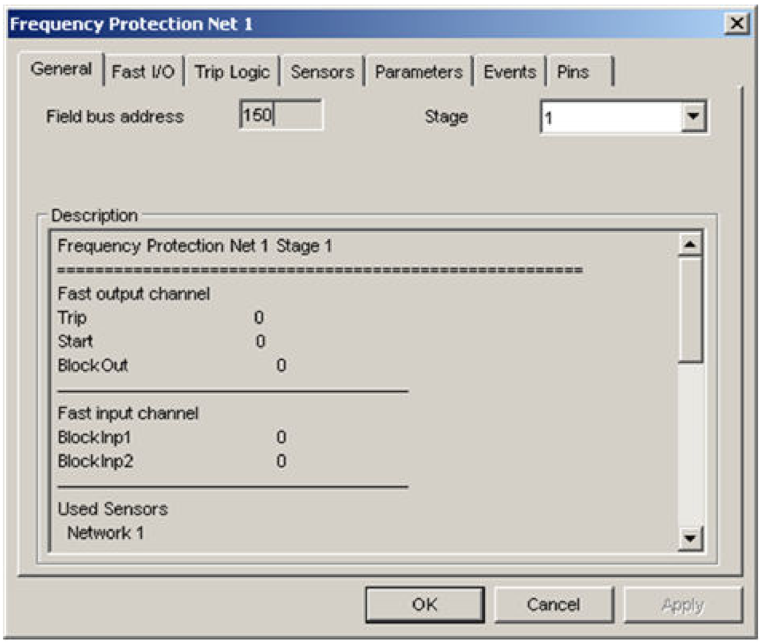


Figure 336: General

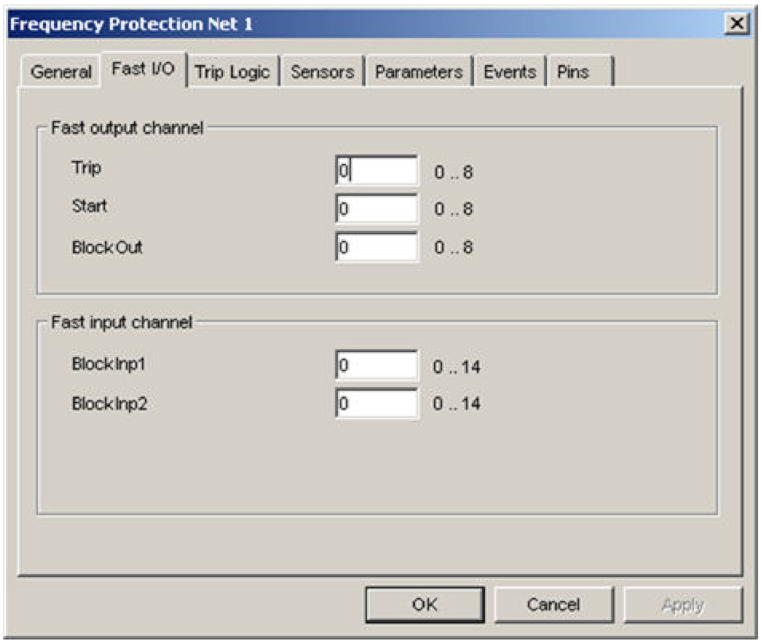


Figure 337: Fast I/O

Output Channel different from 0 means a direct execution of the trip, start or block output command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

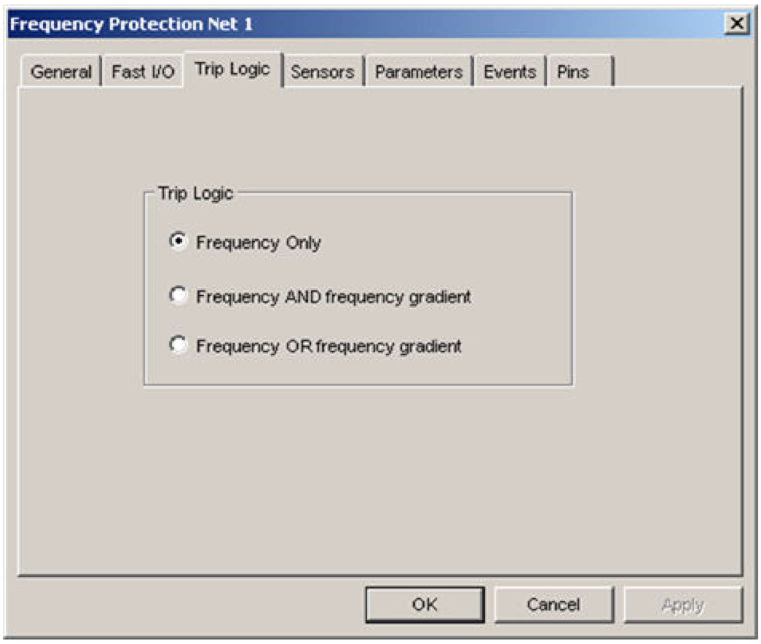


Figure 338: Trip Logic

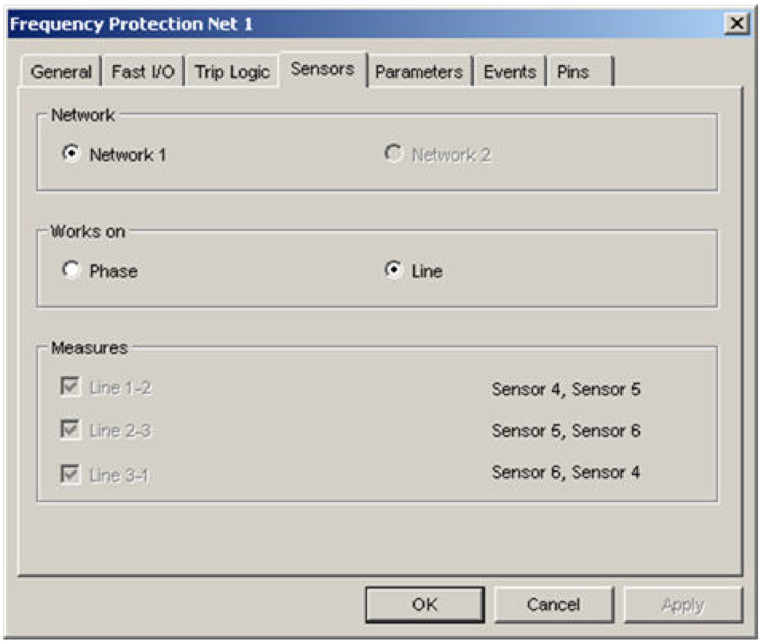


Figure 339: Sensors

The protection functions can operate on any combination of phase or line voltages in a triple, for example, it can operate as single phase or double phase, three-phase protection on voltages belonging to the same system. The default setting is to use the line voltage.

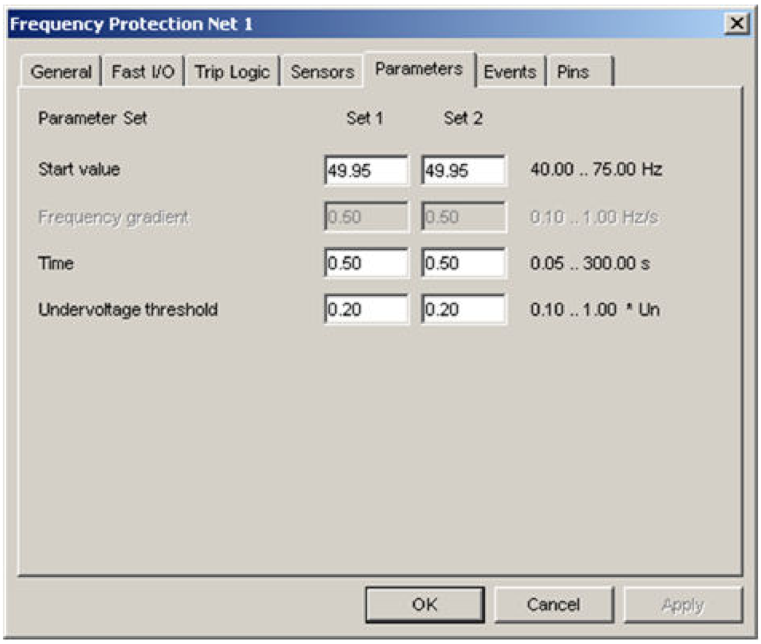


Figure 340: Parameters

Start value	Delta frequency amplitude threshold, with respect to the rated network frequency fr. If set below fr, it behaves as underfrequency, otherwise as overfrequency.
Frequency gradient	Rate of frequency change threshold
Time	Time delay for Trip condition detection
Undervoltage threshold	Minimum voltage threshold to be exceed for protection enabling, otherwise it is blocked

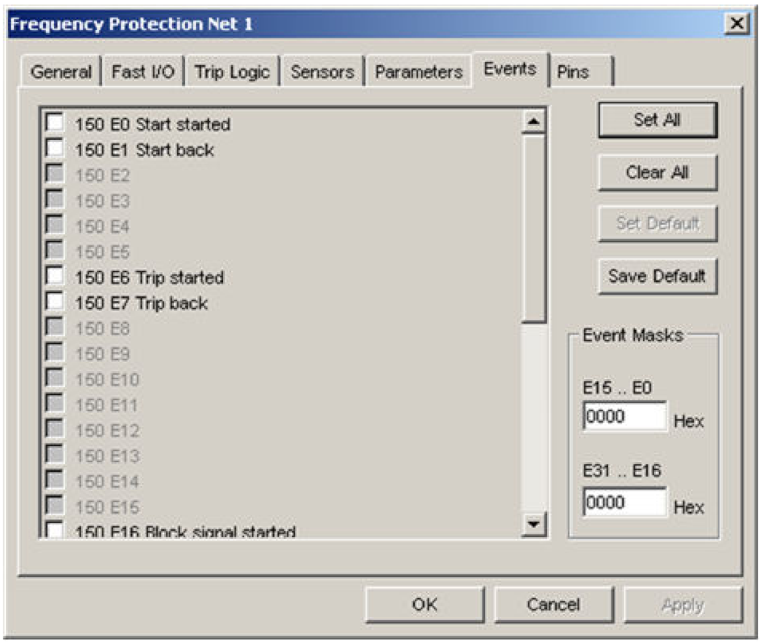


Figure 341: Events

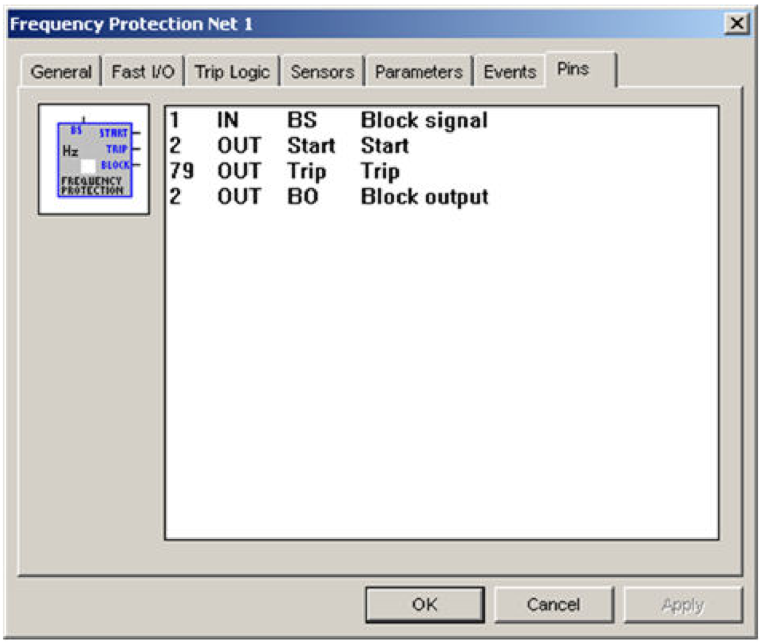


Figure 342: Pins

5.6.8.3 Measurement mode

Frequency protection functions evaluate the frequency and/or the frequency gradient of voltage signals through the zero-crossing detection of the voltage measurement quantity. The measure is performed on the first voltage measure available above the minimum voltage amplitude (*Undervoltage threshold*).

5.6.8.4 Operation criteria

The start condition and trip logic is selected by the user and it can be:

- Frequency only (only frequency value is considered)
- Frequency and frequency gradient (both the values must exceed thresholds to have a start and trip)
- Frequency or frequency gradient (at least one of the values must exceed the threshold to have a start and trip)

Depending on the set frequency threshold (*Start Value*) with respect to the network rated frequency, the protection function behaves either as underfrequency or overfrequency protection. For example, if the set frequency threshold is below rated frequency value, the protection function behaves as underfrequency).

The condition on frequency gradient, when used, is in the same direction as the condition on frequency. For example, if the protection function is set as underfrequency, the frequency gradient is significant only if it is negative and if the actual frequency is below the rated value.

If the frequency cannot be measured or one of the three phases or line voltages (according to the selected setting parameter) falls below 0.95 the *Undervoltage threshold* value, the protection function is blocked and a block signal is generated. Internally the trip time counter is frozen to the present counter value. The protection function will exit the block status and clear the block signal if the minimum voltage amplitude rises above the setting threshold value.

Do not set the *Undervoltage threshold* value too close to 1. The calculated value of the voltage itself is also dependent on the frequency due to the impacts of the applied sampling rate. If the frequency goes down, the calculated value of the voltage might be lower than the actual voltage value, which again will lead to an unwanted blocking of the protection.

In case the minimum voltage amplitude is above the undervoltage threshold value and the frequency can be measured, the start condition is fulfilled if the value of the measured frequency is below or exceeds the *Start value* setting parameter. For setting the value above the rated frequency the overfrequency condition will be detected. On the contrary an underfrequency condition will generate the start signal. For selecting a *Trip Logic* with *Frequency gradient*, the start signal will be generated similarly. The *Frequency gradient* is positive for overfrequency condition and negative for underfrequency condition.

The protection function will exit the Trip status and the trip signal will be cleared when all the start conditions fall below 0.95 of the calculated threshold value setting (*Start*

Value and/or *Frequency gradient*). For example, if the setting for the frequency protection with 50 Hz rated frequency is selected as following:

Start Value	49 Hz
Undervoltage threshold	0.7 Ur

The resetting value for the *Start Value* is 50 Hz – 0.95 (50 Hz – 49 Hz) = 49.05 Hz and for the *Undervoltage threshold* is 0.7 Ur / 0.95 = 0.74 Ur.

When the protection has entered the start status, if the above conditions remain true and the preset operating time (*Time*) has elapsed, the function goes in TRIP status and the trip signal is generated.

The protection function will exit the TRIP status and the trip signal will be cleared when all the start conditions fall below 0.95 the setting threshold value (*Start Value* and/or *Frequency gradient*).

5.6.8.5 Setting groups

Two parameter sets can be configured for each of the frequency protection functions.

5.6.8.6 Parameters and events

Table 160: Setting values

Parameter	Values	Unit	Default	Explanation
Trip criteria	f / f_AND_df/dt / f_OR_df/dt	-	f	Definition of start/trip criteria
Start value	40.00...75.00	Hz	49.95 59.95	Delta frequency amplitude threshold
Frequency gradient	0.10...1.00	Hz/s	0.50	Rate of frequency change threshold
Time	0.10...30.00	s	0.50	Time delay for trip condition detection
Undervoltage threshold	0.10...1.00	Un	0.20	Minimum voltage threshold function block/enabling

Table 161: Events

Code	Event reason
E0	Protection start
E1	Start cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive state
E16	Block output signal is active state

Table continues on next page

Code	Event reason
E17	Block output signal is back to inactive state
E18	Protection block signal is active state
E19	Protection block signal is back to inactive state

By default all events are disabled.

5.6.9 Circuit-breaker failure protection

REF 542plus contains the circuit-breaker failure protection (CBFP) to initiate the isolation of the system fault by the other adjacent circuit breakers.

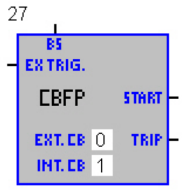


Figure 343: Circuit-breaker failure protection (CBFP)

5.6.9.1 Input/output description

Table 162: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal
EX TRIG	Trigger signal (active high)	External trigger

When the `BS` signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function then remains in idle state until the `BS` signal goes low.

Name	Type	Description
START	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal

The `START` signal is generated when an internal or external trigger is detected.

The internal trigger opens the circuit breaker due to a TRIP of a configured protection. The external trigger is a low to high transition of the EX TRIG input pin.

The trigger activates the CBFP only if the flowing current is exceeding the open current threshold value. The `START` signal drops when all the phase currents fall below the current threshold value.

The `TRIP` signal occurs when the CBFP detects a start condition and at least one phase current exceeds the set current threshold at timer expiration. The `TRIP` signal drops again after all the phase currents fall below the 40% of the current threshold.

5.6.9.2 Configuration

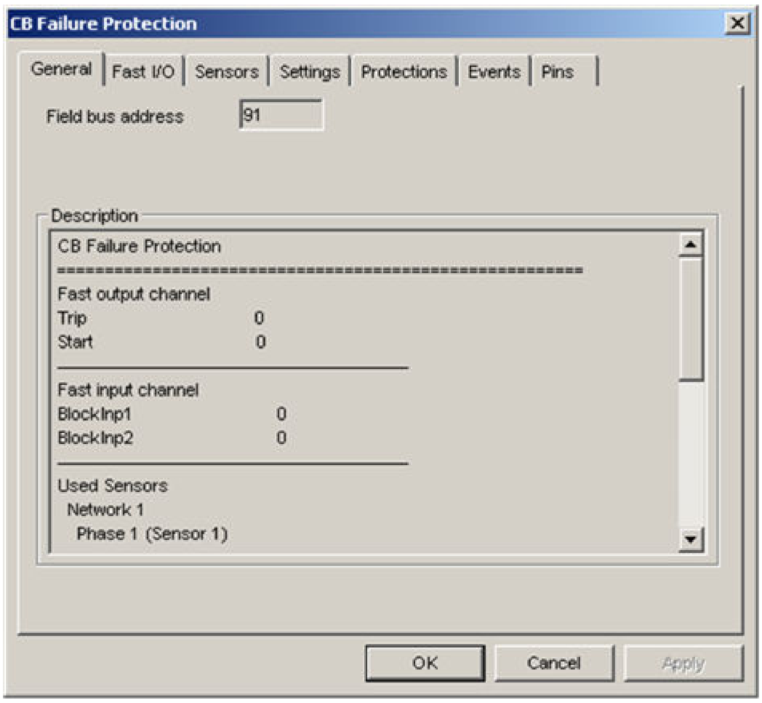


Figure 344: General

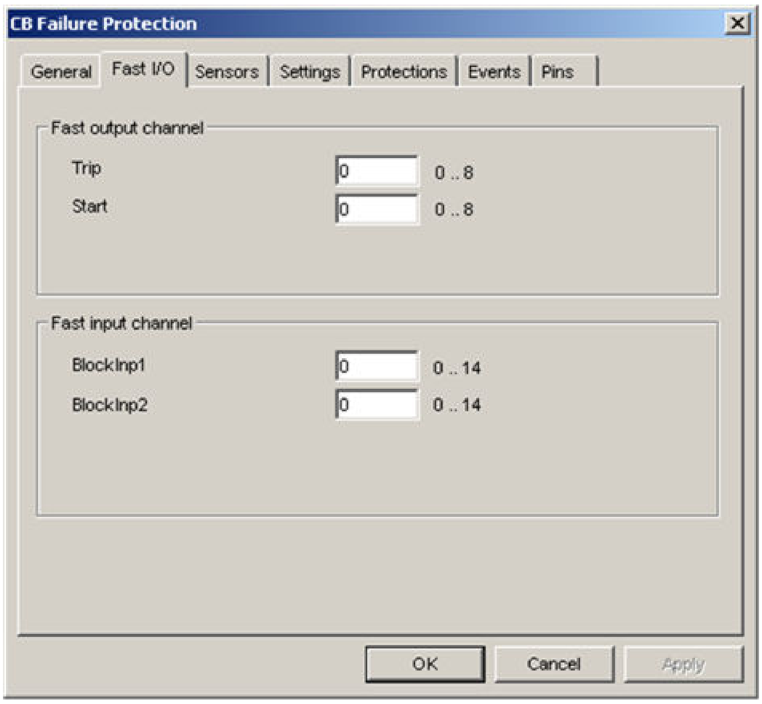


Figure 345: Fast I/O

Output Channel different from 0 means a direct execution of the external circuit breaker trip or start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

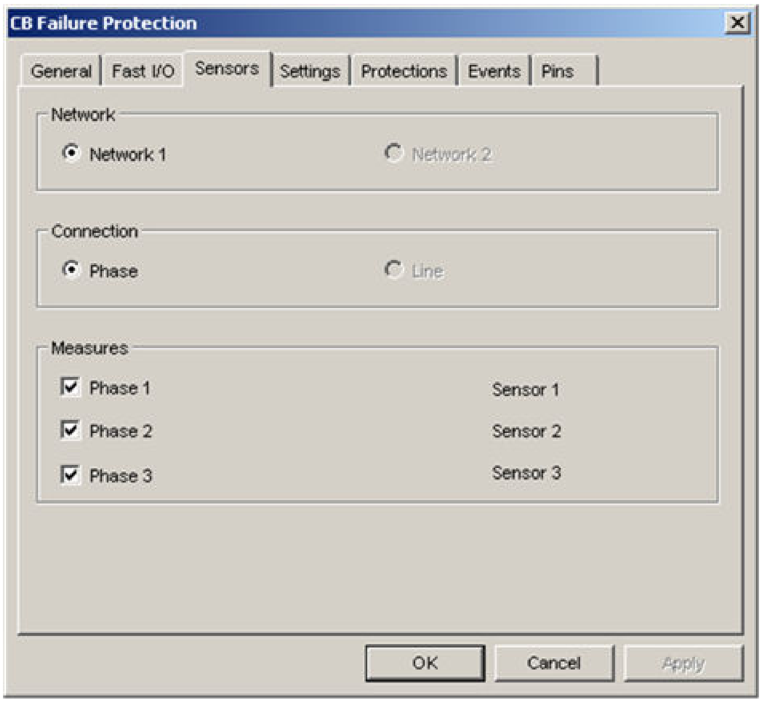


Figure 346: Sensors

The protection functions operate on any combination of phase currents in a triple, for example, it can operate as single-phase, double-phase or three-phase protection on phase currents belonging to the same network.

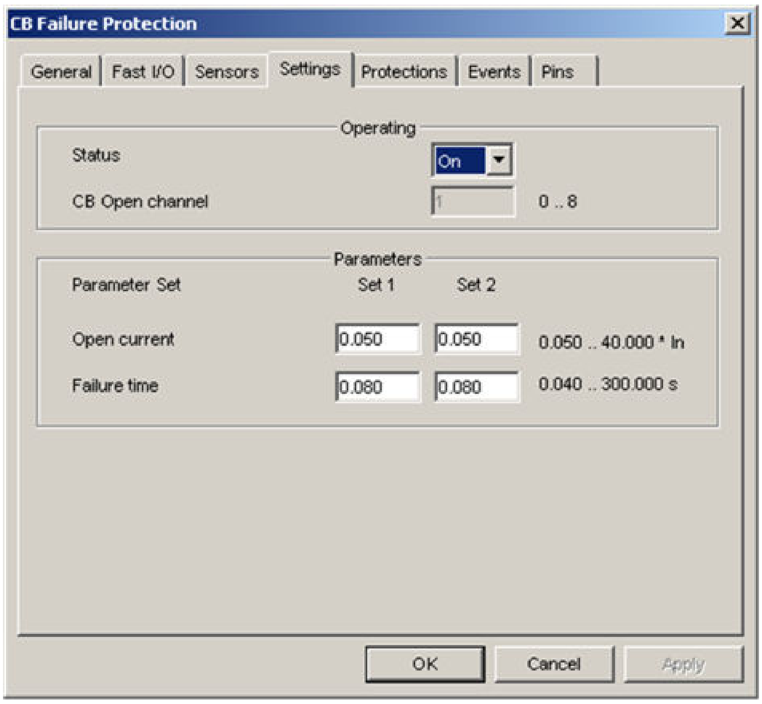


Figure 347: Settings

Status	Operating status
CB Open Channel	Internal circuit breaker open channel. It is taken, if available, from the switching object 2-2 configured as circuit breaker or from PTRC General. If not available, it has to be set with the output channel used to open the internal circuit breaker.
Open Current	Current threshold for internal circuit breaker open detection
Failure time	Time for the protection wait before generating trip signal. Depending on the related circuit breaker open time.

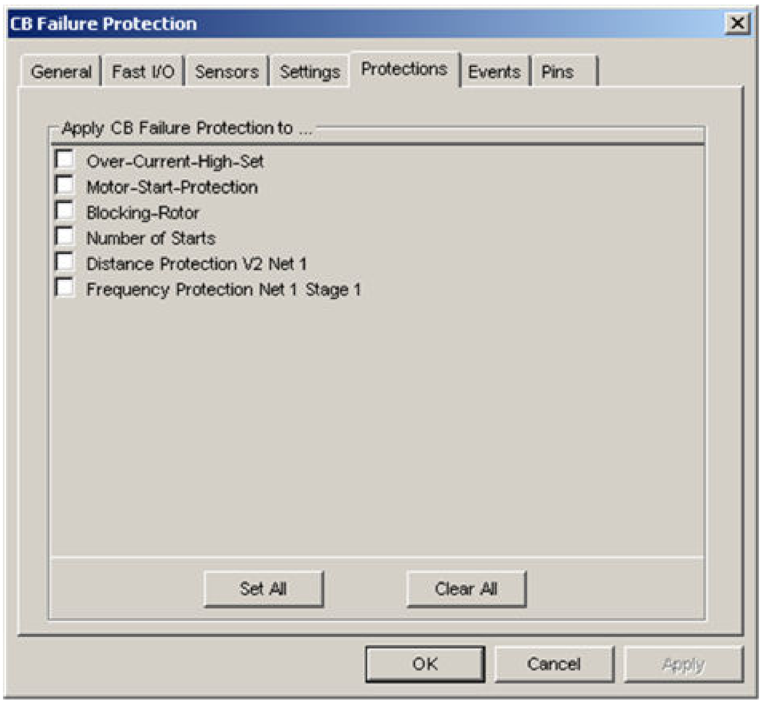


Figure 348: Protection

Selection of protection functions which trigger the circuit breaker failure protection.

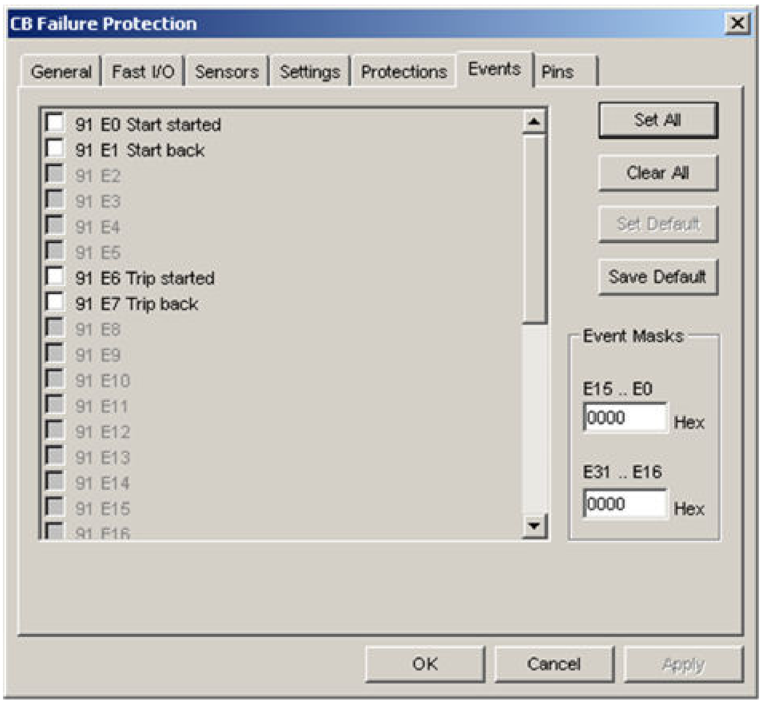


Figure 349: Events

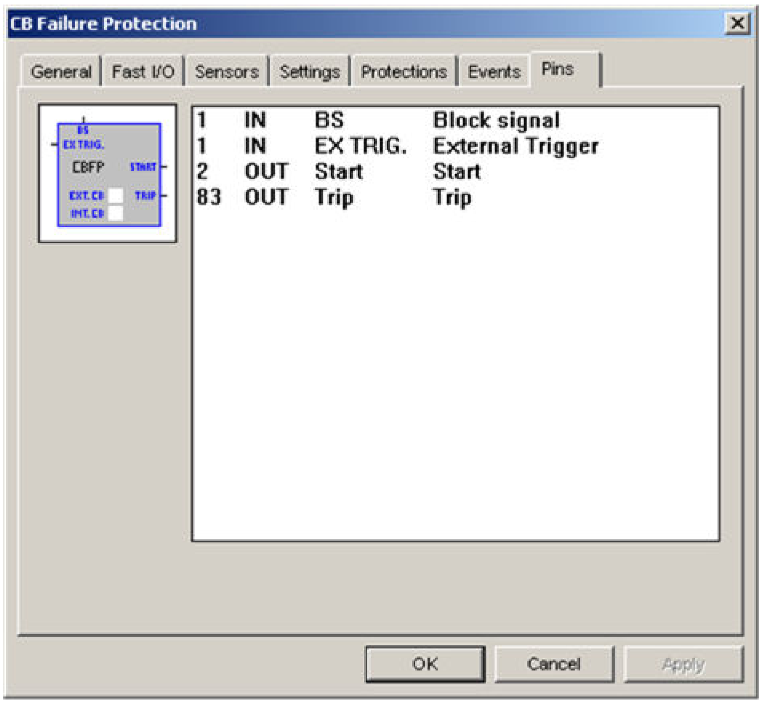


Figure 350: Pins

5.6.9.3 Measurement mode

The CBFP function evaluates the current RMS value at the fundamental frequency.

5.6.9.4 Operation criteria

When the CBFP detects an internal circuit breaker failure or is activated by an external trigger, it starts a timer. If the overcurrent condition in one phase still exists after the timer has expired, the CBFP generates a trip signal at the output channel indicating that the related internal circuit breaker has failed to operate.

If a trigger occurs while CBFP is blocked, the trigger will never be processed also in case the trigger condition is still present after the disappearing of the blocking state.

5.6.9.5 Setting groups

Two parameter sets can be configured for the CBFP function. Switch-over between the parameter sets can be performed in dependency of the network configuration. If this is not required, set 1 and set 2 can be parameterized identically to avoid wrong setting if switch-over of parameters has happened accidentally.

5.6.9.6 Parameters and events

Table 163: Setting values

Parameter	Values	Unit	Default	Explanation
Status	On/Off		On	Operating status
CB Open channel	0...max. output channel		0	Internal CB open channel
Open Current	0.050...40.000	In	0.0500	Current threshold for start
Failure time	0.040...200.000	s	0.080	CB time to open

Table 164: Events

Code	Event reason
E0	Protection start
E1	Start is cancelled
E6	Trip signal is active
E7	Trip signal is back to inactive
E18	Protection block is started
E19	Protection block is back to inactive
E20	External trigger is started
E21	External trigger is back to inactive

By default all events are disabled.

5.6.10 Switching onto fault protection

The switch onto fault protection is introduced in release 3.0, starting from version V4F08x. It is designed as a separate and autonomous function block in order to control the closing sequence of the circuit breaker to energize a disconnected line back to the electrical system. If during the energizing procedure a fault occurs, the switch onto fault protection generates a trip command to open the circuit breaker again.

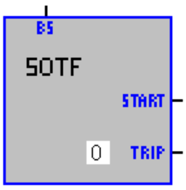


Figure 351: Switch onto fault

5.6.10.1 Input/output description

Table 165: Inputs, common fault detection

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset, regardless of its state. This means that all the output pins go low, generating the required events, if any, and all the internal registers and timers are cleared. The protection function remains in the idle state until the BS signal goes low.

Table 166: Outputs, common fault detection

Name	Type	Description
START	Digital signal (active high)	Start signal
TRIP	Digital signal (active high)	Trip signal

The START signal is activated when the respective start condition is true, that is, the phase currents exceed the setting threshold value without or with voltages lower than the setting threshold value. If the switching onto fault operates depending on the distance protection, its starting conditions are used to activate the switch onto fault protection.

The TRIP signal is activated when at least for the start the conditions are true and the operating time has elapsed.

5.6.10.2 Configuration

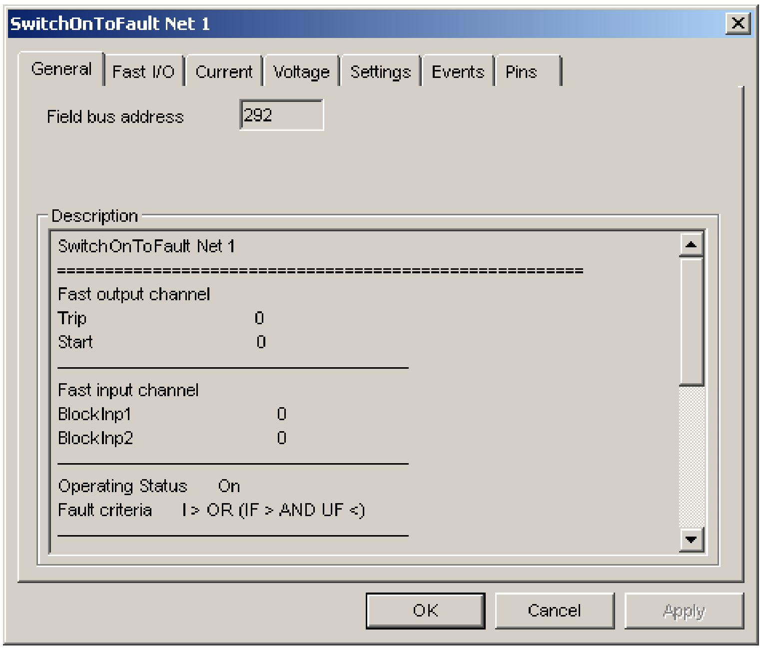


Figure 352: General

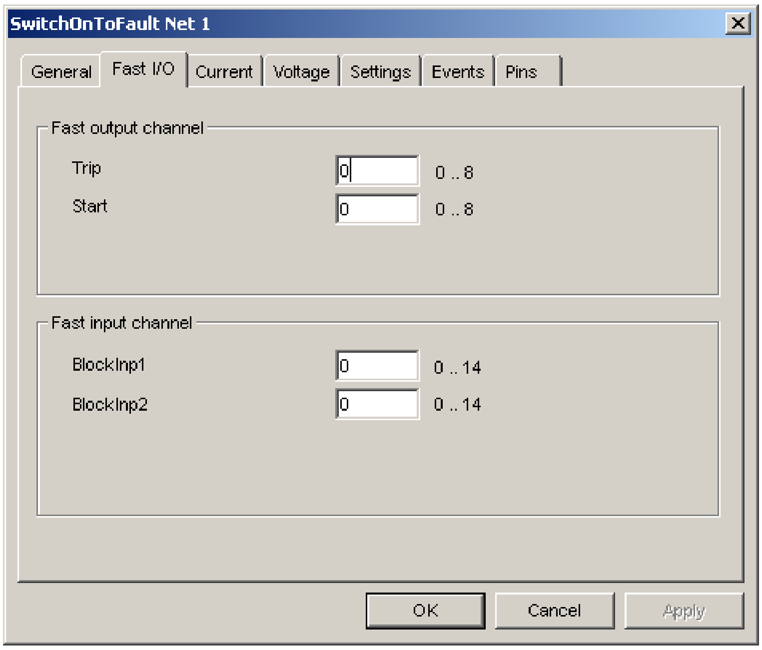


Figure 353: Fast I/O

Trip	Generate trip signal from the subsequent zones
Start	Generate general start signal from the subsequent zones
BlockInp1	Block the operation of all zones
BlockInp2	Block the operation of all zones

Fast output/input channel different from 0 means a direct execution of the trip command, that is, skipping the FUPLA cyclic evaluation.

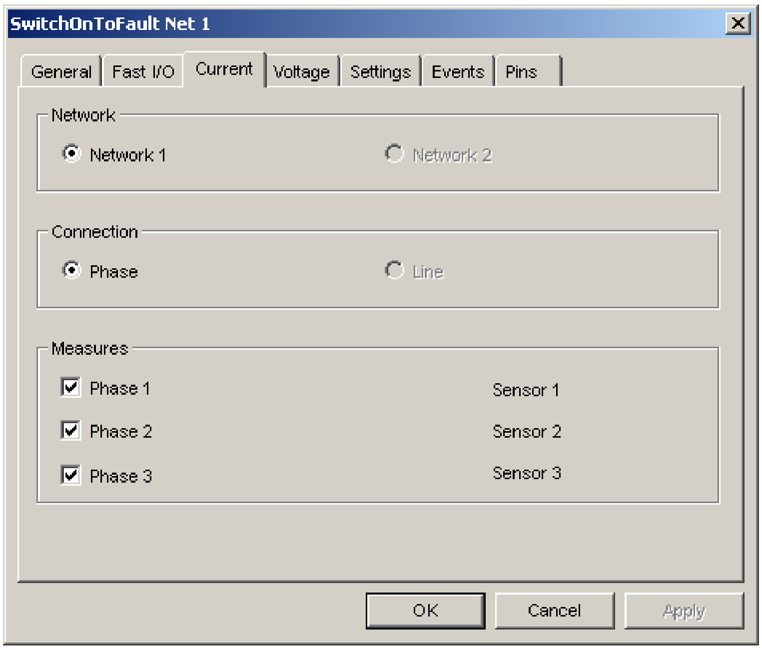


Figure 354: Current

The protection function operates on any combination of the phase current in a triple. For example, it can operate as a single-phase, double-phase or three-phase protection on the phase currents belonging to the same network.

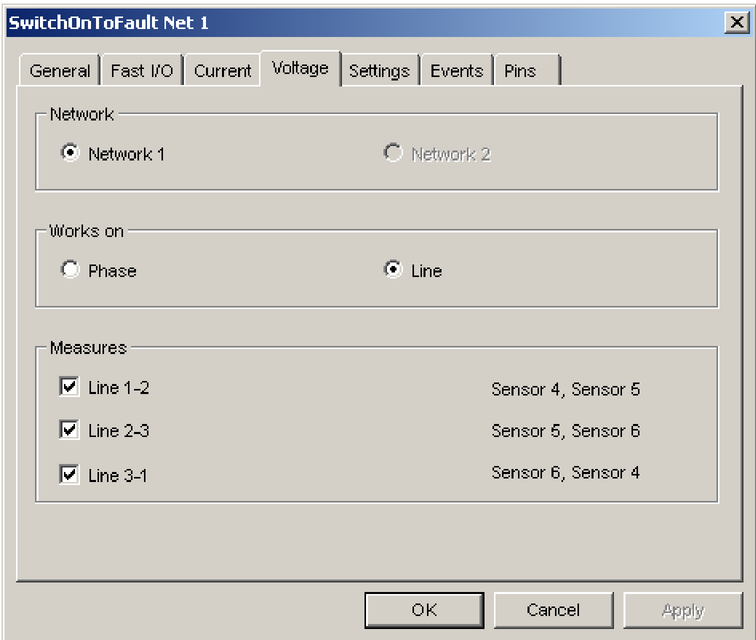


Figure 355: Voltage

The protection function operates on any combination of the phase or line voltage in a triple. For example, it can operate as a single-phase, double-phase or three-phase protection on the phase currents belonging to the same network.

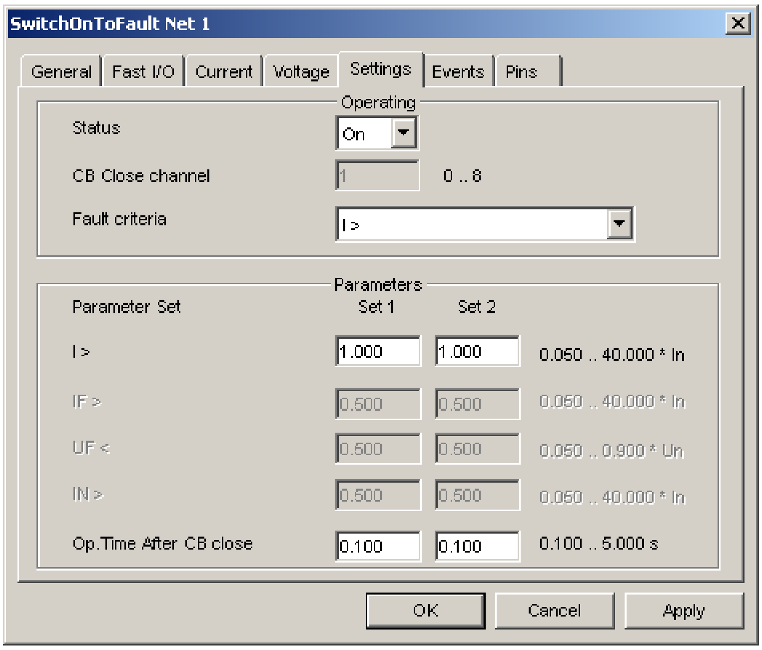


Figure 356: Settings

Status	Operating status
CB Close channel	Output channel used for the CB closing operation
Fault criteria	Criteria used for fault detection after closing the circuit breaker
I>	Current threshold for overcurrent condition detection
IF>	Current threshold for overcurrent condition detection
UF<	Voltage threshold for undervoltage condition detection
IN>	Current threshold for earth or residual current condition detection
Op. Time after CB Close	Time duration for fault monitoring

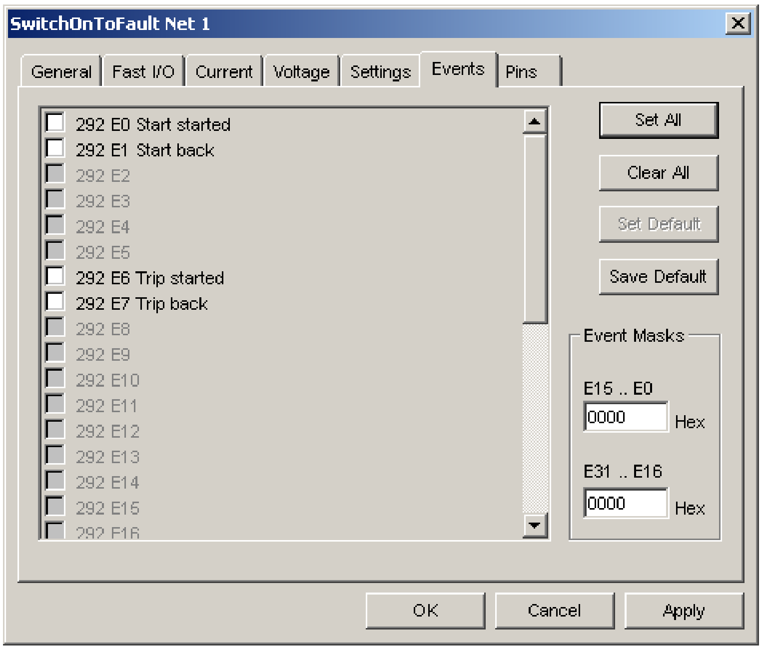


Figure 357: Events

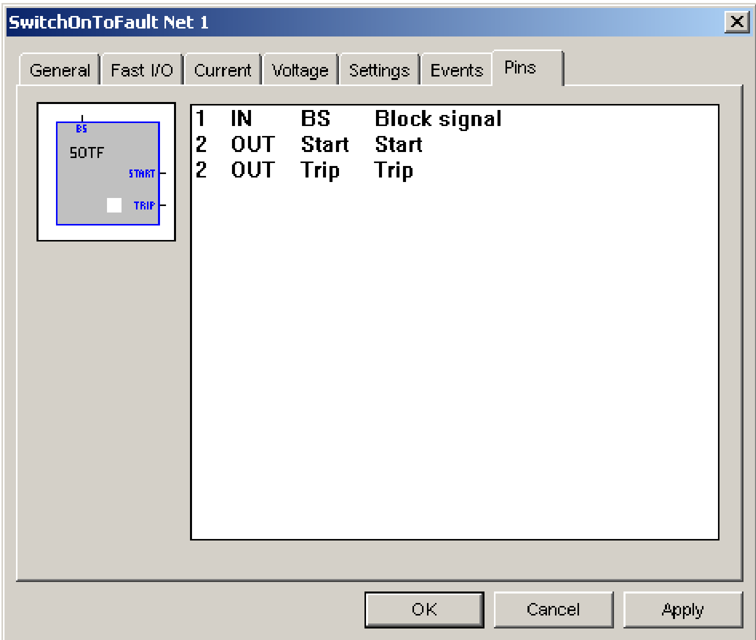


Figure 358: Pins

5.6.10.3 Operation mode

The switch onto fault protection is used to monitor the protected line during the closing of the circuit breaker. If a fault on the monitored line is detected, the switch onto fault protection trips the circuit breaker according to the operation time of the configured protection functions.

Depending on the connection of the measurement transformers to REF 542plus, only current transformers or current and voltage transformers, the detection of the fault can be performed with the following criteria:

- Overcurrent I>
- Overcurrent controlled by undervoltage I> OR (IF> AND UF<)

As soon as a fault condition is detected after closing the circuit breaker, the switch onto fault protection is started for the time duration according to the value of the setting parameter *Operation time after CB close*.

The value of *Operation time after CB close* must be set higher than the operation time setting of the configured protection in the application.

If the switch onto fault protection is configured with the distance protection V2, it is recommended to use the related overreach zone in order to cover the whole length of the line to be protected. In this case, the operation time of the circuit breaker is determined with the time setting of the distance protection V2 overreach zone.

5.6.10.4 Setting groups

Two parameter sets can be configured for the distance protection V2 function. A switch-over between the parameter sets can be performed depending on the network configuration. If this is not required, set 1 and set 2 can be parameterized identically to avoid a wrong setting if the switch-over of the parameters has happened accordingly.

5.6.10.5 Parameters and events

Table 167: Setting values

Parameters	Values	Unit	Default	Explanation
Trip	0...8		0	Fast output channel
Start	0...8		0	Fast output channel
BlockInp1	0...14		0	Fast input channel
BlockInp2	0...14		0	Fast input channel
Status	On/Off		On	Operating status
CB Close channel	0...8		0	Binary output channel used to close the circuit breaker
Fault criteria	I>; I> OR (IF> AND UF<); Overreach zone		I>	Criteria for detection of fault condition
I>	0.05...40.00	In	1.00	Overcurrent condition
IF>	0.05...40.00	In	0.50	Overcurrent condition

Table continues on next page

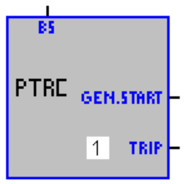
Parameters	Values	Unit	Default	Explanation
UF<	0.05...0.900	Un	0.50	Undervoltage condition
IN>	0.05...40.00	In	0.50	Residual overcurrent condition
Op. Time after CB close	0.100...5.000	s	0.200	Operation time

Table 168: Events

Code	Events
E0	Protection start on phase L1
E1	Start on phase L1 canceled
E6	Trip signal active
E7	Trip signal back to inactive status

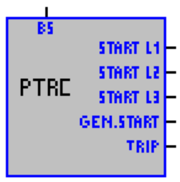
5.7 Trip conditioning

The trip conditioning function block (PTRC) is designed similarly to the same logical node in IEC 61850 standards. The advantage of this approach is to generate start and trip events tagged with correct time stamps, and to avoid delay due to FUPLA cycle time.



General

Figure 359: PTRC general



Over Current

Figure 360: PTRC overcurrent protection

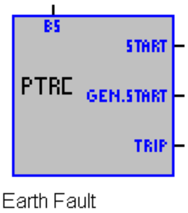


Figure 361: PTRC earth fault protection

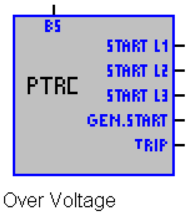


Figure 362: PTRC overvoltage protection

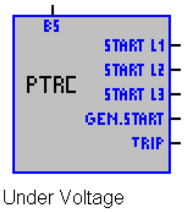


Figure 363: PTRC undervoltage protection

The PTRC model includes four possible intermediate PTRC instances to collect the signals from protection functions belonging to the same family and one general PTRC instance to collect the signals from all installed protection functions (including the intermediate PTRC). The intermediate PTRC includes:

- PTRC overcurrent
- PTRC earth fault
- PTRC overvoltage
- PTRC undervoltage

According to the application needs, it is possible to use intermediate PTRC and include them afterwards in the general PTRC or to use only the general PTRC which includes all the protection functions applied.

PTRC must include only the protection functions tripping to the circuit breaker. This information can be dependent on the application. Therefore the protection functions used by the PTRC have to be selected accordingly.

5.7.1 Input/output description

Table 169: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function remains in idle state until the BS signal goes low.

Each applied protection can be blocked by different conditions:

- Blocking signal active
- Operating status set to off (if available)

If the related PTRC function is blocked, for example by activation of the block signal or by setting the operation status to off, all of the protection functions included in the PTRC are blocked too. The specific protection function is released only when all blocking signals are inactive.

Table 170: Output

Name	Type	Description
START L1	Digital signal (active high)	Start signal of IL1 (fault in set direction)
START L2	Digital signal (active high)	Start signal of IL2 (fault in set direction)
START L3	Digital signal (active high)	Start signal of IL3 (fault in set direction)
GEN.START	Digital signal (active high)	General start signal (logical OR combination of all starts including reset time)
TRIP	Digital signal (active high)	Trip signal

START L1, START L2 and START L3 are the phase selective start signals. The phase starting signal is activated when respective phase current start conditions are true (current exceeds the setting threshold value and the fault is in the specified direction).

GEN.START is a logical OR combination of the start signals START L1, START L2 and START L3, and remains active until the reset time, if used, has expired.

The TRIP signal is activated when, at least for a phase current, the start conditions are true and the operating time has elapsed.

5.7.2 Configuration

The main characteristics of the PTRC function are:

- Collects signals (starts/trips) belonging to different configurable protections
- Generates single optional fast trip output configuration (PTRC general)
- Generates single blocking signal to block all the configured protections
- Gives communication events with correct timestamp
- General start/trip updates recorded in fault recorder using real timestamp (direct connection between the PTRC output pin and the fault recorder input pin)
- Conditioned trip register/events (PTRC general)

The configuration for the PTRC general is shown as an example.

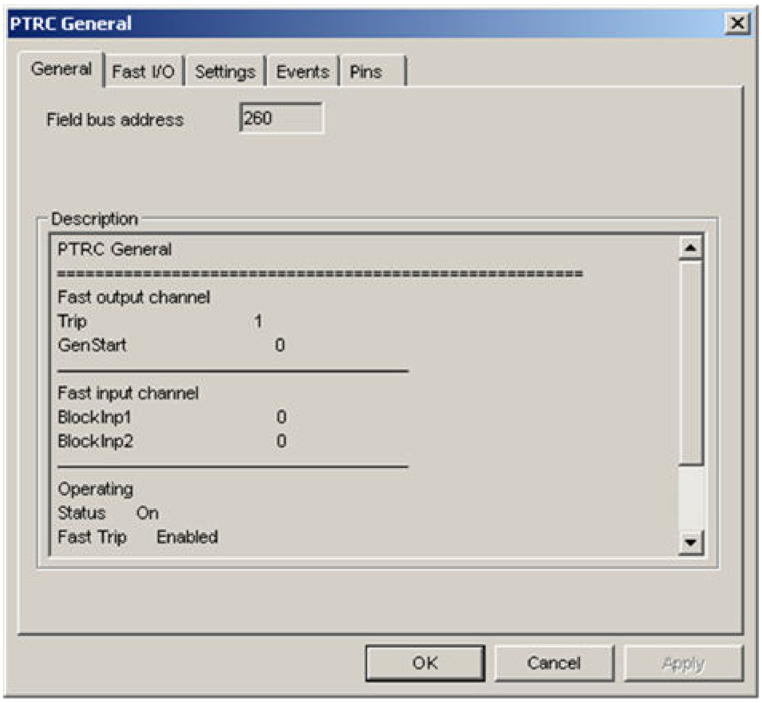


Figure 364: General

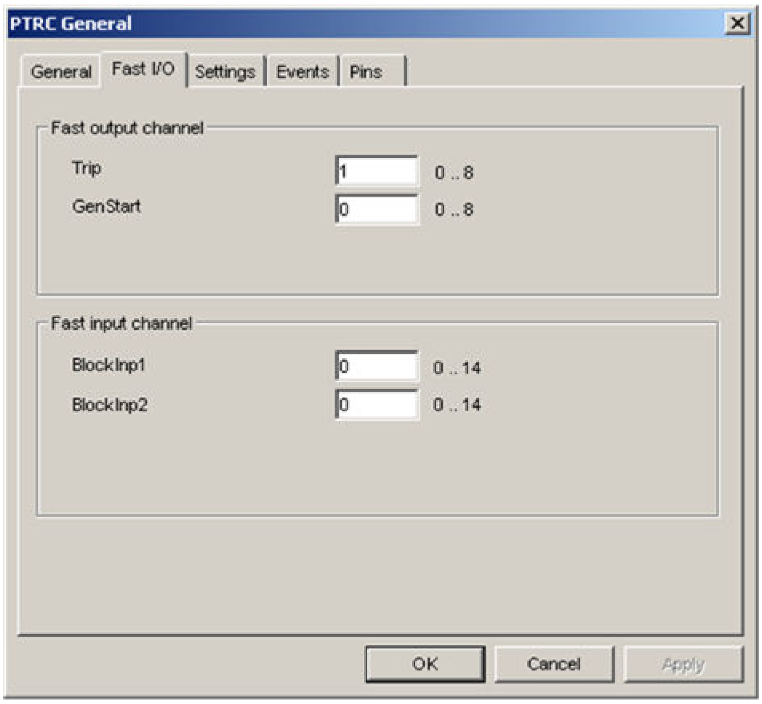


Figure 365: Fast I/O

Output Channel different from 0 means a direct execution of the trip or general start command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

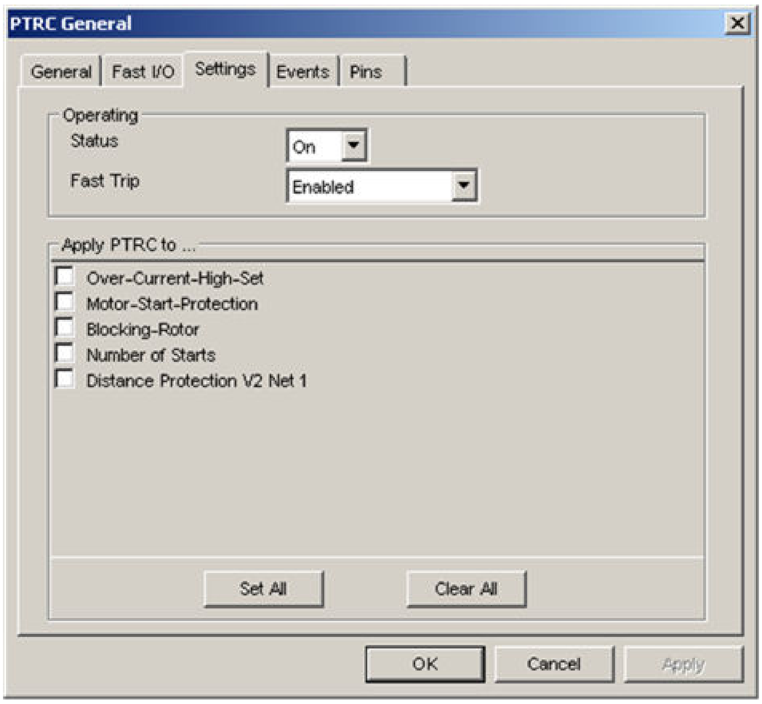


Figure 366: Settings

Operating status (On/ Off):	When the operating status is off, all used protections are set in the inactive status. The off state is equal to the one described for the BS (blocking signal).
Fast trip mode (enabled/ disabled):	This setting is available only in the PTRC general. When enabled, the trip command is directly forwarded to the circuit breaker open channel without any FUPLA cyclic execution.

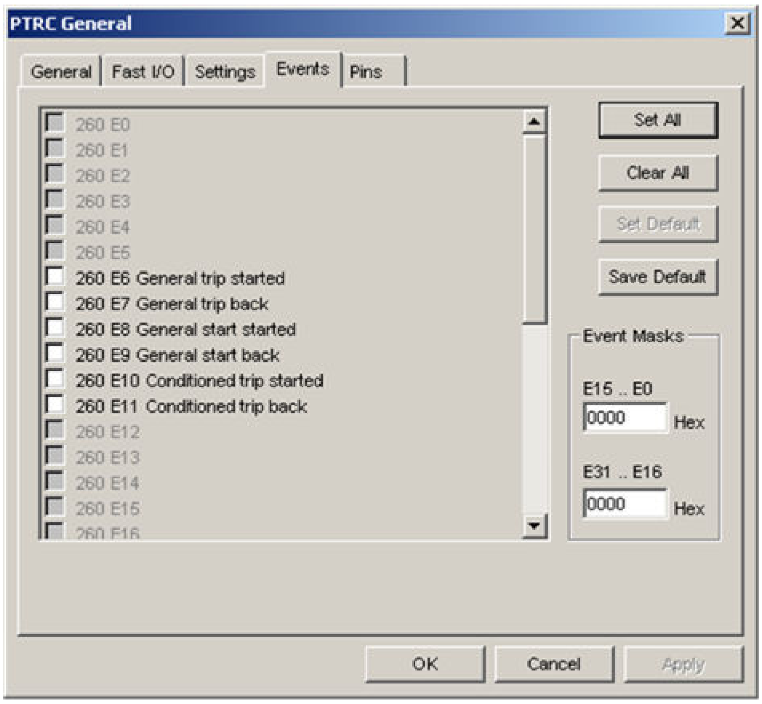


Figure 367: Events

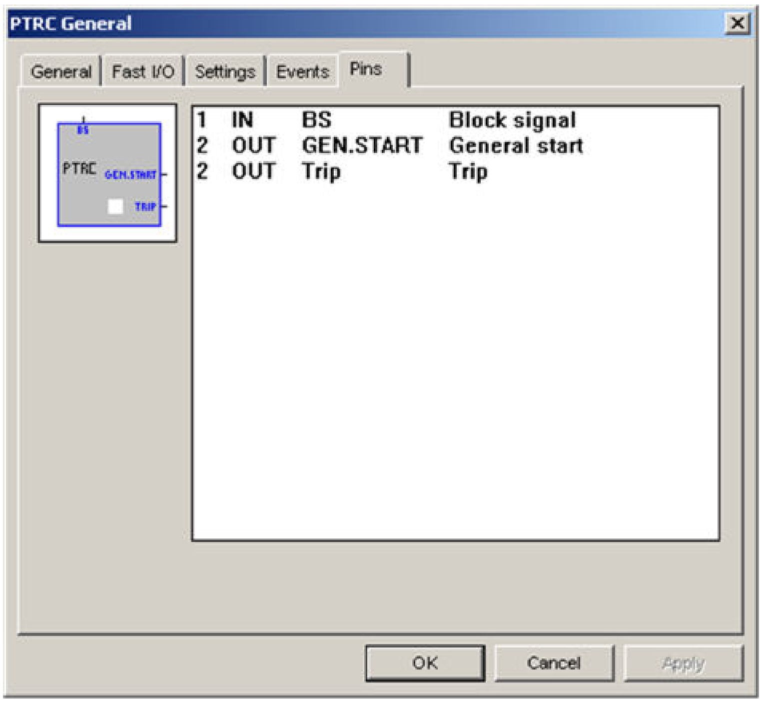


Figure 368: Pins

5.7.3 Conditioned trip events

The conditioned trip events are only available in PTRC general. It is defined to fulfill the IEC 61850 requirements for the common trip of the REF 542plus. If a conditioning logic scheme on the trip signal is used in the application, the correct status is also taken into account accordingly.

5.7.4 Multiple use of output channel

When the fast trip is enabled in the PTRC general, the same cannot be enabled anymore in the used protections.

5.7.5 Different output channel

If the fast trip is not enabled, a used protection cannot have different output channel from the channel configured in the PTRC general.

5.7.6 PTRC general in context wiht IEC-61850

In case the Ethernet board is used and configured with IEC-61850, the PTRC general is mandatory.

5.7.7 Events

Table 171: Events

Code	Event reason
E4	Conditioned trip is active
E5	Conditioned trip back to inactive state
E6	General Trip signal is active
E7	Trip signal is back to inactive state
E8	Protection general start (logical OR combination of starts)
E9	General start is cancelled (after expiration of reset time)
E18	Protection block signal is active
E19	Protection block signal is back to inactive status
E26	Protection general operation[1)] (logical OR combination of all faults)
E27	General operation cancelled (after expiration of reset time)
E28	Operation on fault direction forward[2)]
E29	Operation on fault direction backward
E30	Operation on fault direction unknown
E31	Operation on fault direction both

1) Start of protection on faults independent of the direction
2) The fault direction events are available in overcurrent and earth- fault PTRC. The fault direction is set to both when the direction given by the used protection is both forward and backward.

By default all events are disabled.

5.8 Autoreclose

The autoreclose function can be used to reclose the circuit breaker automatically when a protection function has tripped. This function block can be applied to all the protection functions available in REF 542plus.

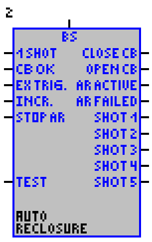


Figure 369: Autoreclose

5.8.1 Input/output description

Table 172: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal
1 SHOT	Digital signal (active high)	ARonly performing single shot
CB OK	Digital signal (active high)	CB drive ready for the following AR
EX. TRIG	Digital signal (active high)	Triggering of AR by an external signal
INCR.	Digital signal (active high)	Increment the number of shots
STOP AR	Digital signal (active high)	Immediate stopping of the AR cycles
TEST	Digital signal (active high)	Test of AR cycle (O-CO-CO…)

When the `BS` signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The protection function will then remain in idle state until the `BS` signal goes low.

Table 173: Output

Name	Type	Description
CLOSE CB	Digital signal (active high)	CB close signal
OPEN CB	Digital signal (active high)	CB open signal
AR ACTIVE	Digital signal (active high)	High as long as AR is active
AR FAILED	Digital signal (active high)	High in case of an unsuccessful AR
Table continues on next page		

Name	Type	Description
SHOT 1	Digital signal (active high)	1st Shot signal ofAR
SHOT 2	Digital signal (active high)	2nd Shot signal of AR
SHOT 3	Digital signal (active high)	3rd Shot signal ofAR
SHOT 4	Digital signal (active high)	4th Shot signal of AR
SHOT 5	Digital signal (active high)	5th Shot signal ofAR

5.8.2 Configuration

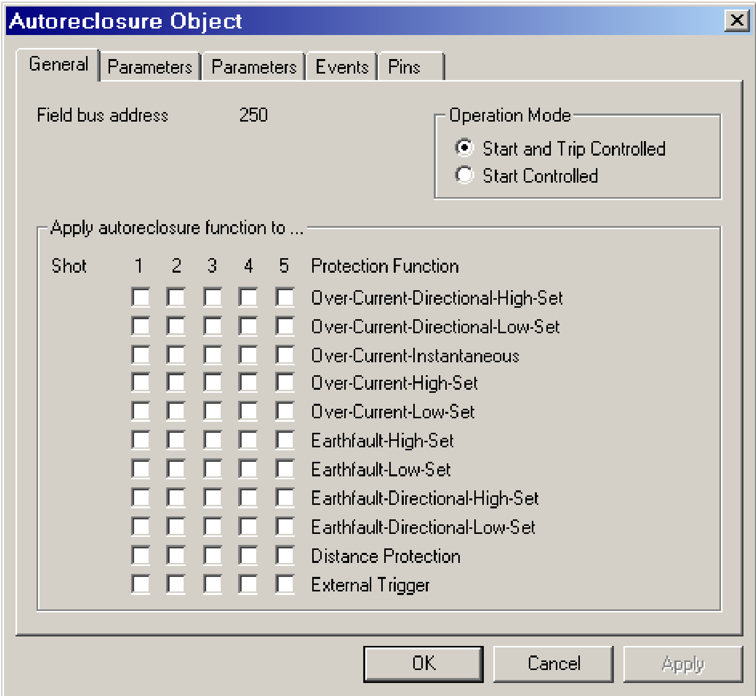


Figure 370: General

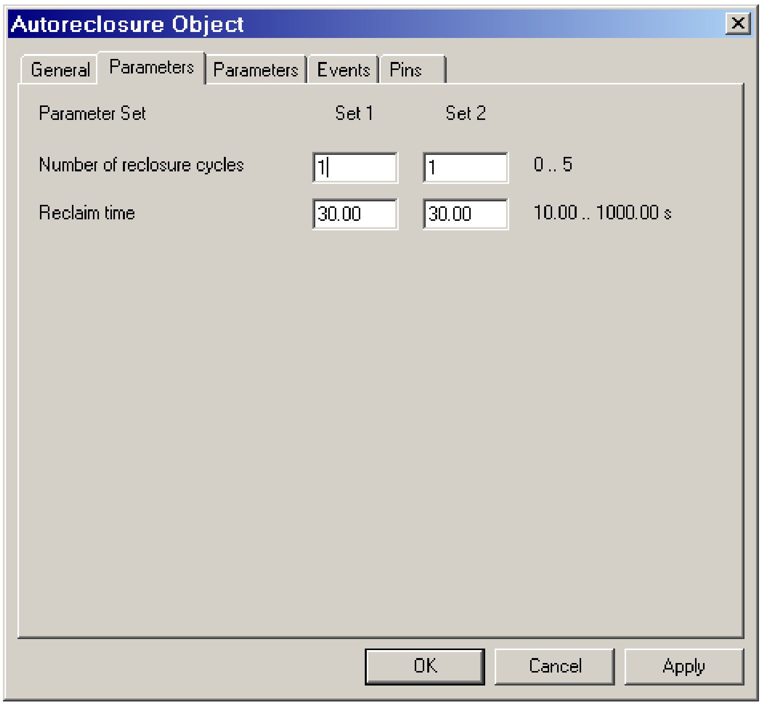


Figure 371: Parameters

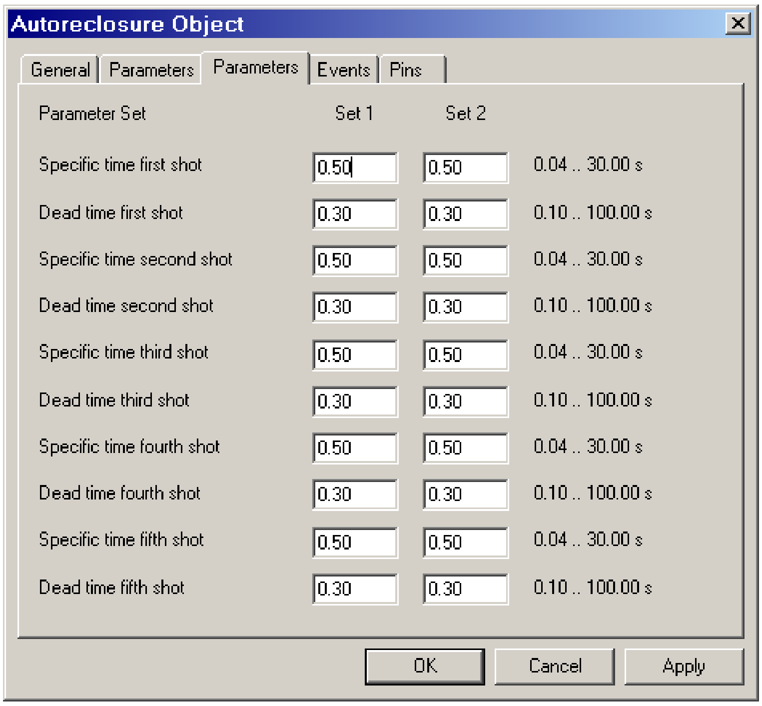


Figure 372: Parameters

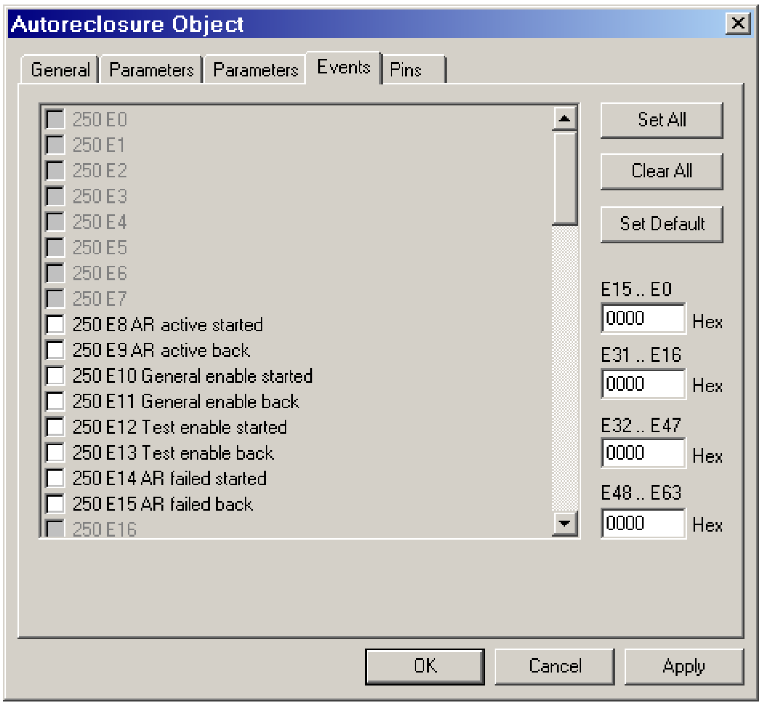


Figure 373: Events

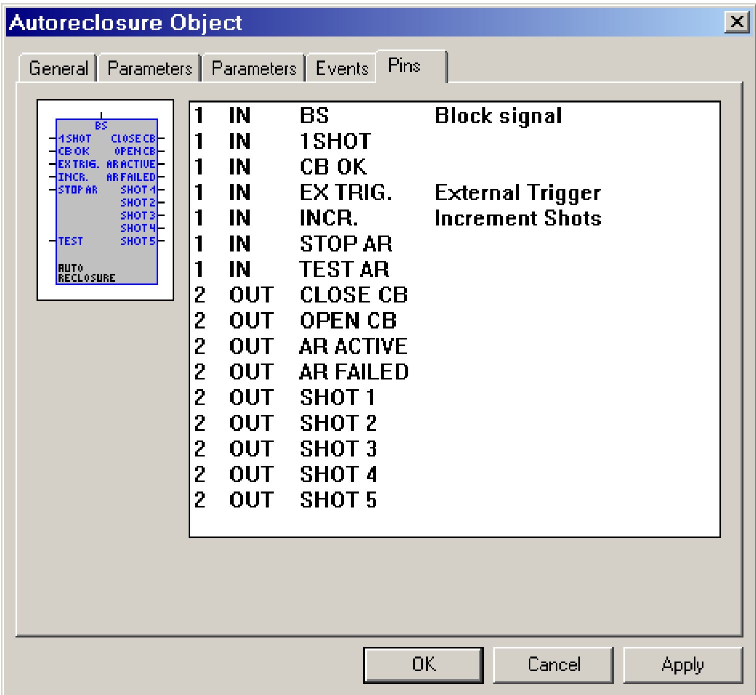


Figure 374: Pins

5.8.3 Operation mode

The autoreclose function block can be operated in two different modes.

Start and trip controlled

In this operation mode, the difference of the time duration between the start and the trip signal of the related protection function is evaluated. Therefore, the different settings of the specified time are provided. If the time difference between the protection start and trip signal is within the specified time, the AR-cycle is released and respectively continued. The corresponding CB shall be reclosed after the relating dead time is elapsed. If the condition is not fulfilled, the AR function block will be blocked. To continue the operation of the feeder, the AR function block needs to be released locally or remotely via the station control system.

Start controlled

This operation mode initiates the AR-Cycle only by a start signal of the related protection function. The tripping time for each shot can be delayed separately. This delayed tripping is need in some application, for example to burn out a falling tree on the overhead line. Therefore, the operation time of the protection function will now be controlled by AR. Normally, the first shot shall have a relatively short operation time in the range of 30 to 100 ms. The second and the following shot shall have longer operation time in the range of 1 to 10 s. If this mode is selected, the settings of the specified time are to be used to control the operation time of the following shots.

Both AR function can carry out a maximum of 5 shots.

The configuration can be done by a selection table. All the protection functions which can be connected are shown in the table. The columns are foreseen to define, which of the protection functions will activate specific AR shots. By selecting the related protection functions in each shot,AR will be initiated according to the operation mode defined previously. The protection function can be redefined after each shot. In the example, AR will operate as follows:

Due to the operation time dependency on the fault current, the IDMT and earth-fault IDMT are not listed. If this protection shall be used to initiate the AR-cycle, the relating trip signal shall be connected by a FUPLA wire to the input EX.TRIG of the AR function block.

The distance protection can only be used in start and trip control mode. If the AR status is ready, the overreach zone of the distance protection will be activated. After the first shot, the overreach zone will not be activated anymore. The trip will be done according to the setting of the related impedance zone.

To ensure the proper function of AR, the trip of the protection shall be send directly to the so-called 2-2 switch object, which controls and operatesCB. There is no need to make a FUPLA wiring between the AR function block, 2-2 switch object and the related protection functions.

The external trigger is to be selected, if AR will be triggered by an external protection function. The trip must be connected to a binary input of REF 542plus. Afterwards, the external trip signal needs to be wired to the external trigger input EX. TRIG of the AR function block.

If the AR-cycle is initiated by the input EX. TRIG, the same wire of this input signal must also be used to open CB via the 2-2 switch object. Otherwise, in case of blocking AR by a blocking signal, no opening of CB by the external protection will be possible.

5.8.4 Setting groups

Two parameter sets can be configured for the thermal overload protection function.

5.8.5 Parameters and events

Table 174: Setting values

Parameter	Values	Unit	Default	Explanation
Number of reclosure cycles	0...5		1	
Reclaim time	10...30	s	30	
Specific time first shot	0.04...30	s	0.5	
Dead time first shot	0.1...100	s	0.3	
Specific time second shot	0.04...30	s	0.5	
Dead time second shot	0.1...100	s	0.3	
Specific time third shot	0.04...30	s	0.5	
Dead time third shot	0.1...100	s	0.3	
Specific time fourth shot	0.04...30	s	0.5	
Dead time fourth shot	0.1...100	s	0.3	
Specific time fourth shot	0.04...30		0.5	
Dead time fourth shot	0.1...100		0.3	

Table 175: Events

Code	Event reason
E8	AR active started
E9	AR active back
E10	General enable started
E11	General enable back
E12	Test enable started
E13	Test enable back
E14	AR failed started
E15	AR failed back
E18	Block AR started
E19	Block AR back
E20	AR 1. shot started
E21	AR 1. shot back
E22	CB OK started
E23	CB OK back
E24	CB OK internal drop delayed started
E25	CB OK internal drop delayed back
E26	External trigger started
E27	External trigger back
E28	Shot increment started
E29	Shot increment back
E30	Stop AR started
E31	Stop AR back
E32	Test started
E33	Test back
E40	Close CB started
E41	Close CB back
E42	Open CB started
E43	Open CB back
E48	Shot 1 started
E49	Shot 1 back
E50	Shot 2 started
E51	Shot 2 back
E52	Shot 3 started
E53	Shot 3 back
E54	Shot 4 started
E55	Shot 4 back
E56	Shot 5 started
E57	Shot 5 back

By default all events are disabled.

5.9 Fault recorder

This function block allows the eight REF 542plus analog input signals to be recorded for a period of at least 1 second and for a maximum of 5 seconds. It is also possible to record up to 32 digital signals simultaneously from the FUPLA.

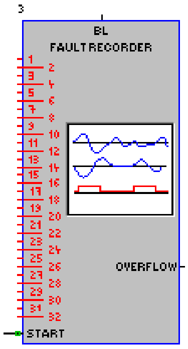


Figure 375: Fault recorder

5.9.1 Input/output description

Inputs

Table 176: Inputs

Name	Type	Description
BL	Digital signal (active high)	Blocking signal
1...32	Digital signal (active high)	32 Input for recording binary signal
START	Digital signal (active high)	Start of the fault recording
OVERFLOW	Digital signal (active high)	Overflow signal indication

When the BL signal becomes active, the fault recorder function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all the internal registers and timers are cleared. The fault recorder function will then remain in idle state until the BL signal goes low.

5.9.2 Configuration

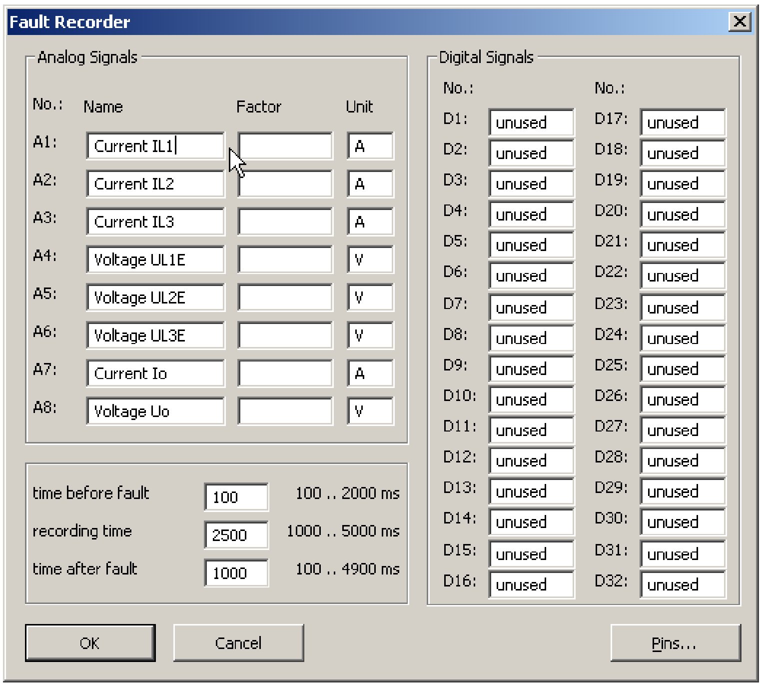


Figure 376: General and setting parameters

Name	User defined Analog Input meaning
Factor	Analog input scaling factor used for display
Time before fault	Recording duration before recorder start input trigger
Recording time	Total allocated duration, it limits the number of records (from 5 to 1) in the ring buffer
Time after fault	Recording duration after recorder start input trigger

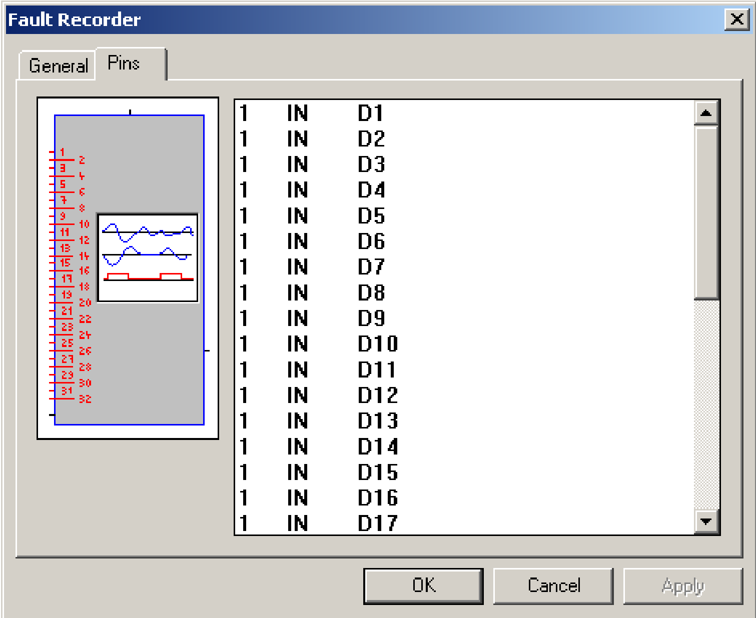


Figure 377: Pins

5.9.3 Operation

The fault recorder is started within the application. The recording time of the fault recorder is a combination of the time before the fault and the time after the fault. The time before the fault refers to the period recorded before the fault recorder is actually started from a protection start signal. The time after the fault is the period after the fault recorder has started. Dynamic recording of the fault record, for example, from start signal to signal CB OFF is not possible.

The ring buffer process saves the specific fault record, that is, the oldest fault record is always overwritten with a new one. The number of saved fault records depends on the record time. The total duration of all saved fault records is 5 seconds the maximum, if it is set to a lower value it limits the number of records in the buffer.

n = int((recording time/(time before + time after)

For example, 5 fault records can be saved with a record time of 1 s, that is, the minimum record time (time before the fault + time after the fault) that can be set.

The fault records are exported with the configuration software and then converted to the COMTRADE format. The fault records can also be exported via the bus of the station control system. The conversion to the COMTRADE format has to be carried out in the station control system.

The following limitations must be taken into account on the use of the fault recorder:

- At least one protective function must be configured.
- The start signal for the fault recorder must be implemented inFUPLA.

The analog signals are digitized and processed with a 1.2 kHz sampling rate, because they are decisive for the protection trips. They are therefore within a time grid of 0.833 ms. The start and trip signals from the protection functions are recorded and sent to the binary outputs immediately.

On the contrary, the digital signals are processed in accordance with the FUPLA cycle time. The cycle time depends on the application in this case. The digital signals are therefore in a grid that is significantly larger than the analog signal grid.

The fault recorder is dedicated for recording the fault data during a short circuit in the network. The data can be exported from the REF 542plus later and displayed with a suitable program.

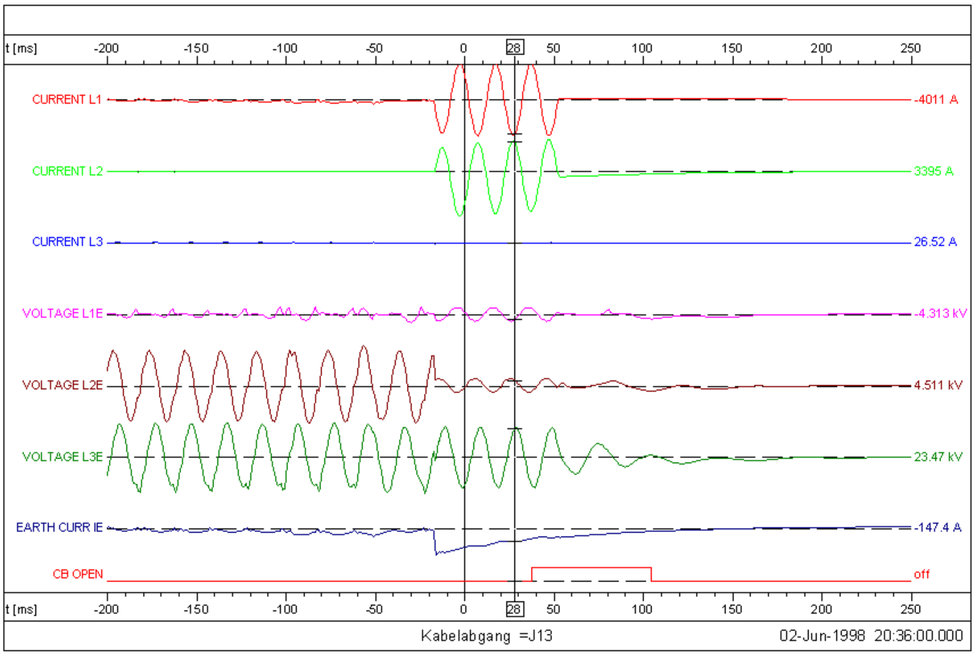


Figure 378: Graphic display of fault record data of a two-pole short circuit with the WINEVE® program

5.9.4 Parameters and events

Table 177: Setting values

Parameter	Values	Unit	Default	Explanation
Time before fault	100...2000	ms	100	Recording duration before the recorder start
Recording time	1000...5000	ms	2500	User defined limit to the total duration of the buffer, that is to records number
Time after fault	100...4900	ms	1000	Recording duration after the recorder start

5.10 High speed transfer system

A high speed transfer system comprises the high speed transfer device SUE3000 and REF 542plus devices. The two REF 542plus devices are used to initiate and release the operation of the high speed transfer system and simultaneously to protect the corresponding feeders.

The high speed transfer system can only be configured on SUE3000. Using the REF 542plus hardware is not possible.

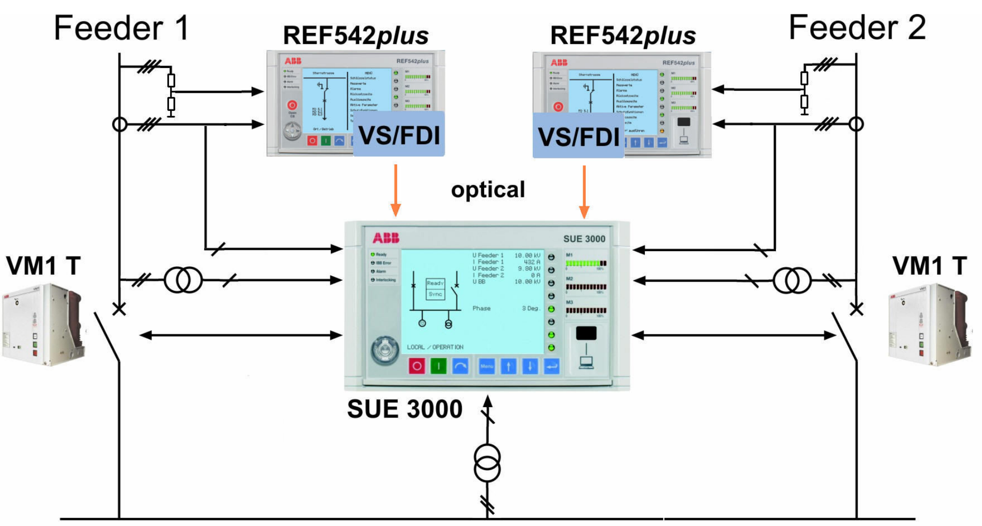


Figure 379: High speed transfer system

The condition for activation of the high speed transfer system depends on the location of the system fault. Therefore the REF 542plus devices are applied for fast detection of the fault location. Only in case of an upstream fault the high speed transfer system may be initiated.

The specific function blocks for high speed transfer system are Fast direction indication (FDI) and Voltage supervision (VS). Both function blocks must be used in REF 542plus to control the operation of the high speed transfer device accordingly. Both functions evaluate the phase currents and phase voltages for the detection of the fault location in the electrical system. In case of a downstream busbar fault, no system transferring may be performed. The control signals for starting the operation of the high speed control device are transferred by using the provided optional optical outputs on the main board of REF 542plus.

5.10.1 Fast directional indication

The Fast directional indication (FDI) monitors the active power flow continuously. If a fault occurs on the feeder side, a change of the active power flow is detected because the motors act as generators. The system transferring is released.

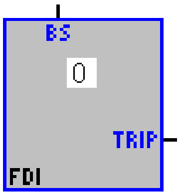


Figure 380: Fast directional indication

5.10.1.1 Input/output description

Table 178: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the `BS` signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function remains in idle state until the `BS` signal goes low.

Table 179: Output

Name	Type	Description
Trip	Digital signal (active high)	Trip signal for activation of SUE3000

The `TRIP` signal is activated when at least one of the start conditions is true and the operating time (*Time*) has elapsed.

5.10.1.2 Configuration

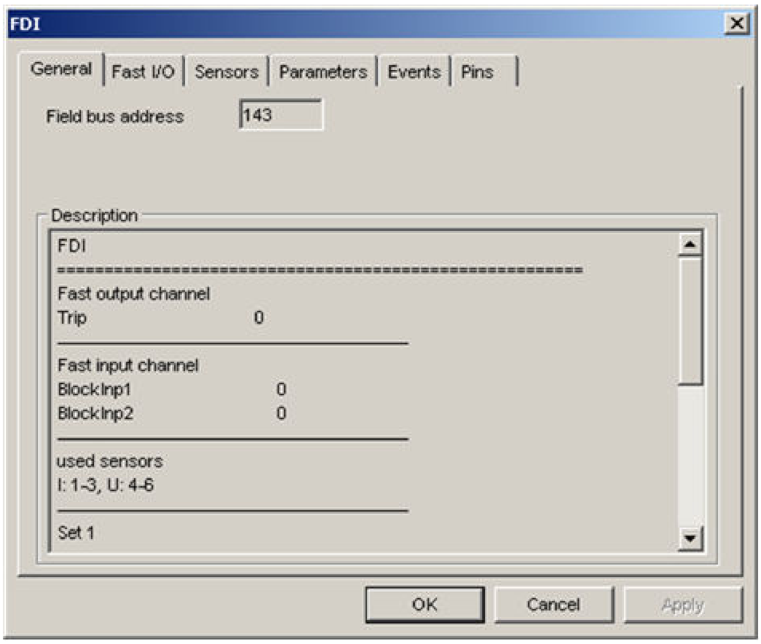


Figure 381: General

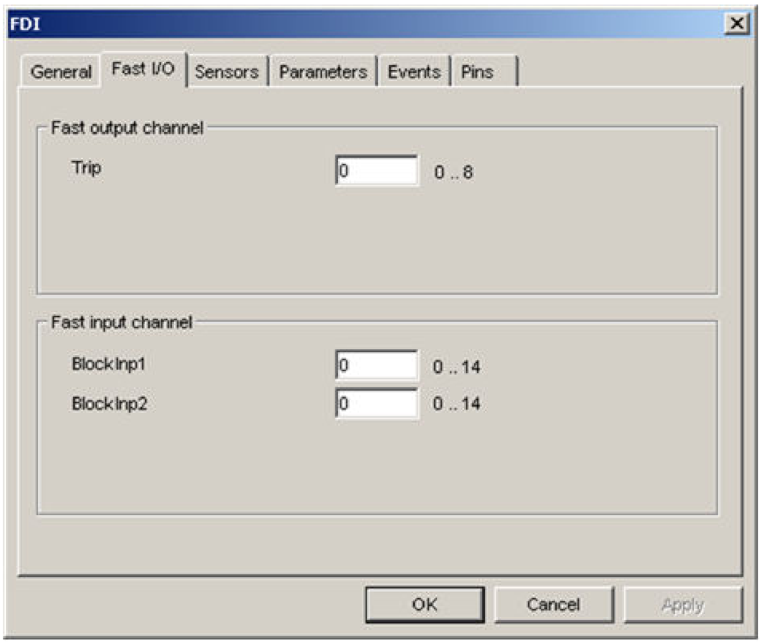


Figure 382: Fast I/O

Output Channel different from 0 means a direct execution of the trip command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

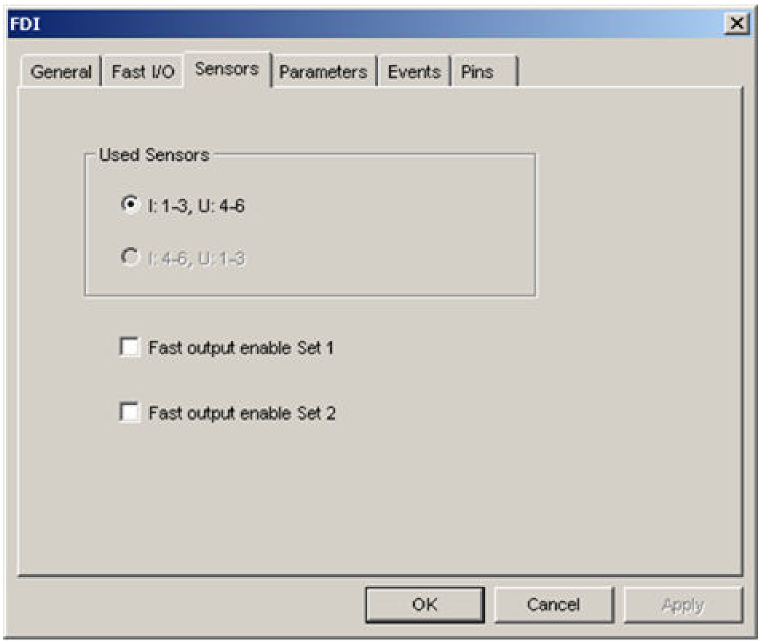


Figure 383: *Sensors*

I: 1-3, U: 4-6	Analog inputs 1 to 3 are current inputs and 4 to 6 voltage inputs
I: 4-6, U: 1-3	Analog inputs 4 to 6 are current inputs and 1 to 3 voltage inputs

FDI operates on any combination of the phase current and phase voltage in a triple belonging to the same system.

The activation of corresponding fast optical output for the FDI should be checked accordingly.

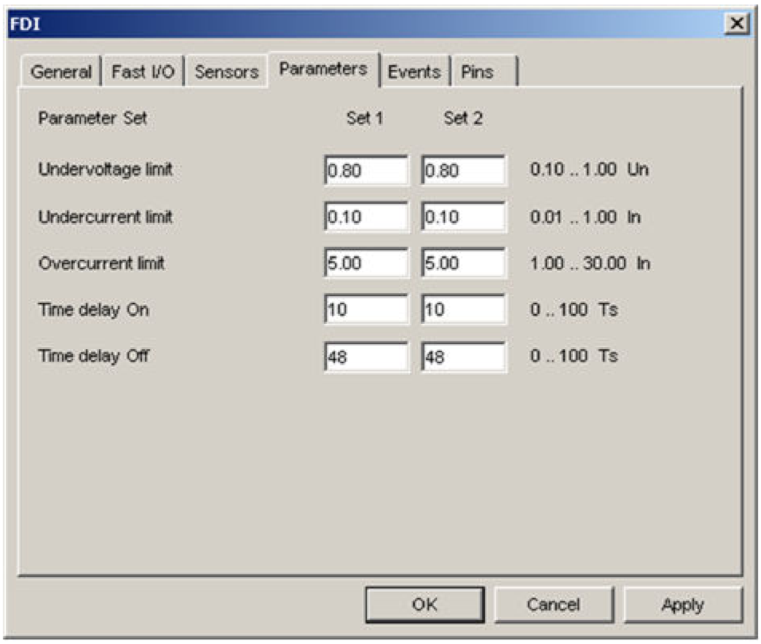


Figure 384: Parameters

Undervoltage limit	Voltage threshold for blocking due to undervoltage condition
Undercurrent limit	Current threshold for releasing due to undercurrent condition
Overcurrent limit	Current threshold for blocking due to overcurrent condition
Time delay On	Switch-on time delay
Time delay Off	Drop-off time delay

The setting of the time delay is related to Ts, which is the sampling period corresponding to sampling frequency of 4.8 KHz (Ts = 208.3 µsec).

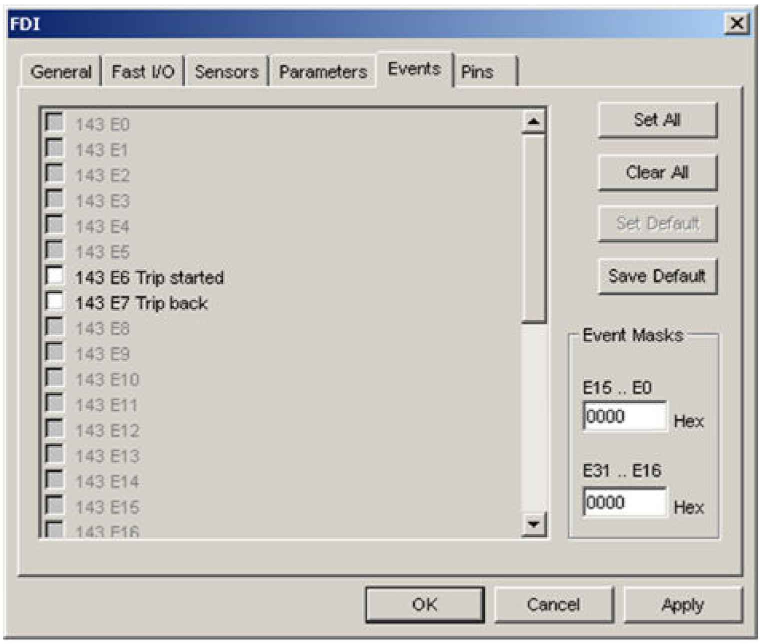


Figure 385: Events

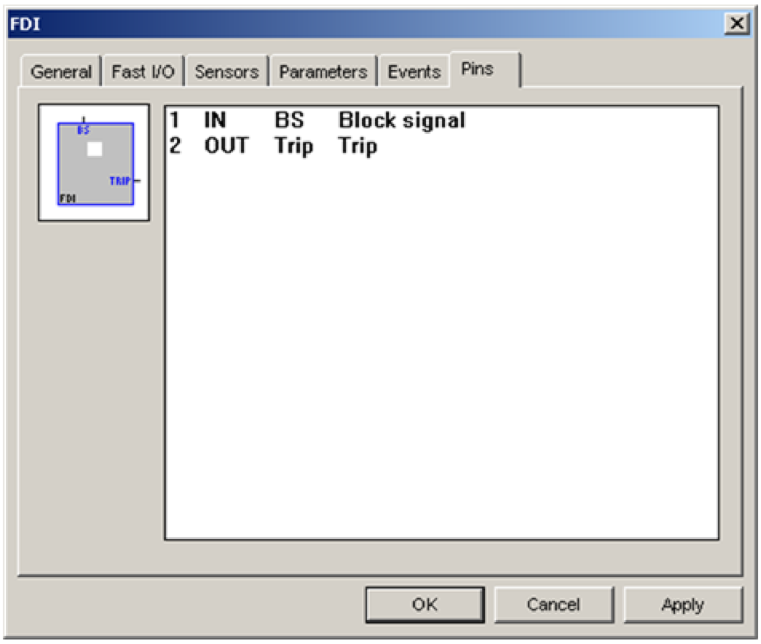


Figure 386: Pins

5.10.1.3 Measurement mode

FDI combines the voltages and current samples using an advanced algorithm to be able to detect a power direction change as fast as possible.

5.10.1.4 Operation criteria

FDI continuously calculates the power in each phase. To ensure that the calculation of the power is performed with relevant and valid voltage signals the phase voltages are continuously supervised. If the phase-voltage value drops below the setting value of the undervoltage limit, the power calculation the voltage values of the previous period is used.

5.10.1.5 Setting groups

Two parameter sets can be configured for FDI. Switch-over between the parameter sets can be performed in dependency of the network configuration. If this is not required, set 1 and set 2 can be parameterized identically to avoid wrong setting if switch-over of parameters has happened accidentally.

5.10.1.6 Parameters and events

Table 180: Setting values

Parameter	Values	Unit	Default	Explanation
Undervoltage limit	0.20...1.00	Un	0.80	Voltage threshold for blocking due to undervoltage condition
Undercurrent limit	1.00...2.00	Un	1.20	Voltage threshold for blocking due to undercurrent condition
Overcurrent limit	0.20...5.00	In	2.00	Current threshold for blocking due to overcurrent condition
Time delay On	0...100	Ts[1)]	3	Switch on time delay for trip conditioning
Time delay Off	0...1000	Ts[1)]	240	Drop off time delay for trip conditioning

1) Ts = 208 μs (in accordance with the sampling frequency of 4.8 kHz)

Table 181: Events

Code	Event reason
E6	Trip signal is active
E7	Trip signal is back to inactive
E18	Protection block is active
E19	Protection block is back to inactive

By default all events are disabled.

5.10.2 Voltage supervision

Voltage supervision (VS) continuously supervises the phase currents and the related phase voltages. A voltage drop with simultaneously high current flow coming from the feeder is detected as an electrical system fault on the busbar.

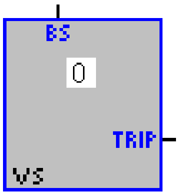


Figure 387: Voltage supervision

5.10.2.1 Input/output description

Table 182: Input

Name	Type	Description
BS	Digital signal (active high)	Blocking signal

When the BS signal becomes active, the protection function is reset no matter its state. This means that all the output pins go low generating the required events, if any, and all internal registers and timers are cleared. The protection function remains in idle state until the BS signal goes low.

Table 183: Output

Name	Type	Description
Trip	Digital signal (active high)	Trip signal

The TRIP signal is activated when a drop down of the system voltage fault is detected and the operating time (*Time Delay On*) has elapsed.

5.10.2.2 Configuration

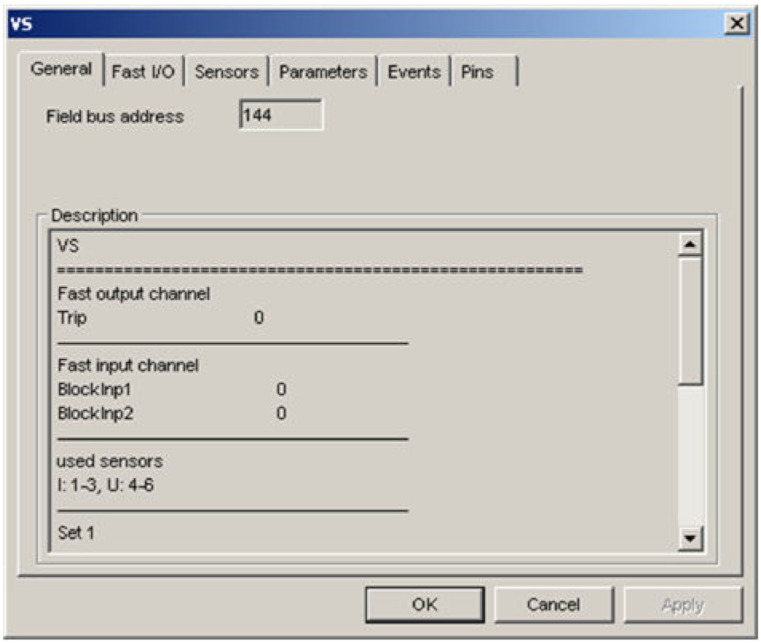


Figure 388: General

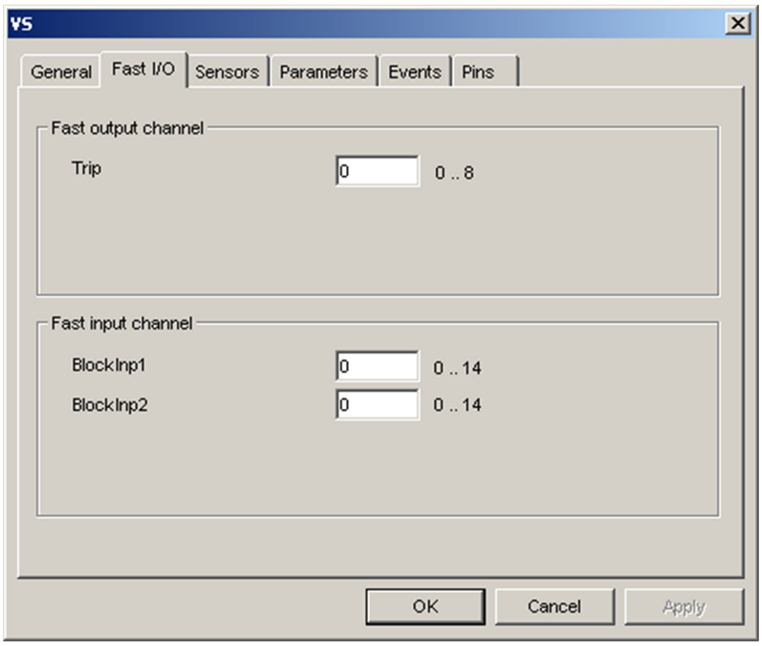


Figure 389: Fast I/O

Output Channel different from 0 means a direct execution of the trip command, that is, skipping the FUPLA cyclic evaluation.

Input Channel different from 0 means a direct execution of the block command, that is, skipping the FUPLA cyclic evaluation.

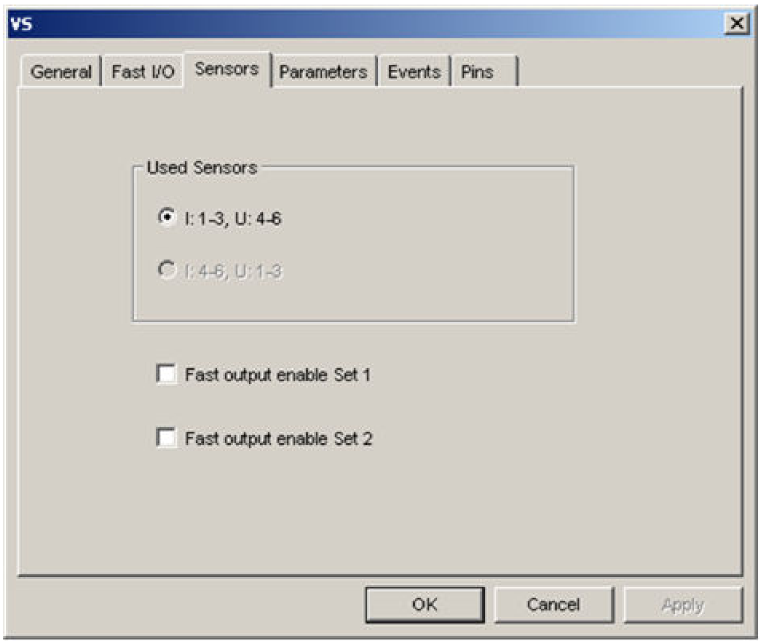


Figure 390: Sensor

I: 1-3, U: 4-6	Analog inputs 1 to 3 are current inputs and 4 to 6 voltage inputs
I: 4-6, U: 1-3	Analog inputs 4 to 6 are current inputs and 1 to 3 voltage inputs

VS operates according to one of the mentioned current and voltage combinations. The valid parameter set must be selected in the Parameters tab.

The fast optical output can be activated by checking the parameter for the corresponding group of the parameter set.

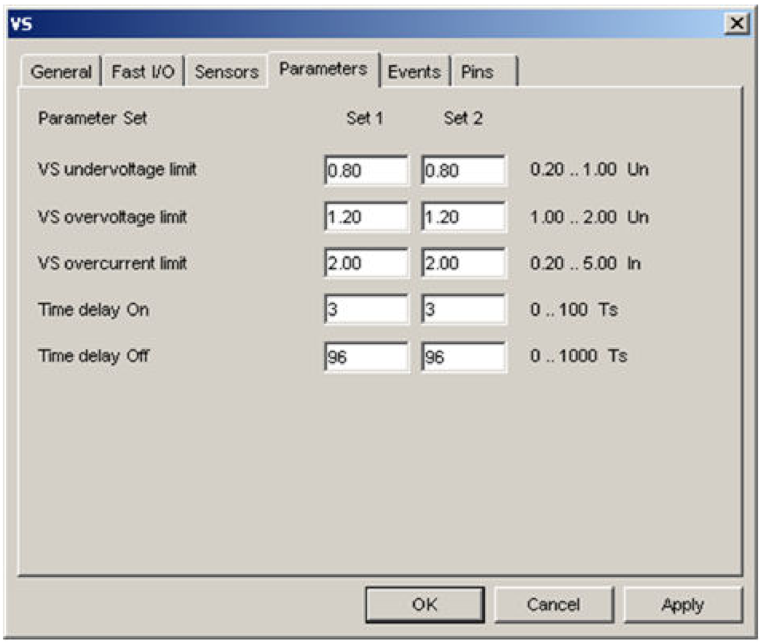


Figure 391: Parameters

VS undervoltage limit	Voltage threshold for blocking due to undervoltage condition
VS overvoltage limit	Voltage threshold for blocking due to overvoltage condition
VS overcurrent limit	Current threshold for blocking due to overvoltage condition
Time delay On	Switch-on time delay
Time delay Off	Drop-off time delay

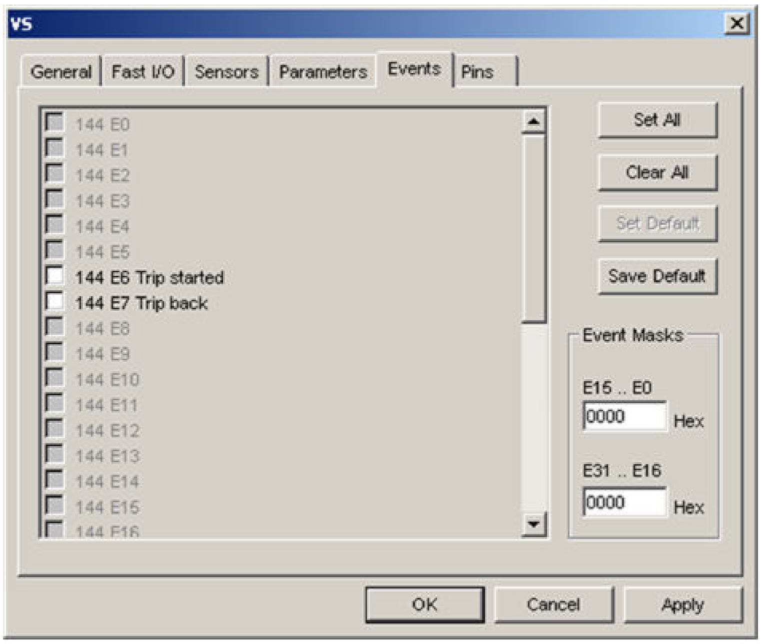


Figure 392: Events

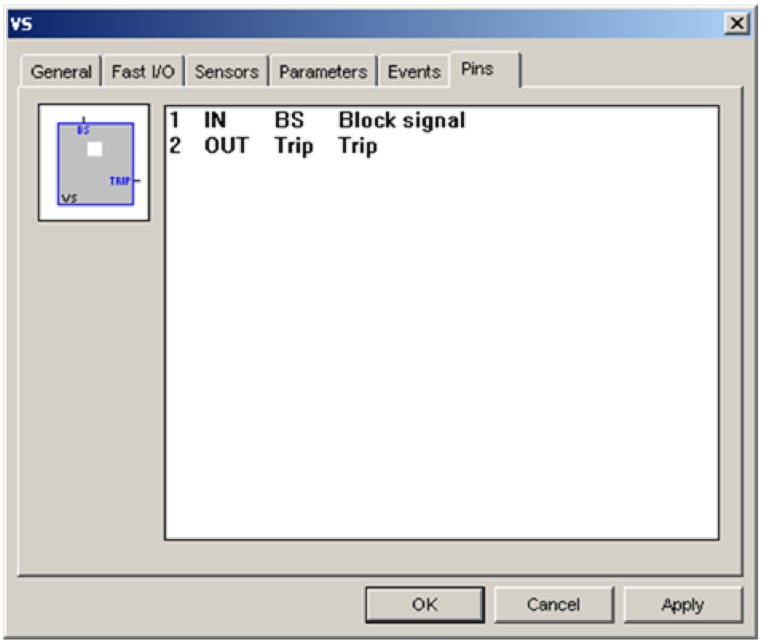


Figure 393: Pins

5.10.2.3 Measurement mode

VS evaluates the RMS value of the phase voltages and the RMS values of the corresponding phase currents.

5.10.2.4 Operation criteria

The phase voltages and the related phase currents are continuously monitored. VS generates a TRIP if one of the three phase modules has detected a fault condition and at the same time no internal blocking has been detected. VS will be internally blocked if one of the measured phase voltage drops below the setting of the VS undervoltage limit or exceeds the setting of the VS overvoltage limit and at the same time the related phase current exceeds the setting of the VS overcurrent limit. The trip signal can additionally be delayed by *Time Delay On*. It disappearing can be defined by *Time Delay Off*.

5.10.2.5 Setting groups

Two parameter sets can be configured for the Voltage supervision function. Switch-over between the parameter sets can be performed in dependency of the network configuration. If this is not required, set 1 and set 2 can be parameterized identically to avoid wrong setting if switch-over of parameters has happened accidentally.

5.10.2.6 Parameters and events

Table 184: Setting values

Parameter	Values	Unit	Default	Explanation
VS undervoltage limit	0.20...1.00	Un	0.80	Voltage threshold for blocking due to undervoltage condition
VS overvoltage limit	1.00...2.00	Un	1.20	Voltage threshold for blocking due to overvoltage condition
VS overcurrent limit	0.20...5.00	In	2.00	Current threshold for blocking due to overcurrent condition
Time delay On	0...100	Ts1)	3	Switch-on time delay for the trip conditioning
Time delay Off	0...1000	Ts1)	240	Drop-off time delay for the trip conditioning

1) Ts = 208 μs (in accordance with the sampling frequency of 4.8 kHz)

Table 185: Events

Code	Event reason
E6	Trip signal is active
E7	Trip signal is back to inactive
E18	Protection block is active
E19	Protection block is back to inactive

By default all events are disabled.

Section 6 Glossary

AR	Autoreclosing
BI	Binary input
CB	Circuit breaker
CT	Current transformer
DFT	Discrete Fourier transform
DT	Definite time
EMC	Electromagnetic compatibility
FUPLA	1. Function block programming language 2. Function chart 3. Function plan 4. Functional programming language
HMI	Human-machine interface
IDMT	Inverse definite minimum time
IEC	International Electrotechnical Commission
IRV	Input rated value
NPS	Negative phase sequence
PFC	Power factor controller
PPS	Pulse per second
PTT	Protection transfer trip scheme by comparison of the related signals
RMS	Root-mean-square (value)
ROA	Relay operating angle
RPV	Rated primary value
RSV	Rated secondary value
RTD	Resistance temperature detector
SI	Sensor input
VS	Voltage supervision
VT	Voltage transformer

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