

# Directional Earth-Fault Protection

## Low-Set Stage (DEF2Low)

## High-Set Stage (DEF2High)

## Instantaneous Stage (DEF2Inst)

Data subject to change without notice

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# 1. Introduction

## 1.1 Features

- Directional earth-fault protection based on the neutral current  $I_0$  and the residual voltage  $U_0$
- Four selectable criteria for directional operation
- Non-directional earth-fault protection based on the criterion for neutral current or residual voltage
- Detection of intermittent earth-faults in compensated network
- Definite-time (DT) operation
- DEF2Low: four internationally standardized inverse-time (IDMT) characteristics
- Neutral current measurement with a core-balance current transformer or residual connection
- Residual voltage measurement with open-delta connected voltage transformers
- Virtual residual voltage and virtual neutral current measurement channels can be used instead of the corresponding analogue measurement channels
- Two alternative measuring principles: the average value of consecutive instantaneous peak-to-peak values or the numerically calculated fundamental frequency component of the earth-fault current and the residual voltage
- Delayed trip output for the circuit-breaker failure protection (CBFP) function

## 1.2 Application

This document specifies the functions of the directional earth-fault protection function blocks DEF2Low, DEF2High and DEF2Inst used products based on the RED 500 Platform. The inverse-time operation is only included in the low-set stage (DEF2Low).

The directional earth-fault protection function blocks are designed to be used for directional or non-directional earth-fault protection whenever the DT characteristic or, as concerns DEF2Low, the IDMT (Inverse Definite Minimum Time) characteristic is appropriate. Suppression of harmonics is possible.

Table 1 . Protection diagram symbols used in the relay terminal

ABB	IEC	ANSI
DEF2Low	Io>-->	67N
DEF2High	Io>>-->	67N
DEF2Inst	Io>>>-->	67N

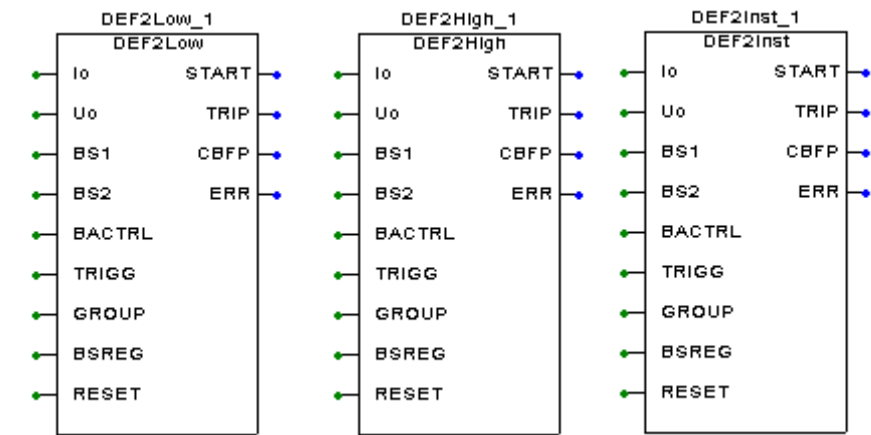


Figure 1.2.-1 Function block symbols of DEF2Low, DEF2High and DEF2Inst

## 1.3

## Input description

Name	Type	Description
Io	Analogue signal (SINT)	Input for measuring neutral current $I_o$
Uo	Analogue signal (SINT)	Input for measuring residual voltage $U_o$
BS1	Digital signal (BOOL, active high)	Blocking signal 1
BS2	Digital signal (BOOL, active high)	Blocking signal 2
BACTRL	Digital signal (BOOL, active high)	Input for changing the basic angle or switching between the cos and sin characteristics (Basic Angle Control)
TRIGG	Digital signal (BOOL, pos. edge)	Control signal for triggering the registers
GROUP	Digital signal (BOOL, active high)	Control input for switching between the setting groups 1 and 2. When GROUP is FALSE, group 1 is active. When GROUP is TRUE, group 2 is active.
BSREG	Digital signal (BOOL, active high)	Input for blocking the recording function
RESET	Reset signal (BOOL, pos. edge)	Input signal for resetting the trip signal and registers of DEF2Low, DEF2High or DEF2Inst

## 1.4

## Output description

Name	Type	Description
START	Digital signal (BOOL, active high)	Start signal
TRIP	Digital signal (BOOL, active high)	Trip signal
CBFP	Digital signal (BOOL, active high)	Delayed trip signal for circuit-breaker failure protection (CBFP)
ERR	Digital signal (BOOL, active high)	Signal for indicating a configuration error

## 2. Description of operation

### 2.1 Configuration

Neutral current  $I_o$  can be measured with a core balance current transformer, residual connection or by digital addition of phase current signals. If the neutral of the network is either isolated or earthed by a high impedance, a core balance current transformer is recommended to be used in earth fault protection. To ensure sufficient accuracy of zero sequence current measurements and consequently the selectivity of the scheme, core balance current transformers should have a transformation ratio of at least 70:1. Lower transformation ratios like 50:1 or 50:5 are not recommended.

The measuring devices and signal types for analogue channels are specified and configured in a special dialogue box of the Relay Configuration Tool included in the CAP 505 Tool Box. Digital inputs are configured in the same programming environment (the number of selectable analogue inputs, digital inputs and digital outputs depends on the type of the hardware used).

Note! When the function block DEF2\_ is used, the intermittent earth-fault protection must be selected for the channel connected to the  $I_o$  input of the function block from the special measurements dialogue box of the configuration tool, regardless of whether the intermittent operation itself is used or not. For more information about the intermittent earth-fault protection, refer to section 2.3.3 Intermittent operation using EFSIGN.

When the analogue channels and digital inputs have been selected and configured in the dialogue box, the inputs and outputs of the function block can be configured on a graphic worksheet of the configuration tool. The neutral current  $I_o$  is connected to the  $I_o$  input of the function block and in the same way, the residual voltage  $U_o$  is connected to the  $U_o$  input. Furthermore, the digital inputs are connected to the Boolean inputs of the function block and the outputs of the function block are connected to the output signals.

### 2.2 Measuring mode

The function block operates on two alternative measuring principles: the average value of consecutive instantaneous peak-to-peak values or the numerically calculated fundamental frequency component of the earth-fault current and the residual voltage. The measuring mode is selected by means of an HMI parameter or a serial communication parameter.

With both the measuring principles, the operation is insensitive to the DC component and the operation accuracy is defined in the frequency range  $f/f_n=0.95...1.05$ . In peak-to-peak measurement, the harmonics of the neutral current and the residual voltage are not suppressed, whereas in fundamental frequency measurement the harmonics suppression is at least -50 dB at  $f = n \times f_n$ , where  $n = 2, 3, 4, 5, \dots$

## 2.3

## Operation criteria

When the function block starts, the START signal is set to TRUE. Should the duration of the earth-fault exceed the set definite operate time or, at the inverse-time operation, the time determined by the level of the measured neutral current, the function block operates. The delay of the heavy-duty output relay is included in the total operate time. When the function block operates, the TRIP signal is set to TRUE.

The DT or IDMT timer is allowed to run only if the blocking signal BS1 is inactive, i.e. its value is FALSE. When the signal becomes active, i.e. its value turns to TRUE, the timer will be stopped (frozen).

When the blocking signal BS2 is active, the TRIP signal cannot be activated. The TRIP signal can be blocked by activating the signal BS2 until the function block drops off. Whenever the TRIP signal has been activated, the minimum pulse width is defined via the parameter "Trip pulse".

The following table presents the functions available in DEF2Low:

Oper. criteria	DT	IDMT	$\phi_b$	$I_0 \sin(\phi)$	$I_0 \cos(\phi)$	$I_0$	$U_0$	EFSIGN*)
BasicAng & Uo (1)	x		x			x	x	x
BasicAng & Uo (2)	x		x			x	x	
BasicAng & Uo (3)		x	x			x	x	
BasicAng (1)	x		x			x		x
BasicAng (2)	x		x			x		
BasicAng (3)		x	x			x		
IoCos & Uo (1)	x				x	x	x	x
IoCos & Uo (2)	x				x		x	
IoCos & Uo (3)		x			x		x	
IoSin & Uo (1)	x			x			x	
IoSin & Uo (2)		x		x			x	
IoCos (1)	x				x	x		x
IoCos (2)	x				x			
IoCos (3)		x			x			
IoSin (1)	x			x				
IoSin (2)		x		x				
Non-dir. Io (1)	x					x		
Non-dir. Io (2)		x				x		
Non-dir. Uo	x						x	

\*) Intermittent earth-fault protection is only available for a compensated network.

The following table presents the functions available in DEF2High and DEF2Inst:

Oper. criteria	DT	$\varphi_b$	$I_0 \sin(\varphi)$	$I_0 \cos(\varphi)$	$I_0$	$U_0$	EFSIGN*)
BasicAng & U <sub>0</sub> (1)	x	x			x	x	x
BasicAng & U <sub>0</sub> (2)	x	x			x	x	
BasicAng (1)	x	x			x		x
BasicAng (2)	x	x			x		
IoCos & U <sub>0</sub> (1)	x			x	x	x	x
IoCos & U <sub>0</sub> (2)	x			x		x	
IoSin & U <sub>0</sub>	x		x			x	
IoCos (1)	x			x	x		x
IoCos (2)	x			x			
IoSin	x		x				
Non-dir. Io	x				x		
Non-dir. U <sub>0</sub>	x					x	

\*) Intermittent earth-fault protection is only available for a compensated network.

At the directional operation the calculation of the angle  $\varphi$ , i.e. the phase angle between residual voltage and neutral current, will start when the neutral current exceeds the value  $0.6\% I_n$  and the residual voltage the value  $0.6\% U_n$ .

- Case 1: Oper. criteria = BasicAng & U<sub>0</sub>

The directional function based on the basic angle and the residual voltage criterion starts if the following three criteria are fulfilled at the same time:

- neutral current  $I_0$  exceeds the set start current
- residual voltage  $U_0$  exceeds the set start voltage
- phase angle  $\varphi$  between the residual voltage and the neutral current is within the operating range  $\varphi_b \pm \Delta\varphi$ , where  $\varphi_b$  denotes the adjustable basic angle and  $\Delta\varphi$  the adjustable operation sector or, if the intermittent earth-fault protection is used (1), a sufficient amount of current peaks is detected during a specified time.

- Case 2: Oper. criteria = BasicAng

The directional function based on the basic angle starts if the following two criteria are fulfilled at the same time:

- neutral current  $I_0$  exceeds the set start current
- phase angle  $\varphi$  between the residual voltage and the neutral current is within the operating range  $\varphi_b \pm \Delta\varphi$  or, if the intermittent earth-fault protection is used (1), a sufficient amount of current peaks is detected during a specified time.

- Case 3: Oper. criteria =  $I_0\sin(\varphi)$  /  $\cos$  &  $U_0$

The directional function based on the  $I_0\sin(\varphi)$  or  $I_0\cos(\varphi)$  characteristic and the residual voltage criterion starts if the following two criteria are fulfilled at the same time:

- the neutral current  $I_0\sin(\varphi)$  or  $I_0\cos(\varphi)$  exceeds the set start current or, if the intermittent earth-fault protection is used ( $I_0\cos(1)$ ), a sufficient amount of current peaks is detected during a specified time and the neutral current exceeds the set start current
- residual voltage  $U_0$  exceeds the set start voltage

- Case 4: Oper. criteria =  $I_0\sin(\varphi)$  /  $\cos$

The directional function based on the  $I_0\sin(\varphi)$  or  $I_0\cos(\varphi)$  characteristic starts if the neutral current  $I_0\sin(\varphi)$  or  $I_0\cos(\varphi)$  exceeds the set start current or, if the intermittent earth-fault protection is used ( $I_0\cos(1)$ ), a sufficient amount of current peaks is detected during a specified time and the neutral current exceeds the set start current.

- Case 5: Oper. criteria = Non-dir.  $I_0$

The non-directional function based on neutral current starts if the neutral current exceeds the set start current.

- Case 6: Oper. criteria = Non-dir.  $U_0$

The non-directional function based on residual voltage starts if the residual voltage exceeds the set start voltage.

### 2.3.1

#### Basic angle criterion

The basic angle of the directional operation depends on the earthing principle of the network so that in an isolated network  $\varphi_b = -90^\circ$  and in a compensated network  $\varphi_b = 0^\circ$ . The basic angle  $\varphi_b$  can be set to be  $-90^\circ \dots 0^\circ$  in steps of 1 degree.

In addition, the basic angle can be changed via the control signal BACTRL, in which case the alternatives are  $-90^\circ$  and  $0^\circ$ . The operation of BACTRL depends on the parameter "Basic angle" as shown in the following table:

Basic angle =	BACTRL = 0	BACTRL = 1
$-90^\circ$	$\varphi_b = -90^\circ$	$\varphi_b = 0^\circ$
$0^\circ$	$\varphi_b = 0^\circ$	$\varphi_b = -90^\circ$

BACTRL = 0 means that the input BACTRL is inactive (FALSE) and BACTRL = 1 means that the input BACTRL is active (TRUE).

The operating sector  $\Delta\varphi$  can be set to  $\pm 80^\circ$  or  $\pm 88^\circ$ . The operating characteristic depends on the values selected for the operate sector  $\Delta\varphi$  and the basic angle  $\varphi_b$ . The "corners" of the operating characteristics are "rounded" to provide better tolerance of CT errors.



Operation criteria for directional operation when  $\Delta\varphi = \pm 80^\circ$ :

- Criterion for phase angle:  $-80^\circ < \varphi - \varphi_b < 80^\circ$
- Criterion for residual voltage if selected:  $U_0 > \text{start voltage}$
- Criterion for neutral current (operating characteristic, see Fig. 2.3.1.-3):
  - when  $-70^\circ \leq \varphi - \varphi_b \leq 70^\circ$ ,  $I_0 > \text{max (start current, 1.0\%)}$
  - when  $-80^\circ \leq \varphi - \varphi_b < -70^\circ$  or  $70^\circ < \varphi - \varphi_b \leq 80^\circ$ ,  $I_0 > \text{max (start current, 3.0\%)}$

Operation criteria for directional operation when  $\Delta\varphi = \pm 88^\circ$ :

- Criterion for phase angle:  $-88^\circ < \varphi - \varphi_b < 88^\circ$
- Criterion for residual voltage if selected:  $U_0 > \text{start voltage}$
- Criterion for neutral current (operating characteristic, see Fig. 2.3.1.-4):
  - when  $-73^\circ \leq \varphi - \varphi_b \leq 73^\circ$ ,  $I_0 > \text{max (start current, 1.0\%)}$
  - when  $-85^\circ \leq \varphi - \varphi_b < -73^\circ$ ,  $I_0 > \text{max (start current, } I_{01})$ ,  
where  $I_{01} = (-1.58333\%/^\circ) \times (\varphi - \varphi_b) - 114.58333\%$
  - when  $-88^\circ < \varphi - \varphi_b < -85^\circ$ ,  $I_0 > \text{max (start current, } I_{02})$ ,  
where  $I_{02} = (-26.66667\%/^\circ) \times (\varphi - \varphi_b) - 2246.66667\%$
  - when  $73^\circ < \varphi - \varphi_b \leq 85^\circ$ ,  $I_0 > \text{max (start current, } I_{03})$ ,  
where  $I_{03} = (1.58333\%/^\circ) \times (\varphi - \varphi_b) - 114.58333\%$
  - when  $85^\circ < \varphi - \varphi_b < 88^\circ$ ,  $I_0 > \text{max (start current, } I_{04})$ ,  
where  $I_{04} = (26.66667\%/^\circ) \times (\varphi - \varphi_b) - 2246.66667\%$

The operating direction “Forward” or “Reverse” can be selected via the parameter “Oper. direction”. The default configuration direction is “forward”, i.e. the power flow direction is away from the busbar, when the voltage and current transformer connections are as drawn in the figure below. The function block will operate on fault currents flowing in the set direction only.

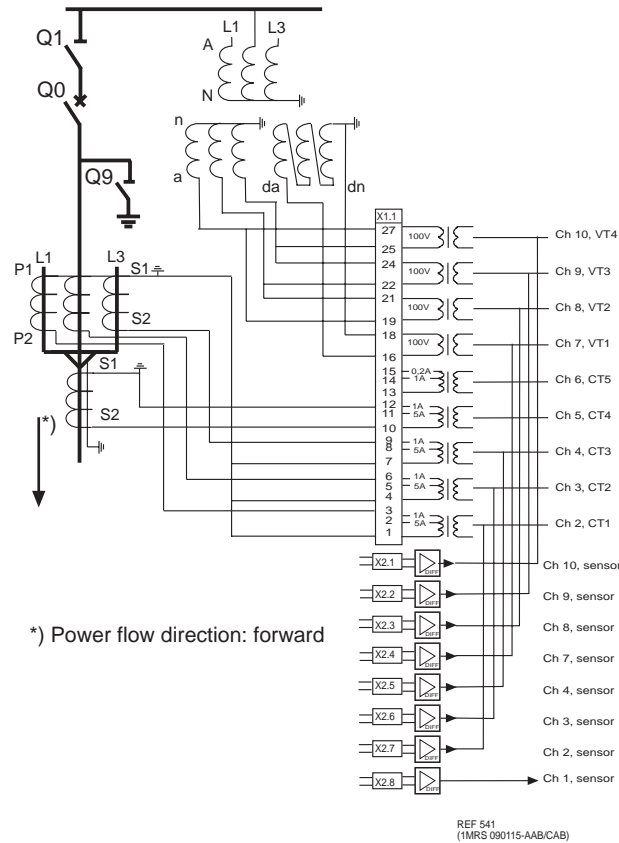


Figure 2.3.1.-1 Voltage and transformer connections of REF 541

When the reverse direction has been selected, the basic angle  $\varphi_b = \text{Basic angle} + 180^\circ$  (calculated internally) and the operating characteristics are the same as those illustrated in Figures 2.3.1.-2 and 2.3.1.-3 but rotated by  $180^\circ$ . The operation equations for DSP processing are exactly the same as above.

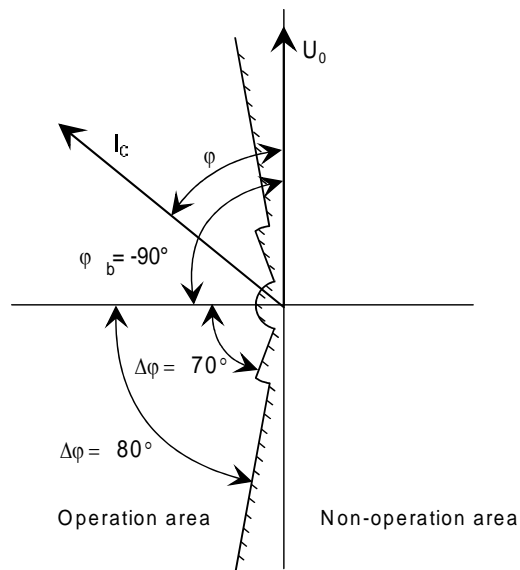


Figure 2.3.1.-2 Operating characteristic when the basic angle  $\varphi_b = -90^\circ$ ,  $\Delta\varphi = 80^\circ$  and start current  $= 1.0\% I_n$

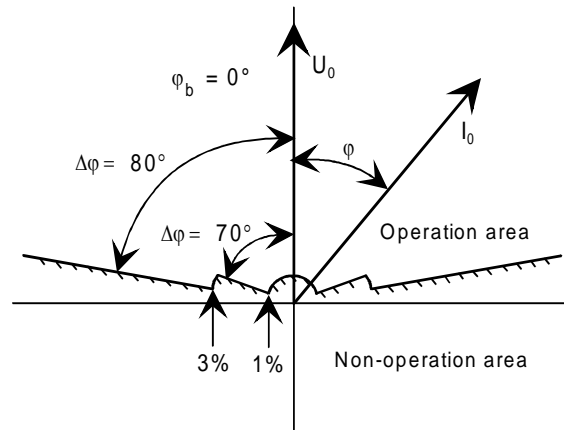


Figure 2.3.1.-3 Operating characteristic when the basic angle  $\varphi_b = 0^\circ$ ,  $\Delta\varphi = 80^\circ$  and start current =  $1.0\% I_n$

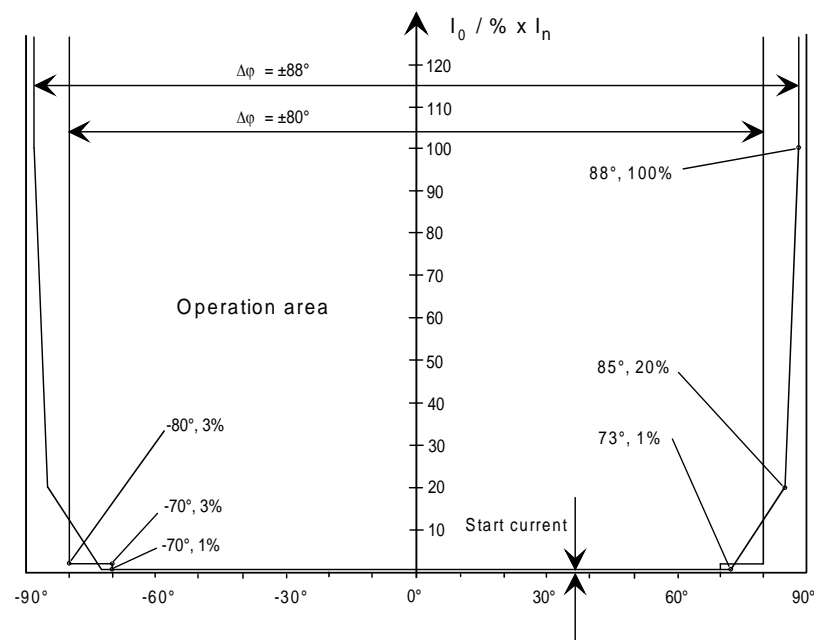


Figure 2.3.1.-4 Operating characteristic illustrated in an  $I_0 - \varphi$  diagram when the basic angle  $\varphi_b = 0^\circ$  and start current =  $1.0\% \times I_n$

## 2.3.2

### $I_0 \cos(\varphi)$ and $I_0 \sin(\varphi)$ characteristics

The operating characteristic of the directional operation depends on the earthing principle of the network so that the  $\sin(\varphi)$  characteristic should be used in an isolated network, whereas the  $\cos(\varphi)$  characteristic should be used in a compensated network. The operating characteristic is selected via the parameter “Oper. charact.”.

In addition, the operating characteristic can be changed via the control signal BACTRL. The operation of BACTRL depends on the parameter “Oper. charact.” as follows:

Oper. charact. =	BACTRL = 0	BACTRL = 1
$I_0 \sin(\varphi)$	$\sin(\varphi)$ char.	$\cos(\varphi)$ char.
$I_0 \cos(\varphi)$	$\cos(\varphi)$ char.	$\sin(\varphi)$ char.

The setting range of the correction factor “AngleCorr” is  $0^\circ \dots 10^\circ$  (see Figures 2.3.2.-1 and 2.3.2.-2). The operating direction “Forward” or “Reverse” can be selected via the parameter “Oper. direction”. When the reverse direction has been selected, the operating characteristics are the same as those illustrated in Figures 2.3.2.-1 and 2.3.2.-2 but rotated by  $180^\circ$ .

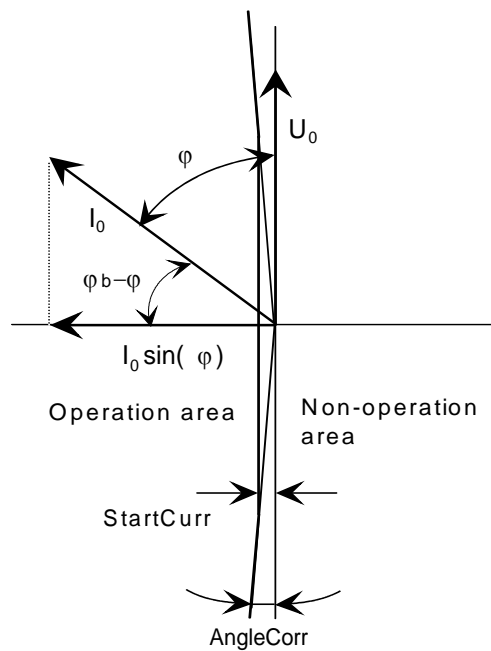


Figure 2.3.2.-1 Operating characteristic  $I_0 \sin(\varphi)$

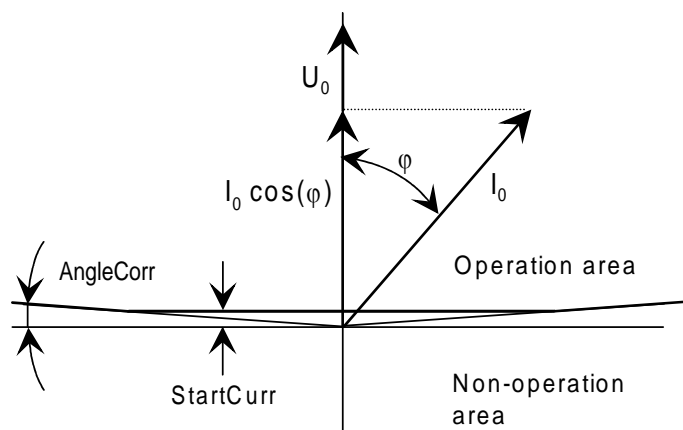


Figure 2.3.2.-2 Operating characteristic  $I_0 \cos(\varphi)$

### 2.3.3

### Intermittent operation using EFSIGN

Intermittent earth fault is a special type of fault that is encountered especially in compensated networks with underground cables. It can be characterized as a series of cable insulation breakdowns because of reduced voltage withstand of it. The fault is initiated as the phase-to-earth voltage exceeds the reduced insulation level of the fault point and extinguishes mostly itself as soon as the fault current crosses zero for the first time.

The intermittent earth-fault can in most cases be detected by means of the current peak detector function. The peak detector triggers when the momentary peak value of the neutral current exceeds the fundamental amplitude of the neutral current by at least three times and also exceeds twice the start current setting. Also the momentary voltage must exceed by 2 % in order to make the directional decision. After the detection, directional decision is carried out with the EFSIGN function.

EFSIGN, which is the result of the multiplication of momentary values  $U_0(k) \times I_0(k)$  (see Figure 2.3.3.-1), increments or decrements a cumulative counter of strikes. If two strikes are counted in forward direction, intermittent earth-fault is detected. The intermittent earth-fault can start the protection if the voltage amplitude exceeds its setting, even if the phase angle between the neutral current and the residual voltage is not within the operation area of the characteristic used. The intermittent earth-fault protection can only be used in a compensated network and with the definite-time (DT) operation. It is recommended that the fundamental frequency measurement mode with the intermittent protection is used.

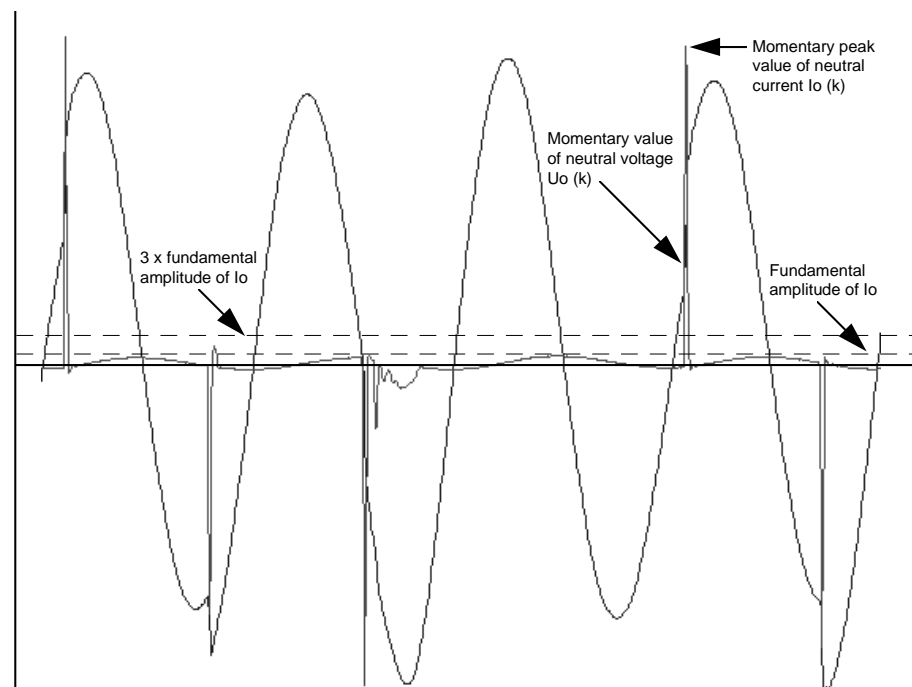


Figure 2.3.3.-1 Intermittent earth-fault in the protected area

After the fault current has self-extinguished, the phase-to-earth voltage of the faulty phase starts to recover and the residual voltage to decay until the next fault initiation occurs. The time between strikes depends on the network parameters and remaining voltage withstand at the fault point. This time can be relatively long, up to several hundred milliseconds. Thus the drop-off time setting must be high enough to prevent the starter to reset between the strikes. The operate time and drop-off time settings shall be coordinated together. It is recommended that the drop-off time setting is not higher than 70 % of the operate time setting. Another factor is the operate time of the residual overvoltage backup protection. There has to be enough clearance between operate times of DEF and ROV, since the operate time accuracy of intermittent protection is largely dependent on the time between strikes. After the operate time of DEF has elapsed, at least one more strike must be detected before the protection trips. Following guidelines can be given for the settings:

$$t_d > t_s$$

$$t_d < 0.7 * t_0$$

$$t_r > t_0 + t_s$$

where

- $t_s$  = maximum estimated time between strikes
- $t_d$  = drop-off time of DEF2Low
- $t_0$  = operate time of DEF2Low
- $t_r$  = operate time of ROV backup protection

For example:

$$t_s = 300\text{ms}, t_d = 400\text{ms}, t_0 = 700\text{ms} \text{ and } t_r \geq 1.2\text{s}.$$

Due to the transient nature of the fault current, the security of directional earth-fault protection at healthy feeders is jeopardized. The phase angle difference of the healthy feeder can cross momentarily the operating sector during the fault pulse itself or right after the fault current has been interrupted due to self-extinguishing or tripping of the faulty feeder CB. If this is enough to start the protection, it may even result to a false trip depending on the selected drop-off time and operate time delay. Thus, to increase security, the operating sector shall be optimized. If the basic angle criterion is applied, it is recommended to use the narrower  $\pm 80^\circ$  sector. If  $I_0 \cos(\varphi)$  criterion is applied, the operating sector can be narrowed down by increasing the angle correction setting.

The operating direction “Forward” or “Reverse” can be selected via the parameter “Oper. direction”. When the reverse direction has been selected, the EFSIGN value is changed accordingly.

When the feeder terminal is used in intermittent earth-fault protection applications the following should be considered:

- degree of compensation
- neutral point resistor
- accuracy class and saturation point of window-type  $I_0$  current transformers
- possible parallel feeder applications

- rated value of the matching transformer input for  $I_0$  channel
- $U_0$  relay operate time in relation to feeder protection operate time
- network earth capacitance

When balance has been established between the application and the settings, relevant intermittent earth-fault protection is obtained. In most cases the feeder or machine terminal detects intermittent earth-faults. Because of the complexity of the phenomenon, situations may however occur, where the operation of the protection function might be affected. This may cause non-selective tripping.

## 2.4

### Delayed reset facility and drop-off time in DT mode

The purpose of the delayed reset function is to enable fast clearance of intermittent faults, e.g. 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 is below the set start current. Without the delayed reset function the DT timer would reset once the current drops off. In the same way, an apparent drop-off period of the secondary current of the saturated current transformer might reset the DT timer. The adjustable delayed reset function also enables closer co-ordination with electromechanical induction disc relays.

When the DT timer has started, it goes on running as normally even if the current drops off, provided the drop-off period is shorter than the set drop-off time. If the drop-off period is longer than the set drop-off time, the DT timer will reset when the drop-off time elapses (Figure 2.4.-1). In Figures 2.4.-1 and 2.4.-2 the input signal IN of the DT timer is TRUE when the neutral current is above the set start value and the directional criterion is fulfilled when in use. The input signal is FALSE when the current is below the set start value or the directional criterion is not fulfilled.

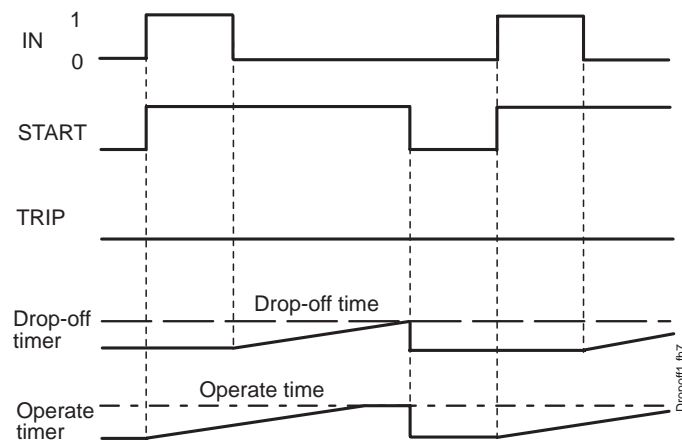


Figure 2.4.-1 The drop-off period is longer than the set drop-off time

If the drop-off period is shorter than the set drop-off time and the DT timer time has elapsed during the drop-off period, the function block will trip once the current exceeds the set start current again (Figure 2.4.-2).

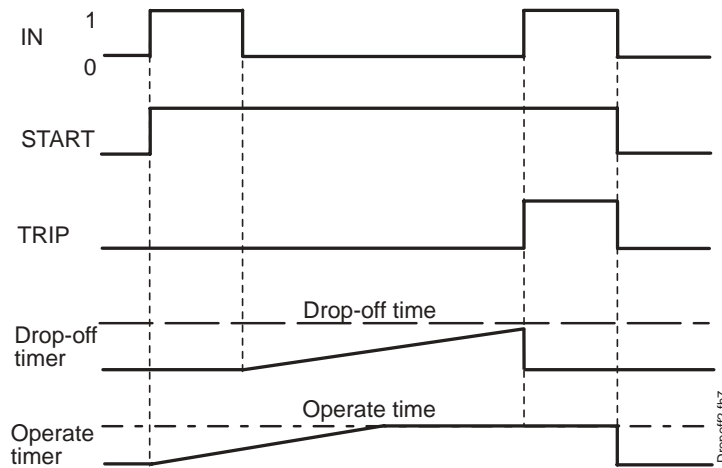


Figure 2.4.-2 The drop-off period is shorter than the set drop-off time

## 2.5

### IDMT type operation of DEF2Low

At the inverse-time mode of DEF2Low the operate time is a function of the current; the higher the current, the shorter is the operate time. Four time/current curve groups are available. The curves comply with the BS 142 and IEC 60255 standards. The desired operate time characteristic is selected with the parameter “Operation mode”. (For a graphical presentation of the curves, refer to the manual Technical Descriptions of Functions, Introduction.)

The shortest operate time at the inverse-time operation is limited by a special adjustable minimum time. The definite minimum time will not allow operate times shorter than the set minimum time, which is why the inverse-time mode is called the IDMT mode (Inverse Definite Minimum Time).

The function incorporates four internationally standardized inverse-time characteristics:

- normal inverse (NI)
- very inverse (VI)
- extremely inverse (EI)
- long-time inverse (LI)

The relationship between time and current is in accordance with the standard IEC 60255-4 and can be expressed as follows

$$t[s] = \frac{k \times \beta}{\left(\frac{I}{I_{>}}\right)^{\alpha} - 1}$$



where

- $t$  = operate time in seconds
- $k$  = adjustable time multiplier
- $I$  = neutral current (RMS value)
- $I_{>}$  = adjustable start current

The values of the constants  $a$  and  $b$  determine the slope as follows

Inverse-time characteristic	$\alpha$	$\beta$
Normal inverse	0.02	0.14
Very inverse	1.0	13.5
Extremely inverse	2.0	80.0
Long-time inverse	1.0	120

According to the standard BS 142:1966, the effective current range is defined to be 2...20 times the set start current. If the time/current characteristic is normal inverse, very inverse or extremely inverse, the function has to start at the latest when the current exceeds the set start current by 1.3 times. For the long-time inverse characteristic the effective current range is specified to be 2...7 times the set start current and the relay is to start at the latest when the current exceeds the setting value by 1.1 times. The function block DEF2Low will start and the IDMT integration will begin once the current exceeds the set start current.

Note: in order to fulfil the effective current measurement range requirement, start current setting higher than 200 %  $I_n$  shall not be used.

The operate time tolerances specified by the standard BS 142:1966 are the following (E denotes the accuracy in percent):

$I/I_{>}$	Normal	Very	Extremely	Long time
2	2.22E	2.34E	2.44E	2.34E
5	1.13E	1.26E	1.48E	1.26E
7	-	-	-	1.00E
10	1.01E	1.01E	1.02E	-
20	1.00E	1.00E	1.00E	-

The tolerance factors have to be smaller than those defined by the standard BS 142:1966 for currents 2 and 5 times the setting. The DEF2Low complies with the tolerances of class 5 (E = 5.0%) for all inverse-time curves.

For example:

$I/I_{>} = 10$ , characteristic = Normal

Operate time tolerance =  $1.01 \times 5.0\% = 5.05\%$

## 2.6 Setting groups

Two different groups of setting values, group 1 and group 2, are available for the function block. Switching between the two groups can be done in the following three ways:

- 1 Locally via the control parameter “Group selection”<sup>1)</sup> of the HMI
- 2 Over the communication bus by writing the parameter V3<sup>1)</sup>
- 3 By means of the input signal GROUP when allowed via the parameter “Group selection” (i.e. when V3 = 2<sup>1)</sup>).

<sup>1)</sup> Group selection (V3): 0 = Group 1; 1 = Group 2; 2 = GROUP input

The control parameter “Active group” indicates the setting group valid at a given time.

## 2.7 Test mode

The digital outputs of the function block can be activated with separate control parameters for each output either locally via the HMI or externally via the serial communication. When an output is activated with the test parameter, an event indicating the test is generated. The protection functions operate normally while the outputs are tested.

## 2.8 START, TRIP and CBFP outputs

The output signal START is always pulse-shaped. The minimum pulse width of the START and TRIP output signals is set via a separate parameter on the HMI or on the serial communication. If the start situation is longer than the set pulse width, the START signal remains active until the start situation is over.

The output signal TRIP may have a non-latching or latching feature. If the start situation is longer than the set pulse width and the non-latching mode has been selected, the TRIP signal remains active until the start situation is over. When the latching mode has been selected, the TRIP signal remains active until the output is reset even if the operation criteria have reset.

The circuit-breaker failure protection function provides a delayed trip signal, CBFP, after the TRIP signal unless the fault has disappeared during the set CBFP time delay. The CBFP output can be used to operate a circuit breaker in front of the circuit breaker of the feeder.

Note! The control parameter "Trip pulse" also sets the pulse width of the CBFP output signal. The CBFP signal resets when the set pulse width elapses, even if the start situation is still active. Therefore, if the CBFP function is used, a setting value of 200ms or longer for the control parameter "Trip pulse" is recommended.

## 2.9

### Resetting

The TRIP output signal and the registers can be reset either via the RESET input, or over the serial bus or the local HMI.

The operation indicators, latched trip signal and recorded data can be reset as follows:

	Operation indicators	Latched trip signal	Recorded data
RESET input of the function block <sup>1)</sup>		X	X
Parameter F040V013 for DEF1Low <sup>1)</sup>		X	X
Parameter F041V013 for DEF1High <sup>1)</sup>		X	X
Parameter F042V013 for DEF1Inst <sup>1)</sup>		X	X
General parameter F001V011 <sup>2)</sup>	X		
General parameter F001V012 <sup>2)</sup>	X	X	
General parameter F001V013 <sup>2)</sup>	X	X	X
Push-button C <sup>2)</sup>	X		
Push-buttons C + E (2 s) <sup>2)</sup>	X	X	
Push-buttons C + E (5 s) <sup>2)</sup>	X	X	X

<sup>1)</sup> Resets the latched trip signal and recorded data of the particular function block.

<sup>2)</sup> Affects all function blocks

### 3. Parameters and events

#### 3.1 General

- Each function block has a specific channel number for serial communication parameters and events. The channel for DEF2Low is 40, that for DEF2High 41 and that for DEF2Inst 42.
- The data direction of the parameters defines the use of each parameter as follows:

Data direction	Description
R, R/M	Read only
W	Write only
R/W	Read and write

- The different event mask parameters (see section “Control settings”) affect the visibility of events on the HMI or on serial communication (LON or SPA) as follows:

Event mask 1 (FxxxV101/102)	SPA / HMI (LON)
Event mask 2 (FxxxV103/104)	LON
Event mask 3 (FxxxV105/106)	LON
Event mask 4 (FxxxV107/108)	LON

For example, if only the events E3, E4 and E5 are to be seen on the HMI of the relay terminal, the event mask value 56 (8 + 16 + 32) is written to the “Event mask 1” parameter (FxxxV101).

In case a function block includes more than 32 events, there are two parameters instead of e.g. the “Event mask 1” parameter: the parameter “Event mask 1A” (FxxxV101) covers the events 0...31 and “Event mask 1B”(FxxxV102) the events 32...63.

## 3.2 Setting values

### 3.2.1 Actual settings

#### DEF2Low

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S1	0 ... 5 <sup>1)</sup>	-	1	R/M	Selection of operation mode and IDMT characteristic
Oper. criteria	S2	0 ... 5 <sup>2)</sup>	-	0	R/M	Selection of operation criteria
Oper. direction	S3	0 or 1 <sup>3)</sup>	-	0	R/M	Operation direction
Basic angle $\varphi_b$	S11	-90 ... 60	°	-90	R/M	Basic angle
Oper. charact.	S5	0 or 1 <sup>4)</sup>	-	0	R/M	Operating characteristic
Start current	S6	1.0...500.0	% In	1.0	R/M	Start current
Start voltage	S7	2.0...100.0	% Un	2.0	R/M	Start voltage
Operate time	S8	0.1...300.0	s	0.1	R/M	Operate time at DT mode
Time multiplier	S9	0.05...1.00	-	0.05	R/M	Time multiplier at IDMT mode
Intermittent E/F	S10	0 or 1 <sup>5)</sup>	-	0	R/M	Selection of intermittent earth-fault protection

<sup>1)</sup> Operation mode      0 = Not in use; 1 = Definite time; 2 = Extremely inv.; 3 = Very inv.;  
4 = Normal inv.; 5 = Long time inv.

<sup>2)</sup> Oper. criteria      0 = BasicAng & Uo; 1 = BasicAng; 2 = IoSin/Cos & Uo; 3 = IoSin/Cos;  
4 = Non-dir. Io; 5 = Non-dir. Uo

<sup>3)</sup> Oper. direction      0 = Forward; 1 = Reverse

<sup>4)</sup> Oper. charact.      0 = IoSin( $\varphi$ ); 1 = IoCos( $\varphi$ )

<sup>5)</sup> Intermittent E/F      0 = Not active; 1 = Active

## DEF2High and DEF2Inst

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S1	0 ... 2 <sup>1)</sup>	-	1	R/M	Selection of operation mode
Oper. criteria	S2	0 ... 5 <sup>2)</sup>	-	0	R/M	Selection of operation criteria
Oper. direction	S3	0 or 1 <sup>3)</sup>	-	0	R/M	Operation direction
Basic angle $\varphi_b$	S10	-90 ... 60	°	-90	R/M	Basic angle
Oper. charact.	S5	0 or 1 <sup>4)</sup>	-	0	R/M	Operating characteristic
Start current	S6	1.0...500.0	% In	1.0	R/M	Start current
Start voltage	S7	2.0...100.0	% Un	2.0	R/M	Start voltage
Operate time	S8	0.1...300.0	s	0.1	R/M	Operate time at DT mode
Intermittent E/F	S9	0 or 1 <sup>5)</sup>	-	0	R/M	Selection of intermittent earth-fault protection

<sup>1)</sup> Operation mode 0 = Not in use; 1 = Definite time; 2 = Instantaneous

<sup>2)</sup> Oper. criteria 0 = BasicAng & Uo; 1 = BasicAng; 2 = IoSin/Cos & Uo; 3 = IoSin/Cos; 4 = Non-dir. Io; 5 = Non-dir. Uo

<sup>3)</sup> Oper. direction 0 = Forward; 1 = Reverse

<sup>4)</sup> Oper. charact. 0 = IoSin( $\varphi$ ); 1 = IoCos( $\varphi$ )

<sup>5)</sup> Intermittent E/F 0 = Not active; 1 = Active

## 3.2.2

## Setting group 1

## DEF2Low

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S41	0 ... 5 <sup>1)</sup>	-	1	R/W	Selection of operation mode and IDMT characteristic
Oper. criteria	S42	0 ... 5 <sup>2)</sup>	-	0	R/W	Selection of operation criteria
Oper. direction	S43	0 or 1 <sup>3)</sup>	-	0	R/W	Operation direction
Basic angle $\varphi_b$	S51	-90 ... 60	°	-90	R/W	Basic angle
Oper. charact.	S45	0 or 1 <sup>4)</sup>	-	0	R/W	Operating characteristic
Start current	S46	1.0...500.0	% In	1.0	R/W	Start current
Start voltage	S47	2.0...100.0	% Un	2.0	R/W	Start voltage
Operate time	S48	0.1...300.0	s	0.1	R/W	Operate time at DT mode
Time multiplier	S49	0.05...1.00	-	0.05	R/W	Time multiplier at IDMT mode
Intermittent E/F	S50	0 or 1 <sup>5)</sup>	-	0	R/W	Selection of intermittent earth-fault protection

<sup>1)</sup> Operation mode 0 = Not in use; 1 = Definite time; 2 = Extremely inv.; 3 = Very inv.; 4 = Normal inv.; 5 = Long time inv.

<sup>2)</sup> Oper. criteria 0 = BasicAng & Uo; 1 = BasicAng; 2 = IoSin/Cos & Uo; 3 = IoSin/Cos; 4 = Non-dir. Io; 5 = Non-dir. Uo

<sup>3)</sup> Oper. direction 0 = Forward; 1 = Reverse

<sup>4)</sup> Oper. charact. 0 = IoSin( $\varphi$ ); 1 = IoCos( $\varphi$ )

<sup>5)</sup> Intermittent E/F 0 = Not active; 1 = Active

## DEF2High and DEF2Inst

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S41	0 ... 2 <sup>1)</sup>	-	1	R/W	Selection of operation mode
Oper. criteria	S42	0 ... 5 <sup>2)</sup>	-	0	R/W	Selection of operation criteria
Oper. direction	S43	0 or 1 <sup>3)</sup>	-	0	R/W	Operation direction
Basic angle $\varphi_b$	S50	-90 ... 60	°	-90	R/W	Basic angle
Oper. charact.	S45	0 or 1 <sup>4)</sup>	-	0	R/W	Operating characteristic
Start current	S46	1.0...500.0	% In	1.0	R/W	Start current
Start voltage	S47	2.0...100.0	% Un	2.0	R/W	Start voltage
Operate time	S48	0.1...300.0	s	0.1	R/W	Operate time at DT mode
Intermittent E/F	S49	0 or 1 <sup>5)</sup>	-	0	R/W	Selection of intermittent earth-fault protection

<sup>1)</sup> Operation mode 0 = Not in use; 1 = Definite time; 2 = Instantaneous

<sup>2)</sup> Oper. criteria 0 = BasicAng & Uo; 1 = BasicAng; 2 = IoSin/Cos & Uo; 3 = IoSin/Cos; 4 = Non-dir. Io; 5 = Non-dir. Uo

<sup>3)</sup> Oper. direction 0 = Forward; 1 = Reverse

<sup>4)</sup> Oper. charact. 0 = IoSin( $\varphi$ ); 1 = IoCos( $\varphi$ )

<sup>5)</sup> Intermittent E/F 0 = Not active; 1 = Active

## 3.2.3

## Setting group 2

## DEF2Low

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S71	0 ... 5 <sup>1)</sup>	-	1	R/W	Selection of operation mode and IDMT characteristic
Oper. criteria	S72	0 ... 5 <sup>2)</sup>	-	0	R/W	Selection of operation criteria
Oper. direction	S73	0 or 1 <sup>3)</sup>	-	0	R/W	Operation direction
Basic angle $\varphi_b$	S81	-90 ... 60	°	-90	R/W	Basic angle
Oper. charact.	S75	0 or 1 <sup>4)</sup>	-	0	R/W	Operating characteristic
Start current	S76	1.0...500.0	% In	1.0	R/W	Start current
Start voltage	S77	2.0...100.0	% Un	2.0	R/W	Start voltage
Operate time	S78	0.1...300.0	s	0.1	R/W	Operate time at DT mode
Time multiplier	S79	0.05...1.00	-	0.05	R/W	Time multiplier at IDMT mode
Intermittent E/F	S80	0 or 1 <sup>5)</sup>	-	0	R/W	Selection of intermittent earth-fault protection

<sup>1)</sup> Operation mode 0 = Not in use; 1 = Definite time; 2 = Extremely inv.; 3 = Very inv.; 4 = Normal inv.; 5 = Long time inv.

<sup>2)</sup> Oper. criteria 0 = BasicAng & Uo; 1 = BasicAng; 2 = IoSin/Cos & Uo; 3 = IoSin/Cos; 4 = Non-dir. Io; 5 = Non-dir. Uo

<sup>3)</sup> Oper. direction 0 = Forward; 1 = Reverse

<sup>4)</sup> Oper. charact. 0 = IoSin( $\varphi$ ); 1 = IoCos( $\varphi$ )

<sup>5)</sup> Intermittent E/F 0 = Not active; 1 = Active

## DEF2High and DEF2Inst

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	S71	0 ... 2 <sup>1)</sup>	-	1	R/W	Selection of operation mode
Oper. criteria	S72	0 ... 5 <sup>2)</sup>	-	0	R/W	Selection of operation criteria
Oper. direction	S73	0 or 1 <sup>3)</sup>	-	0	R/W	Operation direction
Basic angle $\varphi_b$	S80	-90 ... 60	°	-90	R/W	Basic angle
Oper. charact.	S75	0 or 1 <sup>4)</sup>	-	0	R/W	Operating characteristic
Start current	S76	1.0...500.0	% In	1.0	R/W	Start current
Start voltage	S77	2.0...100.0	% Un	2.0	R/W	Start voltage
Operate time	S78	0.1...300.0	s	0.1	R/W	Operate time at DT mode
Intermittent E/F	S79	0 or 1 <sup>5)</sup>	-	0	R/W	Selection of intermittent earth-fault protection

<sup>1)</sup> Operation mode 0 = Not in use; 1 = Definite time; 2 = Instantaneous

<sup>2)</sup> Oper. criteria 0 = BasicAng & Uo; 1 = BasicAng; 2 = IoSin/Cos & Uo; 3 = IoSin/Cos; 4 = Non-dir. Io; 5 = Non-dir. Uo

<sup>3)</sup> Oper. direction 0 = Forward; 1 = Reverse

<sup>4)</sup> Oper. charact. 0 = IoSin( $\varphi$ ); 1 = IoCos( $\varphi$ )

<sup>5)</sup> Intermittent E/F 0 = Not active; 1 = Active



## 3.2.4

## Control settings

## DEF2Low

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Measuring mode	V1	0 or 1 <sup>1)</sup>	-	1	R/W	Selection of measuring mode
Drop-off time	V2	0...1000	ms	0	R/W	Resetting time of the operate time counter
Group selection	V3	0 ... 2 <sup>2)</sup>	-	0	R/W	Selection of the active setting group
Active group	V4	0 or 1 <sup>3)</sup>	-	0	R/M	Active setting group
Start pulse	V5	0...1000	ms	0	R/W	Minimum pulse width of START signal
Trip signal	V6	0 or 1 <sup>4)</sup>	-	0	R/W	Selection of latching feature for TRIP output
Trip pulse	V7	40...1000	ms	40	R/W	Minimum pulse width of TRIP and CBFP
Minimum time	V8	0.03...10.00	s	0.03	R/W	Minimum operate time at IDMT mode
CBFP time	V9	100...1000	ms	100	R/W	Operate time of the delayed trip CBFP
Angle correction	V10	0.0...10.0	°	2.0	R/W	Angle correction factor for $\text{Iosin}(\varphi) / \text{Iocos}(\varphi)$
Oper. sector	V11	0 or 1 <sup>5)</sup>	-	0	R/W	Operation sector
Reset registers	V13	1=Reset	-	0	W	Resetting of latched trip signal and registers
Test START	V31	0 or 1 <sup>6)</sup>	-	0	R/W	Testing of START
Test TRIP	V32	0 or 1 <sup>6)</sup>	-	0	R/W	Testing of TRIP
Test CBFP	V33	0 or 1 <sup>6)</sup>	-	0	R/W	Testing of CBFP
Event mask 1	V101	0...4095	-	63	R/W	Event mask 1 for event transmission (E0 ... E11)
Event mask 2	V103	0...4095	-	63	R/W	Event mask 2 for event transmission (E0 ... E11)
Event mask 3	V105	0...4095	-	63	R/W	Event mask 3 for event transmission (E0 ... E11)
Event mask 4	V107	0...4095	-	63	R/W	Event mask 4 for event transmission (E0 ... E11)

<sup>1)</sup> Measuring mode

0 = Peak-to-peak; 1 = Fundam.freq.

<sup>2)</sup> Group selection

0 = Group 1; 1 = Group 2; 2 = GROUP input

<sup>3)</sup> Active group

0 = Group 1; 1 = Group 2

<sup>4)</sup> Trip signal

0 = Non-latching; 1 = Latching

<sup>5)</sup> Oper. sector

0 = 80°; 1 = 88°

<sup>6)</sup> Test

0 = Do not activate; 1 = Activate

## DEF2High and DEF2Inst

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Measuring mode	V1	0 or 1 <sup>1)</sup>	-	1	R/W	Selection of measuring mode
Drop-off time	V2	0...1000	ms	0	R/W	Resetting time of the operate time counter at DT mode
Group selection	V3	0 ... 2 <sup>2)</sup>	-	0	R/W	Selection of the active setting group
Active group	V4	0 or 1 <sup>3)</sup>	-	0	R/M	Active setting group
Start pulse	V5	0...1000	ms	0	R/W	Minimum pulse width of START signal
Trip signal	V6	0 or 1 <sup>4)</sup>	-	0	R/W	Selection of latching feature for TRIP output
Trip pulse	V7	40...1000	ms	40	R/W	Minimum pulse width of TRIP and CBFP
CBFP time	V8	100...1000	ms	100	R/W	Operate time of the delayed trip CBFP
Angle correction	V9	0.0...10.0	°	2.0	R/W	Angle correction factor for $\text{losin}(\varphi) / \text{locos}(\varphi)$
Oper. sector	V10	0 or 1 <sup>5)</sup>	-	0	R/W	Operation sector
Reset registers	V13	1=Reset	-	0	W	Resetting of latched trip signal and registers
Test START	V31	0 or 1 <sup>6)</sup>	-	0	R/W	Testing of START
Test TRIP	V32	0 or 1 <sup>6)</sup>	-	0	R/W	Testing of TRIP
Test CBFP	V33	0 or 1 <sup>6)</sup>	-	0	R/W	Testing of CBFP
Event mask 1	V101	0...4095	-	63	R/W	Event mask 1 for event transmission (E0 ... E11)
Event mask 2	V103	0...4095	-	63	R/W	Event mask 2 for event transmission (E0 ... E11)
Event mask 3	V105	0...4095	-	63	R/W	Event mask 3 for event transmission (E0 ... E11)
Event mask 4	V107	0...4095	-	63	R/W	Event mask 4 for event transmission (E0 ... E11)

- <sup>1)</sup> Measuring mode  
<sup>2)</sup> Group selection  
<sup>3)</sup> Active group  
<sup>4)</sup> Trip signal  
<sup>5)</sup> Oper. sector  
<sup>6)</sup> Test
- 0 = Peak-to-peak; 1 = Fundam.freq.  
0 = Group 1; 1 = Group 2; 2 = GROUP input  
0 = Group 1; 1 = Group 2  
0 = Non-latching; 1 = Latching  
0 = 80°; 1 = 88°  
0 = Do not activate; 1 = Activate

### 3.3 Measurement values

#### 3.3.1 Input data

##### DEF2Low

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Current $I_0$	I1	0.0...2000.0	% In	0.0	R/M	Neutral current $I_0$
Voltage $U_0$	I2	0.0...120.0	% Un	0.0	R/M	Residual voltage $U_0$
Phase angle $\varphi$	I3	-180...+180	°	0	R/M	Phase angle $\varphi$
Angle $\varphi_b - \varphi$	I4	-180...+180	°	0	R/M	Phase angle $\varphi_b - \varphi$
Input BS1	I5	0 or 1 <sup>1)</sup>	-	0	R/M	Block signal BS1
Input BS2	I6	0 or 1 <sup>1)</sup>	-	0	R/M	Block signal BS2
Input BACTRL	I7	0 or 1 <sup>1)</sup>	-	0	R/M	Input BACTRL
Input TRIGG	I8	0 or 1 <sup>1)</sup>	-	0	R/M	Signal for triggering the registers
Input GROUP	I9	0 or 1 <sup>1)</sup>	-	0	R/M	Signal for switching between the groups 1 and 2
Input BSREG	I10	0 or 1 <sup>1)</sup>	-	0	R/M	Signal for blocking the recording function
Input RESET	I11	0 or 1 <sup>1)</sup>	-	0	R/M	Signal for resetting the output signals and registers of DEF2Low

<sup>1)</sup> Input      0 = Not active; 1 = Active

**DEF2High and DEF2Inst**

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Current I <sub>o</sub>	I1	0.00...60.00	x I <sub>n</sub>	0.00	R/M	Neutral current I <sub>o</sub>
Voltage U <sub>o</sub>	I2	0.0...120.0	% U <sub>n</sub>	0.0	R/M	Residual voltage U <sub>o</sub>
Phase angle $\varphi$	I3	-180...+180	°	0	R/M	Phase angle $\varphi$
Angle $\varphi_b - \varphi$	I4	-180...+180	°	0	R/M	Phase angle $\varphi_b - \varphi$
Input BS1	I5	0 or 1 <sup>1)</sup>	-	0	R/M	Block signal BS1
Input BS2	I6	0 or 1 <sup>1)</sup>	-	0	R/M	Block signal BS2
Input BACTRL	I7	0 or 1 <sup>1)</sup>	-	0	R/M	Input BACTRL
Input TRIGG	I8	0 or 1 <sup>1)</sup>	-	0	R/M	Signal for triggering the registers
Input GROUP	I9	0 or 1 <sup>1)</sup>	-	0	R/M	Signal for switching between the groups 1 and 2
Input BSREG	I10	0 or 1 <sup>1)</sup>	-	0	R/M	Signal for blocking the recording function
Input RESET	I11	0 or 1 <sup>1)</sup>	-	0	R/M	Signal for resetting the output signals and registers of DEF2High or DEF2Inst

<sup>1)</sup> Input      0 = Not active; 1 = Active

**3.3.2****Output data**

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Output START	O1	0 or 1 <sup>1)</sup>	-	0	R/M	Status of start signal
Output TRIP	O2	0 or 1 <sup>1)</sup>	-	0	R/M	Status of trip signal
Output CBFP	O3	0 or 1 <sup>1)</sup>	-	0	R/M	Status of CBFP signal

<sup>1)</sup> Output      0 = Not active; 1 = Active

**3.3.3****Recorded data****3.3.3.1****General**

The information required for later fault analysis is recorded when the function block starts or trips, or when the recording function is triggered via an external triggering input.

The data of the last three events are stored in Recorded data 1...3, beginning from Recorded data 1. These registers are updated in a cyclical manner, where the values of the most recent event overwrite the oldest recorded data. If the recorded data has been reset or the relay has been restarted, the first event is again stored in Recorded data 1.

The recording function can be blocked by means of the BSREG input. For example, if an auto-reclose sequence is initiated by the trip signal of the function block, the values recorded just before Shot 1 are most reliable for later fault analysis. When the auto-reclose sequence has started, no recordings are needed at the moment of tripping. The output signal ACTIVE in AR5Func indicating AR in progress is connected to the BSREG input to prevent useless recording.

### **3.3.3.2 Date and time**

The time stamp indicates the rising edge of the START, TRIP or TRIGG signal.

### **3.3.3.3 Duration**

At the DT mode of operation the duration of the start situation is recorded as a percentage of the set operate time and, as concerns DEF2Low, at the IDMT mode of operation as a percentage of the calculated operate time.

### **3.3.3.4 Neutral current and residual voltage**

If the function block trips, the current and voltage values are updated at the moment of tripping i.e. on the rising edge of the TRIP signal. For external triggering, the current and voltage values are updated at the moment of triggering i.e. on the rising edge of the input signal TRIGG. If the function block starts but does not trip, the neutral current and residual voltage values captured one fundamental cycle (20 ms at rated frequency 50 Hz) after the beginning of the start situation are recorded. The values of the neutral current  $I_0$  and residual voltage  $U_0$  are recorded as multiples of the rated value.

### **3.3.3.5 Angle values and Intermittent E/F**

The values of Angle( $\varphi$ ), Angle( $\varphi_b - \varphi$ ) and Intermittent E/F are recorded at the moment of triggering.

### **3.3.3.6 Status data**

The status data of the input signals BS1, BS2 and BACTRL as well as the “Active group” parameter are recorded at the moment of triggering. The “Active group” parameter indicates the setting group valid for the recorded data.

## 3.3.3.7

## Priority

The priority of the recording function is the following:

- 1 Tripping
- 2 Starting
- 3 External triggering,

which means that if the function block has started, it will neglect an external triggering request.

## 3.3.3.8

## Recorded data 1

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Date	V201	YYYY-MM-DD	-	-	R/M	Recording date
Time	V202	hh:mm:ss.mss	-	-	R/M	Recording time
Duration	V203	0.0...100.0	%	0.0	R/M	Duration of start situation
Io mean	V204	0.0...2000.0	% In	0.0	R/M	Io mean value
Io peak	V205	0.0...2000.0	% In	0.0	R/M	Io peak value
Voltage Uo	V206	0.0...120.0	% Un	0.0	R/M	Residual voltage Uo
Angle $\varphi$	V207	-180...+180	°	0	R/M	Angle between Uo & Io
Angle $\varphi_b - \varphi$	V208	-180...+180	°	0	R/M	Angle between $\varphi_b$ & $\varphi$
Intermittent E/F	V209	0 or 1 <sup>3)</sup>	-	0	R/M	Status of Intermittent E/F
BS1	V210	0 or 1 <sup>1)</sup>	-	0	R/M	Status of BS1 input
BS2	V211	0 or 1 <sup>1)</sup>	-	0	R/M	Status of BS2 input
BACTRL	V212	0 or 1 <sup>1)</sup>	-	0	R/M	Status of BACTRL input
Active group	V213	0 or 1 <sup>2)</sup>	-	0	R/M	Active setting group

<sup>1)</sup> Status 0 = Not active; 1 = Active

<sup>2)</sup> Active group 0 = Group 1; 1 = Group 2

<sup>3)</sup> Intermittent E/F 0 = Not detected; 1 = Detected

## 3.3.3.9

## Recorded data 2

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Date	V301	YYYY-MM-DD	-	-	R/M	Recording date
Time	V302	hh:mm:ss.mss	-	-	R/M	Recording time
Duration	V303	0.0...100.0	%	0.0	R/M	Duration of start situation
Io mean	V304	0.0...2000.0	% In	0.0	R/M	Io mean value
Io peak	V305	0.0...2000.0	% In	0.0	R/M	Io peak value
Voltage Uo	V306	0.0...120.0	% Un	0.0	R/M	Residual voltage Uo
Angle $\varphi$	V307	-180...+180	°	0	R/M	Angle between Uo & Io
Angle $\varphi_b - \varphi$	V308	-180...+180	°	0	R/M	Angle between $\varphi_b$ & $\varphi$
Intermittent E/F	V309	0 or 1 <sup>3)</sup>	-	0	R/M	Status of Intermittent E/F
BS1	V310	0 or 1 <sup>1)</sup>	-	0	R/M	Status of BS1 input
BS2	V311	0 or 1 <sup>1)</sup>	-	0	R/M	Status of BS2 input
BACTRL	V312	0 or 1 <sup>1)</sup>	-	0	R/M	Status of BACTRL input
Active group	V313	0 or 1 <sup>2)</sup>	-	0	R/M	Active setting group

<sup>1)</sup> Status

0 = Not active; 1 = Active

<sup>2)</sup> Active group

0 = Group 1; 1 = Group 2

<sup>3)</sup> Intermittent E/F

0 = Not detected; 1 = Detected

## 3.3.3.10

## Recorded data 3

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Date	V401	YYYY-MM-DD	-	-	R/M	Recording date
Time	V402	hh:mm:ss.mss	-	-	R/M	Recording time
Duration	V403	0.0...100.0	%	0.0	R/M	Duration of start situation
Io mean	V404	0.0...2000.0	% In	0.0	R/M	Io mean value
Io peak	V405	0.0...2000.0	% In	0.0	R/M	Io peak value
Voltage Uo	V406	0.0...120.0	% Un	0.0	R/M	Residual voltage Uo
Angle $\varphi$	V407	-180...+180	°	0	R/M	Angle between Uo & Io
Angle $\varphi_b - \varphi$	V408	-180...+180	°	0	R/M	Angle between $\varphi_b$ & $\varphi$
Intermittent E/F	V409	0 or 1 <sup>3)</sup>	-	0	R/M	Status of Intermittent E/F
BS1	V410	0 or 1 <sup>1)</sup>	-	0	R/M	Status of BS1 input
BS2	V411	0 or 1 <sup>1)</sup>	-	0	R/M	Status of BS2 input
BACTRL	V412	0 or 1 <sup>1)</sup>	-	0	R/M	Status of BACTRL input
Active group	V413	0 or 1 <sup>2)</sup>	-	0	R/M	Active setting group

<sup>1)</sup> Status

0 = Not active; 1 = Active

<sup>2)</sup> Active group

0 = Group 1; 1 = Group 2

<sup>3)</sup> Intermittent E/F

0 = Not detected; 1 = Detected

## 3.3.4

## Events

Code	Weighting coefficient	Default mask	Event reason	Event state
E0	1	1	START signal from lo> →, lo>> → or lo>>> → stage	Reset
E1	2	1	START signal from lo> →, lo>> → or lo>>> → stage	Activated
E2	4	1	TRIP signal from lo> →, lo>> → or lo>>> → stage	Reset
E3	8	1	TRIP signal from lo> →, lo>> → or lo>>> → stage	Activated
E4	16	1	CBFP signal from lo> →, lo>> → or lo>>> → stage	Reset
E5	32	1	CBFP signal from lo> →, lo>> → or lo>>> → stage	Activated
E6	64	0	BS1 signal of lo> →, lo>> → or lo>>> → stage	Reset
E7	128	0	BS1 signal of lo> →, lo>> → or lo>>> → stage	Activated
E8	256	0	BS2 signal of lo> →, lo>> → or lo>>> → stage	Reset
E9	512	0	BS2 signal of lo> →, lo>> → or lo>>> → stage	Activated
E10	1024	0	Test mode of lo> →, lo>> → or lo>>> → stage	Off
E11	2048	0	Test mode of lo> →, lo>> → or lo>>> → stage	On



## 4. Technical data

<b>Operation accuracies</b>	At the frequency $f/f_n = 0.95 \dots 1.05$ :  current $\pm 2.5\%$ of set value $+0.0005 \times I_n$ . voltage $\pm 2.5\%$ of set value or $\pm 0.01 \times U_n$ . phase angle $\pm 2^\circ$
<b>Start time</b>	Injected neutral current $> 2.0 \times$ start current and residual voltage $> 2.0 \times$ start voltage:  $f/f_n = 0.95 \dots 1.05$ internal time $< 72 \text{ ms}$ total time <sup>1)</sup> $< 80 \text{ ms}$
<b>Reset time</b>	40...1000 ms (depends on the minimum output pulse width set for the TRIP output)
<b>Reset ratio</b>	Typ. 0.95 (range 0.95...0.98)
<b>Retardation time</b>	Total retardation time when the current drops below the start value <sup>2)</sup> $< 50 \text{ ms}$
<b>Operate time accuracy at definite-time mode</b>	Depends on the frequency of the current and voltage measured:  $f/f_n = 0.95 \dots 1.05$ : $\pm 2\%$ of set value or $\pm 20 \text{ ms}^{2)}$
<b>Accuracy class index E at inverse-time mode (DEF2Low)</b>	Depends on the frequency of the current and voltage measured:  $f/f_n = 0.95 \dots 1.05$ : Class index E = 5.0 or $\pm 20 \text{ ms}^{2)}$
<b>Frequency dependence of the settings and operate times (see above)</b>	Measuring mode      Suppression of harmonics  0      No suppression  1      -50 dB at $f = n \times f_n$ , where $n = 2, 3, 4, 5, \dots$
<b>Configuration data</b>	Task execution interval (Relay Configuration Tool): 10 ms at the rated frequency $f_n = 50 \text{ Hz}$

<sup>1)</sup> Includes the delay of the signal relay

<sup>2)</sup> Includes the delay of the heavy-duty output relay

Technical revision history	
Technical revision	Change
B	-
C	-
D	Basic angle setting step changed to 1 degree; extended start current and angle correction setting ranges.  Several new enhancements have been implemented to intermittent earth-fault detector.
E	Basic angle setting range changed $-90^\circ \dots 0^\circ \rightarrow -90^\circ \dots 60^\circ$