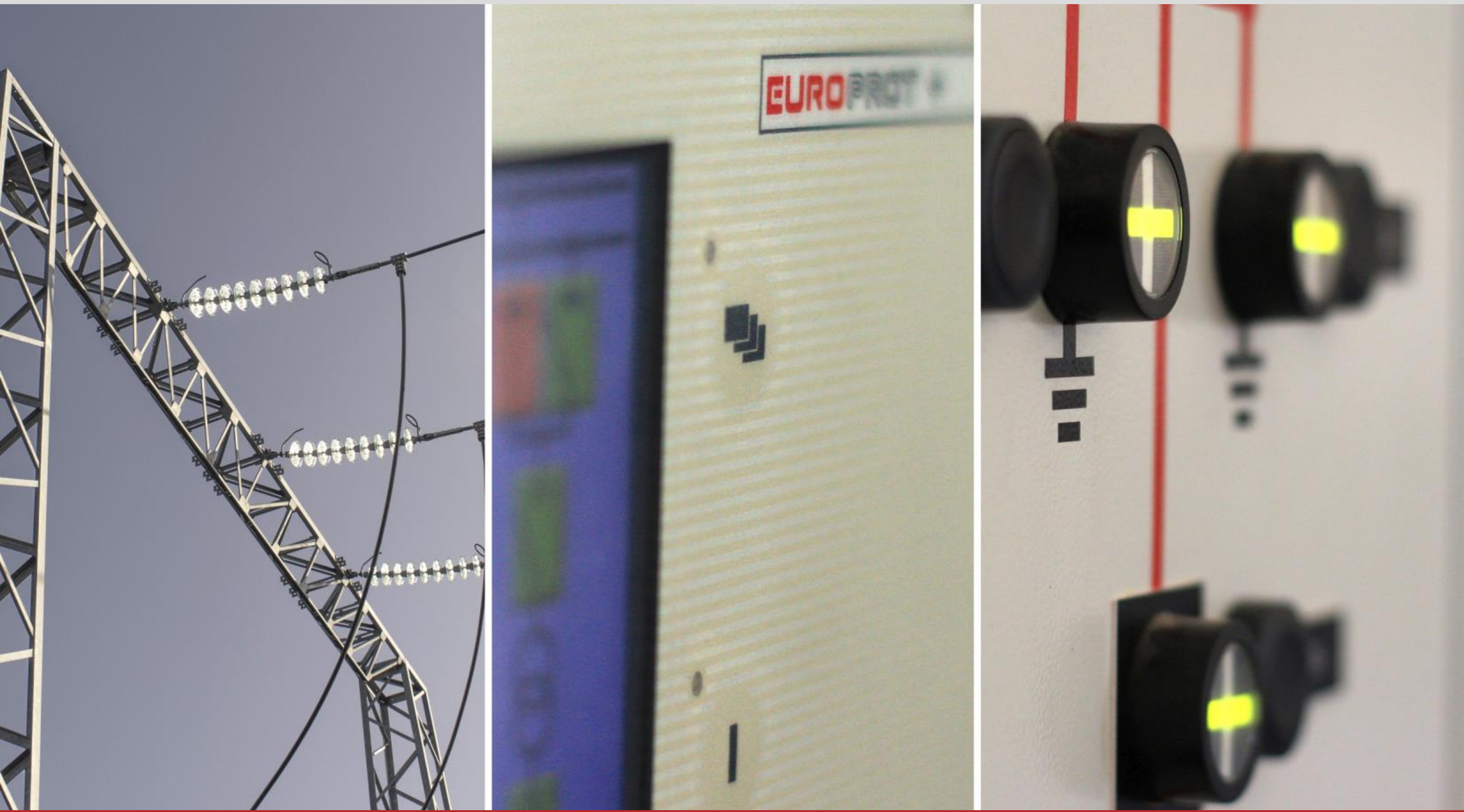

FUNCTION BLOCK DESCRIPTION

Restricted Earth-Fault protection

ANSI 87N, IEC REF

PROTECTA HUNGARY

DOCUMENT ID: PP-13-23048
VERSION: 2.0
2024-12-04, BUDAPEST

PROTECTION, AUTOMATION AND CONTROL FOR POWER INDUSTRY

VERSION INFORMATION

VERSION	DATE	MODIFICATION	COMPILED BY
Preliminary	2009-10-30	Preliminary version, without technical information	Petri
	2010-10-05	Naming revision	Csipke
1.0	2010-11-11	First edition	Petri
1.1	2016-04-26	Neut. comp parameter title change, minor corrections	Erdős
2.0	2024-12-04	**Additions and modifications** - Function block version with graphical analogue signals incorporated - CT compensation parameters updated - New format, new chapters (notes for testing)	Saina, Erdős

CONTENTS

USED SYMBOLS

Additional information

Useful information for settings.

Important part for proper usage.

1 Application

The restricted earth-fault protection function is basically a low-impedance differential protection function based on zero sequence current components. It can be applied to transformers with grounded neutral. The function compares the measured neutral current, at the star point and the calculated zero sequence current component of the phase currents and generates a trip command if the difference of these currents is above a given threshold.

1.1 Structure of the restricted earth-fault protection algorithm

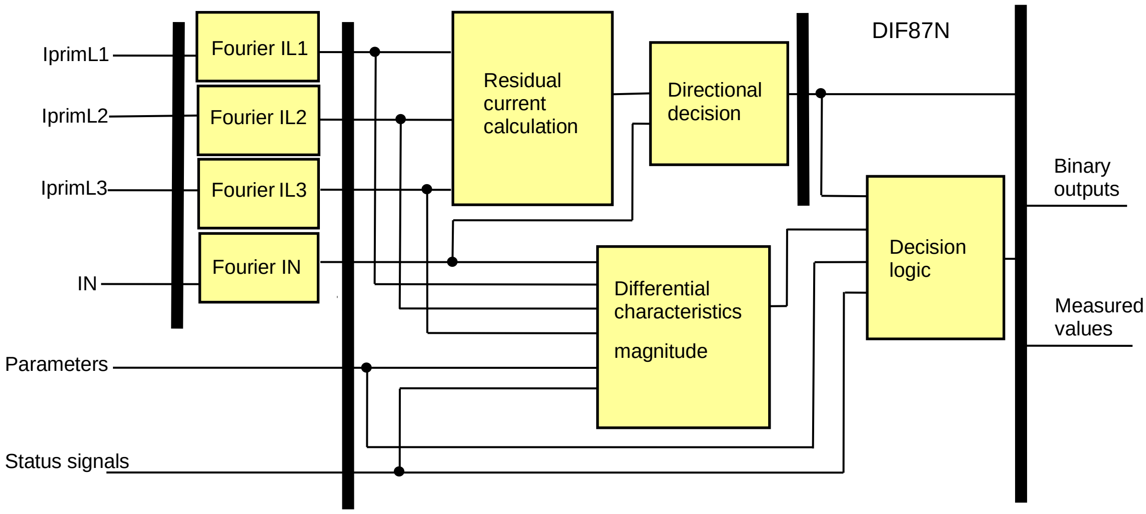

Figure 1-1 Structure of the restricted earth-fault protection algorithm

The **inputs** for the preparation are:

- the sampled values of three phase currents,
- the sampled value of the neutral current.

The **outputs** of the preparation are:

- the RMS values of the fundamental Fourier components of the phase currents,
- the RMS values of the fundamental Fourier component of the neutral current.

The **inputs** for the DIF87N function are:

- the RMS values of the fundamental Fourier components of the phase and neutral currents,
- parameters,
- status signal.

The **outputs** of the DIF87N function are:

- the binary output status signal,
- the measured values for displaying.

The **software modules** of the restricted earth-fault protection function are:

Fourier calculations

These modules calculate the fundamental Fourier current components of the phase currents and that of the neutral current individually. These modules belong to the preparatory phase.

Residual current calculation

This module calculates the residual current based on the Fourier components of the phase currents. These modules belong to the preparatory phase.

Directional decision

This module compares the direction of the neutral current and that of the calculated residual current. In case of small zero sequence components of the high fault currents in the phases, this decision improves the stability of the function.

Differential characteristics

This module performs the necessary calculations for the evaluation of the “percentage differential characteristics” and decides if the differential current is above the characteristic curve of the restricted earth-fault protection function. This curve is the function of the restraint current, which is the maximum of the phase currents and the current of the neutral point. The result of this calculation is needed for the decision logic.

Decision logic

The decision logic module combines the status signals, binary and enumerated parameters to generate the trip command of the function.

The following sections explain the details of the individual components.

1.1.1 The Fourier calculation (Fourier)

These modules calculate the fundamental Fourier current components of the phase currents and that of the neutral current individually. The magnitudes of these currents are matched to each other using the current transformer rated current values. These modules belong to the preparatory phase.

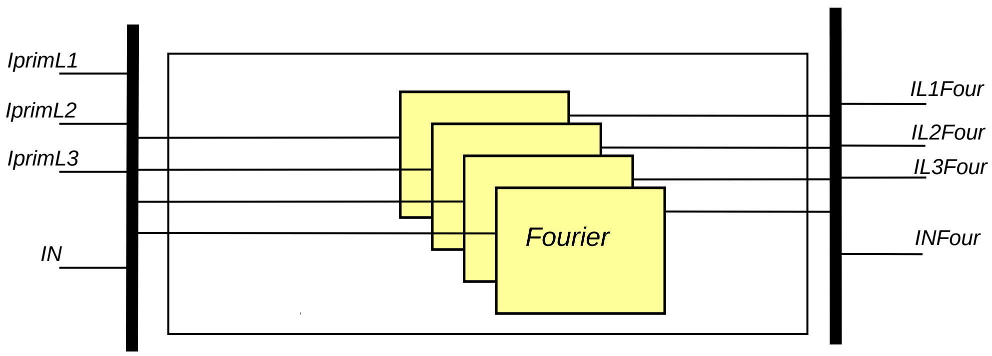

Figure 1-2 Principle scheme of the Fourier calculation

The **inputs** are the sampled values of:

- the three phase currents of the primary side (IprimL1, IprimL2, IprimL3)
- the current measured at the neutral point (IN)

The **outputs** are the fundamental Fourier components of the analyzed currents (IL1Four, IL2Four, IL3Four, INFour).

The integer parameters of the Fourier calculation are listed in Table 1-1.

Table 1-1 Integer parameters of the Fourier calculation

PARAMETER TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Sn	MVA	1.00 – 1000.00	0.01	125.00	Rated apparent power of the transformer
Un	kV	1.00 – 1000.00	0.01	132.00	Primary/phase rated voltage of the transformer

It's important to note that the currents used by the function are magnitude compensated depending on the CT ratios. More precisely:

$$ILxFour = \frac{ILx}{C.F\_Phase}$$

$$INFour = \frac{IN}{C.F\_Neut}$$

Where *x* stands for the phase number (1, 2, or 3) and *C.F.* is the compensation factor.

$$C.F\_Phase = \frac{Sn}{1.732 * Un * I\_CT\_Phase}$$

$$C.F\_Neut = \frac{Sn}{1.732 * Un * I\_CT\_Neut}$$

I_CT_Phase = *Rated Primary I1-3* parameter while I_CT_Neut = *Rated Primary I4* parameter of the current input function block.

1.1.2 The residual current calculation (Residual current calculation)

This module calculates the residual current component based on the Fourier components of the phase currents. This module belongs to the preparatory phase.

The **inputs** are the fundamental Fourier components of the phase currents (IL1Four, IL2Four, IL3Four).

The **outputs** are the Fourier components of the calculated residual current (3IoFour).

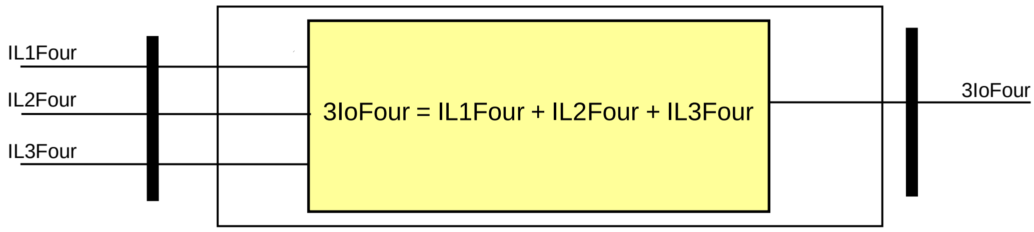

Figure 1-3 Principle scheme of the residual current calculation

1.1.3 Directional decision (Directional decision)

This module compares the direction of the neutral current and that of the calculated residual current. In case of small zero sequence component of the high fault currents in the phases, this decision improves the stability of the function.

For the directional decision, the positive directions are drawn in Figure 1-3. In this system, if the angle between the calculated residual current 3Io and the measured neutral current IN is out of the range of ±90 degrees, then the restricted earth fault protection can be blocked, the status signal DIF87N_**StDir**_GrI_ (Dir.element Start) is set to TRUE value.

The blocking of the directional decision is decided in the decision logic of the function, using the binary parameter *Directional check*.

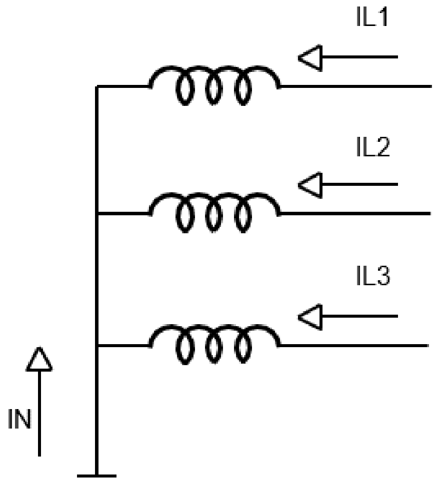

Figure 1-4 Positive directions for the directional decision

The **inputs** are the Fourier components of the calculated residual current (3IoFour) and that of the neutral current (INFour).

The **binary output status signal** of the directional decision is shown in Table 1-2.

Table 1-2 The binary output signal of the directional decision module

BINARY OUTPUT SIGNALS	SIGNAL TITLE	EXPLANATION
DIF87N_**StDir**_GrI_	Dir.element Start	Directional blocking signal of the residual directional element

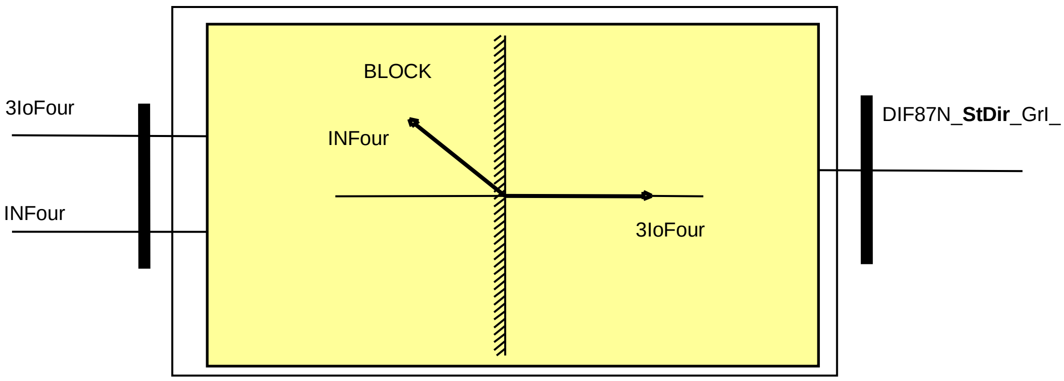

Figure 1-5 Principle decision of the directional decision

1.1.4 The differential characteristics (Differential characteristics)

This module performs the necessary calculations for the evaluation of the "percentage differential characteristics", and decides if the differential current is above the characteristic curve of the REF function. This curve is the function of the restraint current, which is the maximum of the phase currents and the current of the neutral point. The result of this calculation is processed in the decision logic.

The differential current is calculated using the following formula:

$$Diff\,Current = IL1Four + IL2Four + IL3Four + INFour$$

The bias current is calculated using the following formula:

$$Bias\,Current = MAX(IL1Four, IL2Four, IL3Four, INFour)$$

Based on these values, the REF protection differential characteristics are shown in Figure 1-6.

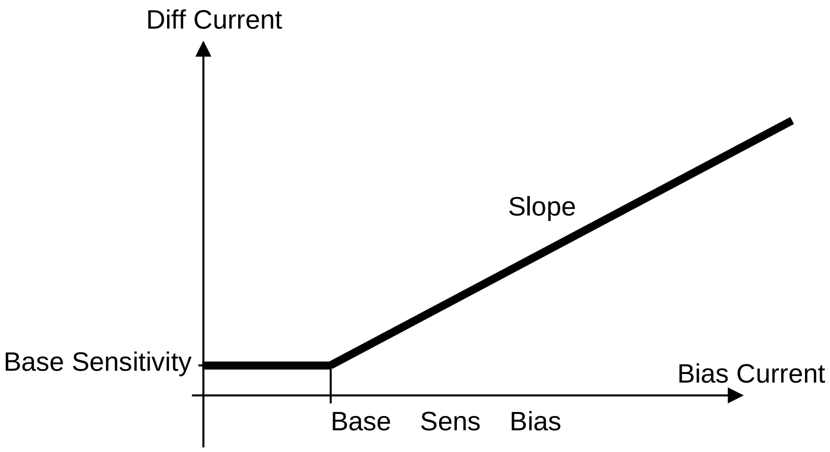

Figure 1-6 REF protection differential characteristics

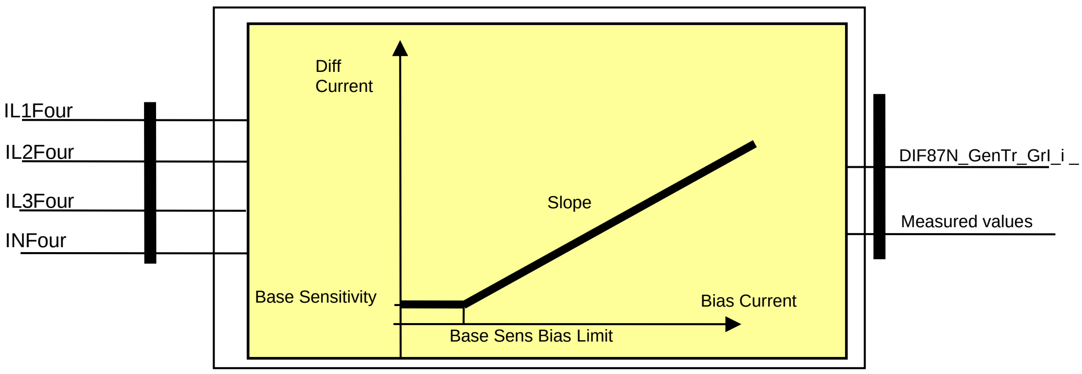

Figure 1-7 Principle scheme of the REF protection

The **measured values** of the restricted earth-fault protection function are listed in Table 1-3 below:

Table 1-3 The measured values of the restricted earth-fault protection function

MEASURED VALUE	TITLE	DIM	EXPLANATION
DIF87N_**Id**_OLM_	Diff Current	In %	The calculated differential current
DIF87N_**Bias**_OLM_	Bias Current	In %	The calculated restraint current

The **binary output status signal** of the restricted earth-fault protection characteristics is shown in Table 1-4.

Table 1-4 The generated trip signal of restricted earth-fault protection function

BINARY OUTPUT SIGNALS	TITLE	EXPLANATION
DIF87N_GenTr_GrI_i	General Trip_i	Internal general trip signal of the differential characteristics

The parameters of the restricted earth-fault protection characteristics are explained in the following tables.

The integer parameters of the restricted earth-fault protection characteristics are listed in Table 1-5.

Table 1-5 The integer parameters of the restricted earth-fault protection function

PARAMETER TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Base Sensitivity	%*	10 – 50	1	30	Base sensitivity
Slope	%**	50 – 100	1	70	Slope of the second section of the characteristics
Base Sens Bias Limit	%*	100 – 200	1	125	Break point of the characteristic line

(* % with reference to the magnitude-compensated current – see Table 1-1)

** % with reference to the bias current)

The binary input signal serves to increase the base sensitivity by 4 times. **The conditions of increasing are defined by the user, applying the graphic equation editor.**

Table 1-6 The binary output signals of the restricted earth-fault function block

BINARY INPUT SIGNAL	EXPLANATION
DIF87N_**UnSens**_GrO_	Output status of a graphic equation defined by the user to increase the base sensitivity by 4 times

1.1.5 The decision logic (Decision logic)

The decision logic module combines the status signals, binary and enumerated parameters to generate the trip command of the function.

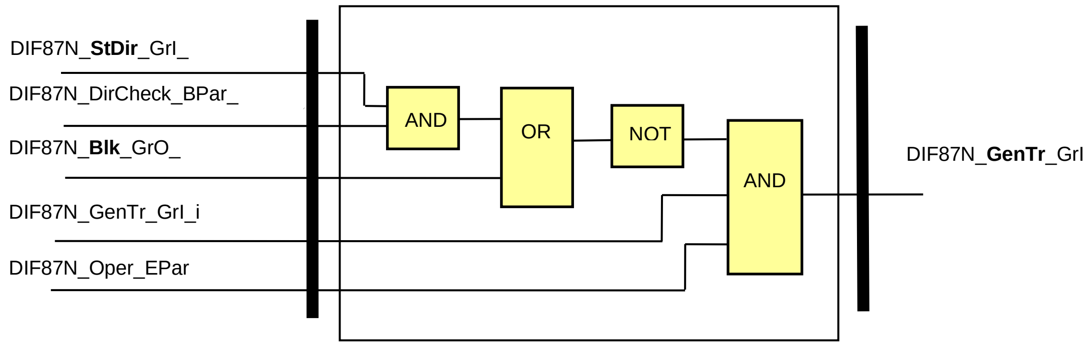

Figure 1-8 The logic scheme of the restricted earth-fault protection function

Table 1-7 The binary status signals of the decision logic module

BINARY INPUT SIGNALS	TITLE	EXPLANATION
DIF87N_GenTr_GrI_i	General Trip_i	Internal general trip signal of the differential characteristics
DIF87N_**StDir**_GrI_	Dir.element Start	Directional blocking signal restricted earth-fault protection function

The restricted earth-fault protection function has a binary input signal, which serves the purpose of disabling the function**. The conditions of disabling are defined by the user applying the graphic equation editor.**

Table 1-8 Blocking binary input signal of the REF function

BINARY INPUT SIGNAL	EXPLANATION
DIF87N_**Blk**_GrO_	Output status of a graphic equation defined by the user to disable the restricted earth-fault protection function.

The binary output signals of the restricted earth-fault protection function are listed in Table 1-9.

Table 1-9 The binary output signals of the REF function

BINARY INPUT SIGNALS	TITLE	EXPLANATION
DIF87N_**GenTr**_GrI_	General Trip	General trip signal of the REF differential protection characteristics
DIF87N_**StDir**_GrI_	Dir.element Start	Directional blocking signal of the restricted earth-fault protection function

The enumerated parameter of the restricted earth-fault protection function is shown in Table 1-10 below:

Table 1-10 The enumerated parameter of the REF function

PARAMETER TITLE	RANGE	DEFAULT	EXPLANATION
Operation	Off, On	On	Parameter to enable the restricted earth-fault protection function

The Boolean parameter of the restricted earth-fault protection function is shown in Table 1-11:

Table 1-11 The boolean parameter of the REF function

PARAMETER TITLE	RANGE	DEFAULT	EXPLANATION
Directional check	TRUE, FALSE	TRUE	Enabling the directional checking of the measured and calculated residual currents

The restricted earth-fault protection function generates a trip signal if the differential current as the function of the bias current is above the differential characteristic lines and the function is not blocked and the operation of the function is enabled by parameter setting.

Blocking can be caused by the directional decision if it is enabled by parameter setting and the angle of the currents is in the blocking area or the user has composed a blocking graphic equation, and the conditions result a TRUE value for the blocking.

2 Restricted Earth Fault Protection Function Overview

The function block of the impedance protection function is shown in the figure below. This block shows all binary input and output status signals that are applicable in the graphic equation editor. On the right, analogue inputs are shown as well (from system version 2.10 and up).

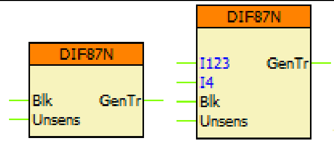

Figure 2-1 The graphic appearance of the restricted earth-fault function block

2.1 Settings

2.1.1 Parameters

Table 2-1 The parameter settings of the restricted earth-fault protection function

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Operation	-	Off, On	-	Off	Enabling the function
Directional check	-	TRUE, FALSE	-	TRUE	Enabling the directional check for the measured and calculated residual currents
Sn	MVA	1.00 – 1000.00	0.01	125.00	Transformer Rated Apparent Power
Un	kV	1.00 – 1000.00	0.01	132.00	Transformer Rated Primary Voltage
Base Sensitivity	%	10 – 50	1	30	Base sensitivity of the differential characteristic
Slope	%	100 – 60000	1	70	Slope of the second section of the characteristics
Base Sens Bias Limit	%	0 – 60000	1	125	Break point of the characteristic line

2.2 Function Inputs and Outputs

This section briefly describes the analogue and binary inputs and outputs of the function block.

2.2.1 Analogue Inputs

The analogue inputs are the sampled values of three-phase currents, and the sampled values of the residual voltage.

Table 2-2 below shows the function block analogue inputs for configurations running on firmware version 2.10.2.3010 and above, i.e. with graphical analogue signals. Parts written in **bold** are seen on the left side of the function block in the logic editor.

Table 2-2 The graphical analogue input signals of the REF protection function

ANALOGUE INPUT SIGNAL	SIGNAL TITLE	EXPLANATION
DIF87N_**I123**_AnIn_	3-Phase voltage	Input for sampled values of the 3-Phase voltages
DIF87N_**I4**_AnIn_	Residual voltage	Input for sampled values of the residual voltage

2.2.2 Analogue Outputs

There are no analogue outputs for this function block.

2.2.3 Binary Input Signals (Graphed Output Statuses)

The conditions of the binary inputs are defined by the user, applying the graphic equation editor (*Logic Editor*). Parts written in **bold** are seen on the left side function block in the Logic editor.

Table 2-3 The binary input signals of the REF protection function

BINARY INPUT SIGNAL	EXPLANATION
DIF87N_**Blk**_GrO_	A signal used to block the function can be connected here
DIF87N_**UnSens**_GrO_	A signal used to increase the base sensitivity by 4 times can be connected here

2.2.4 Binary Output Signals (Graphed Input Statuses)

These signals can be used in EuroCAP to assign to LED, user LCD object etc. Parts written in **bold** are seen on the right side of the function block in the *Logic Editor*.

Table 2-4 The binary output signals of the REF protection function

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
DIF87N_**GenTr**_GrI_	General Trip	General trip signal of the restricted earth-fault protection function

2.2.5 Online Data

Visible values on the *online data* page.

Table 2-5 Online displayed data of the REF protection function

SIGNAL TITLE	DIMENSION	EXPLANATION	IEC61850 DATA ATTRIBUTES*
Differential current	*In	Compensated differential current	REFPDIF1MXDifAClc1I
Bias current	*In	Compensated bias current	REFPDIF1MXRstA1
Primary current input assignment	-	*Status of the graphical analogue input (if exists) (Complete if OK, Missing if not connected)*	
Neutral current input assignment	-	*Status of the graphical analogue input (if exists) (Complete if OK, Missing if not connected)*	

**Differential and Bias current reporting available only on 2.10 systems*

NOTE: These current values measured by the function are with reference to the Transformer Nominal Current for the primary. Online measured current values should be multiplied with Transformer Nominal Current to get the corresponding primary values. This is what the dimension "*In" stands for.

2.2.6 Events

The following events are generated in the event list, as well as sent to the SCADA according to the configuration.

The events in grey are not actually shown in the event list, but they are still accessible in IEC61850 reporting. See the On-Line data chapter above for them.

Table 2-6 Generated events of the REF protection function

EVENT	VALUE	EXPLANATION	IEC61850 DATA ATTRIBUTES**
General Trip	on, off	General trip signal of the function	REFPDIF1STOp
Differential current	*In	Compensated differential current*	REFPDIF1MXDifAClc1I
Bias current	*In	Compensated bias current*	REFPDIF1MXRstA1

**Same note about current reference applies. See Online Data section.*
***Differential and Bias current reporting available only on 2.10 systems*

2.3 Technical Data

Table 2-7 Technical data of the REF protection function

FUNCTION	VALUE
Operating characteristic	1 breakpoint
Reset ratio	0,95
Characteristic accuracy	< 2%
Operate time	< 35 ms
Reset time	< 25 ms

2.4 Notes for Testing

Normally in the EuroProt+ devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this, the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the testing, otherwise there will be no physical trip on the relay.

Being an instantaneous operation function, its connection to the Trip Logic function is done in the Fast Equations (by default) and not in the Logic Editor (usually, there are comments inserted in the Logic Editor if such connections exist). This can be checked in EuroCAP.

Additional notes for Graphic Analogue inputs *(only from firmware version 2.10.2.3010 and up):*

Starting from the firmware version **2.10.2.3010**, the majority of the function blocks can be updated to be equipped with graphic analogue inputs which **allow the user to assign the functions' analogue inputs by applying the graphic equation editor**.

The analogue connections of these functions can be checked by examining the source that is connected to their inputs (just like examining the source of a logic signal).

These functions must be placed in the Logic Editor and their graphic analogue inputs must be connected to make them operate. If a connection is intact, the online status of the corresponding analogue input will show "Complete". If it is missing, the status will be "Missing" and the function will not operate.

Note that these graphical inputs do not exist in the earlier firmware/function versions (2.8.x.xxxx)! Checking and modifying the analogue assignments in these cases are done by using the EuroCAP Software Configuration menu.

2.5 Notes for legacy DIF87N function versions

The earlier versions of this function used compensation parameters for the phase and neutral CTs. These are now calculated automatically, based on the given nominal Sn, Un parameters. They are listed in the following table.

Table 2-8 The previous magnitude compensation parameters of the REF protection function

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
TR Primary Comp	%	20 – 500	%	100	Magnitude compensation for the primary 3ph CT
TR Neutral Comp	%	100 – 1000	%	500	Magnitude compensation for the neutral CT

2.5.1 Example for the calculation of settings (legacy version)

As an example, the transformer data:

Sn = 25 MVA

U1/U2 = 120/22 kV/kV

Y(d)y6

Current transformers:

CT1	600/1 A/A
CT2	800/1 A/A
CTN	250/1 A/A

The selected base current is the primary rated current of the transformer: 120 A. If a lower current value is selected, the zero-sequence differential protection becomes more sensitive.

REF on the secondary side:

I1np = 120 A

I2np = 656 A	On the secondary side of the CT	I2n = 0.82 A
INp = 656 A	On the secondary side of the CT	IN = 2.6 A

The calculated parameter settings are as follows:

Table 2-9 The settings of the previous magnitude compensation parameters

PARAMETER TITLE	SETTING VALUE
TR Primary Comp	82%
TR Neutral Comp	260%

The base sensitivity refers to the selected “base current” expressed in %, the slope is the ratio of the differential current and the bias current expressed in %.