

**EURO**PROT +

**Setting guide  
to the differential protection function**

**PROTECT**  
HUNGARY

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### Setting guide version information

Version	Date	Modification	Compiled by
V1.0H	2014.06.03	Hungarian version	Póka
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## 1 Example for application

For the application example consider a transformer with three voltage levels, according to Figure 1-1. The coils for the primary are connected Y with solidly grounded neutral. The secondary coils are delta connected, and the tertiary coils are also Y connected, but the neutral point is isolated. In this example it is supposed that no neutral grounding transformer is connected within the protected zone.

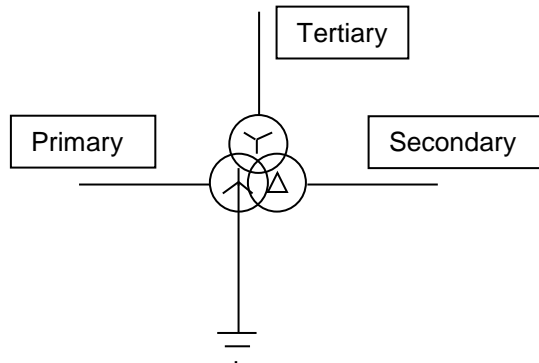


Figure 1-1 Application example

Example transformer data for the application:

Rated voltages:	$U1/U2/U3 = 120/36,75/22$ kV
Rated power:	$S_n = 40/30/20$ MVA
Connection group:	YNd11y6

Current transformers installed for the application are shown in Figure 1-2. All P1 points are arranged towards the transformer.

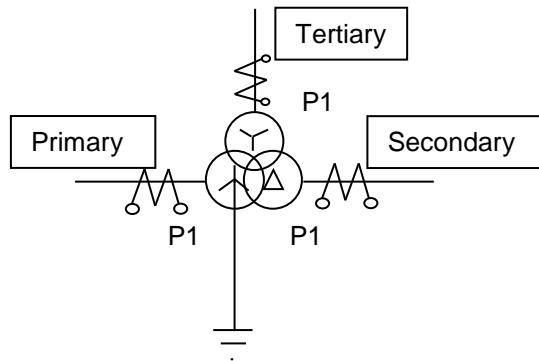


Figure 1-2 Current transformers, assigned to the differential protection function

Current transformer data:

Primary side	1000/1 A
Secondary side	500/1 A
Tertiary side	600/1 A

Suppose that the transformer is to be protected by differential protection.



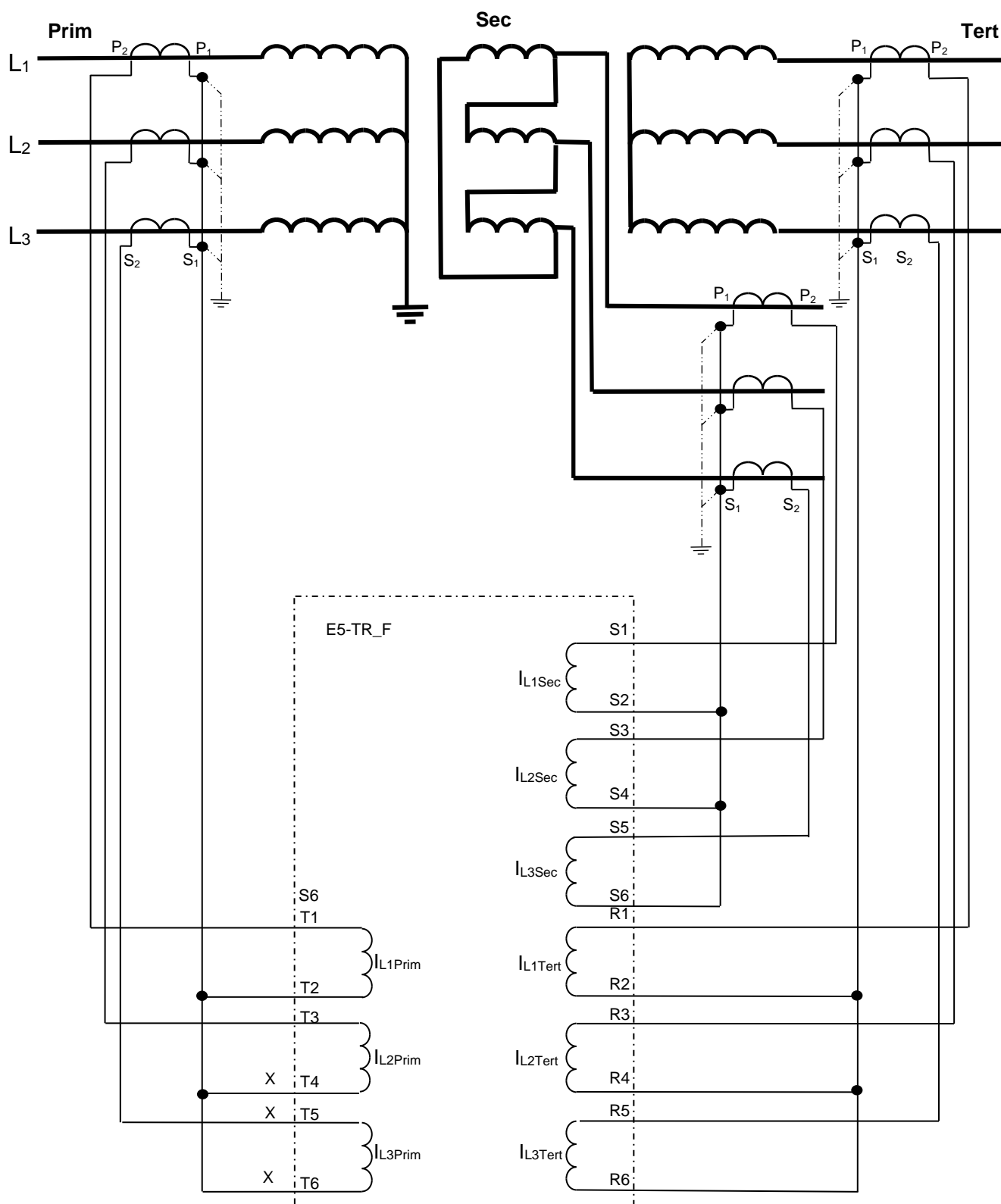


Figure 1-4 Connection diagram for the example

## 2 Setting the CT input function blocks

In the EuroProt+ devices the CT inputs are assigned to CT function blocks. They need parameter setting and also displaying functions are assigned to them. Parameters can be set in the parameter screen of a WEB browser, when there is Internet connection with the device. For details about this communication see the Protecta document “**Remote user interface description**” available in Protecta WEB site [www.protecta.hu](http://www.protecta.hu).

NOTE: the parameters can be set also using the local LCD touch-screen of the device, if no internet connection is available. For details about this communication see the Protecta document “**LCD touchscreen interface description**” available in Protecta WEB site [www.protecta.hu](http://www.protecta.hu).

The parameters of the current input function are explained in the following tables.

### Enumerated parameters

Parameter name	Title	Selection range	Default
Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed.			
CT4_Ch13Nom_EPar_	Rated Secondary I1-3	1A,5A	1A
Rated secondary current of the fourth input channel. 1A or 5A (0.2A, 1A) is selected by parameter setting, no hardware modification is needed.			
CT4_Ch4Nom_EPar_	Rated Secondary I4	1A,5A (0.2A, 1A)	1A
Definition of the positive direction of the first three currents, given by location of the secondary star connection point			
CT4_Ch13Dir_EPar_	Starpoint I1-3	Line,Bus	Line
Definition of the positive direction of the fourth current, given as normal or inverted			
CT4_Ch4Dir_EPar_	Direction I4	Normal,Inverted	Normal

Table 2-1 The enumerated parameters of the current input function

### Floating point parameters

Parameter name	Title	Dim.	Min	Max	Default
Rated primary current of channel1-3					
CT4_Pr13_FPar_	Rated Primary I1-3	A	100	4000	1000
Rated primary current of channel4					
CT4_Pr14_FPar_	Rated Primary I4	A	100	4000	1000

Table 2-2 The floating point parameters of the current input function

NOTE: The rated primary current of the channels is not needed for the current input function block itself. These values are passed on to the subsequent function blocks.

Using the information given in this example above, the following setting values are assigned:

**Primary side and grounding CT:**

Rated Secondary I1-3	1A	Selected, according to the CT applied at the primary side.
Rated Secondary I4	1A	Not applied, the value is not considered.
Starpoint I1-3	Line	"Line" in this case means "Toward protected object = Transformer"
Direction I4		Not applied, the value is not considered.
Rated Primary I1-3	1000	Setting, according to the CT applied at the primary side. This parameter is used for scaling the displayed values only
Rated Primary I4		Not applied, the value is not considered.

**Secondary side:**

Rated Secondary I1-3	1A	Selected, according to the CT applied at the secondary side.
Rated Secondary I4		Not applied, the value is not considered.
Starpoint I1-3	Line	"Line" in this case means "Toward protected object = Transformer"
Direction I4		Not applied, the value is not considered.
Rated Primary I1-3	500	Setting, according to the CT applied at the secondary side. This parameter is used for scaling the displayed values only
Rated Primary I4		Not applied, the value is not considered.

**Tertiary side:**

Rated Secondary I1-3	1A	Selected, according to the CT applied at the tertiary side.
Rated Secondary I4		Not applied, the value is not considered.
Starpoint I1-3	Line	"Line" in this case means "Toward protected object = Transformer"
Direction I4		Not applied, the value is not considered.
Rated Primary I1-3	600	Setting, according to the CT applied at the tertiary side. This parameter is used for scaling the displayed values only
Rated Primary I4		Not applied, the value is not considered.

*Table 2-3 Summary of the CT parameter setting*



### 3 Parameter setting for the differential function

The parameters with the selected settings for the example application for the differential protection function are summarized in Table 3-1 below. Some parameters need basic considerations some of them need also calculation. This is explained in the paragraphs below:

Operation	On	Set this parameter to "On" for enabling the function. NOTE: In tests, when other protection functions are tested. Switch this parameter to "Off" to prevent false test results. The details see in paragraph 3.1
Pri-Sec VGroup	Yy6	This setting is selected according to the protected object. NOTE: see explanation in paragraph 3.2
Pri-Ter VGroup	Yd11	This setting is selected according to the protected object. (Example) NOTE: see explanation in paragraph 3.2
Zero Seq Elimination	False	Not checked. This parameter is needed only if there is isolated (Not grounded) side of the transformer and there is and additional neutral grounding transformer within the protected zone. As this additional neutral grounding transformer is not supposed to be present, the checkbox can remain unchecked. This is described in paragraph 3.6
TR Primary Comp	20	This value needs calculation. This is described in paragraph 3.3
TR Secondary Comp	132	This value needs calculation. This is described in paragraph 3.3
TR Tertiary Comp	184	This value needs calculation. This is described in paragraph 3.3
2nd Harm Ratio	15	This value needs some considerations. These are described in paragraph 3.4
5nd Harm Ratio	25	This value needs some considerations. These are described in paragraph 3.4
Base Sensitivity	50	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.5
1st Slope	50	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.5
1st Slope Bias Limit	400	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.5
UnRst Diff Current	800	Parameter for the differential characteristic. This value needs some considerations. These are described in paragraph 3.5

*Table 3-1 Summary of the differential protection parameter setting*

### 3.1 Enabling the differential protection function

The DIF87 differential protection function can be applied as main protection for transformers, generators, large motors and also for protection of lines or cables on solidly grounded networks, or any combination of the mentioned protected objects.

The version DIF87\_3w can be applied to protect transformers with three voltage levels. The simpler version DIF87\_2w is designed to protect two winding transformers.

The parameter for enabling the differential protection function is shown in table below:

Parameter name	Title	Selection range	Default
Parameter to enable the differential protection function:			
DIF87_Op_EPar_	Operation	Off, On	Off

For enabling the function, set this Boolean parameter:

„Operation” = „On”

Additionally the differential protection function block has a binary input signal: „Blk”. In active state of this input signal the function is blocked. The conditions for blocking can be programmed using the graphic logic editor.

### 3.2 Setting the vector compensation

A three-phase transformer transforms the primary current to the secondary side according to the turn's ratio and the connection of the coils. The connection of the coils Y (star), D (delta) or Z (zig-zag) results phase shift of the current vectors. The numerical transformer differential protection function applies matrix transformation for the phase currents, according to the connection group to match them on all sides of the transformer.

The required matrix transformation is defined by correct selection of the transformer's connection group.

The transformer differential protection function in Protecta EuroProt+ devices transforms all currents to the delta side. This method is the numerical realization of the traditional principle: connect the secondary coils of the current transformers on the Y side of the transformer to delta, and apply y connection of the CT secondary coils on the delta side of the transformer. This transformation automatically eliminates also the problem caused by zero sequence current components.

Parameters for matching the vector group of the transformer are listed in the table below:

Parameter name	Title	Selection range	Default
Parameter to select connection group of the transformer coils in primary-secondary relation:			
DIF87_VGrSec_EPar_	Pri-Sec VGroup*	Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2, Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5, Yd7,Yd11,Yz1,Yz5,Yz7,Yz11	Dd0
Parameter to select connection group of the transformer coils in primary-secondary relation:			
DIF87_VGrTer_EPar_	Pri-Ter VGroup*	Dy1,Dy5,Dy7,Dy11,Dd0,Dd6,Dz0,Dz2, Dz4,Dz6,Dz8,Dz10,Yy0,Yy6,Yd1,Yd5, Yd7,Yd11,Yz1,Yz5,Yz7,Yz11	Dd0

\* If the connection of the primary winding in primary-secondary and primary tertiary relation is selected in contradiction then the protection function is automatically disabled, and the function generates a warning signal.

The selection of these parameters is easy: select the real connection relationship of the protected transformer. For autotransformers select always Yy0.

If the protection function is applied to protect the unit of transformer-line or transformer-cable then the parameters should be selected as the connection group can be seen from the location of the protection. As an example: a transformer of Yd11 connection group is seen at the other side as a transformer Dy1.

### 3.3 Setting the magnitude matching

The basic principle is that in case of power transfer at rated current the currents to be compared should be the same, 100%. This means that in case of any external faults there will be no current difference, the differential function is balanced and stable.

For a two winding transformer, usually the rated current of the transformer is considered to be the base current, considered to be 100%. (NOTE: any other current value could also be selected for this reference current.) The ratio of the secondary and primary rated currents is the turn's ratio of the transformer. For the setting calculation, calculate the ratio of the transformer rated current and the CT rated primary current. These values expressed in % are the parameter values to be set for parameters „TR Primary Comp” and “TR Secondary Comp”.

For a three winding transformer in the example the rated power of the winding is not the same (40 MVA, 30 MVA and 20 MVA), consequently the ratio of rated currents for the windings do not match the turn's ratio of the coils. In this case the usual procedure is to consider the rated current of the primary side, and transform this current both for the secondary and to the tertiary side. These calculated currents should be related to the rated currents of the CT-s. These values expressed in % are the parameter values to be set for parameters „TR Primary Comp”, “TR Secondary Comp” and “TR Tertiary Comp”

In the example:

The rated primary current is calculated from the transformer data above. This is the reference current.

$I_{1nprimary} = 192 \text{ A}$

$I_{2nprimary} = 471 \text{ A}$  based on the turn's ratio it is: 627 A

$I_{3nprimary} = 525 \text{ A}$  based on the turn's ratio it is: 1047 A

The calculation of the setting values is as follows

„TR Primary Comp”=  $100 \cdot 192 \text{ A} / 1000 \text{ A} = 19.2\%$  It needs correction.

„TR Secondary Comp”=  $100 \cdot 627 \text{ A} / 500 \text{ A} = 125.4\%$  It needs correction, using the same factor

„TR Tertiary Comp” =  $100 \cdot 1047 \text{ A} / 600 \text{ A} = 174.5\%$  It needs correction, using the same factor

For the 120 kV side the setting of 19% is below the low limit of the parameter range. Select instead 20 %. Consequently the compensation values both for the secondary and tertiary sides should be multiplied by 20/19. Note this correction means only that not the rated current but a slightly different value is selected as the base current.

„TR Primary Comp”= 20 %

„TR Secondary Comp”=  $20/19 \cdot 125.4 \% = 132 \%$

„TR Tertiary Comp” =  $20/19 \cdot 174.5 \% = 184 \%$

### 3.4 Considerations, related to the harmonic restraint

When a transformer is energized then due to the asymmetric saturation of the iron core a high “inrush current” can flow from one side into the transformer. This is a pure differential current. To prevent unwanted operation of the differential protection the special waveform of the inrush current is identified. The principle is the detection of the second harmonic content, which is present in the inrush current, but its value can be neglected in any fault current. For the differential current, the second harmonic component in the evaluation is related to the value of the base harmonic. This is the parameter „2nd Harm Ratio”. If this ratio gets higher due to inrush current, the trip command is blocked.

When a transformer is overexcited then the iron core is saturated symmetrically, resulting high current peaks, distorting both the positive and the negative sinusoidal current shape. In this current shape the fifth harmonic is characteristic. To prevent mal-operation, this component of the differential current is analyzed and compared to the base harmonic. If the ratio is high, then the differential current is caused by the over-excitation, the trip command is blocked. If however the fifth harmonic content is low, then the high differential current, which is a fault current, results trip command. The ratio is the parameter „5th Harm Ratio”.

If no results of detailed harmonic analysis are available, apply the factory setting, which can be corrected later. The proposed setting values are:

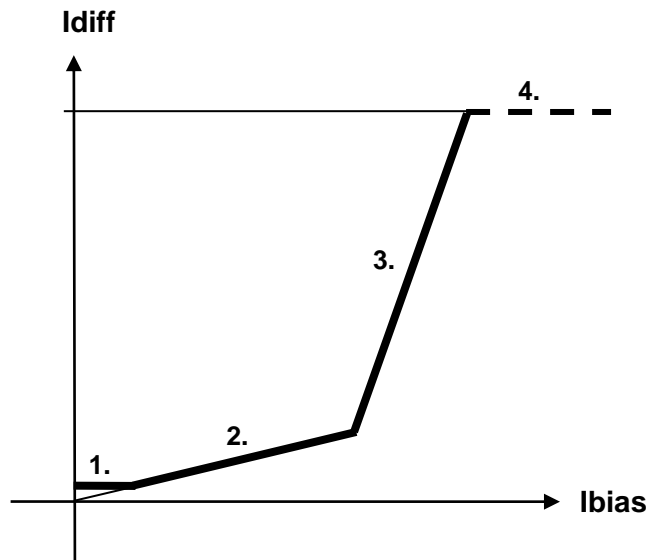
„2nd Harm Ratio”.= 15 %

and

„5th Harm Ratio”= 25 %

### 3.5 Considerations, related to the differential characteristic for the differential protection function

The differential characteristic is shown in *Figure 3-1*. If the calculated ( $I_{bias}, I_{diff}$ ) operating point is above the characteristic, then the differential protection operates.



*Figure 3-1 The differential characteristic*

This characteristic has four sections; each of them is a straight line. The parameters define the position of these lines on the  $I_{diff}$ - $I_{bias}$  plane.

The first parameter is “Base Sensitivity”. It defines the minimum differential current for the operation. Its role is to prevent mal-operation in case of current noises and measuring errors for small currents. In this example the selected setting value is the less sensitive selection:

„Base Sensitivity” = 50 %,

This value can be tested easily: inject three phase symmetrical currents from one side only and increase its value. The operation is expected if this current gets above 50% of the reference current. (In this example it is  $0.5 \cdot 0.87A$ . NOTE: for asymmetrical fault current this value changes due to the matrix transformation.)

The second section of the characteristic is a line through the origin of the  $I_{diff}$ - $I_{bias}$  plane. The slope of this line serves to compensate the not correct matching of the CT-s, e.g. due to the different tap-changer positions and the CT errors. Due to these causes the error current increases if the current flowing through the transformer increases. The parameter is "1st Slope". The mathematical expression of the second section of the characteristic is:

$$I_{diff} = \frac{1stSlope}{100} * I_{bias}$$

The steps for getting the parameter value are as follows:

- Calculate the error in percent, due to not correct matching (To be calculated for all three voltage levels):

$$x\% = \left( 1 - \left| \frac{I1 \cdot required\_matching}{I1 \cdot matching} \right| \right) * 100$$

- The unbalance of the differential protection at top or bottom position of the tap changer in percent, related to the value of 0 position ( $r_{max}\%$ ):

$$x\% = |r_{max}\%|$$

Select the biggest value of the calculated  $x\%$  values above. The setting value is advised to be above this value.

Example: suppose the voltage control range to be  $+18\%/-12\%$ , and the reference position for current balancing is the 0 position, then the parameter value with 1,5x safety is:

$$\text{„1st Slope”} = 1,5 \cdot 18 = 27 \rightarrow 30\%$$

Another choice for calculation is the selection the mid-position of the tap-changer. This is in this example as follows: The full position range is  $18 + 12 = 30\%$ . The half value is  $15\%$ , accordingly the mid-position is  $+3\%$ . With this the voltage ratio of the transformer to be considered is to be increased by  $118/115$ , and the balancing of the current is to be determined for this voltage. In this case only  $\pm 15\%$  tap position range can be considered, and the value of this parameter is decreased to:

$$\text{„1st Slope”} = 1,5 \cdot 15 = 22,5 \rightarrow 25\%$$

The slope of the third section of the characteristic is higher. This is to compensate the increased CT error, due to the CT saturation at higher currents. This higher slope is a factory setting: 200%. The parameter "1st Slope Bias Limit" defines the intersection point of section 2 and 3.

This parameter value is influenced by the highest fault current in the protected object and the applied current transformer saturation point related to the rated value. If the current transformer is less over-dimensioned then select the parameter value for "1st Slope Bias Limit" low. The usual consideration is: for relatively high currents select 200%, for low fault currents select 1000%.

The fourth section of the characteristic is the unrestrained section. The related parameter is "UnRst Diff Current". This parameter serves unrestrained fast operation if the high magnitude of the fault current indicates internal fault. The calculation determines the maximal external fault current, and the setting value should be above this current.

### 3.6 Considerations for zero sequence elimination

In solidly grounded high voltage networks, in case of external earth faults, the Y-delta transformers supply zero sequence current, which is present on the Y side only. No zero sequence current can flow on the delta side. When comparing the currents in the differential protection, this could cause unwanted operation.

The differential protection function in the Protecta EuroProt+ devices eliminates the Y side zero sequence current by matrix transformation (simulating the old type delta connected CT secondary behavior). This elimination is automatic, no additional solution is needed.

In several cases, however, there is additional neutral grounding transformer on the delta side of the transformer within the protected zone. Between the neutral point of this additional transformer an arc suppression Petersen coil, or a grounding resistor is connected. The Petersen coil minimizes the earth-fault current to some Amperes, the resistor limits the earth-fault current to 100 A (in some cases to 200 A).

If the neutral grounding transformer is not in the protected zone, it is outside the current transformers, then set:

„ZeroSeq Elimination” = „False” (Not checked)

In some cases, however, the neutral grounding transformer is closely connected to the main transformer's delta side terminals; it is in the protected zone. The advantage of this arrangement is that the energizing the transformer immediately solves the neutral grounding problems.

In case of external earth-fault the zero sequence current of the neutral grounding transformer is detected by the delta side current transformers. The zero sequence elimination is needed. In this case set

„ZeroSeq Elimination” = „True” (Checked)

## 4 Application of the binary signals

The binary output status signals are usually applied in the graphic logic editor as input signals. The logic relationship can be programmed freely.

The available binary output status signals of the differential protection function are listed in the table below:

Binary output signals	Signal title	Explanation
Restrained differential protection function		
DIF87_L1St_Grl_	Start L1	Start of the restrained differential protection function in phase L1 (after vector group compensation)
DIF87_L2St_Grl_	Start L2	Start of the restrained differential protection function in phase L2 (after vector group compensation)
DIF87_L3St_Grl_	Start L3	Start of the restrained differential protection function in phase L3 (after vector group compensation)
DIF87_GenSt_Grl	General Start	General start of the restrained differential protection function
Unrestrained differential protection function		
DIF87_UnRL1St_Grl_	Start L1 unrestr.	Start of the unrestrained differential protection function in phase L1 (after vector group compensation)
DIF87_UnRL2St_Grl_	Start L2 unrestr.	Start of the unrestrained differential protection function in phase L2 (after vector group compensation)
DIF87_UnRL3St_Grl_	Start L3 unrestr.	Start of the unrestrained differential protection function in phase L3 (after vector group compensation)
DIF87_UnRGenSt_Grl_	General Start unrestr	General start of the unrestrained differential protection function
Harmonic blocking		
DIF87_2HBik_Grl	2.Harm Restr.	Restraint caused by high second harmonic content in any of the differential currents
DIF87_5HBik_Grl	5.Harm Restr.	Restraint caused by high fifth harmonic content in any of the differential currents

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

Binary input signal	Explanation
DIF87_Bik_GrO	Output status of a graphic equation defined by the user to disable the differential protection function.