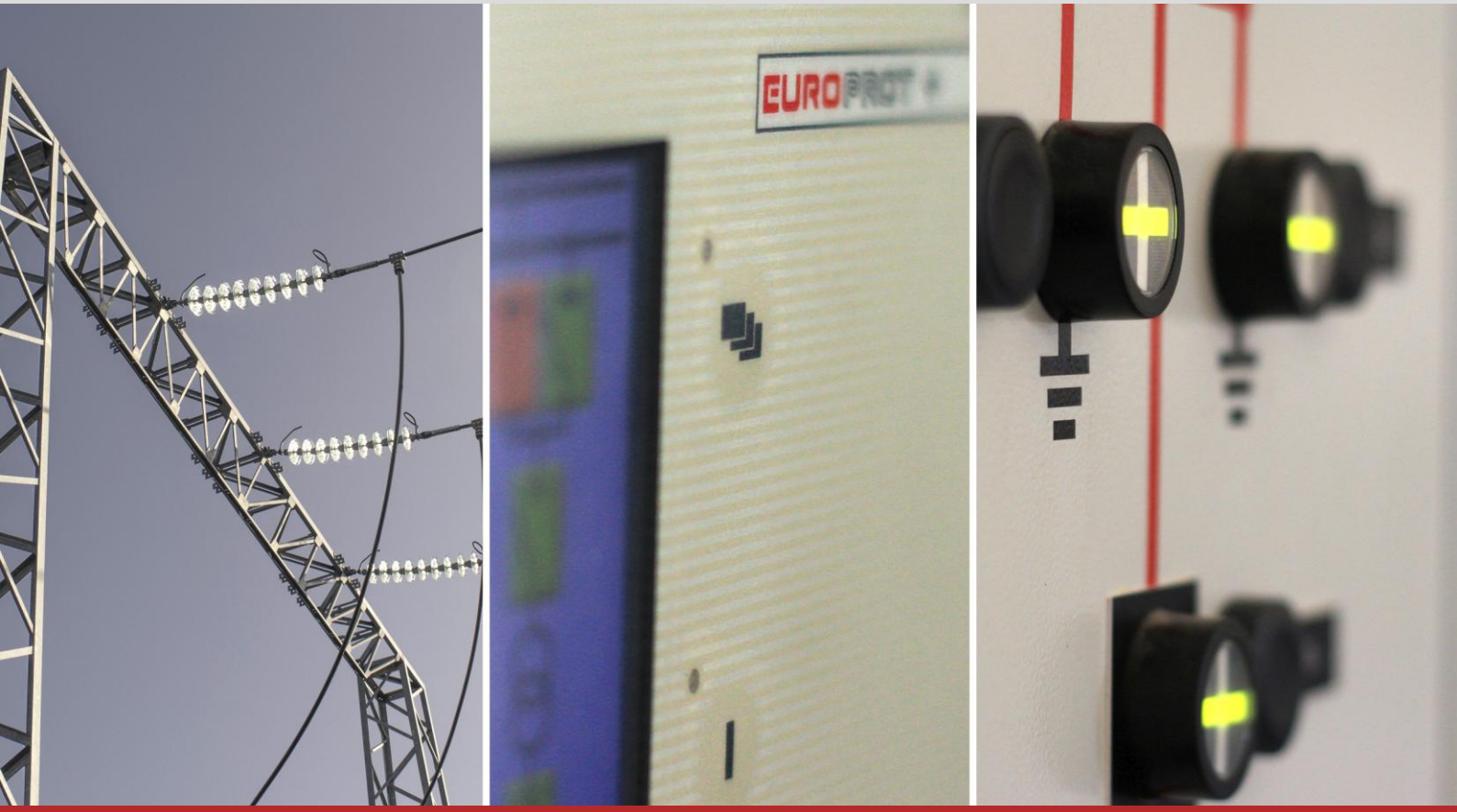


FUNCTION BLOCK DESCRIPTION

Directional residual overcurrent protection function

ANSI 67N/67G, IEC Io Dir>, Io Dir>>

PROTECTA HUNGARY

DOCUMENT ID: PP-13-20322
VERSION: 2.1
2025-12-03, BUDAPEST

PROTECTION, AUTOMATION AND CONTROL FOR POWER INDUSTRY

VERSION INFORMATION

VERSION	DATE	MODIFICATION	COMPILED BY
Preliminary	2009-11-24	Preliminary version, without technical information	Petri
	2010-06-18	Technical information added	Petri
	2010-06-25	New Fig. 1-2 added	Petri
	2010-10-05	Naming revision	Csipke
1.0	2010-11-11	First edition	Petri
1.1	2013-02-15	Appendix added	Petri
1.2	2016-04-25	Timer parameter min. values changed, min res voltage max. changed to 20%	Erdős
1.3	2022-08-12	• The ranges and the default values of some parameters updated • More details for the pickup time in chapter Technical data	Seida
2.0	2024-11-26	New documentation design, new chapters, IEC61850 info added	Ádám, Erdős
2.1	2025-12-03	Minor corrections	Erdős

CONTENTS

USED SYMBOLS

Additional information

Useful information for settings.

Important part for proper usage.

1 Operation principle

1.1 Application

The main application area of the directional residual overcurrent protection function is the earth-fault protection.

1.2 Mode of operation

The inputs of the function are the Fourier basic harmonic components of the zero sequence current and those of the zero sequence voltage.

The block of the directional decision generates a signal of TRUE value if the UN=3Uo zero sequence voltage and the IN=-3Io current are sufficient for directional decision, and the angle difference between the vectors is within the preset range. This decision enables the output start and trip signals of the residual overcurrent protection function block (TOC51N).

Note: the position of the vectors in Figure 1-1 indicates a forward fault, i.e., the location of the earth fault is on the protected line (the positive direction of the current is from the busbar to the line).

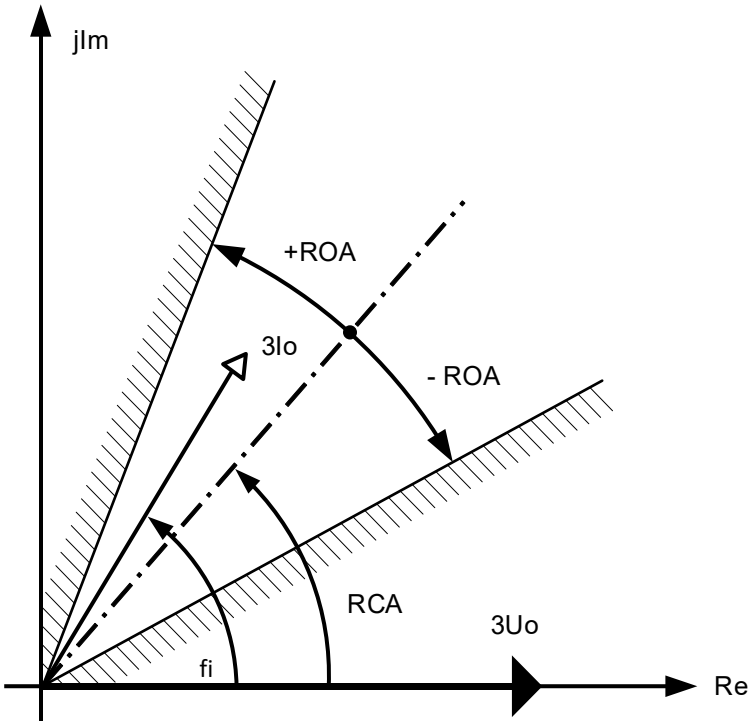


Figure 1-1 The directional decision

1.3 Structure of the directional residual overcurrent protection algorithm

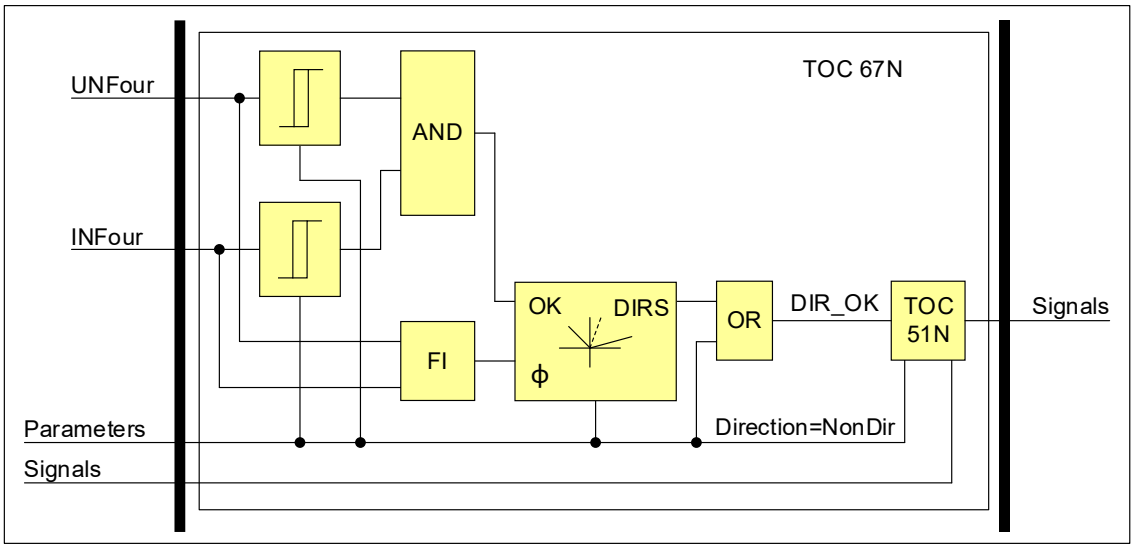


Figure 1-2 shows the structure of the directional residual overcurrent protection (TOC51N) algorithm.

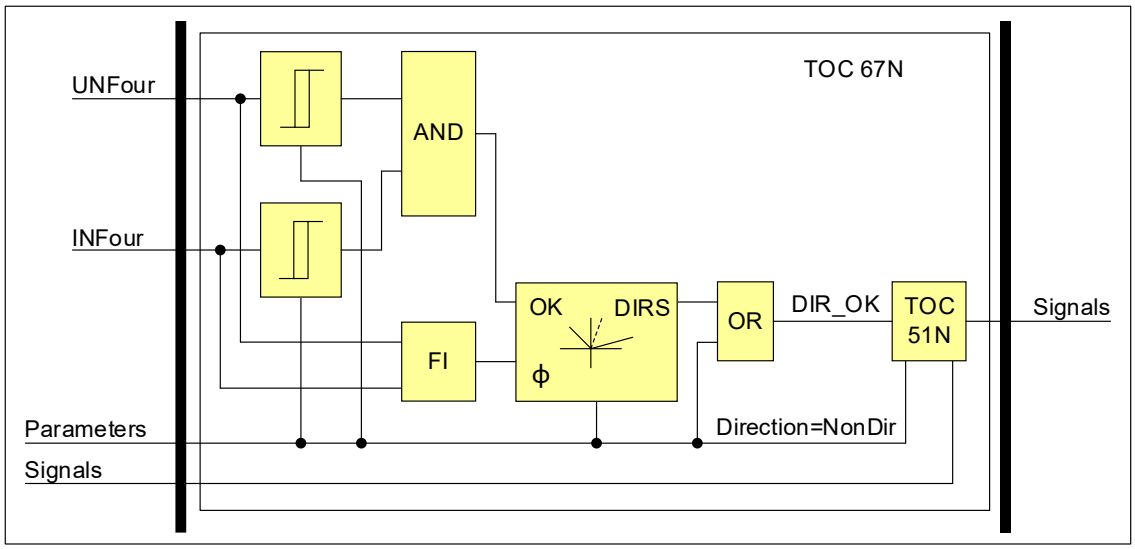


Figure 1-2 Structure of the residual directional overcurrent protection algorithm

The **inputs** are

- the RMS value of the fundamental Fourier component of the residual current (IN=3Io),
- the RMS value of the fundamental Fourier component of the residual voltage (UN=3Uo),
- parameters,
- status signals.

The **outputs** are

- the binary output status signals.

The **software modules** of the residual directional overcurrent protection function:

Comparison

These modules decide if the RMS values of the fundamental Fourier component of the residual current and voltage are above the limits needed for correct directional decision.

FI calculation

This module calculates the vector angle between the residual voltage and the residual current.

DIRST

The directional decision.

TOC51N

Non-directional residual overcurrent protection function.

The following description explains the details of the individual components.

1.3.1 Enabling the directional decision (Comparison)

These modules decide if the RMS values of the fundamental Fourier component of the residual current and voltage are above the limits needed for correct directional decision.

Table 1-1 The integer parameters for enabling the directional decision

PARAMETER NAME	TITLE	UNIT	MIN	MAX	STEP	DEFAULT
The threshold value for the 3Uo zero sequence voltage, below which no directionality is possible. % of the rated voltage of the voltage transformer input.						
TOC67N_UoMin_IPar_	Min Res Voltage	%	1	20	1	2
The threshold value for the 3Io zero sequence current, below which no operation is possible. % of the rated current of the current transformer input.						
TOC67N_IoMin_IPar_	Min Res Current	%	1	50	1	5

The **input signals are** the RMS values of the fundamental Fourier component of the residual current and voltage.

The **internal output status signal** for enabling the directional decision is true if both the residual voltage and the residual current is above the preset limits.

1.3.2 Calculation of the vector angle (FI calculation)

This module calculates the phase angle between the residual voltage and the residual current. The reference signal is the residual voltage according to Figure 1-1.

The **input signals are** the fundamental Fourier components of the residual current and voltage.

The **internal output signal** is the calculated phase angle.

1.3.3 Directional decision (DIRST)

This module decides if the phase angle between the residual voltage and the residual current is within the limit range defined by the preset parameter. The operation of this function is explained in Figure 1-1.

The **input signals are**

- The enabling status signal from the Comparison modules in AND relationship.
- The calculated phase angle between the residual voltage and the residual current.
- Parameters.

The **internal output signal** of the directional decision is TRUE if the phase angle between the residual voltage and the residual current is within the limit range defined by the preset parameters OR if non-directional operation is selected by the preset parameter TOC67N_Dir_EPar_ (Direction=NonDir).

Table 1-2 The enumerated parameters of the directional decision

PARAMETER NAME	TITLE	SELECTION RANGE	DEFAULT
Directionality of the function			
TOC67N_Dir_EPar_	Direction	NonDir, Forward-Angle, Backward-Angle, Forward-I*cos(fi), Backward-I*cos(fi), Forward-I*sin(fi), Backward-I*sin(fi), Forward-I*sin(fi+45), Backward-I*sin(fi+45)	Forward-Angle

**The forward direction is defined by the RCA characteristic angle (See Table 2-7 below).*

Table 1-3 Explanation of the enumerated parameter "Direction"

SELECTED VALUE	EXPLANATION
NonDir,	Operation according to non-directional TOC51N
Forward-Angle	See Figure 1-1, set ROA and RCA as required
Backward-Angle	RCA=RCAset+180°, set ROA and RCA as required
Forward-I*cos(fi)	RCA=0°fix, ROA=85°fix, the setting values RCA and ROA are not applied
Backward-I*cos(fi)	RCA=180°fix, ROA=85°fix, the setting values RCA and ROA are not applied
Forward-I*sin(fi)	RCA=90°fix, ROA=85°fix, the setting values RCA and ROA are not applied
Backward-I*sin(fi)	RCA=-90°fix, ROA=85°fix, the setting values RCA and ROA are not applied
Forward-I*sin(fi+45)	RCA=45°fix, ROA=85°fix, the setting values RCA and ROA are not applied
Backward-I*sin(fi+45)	RCA=-135°fix, ROA=85°fix, the setting values RCA and ROA are not applied

Table 1-4 Integer parameters of the directional decision

PARAMETER NAME	TITLE	UNIT	MIN	MAX	STEP	DEFAULT
Operating angle (See Figure 1-1)						
TOC67N_**ROA**_IPar_	Operating Angle	deg	30	85	1	60
Characteristic angle (See Figure 1-1)						
TOC67N_**RCA**_IPar_	Characteristic Angle	deg	-180	180	1	60

1.3.4 Non-directional residual overcurrent protection function (TOC51N)

This module is equivalent to the TOC51N function block described in a separate document.

2 Overview

The function block of the residual directional overcurrent protection function is shown in Figure 2-1 for both main system versions (2.8 and 2.10). This block shows all binary input and output status signals that are applicable in the graphic equation editor.

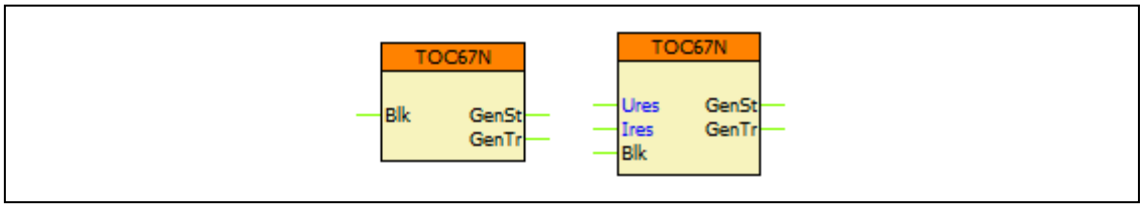


Figure 2-1 The function block of the residual overcurrent protection function

2.1 Settings

2.1.1 Parameters

The parameters are listed as they are seen on the local or remote HMI.

Table 2-1 Parameters of the directional residual overcurrent protection function

TITLE	DIM	RANGE	STEP	DEFAULT	EXPLANATION
Direction	-	NonDir, Forward-Angle, Backward-Angle, Forward-I*cos(fi), Backward-I*cos(fi), Forward-I*sin(fi), Backward-I*sin(fi), Forward-I*sin(fi+45), Backward-I*sin(fi+45)	-	Forward-Angle	Directionality of the function
Start Signal Only	-	TRUE, FALSE	-	FALSE	
Min Res Voltage	%	1 – 20	1	2	The threshold value for the 3Uo zero sequence voltage, below which no directionality is possible. % of the rated voltage of the voltage transformer input.
Min Res Current	%	1 – 50	1	5	The threshold value for the 3Io zero sequence current, below which no operation is possible. % of the rated current of the current transformer input.
Operating Angle	deg	30 – 85	1	60	Operating angle (See Figure 1-1)
Characteristic Angle	deg	-180 – 180	1	60	Characteristic angle (See Figure 1-1)

Operation	-	Off, DefiniteTime, IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv	-	Off	Operating characteristic selection of the TOC51N module
Start Current*	%	10 – 1000	1	50	Start current (TOC51N module)
Time Multiplier	-	0.05 – 15.00	0.01	1.00	Time multiplier of the inverse characteristics (TOC51N module)
Min Time Delay**	msec	30 – 60000	1	100	Minimal time delay for the inverse characteristics (TOC51N module)
Definite Time Delay***	msec	30 – 60000	1	100	Definie time delay (TOC 51N module)
Reset Time**	msec	60 – 60000	1	100	Reset time delay for the inverse characteristics (TOC51N module)

* *In = 1 A or 5 A*
** *Valid for inverse type characteristics only*
*** *Valid for definite type characteristics only*

2.2 Function I/O

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

2.2.1 Analogue inputs

Graphic Analogue inputs ***(only from firmware version 2.10.2.3010 and up)***

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

The function uses the following analogue signals as inputs:

Table 2-2 Analogue input signals of the directional residual overcurrent protection function

ANALOGUE INPUT SIGNAL	SIGNAL TITLE	EXPLANATION
TOC67N_**Ures**_AnIn_	Residual voltage	For using calculated 3Uo, connect 3ph current signal (U123 output of the VT function) For using measured 3Uo, connect 1ph current signal (U4 output of the VT function)
TOC67N_**Ires**_AnIn_	Residual current	For 67N (calculated 3Io) operation, connect 3ph current signal (I123 output of the CT function) For 67G (measured 3Io) operation, connect 1ph current signal (I4 output of the CT function)

The applied analogue connectors must be identical to the analogue input type (i.e. voltage to voltage input etc.), Invalid connections are not allowed.

2.2.2 Analogue outputs (measurements)

The function has no analogue output signals.

2.2.3 Binary input signals (graphed output statuses)

The conditions of the inputs are defined by the user, applying the graphic equation editor (logic editor). The part written in **bold** is seen on the function block in the logic editor.

Table 2-3 Binary input status signal of the directional residual overcurrent protection function

BINARY INPUT SIGNAL	EXPLANATION
TOC67N_**Blk**_GrO_	Blocking input status signal

2.2.4 Binary output signals (graphed input statuses)

The binary output status signals of the directional residual overcurrent protection function. Parts written in **bold** are seen on the function block in the logic editor.

Table 2-4 Binary output status signals of the directional residual overcurrent protection function

BINARY OUTPUT SIGNAL	SIGNAL TITLE	EXPLANATION
TOC67N_**GenSt**_Grl_	Start	General start signal of the function
TOC67N_**GenTr**_Grl_	Trip	General trip command of the function

2.2.5 On-line data

Visible values on the on-line data page:

Table 2-5 The displayed on-line data of the directional residual overcurrent protection function

SIGNAL TITLE	DIMENSION	EXPLANATION
Direction	-	Directionality of the function
Start	Off, On	General start signal of the function
Trip	Off, On	General trip command of the function
Voltage input assignment		*Status of the graphical analogue input (if exists) (Complete if OK, Missing if not connected)*
Current input assignment		*Status of the graphical analogue input (if exists)*

2.2.6 Events

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

Table 2-6 Events of the directional residual overcurrent protection function

EVENT	VALUE	EXPLANATION	IEC61850 DATA ATTRIBUTES
Start	Off, On	General start signal of the function	F1PTOC1STStr
Trip	Off, On	General trip command of the function	F1PTOC1STOp

2.3 Technical data

Table 2-7 Technical data of the directional residual overcurrent protection function

FUNCTION	VALUE	ACCURACY
Operating accuracy		< ±2 %
Operate time accuracy		±5% or ±15 ms, whichever is greater
Accuracy in minimum time range		±35 ms
Reset ratio	0,95	
Reset time	Approx 50 ms	±35 ms
Transient overreach	<2 %	
Pickup time with non-directional setting Pickup time with directional setting	25 – 30 ms <100ms	
Angular accuracy Io ≤ 0.1 In 0.1 In < Io ≤ 0.4 In 0.4 In < Io		 < ±10° < ±5° < ±2°
Angular reset ratio Forward and backward All other selection	 10° 5°	

2.3.1 Notes for testing

Keep in mind that the angles are between the 3Uo and 3Io phasors which can either be measured or calculated, depending on the assigned/connected analogue signals.

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).

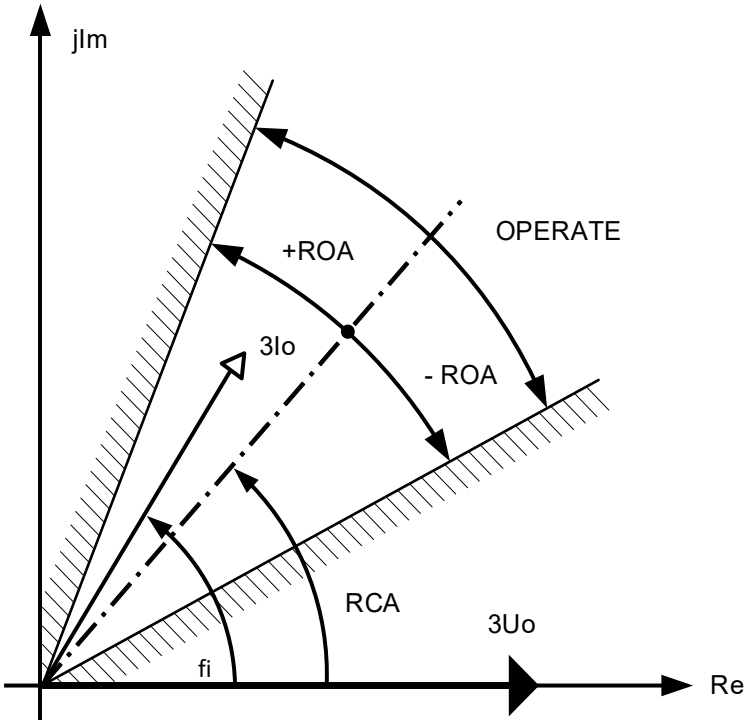
These functions must be placed in the Logic Editor and their graphic analogue inputs must be connected to make them operate. If a connection is intact, the online status of the corresponding analogue input will show "Complete". If it is missing, the status will be "Missing" and the function will not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

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

3 APPENDIX

3.1 Pre-configured setting values of the directional residual overcurrent protection function

3.1.1 Setting: Direction = Forward-Angle



For the operation the residual current (3Io) must be within the “OPERATE” area.

Additional conditions for operation:

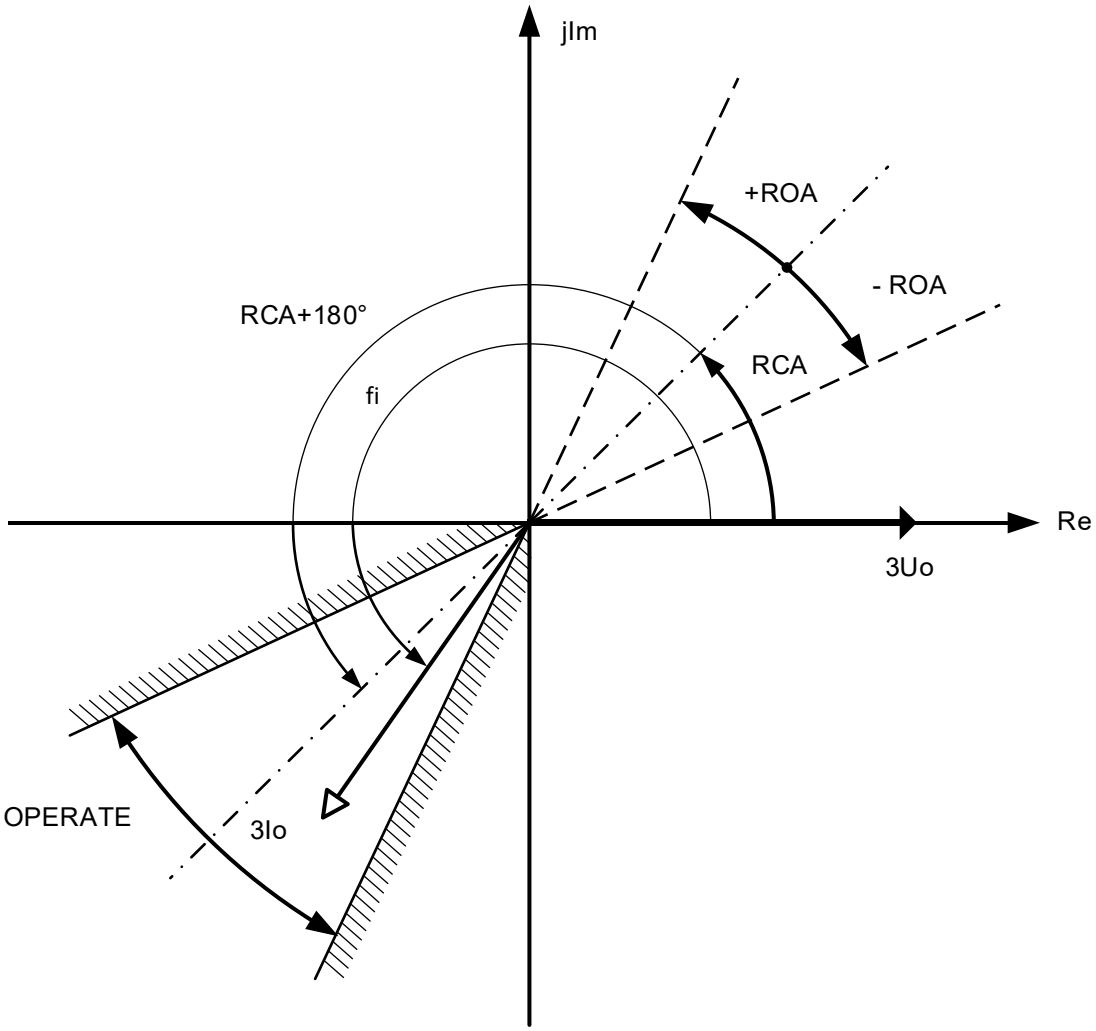
- The magnitude of the residual current is above the setting value:

  |3Io| > “Start current”

- The magnitude of the residual voltage is above the setting value:

  |3Uo| > ”Min Res Voltage”

3.1.2 Setting: Direction = Backward-Angle



For the operation the residual current (3Io) must be within the “OPERATE” area.

Additional conditions for operation:

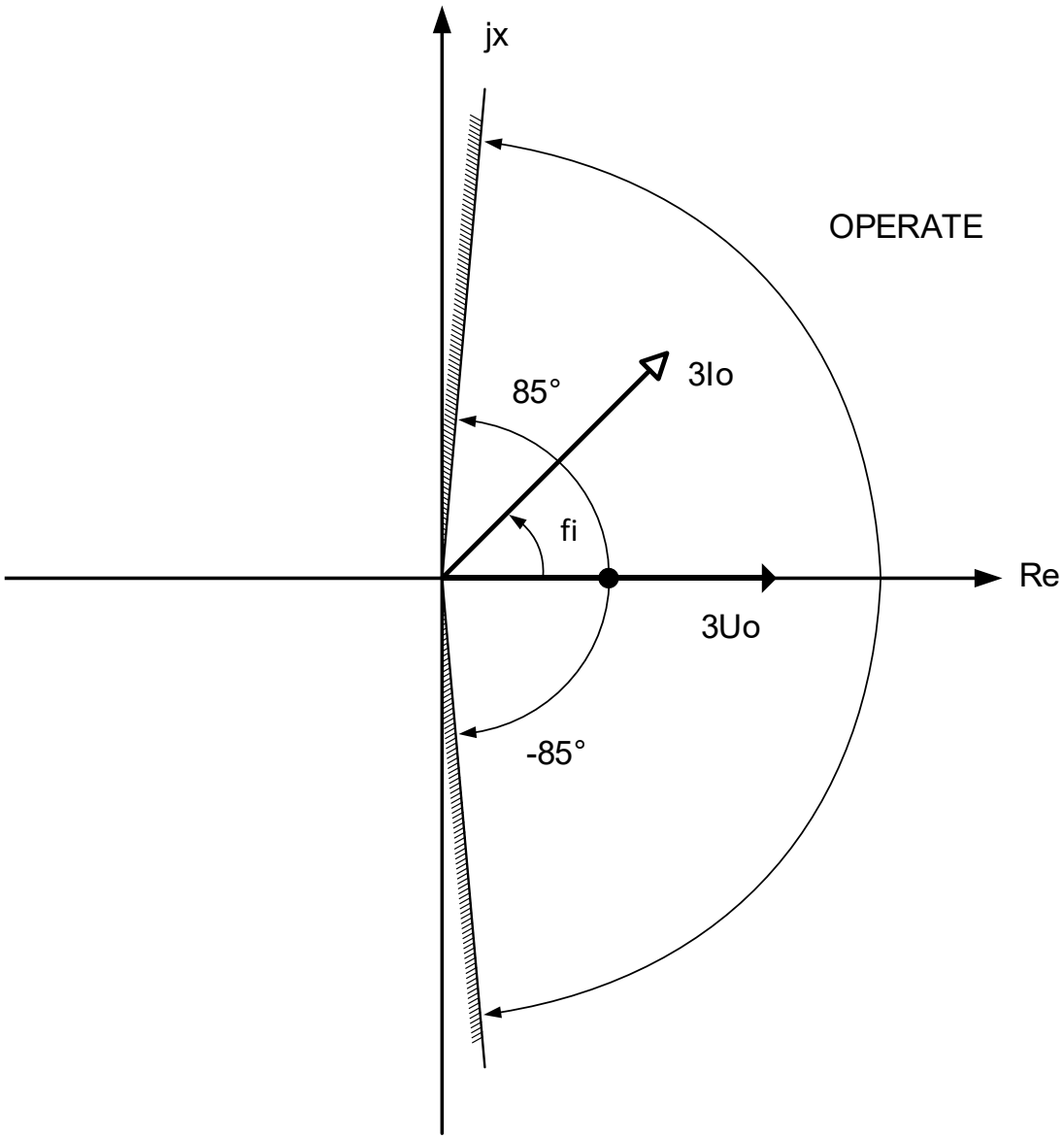
- The magnitude of the residual current is above the setting value:

  |3Io| > “Start current”

- The magnitude of the residual voltage is above the setting value:

  |3Uo| >”Min Res Voltage”

3.1.3 Setting: Direction = Forward-I*cos(fi)



For the operation the residual current (3Io) must be within the “OPERATE” area.

Additional conditions for operation:

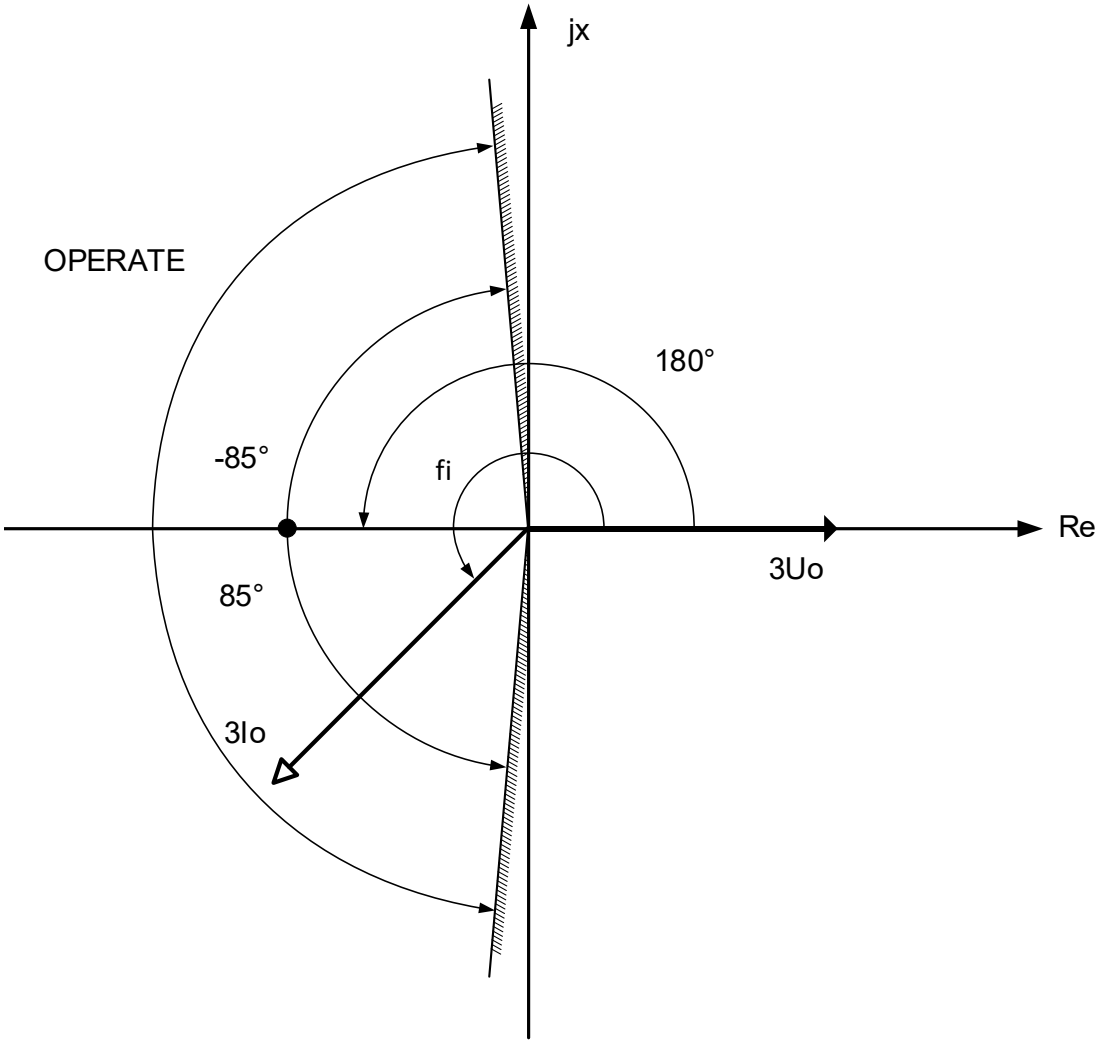
- The magnitude of the residual current projected to the real axis is above the setting value:

  |3Io|*cos(fi) > “Start current”

- The magnitude of the residual voltage is above the setting value:

  |3Uo| >”Min Res Voltage”

3.1.4 Setting: Direction = Backward-I*cos(fi)



For the operation the residual current (3Io) must be within the “OPERATE” area.

Additional conditions for operation:

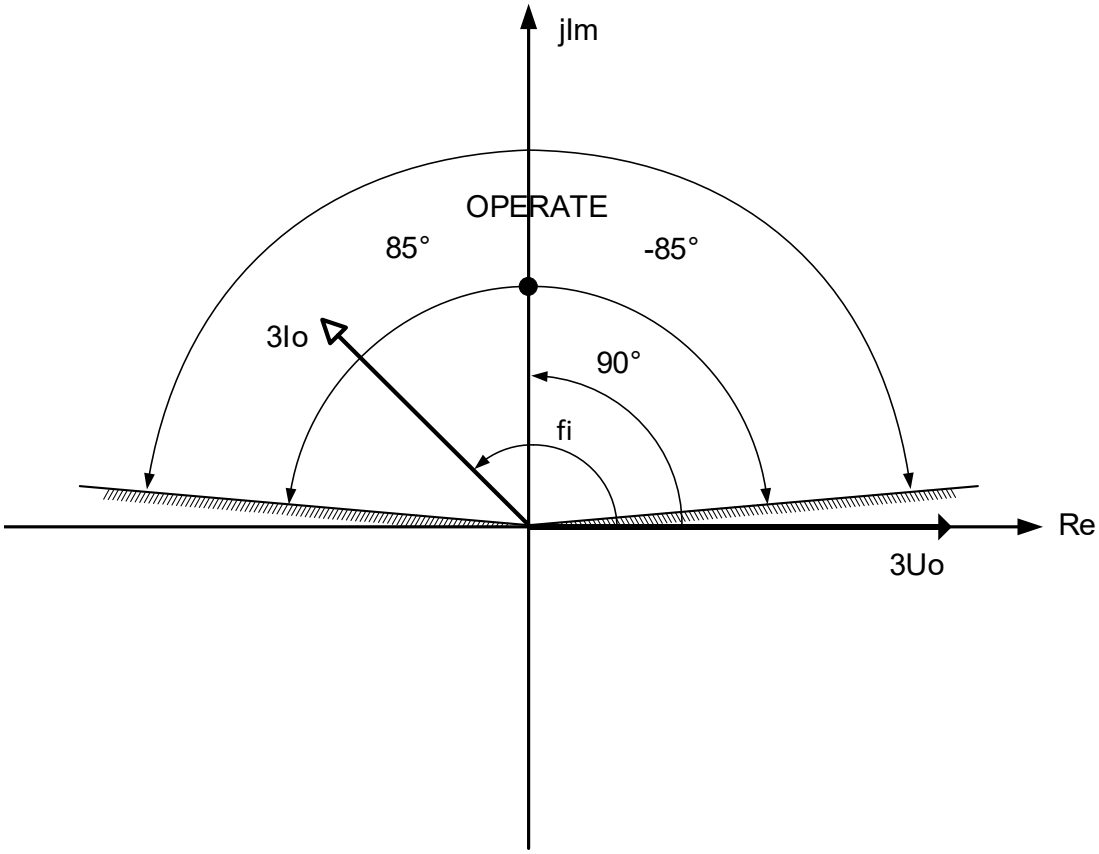
- The magnitude of the residual current projected to the negative real axis is above the setting value:

  |3Io|*cos(fi-180) > “Start current”

- The magnitude of the residual voltage is above the setting value:

  |3Uo| >”Min Res Voltage”

3.1.5 Setting: Direction = Forward-I*sin(fi)



For the operation the residual current (3Io) must be within the “OPERATE” area.

Additional conditions for operation:

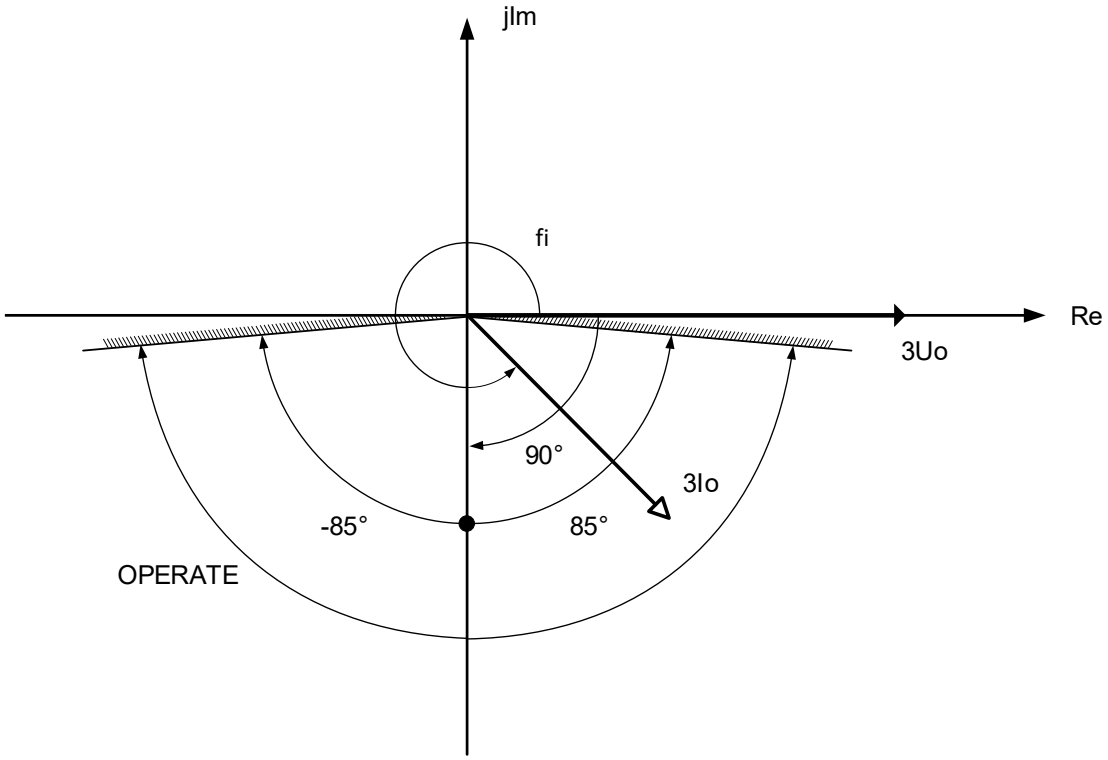
- The magnitude of the residual current projected to the imaginary axis is above the setting value:

  |3Io|*sin(fi) > “Start current”

- The magnitude of the residual voltage is above the setting value:

  |3Uo| >”Min Res Voltage”

3.1.6 Setting: Direction = Backward-I*sin(fi)



For the operation the residual current (3Io) must be within the “OPERATE” area.

Additional conditions for operation:

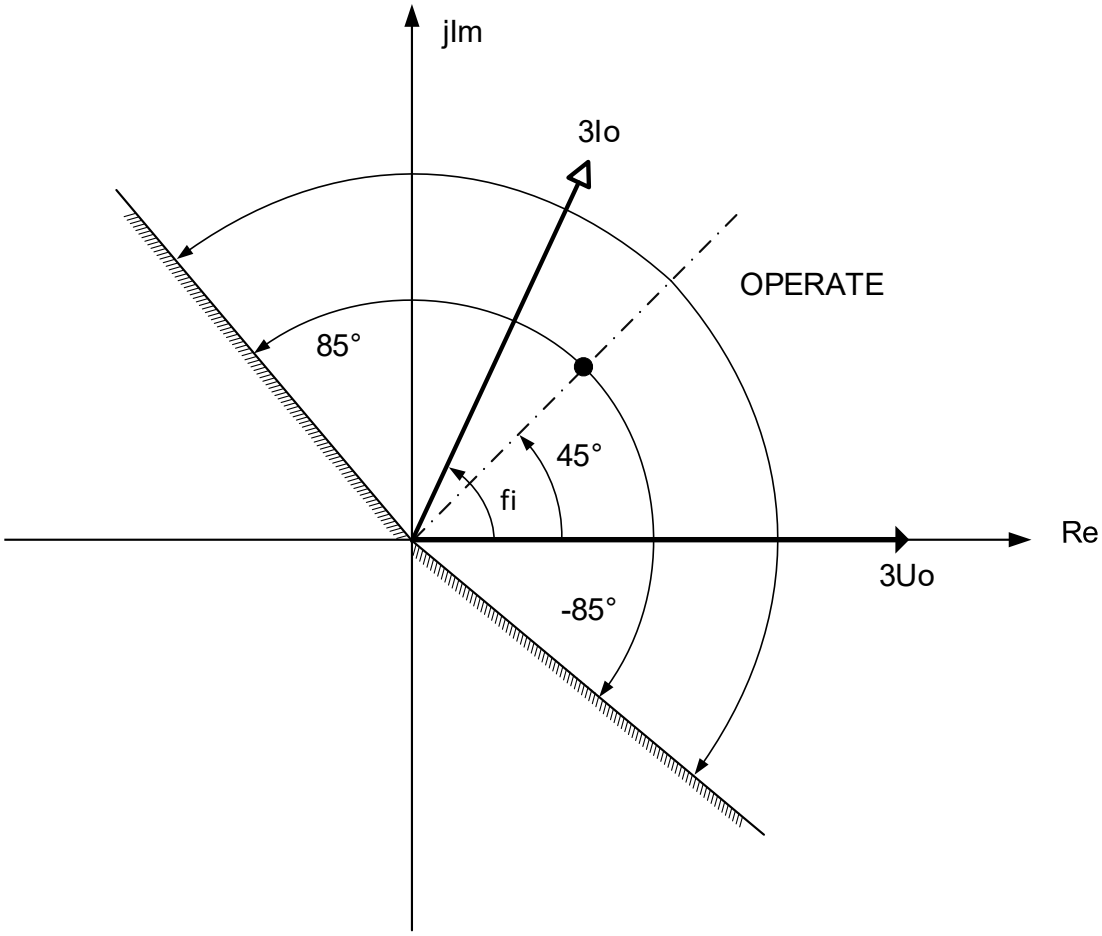
- The magnitude of the residual current projected to the negative imaginary axis is above the setting value:

  |3Io|*sin(fi-180) > “Start current”

- The magnitude of the residual voltage is above the setting value:

  |3Uo| >”Min Res Voltage”

3.1.7 Setting: Direction = Forward-I*sin(fi+45)



For the operation the residual current (3Io) must be within the “OPERATE” area.

Additional conditions for operation:

- The magnitude of the residual current projected to the line of the characteristic angle (45°) is above the setting value:

$$|3Io|*\cos(fi-45°) > \text{“Start current”}$$

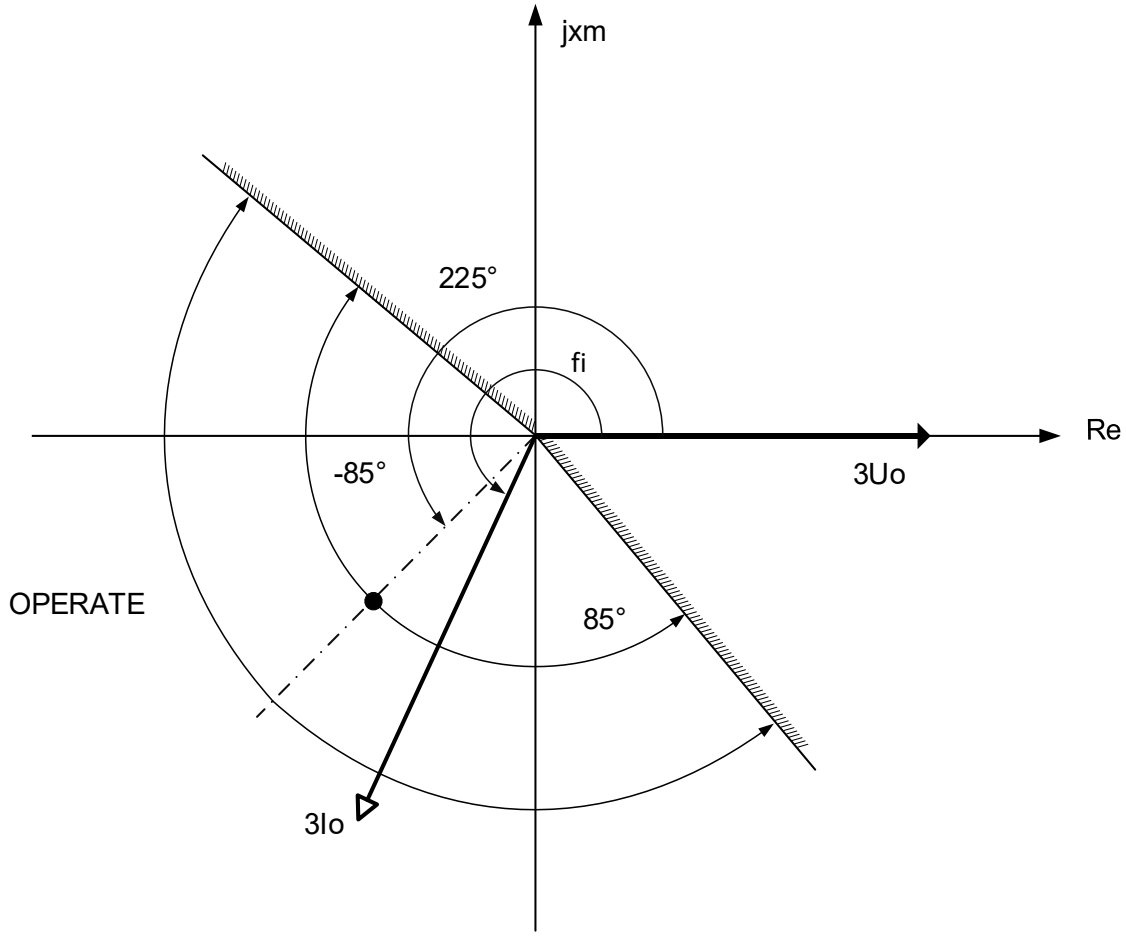
- The magnitude of the residual voltage is above the setting value:

$$|3Uo| > \text{”Min Res Voltage”}$$

Note: Because of the characteristic angle is 45°,

$$\cos(fi-45°) = \sin(fi+45°)$$

3.1.8 Setting: Direction = Backward-I*sin(fi+45)



For the operation the residual current (3Io) must be within the “OPERATE” area.

Additional conditions for operation:

- The magnitude of the residual current projected to the line of the characteristic angle (225°) is above the setting value:

  |3Io|*cos(fi-225°) > “Start current”

- The magnitude of the residual voltage is above the setting value:

  |3Uo| >”Min Res Voltage”

Note: Because of the characteristic angle is 225°,

$$\cos(fi-225°) = \sin(fi+45°)|_{BW}$$