POWERFACTORY

PowerFactory 2021

Technical Reference

Polarizing unit

RelZpol, TypZpol

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POWER SYSTEM SOLUTIONS

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1 General Description

The *Polarizing* block is an element which has been conceived to be used in the distance protection models; it provides the *polarized* current and voltage signals to the distance protection zones for use in evaluating the trip rules. The block receives voltage and current signals as inputs and provides the following as outputs:

- The *operating* currents.
- The *polarizing* voltages.
- The *operating* voltages.

1.1 *Distance Polarising Type*

The *Polarizing* element configuration is made in the *Distance Polarising Type* dialogue (TypZpol class). The dialogue contains three tab pages: *Basic Data*,*Voltage Memory* , and *RMD*.

1.1.1 Basic Data

Polarizing unit The types of polarizing units is set by the *Polarisation unit* combo box (“itype” parameter). The type of polarizing unit affects which kind of polarizing signals are processed. The polarizing types are:

- *Phase-Phase/Phase-Earth* (both the phase-phase loop and the phase-earth polarizing signals are calculated).
- *Phase-Earth* (only the phase-earth loop polarizing signals are calculated).
- *Phase-Phase* (only the phase-phase loop polarizing signals are calculated).
- *Earth fault* switching(the phase-phase or the phase-earth polarizing signals are calculated accordingly with the detected fault type).
- *Fault type switching* (the polarizing signals are calculated only for the loop affected by the fault, it works like a single phase polarizing block).
- *Single phase*.

Polarizing method The methods used for the polarizing signals calculation are set by the *Polarising Method* combo box (“ipol” parameter) and by the *2nd Polarising Method* combo box (“ipol2” parameter).
The *polarizing* methods are:

- *Self*
- *Cross (Quadrature)*
- *Cross (Quad L-L)*
- *Positive Sequence*
- *Self, ground compensated*

- *User Configurable* (the *polarizing* method is configurable in the Polarizing relay dialogue ("RelZpol" class))

The logic combining the two methods is set by the *Polarising Equation* combo box ("ipoleq" parameter). Two logics are available:

- *additive*
- *relative*

When the *additive* logic has been selected the values calculated by the two polarizing method are combined using the following equation:
$value = "method1Value" + "method2Value" * multiplier$

The *relative* logic uses the following equation:
$value = "method1Value" * (1 - multiplier) + "method2Value" * multiplier$

The range of the multiplier applied to the values calculated by the polarizing method is set in the *Factor Kp* edit box ("rpol2k" parameter) which is visible only when the selected item in the *2nd Polarising Method* combo box is not *None*.

When the *Positive Sequence Polarizing method* has been selected, the "Remove faulted loops" ("iremfloop" parameter) checkbox is displayed on the left of the *Polarising Method* combo box. When it's set, the positive sequence voltage is calculated without considering the voltage of the loops which have been declared as faulted.

Seconday Ohm The *Secondary ohm* combo box allows to configure the representation of the calculated impedances. When the *Sec.Ohm*In* option is selected, the calculated impedances are multiplied by the nominal current of the measurement unit. An impedance value is thereby obtained that is independent from the CT secondary side (and the relay) nominal current and always equal to the impedance calculated with a CT with secondary rated current equal to 1 A. In addition, all output current signals are divided by the nominal current of the measurement unit.

Earth Factor The *polarizing* block supports different representations of the earth fault compensation factor. This factor is usually used by the distance protection to allow the user to insert the same trip impedance values for the phase-phase faults and the phase-ground faults.
The *polarizing* block can represent the factor as a complex number or as a *decoupled values* (for the Siemens devices). A special compensation factor representation is provided to support the ASEA RAZFE relay.
Three different kinds of the *complex number* earth fault compensation factor can be used. The selection of the active representation of the compensation factor is made using the "Earth factor representation" combo box ("iEFactRep" parameter) . The K0 factor module can be one of the following forms:

- $K_0 = (Z_0 - Z_1)/3Z_1$
- $K_0 = (Z_0 - Z_1)/Z_1$
- $K_0 = Z_0/Z_1$
- RAZFE
- Decoupled

- Complex Number or Decoupled

The “decoupled values” earth fault compensation factor equations are:

$$R_E/R_L = \frac{R_0 - R_1}{3 \cdot R_1}$$

$$X_E/X_L = \frac{X_0 - X_1}{3 \cdot X_1}$$

When the *Complex Number or Decoupled* K0 representation has been selected the “Show as complex number” check box (“complexrepr” parameter) is displayed in the “Distance Polarizing Unit” dialogue and allows to select the desired representation.

The mutual earth factor is used to take care of the fault contribution from a parallel line. Also in this case a *Complex Number* and a *Decoupled Values* factor representation is available.

When the *User Configurable* polarizing method is set an additional combo box is displayed in the “Distance Polarizing Unit” relay dialogue.

Zone the *Zone* combobox allow to set at which distance protection zone(s) the polarizing element is connected. This value affects the impedances representation in the RX diagram (“Zone” combobox (“izones” parameter) of “R-XPlot Settings” (“SetDisplt” class)).

Impedance Signals When the *Has additional R,X signal* checkbox (“iRXsigs” parameter) is set the *polarizing* block calculates the impedance values; one between the following impedance calculation methods can be used setting the *R,X calculation method* combo box (“iRXCMethod” parameter):

- *Integral*.
- *Differential*.
- *Both* (an average value is calculated using the “Integral” and the “Differential” method results).
- *DFT*.
- *Load compensated DFT* (DFT taking care of the pre-fault load current)
- *Load compensated DFT* (Z1 only) (the load compensation is applied only to the zone 1 signals, the signals for the other zones are calculated using the “DFT” method)

1.1.2 Voltage Memory

The polarizing block implements a *voltage buffer* to model the protective devices with such a feature. In case of a close 3 phase short circuit the voltage drops to very small values and to guarantee a correct response of the protection algorithms (i.e. the directional algorithm) the voltage values previous stored inside the buffer are used. All the *voltage buffer* configuration and settings range are stored inside the *Voltage memory* tab page.

The *voltage buffer* can be enabled/disabled and its usage configured using the “Voltage Memory” combo box (“imem” parameter). One between the following items can be selected:

- *off*
- *Only for Polarizing Voltage Signals* (The *voltage buffer* is used only to calculate the polarizing voltages)
- *For all Voltage/Impedance Signals* (The *voltage buffer* is used to calculate the polarizing voltages and the impedance values)

When the selected item is *off* all other controls in the tab page are hidden.

The memory buffer can be configured using the *Memory Type* (“imemtype” parameter); three options are available:

- *Activated by Threshold*.
- *Always on (delay memory)*
- *Activated by Signal*

When the *Activated by Threshold* option is selected the *voltage buffer* provides the stored values when the voltage input values drop below the “Memory use threshold” voltage threshold (“memuse”parameter). It stops to provide the data if the voltage input values become greater than the “Memory use reset threshold” voltage threshold (“memreset”).
When the *Always on (delay memory)* option is selected the *voltage buffer* always provides the values stored in the past at a time equal to the length of the buffer before the actual simulation time.
When the *Activated by Signal* option is selected the *voltage buffer* provides the stored values for the loop signals corresponding to the value of the “wloop” input signal. Please notice that the*Has additional R,X signal* checkbox (“iRXsigs” parameter) must be set.
The loop Ids are listed in table 1.1

The “Memory Time” settings (“Tmem” parameter)define the length of the buffer.

The “Circular memory” (“icircularmem”) combo box can be *Disabled* or *Enabled* or *User configurable*. When it is *User configurable* a check box is displayed inside the *Distance Polarizing Unit* relay dialogue (“RelZpol” class) and the user can configure the model behavior without modifying the type settings. If the “Circular buffer” feature is enabled and the buffer has provided all the stored values, it resets itself and starts again providing the first values in the buffer.

Table 1.1: loop id

Loop ID	**Loop**	**Loop ID**	**Loop**	**Loop ID**	**Loop**
0	None	10	AB & BC	20	B & C & BC
1	A	11	BC & CA	21	C & A & CA
2	B	12	CA & AB	22	A & B & C
3	C	13	A & AB	23	AB & BC & CA
4	AB	14	B & BC	24	AB & BC & CA &
5	BC	15	C & CA		A & B & C
6	CA	16	B & AB		
7	A & B	17	C & BC		
8	B & C	18	A & CA		
9	C & A	19	A & B & AB		

1.1.3 RMD

The *RMD* tab page allows to define the range of the zero sequence (“rCompAngle0” parameter) and of the negative sequence compensation angle (“rCompAngle2” parameter) which are used by the *Reactance Method* for the impedance calculation (see 1.4.5). The graphical controls are displayed only when the *RMD* item has been selected in the “R,X Calculation Method” (“iRXCmethod” parameter) in the *Basic Data* tab page.

1.2 *Distance Polarising Unit*

The user can change the block settings using the “Distance Polarizing Unit” dialogue (“RelZpokl” class). The dialogue consists of four tab pages: *Basic Data*, *Voltage memory*, *RMD*, and *Description*.

1.2.1 Basic data

The “Basic Data” tab page contains the block name, a link to the relevant starting type object, the graphical controls which allow to insert the *Earth Factor* and the *Mutual Earth Factor*. Both factors can be entered, depending up on the selected representation, as *Complex Numbers* or using the *Decoupled* representation.
If in the “Distance Polarising Type” dialogue the *Earth Factor Representation* is *Complex Number or Decoupled* the “Show as complex number” check box is shown and it’s possible to switch between the two representations. The entered values will be automatically converted in the other representation using the “Line Angle” (“lineangle” parameter) value.
The *Assume Re/Rl* and the *Assume Xe/Xl* buttons allow to calculate automatically the *Decoupled* representation *Earth Factor* values getting the parameters of the line connected to the cubicle where the relay is located. Similar calculation is performed by the *Assume k0* button when the *Complex Numbers* representation is active.

1.2.2 Voltage memory

If the *Voltage Buffer* is disabled no graphical control is displayed in the *Voltage memory* tab page. If the *Voltage Buffer* is enabled and the *Activated by Threshold* “Memory Type” has been selected the following graphical controls are displayed

- *Memory Time*: voltage buffer length in cycle
- *Memory use threshold*: the voltage level below which the Voltage Buffer is activated
- *Memory use reset threshold* the voltage level above which the Voltage Buffer is deactivated after been activated

The “Circular Memory” (“iencircmem” parameter) is displayed only if in the “Circular Buffer” combo box (“icircularmem” parameter) the *User Configurable* option has been set.

1.2.3 RMD

The *RMD* tab page allows to define the zero sequence (“CompAngle0” parameter) and the negative sequence compensation angle (“CompAngle2” parameter) which are used by the *Reactance Method* for the impedance calculation (see 1.4.5). The graphical controls are displayed only when the *RMD* item has been selected in the “R,X Calculation Method” (“iRXCmethod” parameter) in the *Basic Data* tab page of the *Distance Polarising Type* dialogue(“TypZpol” class).

1.2.4 Description

The *Description* tab page can be used to insert some information to identify the polarizing element (both with a generic string and with an unique textual string similar to the *Foreign Key* approach used in the relational databases) and to identify the source of the data used to create it.

1.3 *The polarizing calculation*

The calculation of the polarizing voltages, operating current and voltages is affected by the selected polarizing type and polarizing method.

1.3.1 Phase-Phase/Phase-Earth, Phase-Phase, Phase-Earth and Earth Fault Switching type

The main difference between the *Phase-phase/Phase-Earth* type and the *Phase-Phase*, *Phase-Earth* and *Earth Fault Switching* types is that the *Phase-Phase/Phase-Earth* type is calculating both the phase and the ground operating and polarizing quantities (currents & voltages); the *Phase-Phase*, *Phase-Earth* and *Earth Fault Switching* types are calculating the phase polarizing quantities only when a phase fault has been detected and the ground polarizing quantities only when a ground fault has been detected. The *wearth* super visioning signal is providing the fault type info.

Phase operating currents :

The phase operating currents are the delta currents:

$$\begin{aligned} \underline{I}_{op_A} &= (\underline{I}_a - \underline{I}_b) \\ \underline{I}_{op_B} &= (\underline{I}_b - \underline{I}_c) \\ \underline{I}_{op_C} &= (\underline{I}_c - \underline{I}_a) \end{aligned} \tag{1}$$

when the *Sec.Ohm*In* option is selected the operating currents are divided by nominal current of the measurement unit.

Ground operating currents :

***Self, Ground compensated* polarizing method** The ground operating currents are calculated rotating the input phase current vector accordingly with the earth compensation factor angle (the compensation factor K0 is a vector).

$$\begin{aligned} \underline{I}_{gop_A} &= |\underline{I}_a| \cdot e^{\varphi_{I_a} - \varphi_{k_0}} \\ \underline{I}_{gop_B} &= |\underline{I}_b| \cdot e^{\varphi_{I_b} - \varphi_{k_0}} \\ \underline{I}_{gop_C} &= |\underline{I}_c| \cdot e^{\varphi_{I_c} - \varphi_{k_0}} \end{aligned} \tag{2}$$

when the *Sec.Ohm*In* option is selected the operating currents are divided by nominal current of the measurement unit.

Other polarizing methods The ground operating currents are calculated adding to the phase current the zero sequence current multiplied by the earth compensation factor. The zero sequence currents multiplied by the mutual earth compensation factor are added to the value previously calculated only if

$|\underline{I}_0| > "EarthCurrentratio" \cdot |\underline{I}_{0m}|$

$\underline{I}_{0m}$ is the mutual zero sequence current.
If the above condition is verified the ground operating currents are

$$\begin{aligned}\underline{I}_{gop_A} &= \underline{I}_a + \underline{k}_0 \cdot 3\underline{I}_0 + \underline{k}_{0m} \cdot 3\underline{I}_{0m} \\ \underline{I}_{gop_B} &= \underline{I}_b + \underline{k}_0 \cdot 3\underline{I}_0 + \underline{k}_{0m} \cdot 3\underline{I}_{0m} \\ \underline{I}_{gop_C} &= \underline{I}_c + \underline{k}_0 \cdot 3\underline{I}_0 + \underline{k}_{0m} \cdot 3\underline{I}_{0m}\end{aligned} \tag{3}$$

otherwise they are

$$\begin{aligned}\underline{I}_{gop_A} &= \underline{I}_a + \underline{k}_0 \cdot 3\underline{I}_0 \\ \underline{I}_{gop_B} &= \underline{I}_b + \underline{k}_0 \cdot 3\underline{I}_0 \\ \underline{I}_{gop_C} &= \underline{I}_c + \underline{k}_0 \cdot 3\underline{I}_0\end{aligned} \tag{4}$$

where
$k_0 = earthcompensationfactor$
and
$k_{0m} = mutualearthcompensationfactor$

when the *Sec.Ohm*In* option is selected the operating currents are divided by nominal current of the measurement unit.

Phase and ground operating voltages :

The phase operating voltages are the delta voltages:

$$\begin{aligned}\underline{U}_{op_A} &= \underline{U}_a - \underline{U}_b \\ \underline{U}_{op_B} &= \underline{U}_b - \underline{U}_c \\ \underline{U}_{op_B} &= \underline{U}_c - \underline{U}_a\end{aligned} \tag{5}$$

The ground operating voltages are the phase voltages:

$$\begin{aligned}\underline{U}_{op_A} &= \underline{U}_a \\ \underline{U}_{op_B} &= \underline{U}_b \\ \underline{U}_{op_C} &= \underline{U}_c\end{aligned} \tag{6}$$

Polarizing voltages :

***Self polarizing* method** :

The phase polarizing voltages are the delta voltages:

$$\begin{aligned}\underline{U}_{pol_A} &= \underline{U}_a - \underline{U}_b \\ \underline{U}_{pol_B} &= \underline{U}_b - \underline{U}_c \\ \underline{U}_{pol_C} &= \underline{U}_c - \underline{U}_a\end{aligned} \tag{7}$$

The ground polarizing voltages are the phase voltages:

$$\begin{aligned}\underline{U}_{gpol_A} &= \underline{U}_a \\ \underline{U}_{gpol_B} &= \underline{U}_b \\ \underline{U}_{gpol_C} &= \underline{U}_c\end{aligned} \tag{8}$$

Cross (Quadrature) polarizing method :

The phase polarizing voltages are:

$$\begin{aligned}\underline{U}_{pol_A} &= |\underline{U}_c| \cdot e^{\varphi_{U_c} - 90°} \; (\widehat{=}\, U_{ab}) \\ \underline{U}_{pol_B} &= |\underline{U}_a| \cdot e^{\varphi_{U_a} - 90°} \; (\widehat{=}\, U_{bc}) \\ \underline{U}_{pol_C} &= |\underline{U}_b| \cdot e^{\varphi_{U_b} - 90°} \; (\widehat{=}\, U_{ca})\end{aligned} \tag{9}$$

The ground polarizing voltages are:

$$\begin{aligned}\underline{U}_{gpol_A} &= |\underline{U}_b - \underline{U}_c| \cdot e^{\varphi_{U_b} - \varphi_{U_c} + 90°} \\ \underline{U}_{gpol_B} &= |\underline{U}_c - \underline{U}_a| \cdot e^{\varphi_{U_c} - \varphi_{U_a} + 90°} \\ \underline{U}_{gpol_C} &= |\underline{U}_a - \underline{U}_b| \cdot e^{\varphi_{U_a} - \varphi_{U_b} + 90°}\end{aligned} \tag{10}$$

Cross (Quad L-L) polarizing method :

The phase polarizing voltages are:

$$\begin{aligned}\underline{U}_{pol_A} &= |\underline{U}_{bc} - \underline{U}_{ca}| \cdot e^{\varphi_{U_{bc}} - \varphi_{U_{ca}} + 90°} \\ \underline{U}_{pol_B} &= |\underline{U}_{ca} - \underline{U}_{ab}| \cdot e^{\varphi_{U_{ca}} - \varphi_{U_{ab}} + 90°} \\ \underline{U}_{pol_C} &= |\underline{U}_{ab} - \underline{U}_{bc}| \cdot e^{\varphi_{U_{ab}} - \varphi_{U_{bc}} + 90°}\end{aligned} \tag{11}$$

where
$\underline{U}_{bc} = \underline{U}_b - \underline{U}_c, \quad \underline{U}_{ca} = \underline{U}_c - \underline{U}_a$ and $\underline{U}_{ab} = \underline{U}_a - \underline{U}_b$

The ground polarizing voltages are (like the cross(quadrature) polarizing method):

$$\begin{aligned}\underline{U}_{gpol_A} &= |\underline{U}_b - \underline{U}_c| \cdot e^{\varphi_{U_b} - \varphi_{U_c} + 90°} \\ \underline{U}_{gpol_B} &= |\underline{U}_c - \underline{U}_a| \cdot e^{\varphi_{U_c} - \varphi_{U_a} + 90°} \\ \underline{U}_{gpol_C} &= |\underline{U}_a - \underline{U}_b| \cdot e^{\varphi_{U_a} - \varphi_{U_b} + 90°}\end{aligned} \tag{12}$$

Positive Sequence polarizing method :

The phase polarizing voltages are:

$$\begin{aligned}\underline{U}_{pol_A} &= \underline{U}_1 \cdot (1.5 + j\sqrt{3}/2) \\ \underline{U}_{pol_B} &= \underline{U}_1 \cdot (0. - j\sqrt{3}) \\ \underline{U}_{pol_C} &= \underline{U}_1 \cdot (-1.5 + j\sqrt{3}/2)\end{aligned} \tag{13}$$

where
$\underline{U}_1$ is the positive sequence voltage calculated using the phase voltages

The ground polarizing voltages are:

$$
\begin{aligned}
\underline{U}_{pol_A} &= \underline{U}_1 \\
\underline{U}_{pol_B} &= \underline{U}_1 \cdot (-0.5 - j\sqrt{3}/2) \\
\underline{U}_{pol_C} &= \underline{U}_1 \cdot (-0.5 + j\sqrt{3}/2)
\end{aligned} \tag{14}
$$

where
$\underline{U}_1$ is the positive sequence voltage calculated using the phase voltages

***Self, ground compensated* polarizing method** :

The phase polarizing voltages are the delta voltages:

$$
\begin{aligned}
\underline{U}_{pol_A} &= \underline{U}_a - \underline{U}_b \\
\underline{U}_{pol_B} &= \underline{U}_b - \underline{U}_c \\
\underline{U}_{pol_C} &= \underline{U}_c - \underline{U}_a
\end{aligned} \tag{15}
$$

The ground polarizing voltages are:

$$
\begin{aligned}
U_{gpolr_A} &= Ur_A - Ir_A * k0r \\
U_{gpoli_A} &= Ui_A + Ii_A * k0i \\
U_{gpolr_B} &= Ur_B - Ir_B * k0r \\
U_{gpoli_B} &= Ui_B + Ii_B * k0i \\
U_{gpolr_C} &= Ur_C - Ir_C * k0r \\
U_{gpoli_C} &= Ui_C + Ii_C * k0i
\end{aligned} \tag{16}
$$

where:
$Ugpolr_A$ is the phase A polarizing voltage real part
$Ur_A$is the phase A input voltage real part
Ir_A is the phase A input current real part
$k0r$ is the earth compensation factor real part
$Ugpoli_A$ is the phase A polarizing voltage imaginary part
Ui_A is the phase A input voltage imaginary part
Ii_A is the phase A input current imaginary part
$k0i$ is the earth compensation factor imaginary part etc

1.3.2 Single Phase and Fault Type Switching

The operating and the polarizing quantities depend upon the detected fault type.

Operating current :

Table 1.2: Single Phase and Fault Type Switching Operating currents

Fault Type	**Operating Current**
3 Phases fault	$\underline{I}_{op} = (\underline{I}_a - \underline{I}_b)$
2 Phases fault(AB)	$\underline{I}_{op} = (\underline{I}_a - \underline{I}_b)$
2 Phases fault(BC)	$\underline{I}_{op} = (\underline{I}_b - \underline{I}_c)$
2 Phases fault(CA)	$\underline{I}_{op} = (\underline{I}_c - \underline{I}_a)$
1 Phase-ground fault (AE)	$\underline{I}_{op} = (\underline{I}_a + \underline{I}_{ecomp})$
1 Phase-ground fault (BE)	$\underline{I}_{op} = (\underline{I}_b + \underline{I}_{ecomp})$
1 Phase-ground fault (CE)	$\underline{I}_{op} = (\underline{I}_c + \underline{I}_{ecomp})$
2 Phases-ground fault (AB-E)	$\underline{I}_{op} = (\underline{I}_a + \underline{I}_{ecomp})$
2 Phases-ground fault (BC-E)	$\underline{I}_{op} = (\underline{I}_b + \underline{I}_{ecomp})$
2 Phases-ground fault (CA-E)	$\underline{I}_{op} = (\underline{I}_c + \underline{I}_{ecomp})$

when the *Sec.Ohm*In* option is selected the operating currents are divided by nominal current of the measurement unit.

Where
$I_{ecomp} = k0 * 3I_0 + k0m * 3 * I_{0mutual}$ if $|I_0| > "EarthCurrentratio" \cdot |I_{0mutual}|$
$I_{ecomp} = k0 * 3I_0$ if $|I_0| <= "EarthCurrentratio" \cdot |I_{0mutual}|$

Operating voltages :

Table 1.3: Single Phase and Fault Type Switching Operating voltages

Fault Type	Operating Voltage
3 Phases fault	$\underline{U}_{op} = \underline{U}_a - \underline{U}_b$
2 Phases fault(AB)	$\underline{U}_{op} = \underline{U}_a - \underline{U}_b$
2 Phases fault(BC)	$\underline{U}_{op} = \underline{U}_b - \underline{U}_c$
2 Phases fault(CA)	$\underline{U}_{op} = \underline{U}_c - \underline{U}_a$
1 Phase-ground fault (AE)	$\underline{U}_{op} = \underline{U}_a$
1 Phase-ground fault (BE)	$\underline{U}_{op} = \underline{U}_b$
1 Phase-ground fault (CE)	$\underline{U}_{op} = \underline{U}_c$
2 Phases-ground fault (AB-E)	$\underline{U}_{op} = \underline{U}_a$
2 Phases-ground fault (BC-E)	$\underline{U}_{op} = \underline{U}_b$
2 Phases-ground fault (CA-E)	$\underline{U}_{op} = \underline{U}_c$

Polarizing voltages :

***Self* and *Self, ground compensated* polarizing method** :

Table 1.4: Single Phase and Fault Type Switching *Self* and *Self, ground compensated* Polarizing voltages

Fault Type	Operating Current
3 Phases fault	$U_{pol} = U_a - U_b$
2 Phases fault(AB)	$U_{pol} = U_a - U_b$
2 Phases fault(BC)	$U_{pol} = U_b - U_c$
2 Phases fault(CA)	$U_{pol} = U_c - U_a$
1 Phase-ground fault (AE)	$U_{pol} = U_a$
1 Phase-ground fault (BE)	$U_{pol} = U_b$
1 Phase-ground fault (CE)	$U_{pol} = U_c$
2 Phases-ground fault (AB-E)	$U_{pol} = U_a$
2 Phases-ground fault (BC-E)	$U_{pol} = U_b$
2 Phases-ground fault (CA-E)	$U_{pol} = U_c$

***Cross (Quadrature)* polarizing method** :

Table 1.5: Single Phase and Fault Type Switching *Self* and *Cross (Quadrature)* Polarizing voltages

Fault Type	Operating Current
3 Phases fault	$\underline{U}_{pol} = \underline{U}_a - \underline{U}_b$
2 Phases fault(AB)	$\underline{U}_{pol} = \underline{U}_a - \underline{U}_b$
2 Phases fault(BC)	$\underline{U}_{pol} = \underline{U}_b - \underline{U}_c$
2 Phases fault(CA)	$\underline{U}_{pol} = \underline{U}_c - \underline{U}_a$
1 Phase-ground fault (AE)	$\underline{U}_{pol} = \lvert\underline{U}_b - \underline{U}_c\rvert \cdot e^{\varphi_{U_b} - \varphi_{U_c} + 90°}$
1 Phase-ground fault (BE)	$\underline{U}_{pol} = \lvert\underline{U}_c - \underline{U}_a\rvert \cdot e^{\varphi_{U_c} - \varphi_{U_a} + 90°}$
1 Phase-ground fault (CE)	$\underline{U}_{pol} = \lvert\underline{U}_a - \underline{U}_b\rvert \cdot e^{\varphi_{U_a} - \varphi_{U_b} + 90°}$
2 Phases-ground fault (AB-E)	$\underline{U}_{pol} = \lvert\underline{U}_b - \underline{U}_c\rvert \cdot e^{\varphi_{U_b} - \varphi_{U_c} + 90°}$
2 Phases-ground fault (BC-E)	$\underline{U}_{pol} = \lvert\underline{U}_c - \underline{U}_a\rvert \cdot e^{\varphi_{U_c} - \varphi_{U_a} + 90°}$
2 Phases-ground fault (CA-E)	$\underline{U}_{pol} = \lvert\underline{U}_a - \underline{U}_b\rvert \cdot e^{\varphi_{U_a} - \varphi_{U_b} + 90°}$

Cross (Quad L-L) **polarizing method** :

Table 1.6: Single Phase and Fault Type Switching *Self* and *Cross (Quad L-L)* Polarizing voltages

Fault Type	Operating Voltage
3 Phases fault	$\underline{U}_{pol} = \lvert\underline{U}_{bc} - \underline{U}_{ca}\rvert \cdot e^{\varphi U_{bc} - \varphi U_{ca} + 90°}$
2 Phases fault(AB)	$\underline{U}_{pol} = \lvert\underline{U}_{bc} - \underline{U}_{ca}\rvert \cdot e^{\varphi U_{bc} - \varphi U_{ca} + 90°}$
2 Phases fault(BC)	$\underline{U}_{pol} = \lvert\underline{U}_{ca} - \underline{U}_{ab}\rvert \cdot e^{\varphi U_{ca} - \varphi U_{ab} + 90°}$
2 Phases fault(CA)	$\underline{U}_{pol} = \lvert\underline{U}_{ab} - \underline{U}_{bc}\rvert \cdot e^{\varphi U_{ab} - \varphi U_{bc} + 90°}$
1 Phase-ground fault (AE)	$\underline{U}_{pol} = \lvert\underline{U}_{b} - \underline{U}_{c}\rvert \cdot e^{\varphi U_{b} - \varphi U_{c} + 90°}$
1 Phase-ground fault (BE)	$\underline{U}_{pol} = \lvert\underline{U}_{c} - \underline{U}_{a}\rvert \cdot e^{\varphi U_{c} - \varphi U_{a} + 90°}$
1 Phase-ground fault (CE)	$\underline{U}_{pol} = \lvert\underline{U}_{a} - \underline{U}_{b}\rvert \cdot e^{\varphi U_{a} - \varphi U_{b} + 90°}$
2 Phases-ground fault (AB-E)	$\underline{U}_{pol} = \lvert\underline{U}_{b} - \underline{U}_{c}\rvert \cdot e^{\varphi U_{b} - \varphi U_{c} + 90°}$
2 Phases-ground fault (BC-E)	$\underline{U}_{pol} = \lvert\underline{U}_{c} - \underline{U}_{a}\rvert \cdot e^{\varphi U_{c} - \varphi U_{a} + 90°}$
2 Phases-ground fault (CA-E)	$\underline{U}_{pol} = \lvert\underline{U}_{a} - \underline{U}_{b}\rvert \cdot e^{\varphi U_{a} - \varphi U_{b} + 90°}$

Positive Sequence **polarizing method** :

Table 1.7: Single Phase and Fault Type Switching *Self* and *Positive Sequence* Polarizing voltages

Fault Type	Operating Voltage
3 Phases fault	$\underline{U}_{pol} = \underline{U}_a - \underline{U}_b$
2 Phases fault(AB)	$\underline{U}_{pol} = \underline{U}_a - \underline{U}_b$
2 Phases fault(BC)	$\underline{U}_{pol} = \underline{U}_b - \underline{U}_c$
2 Phases fault(CA)	$\underline{U}_{pol} = \underline{U}_c - \underline{U}_a$
1 Phase-ground fault (AE)	$\underline{U}_{pol} = \underline{U}_1$
1 Phase-ground fault (BE)	$\underline{U}_{pol} = \underline{U}_b$
1 Phase-ground fault (CE)	$\underline{U}_{pol} = \underline{U}_c$
2 Phases-ground fault (AB-E)	$\underline{U}_{pol} = \underline{U}_1$
2 Phases-ground fault (BC-E)	$\underline{U}_{pol} = \underline{U}_b$
2 Phases-ground fault (CA-E)	$\underline{U}_{pol} = \underline{U}_c$

where
$\underline{U}_1$ is the positive sequence voltage calculated using the phase voltages.

1.4 *Impedance calculation algorithms*

The impedance calculation algorithms solve the line equation

$$u = L\frac{di}{dt} + Ri \tag{17}$$

to find the R and $X(=\omega L)$ values used by the distance elements. They are used only for the EMT simulation.

The following types of Z calculation are available:

- Integral
- Differential
- Both (Integral and differential)
- DFT
- RMD (Reactance method)

1.4.1 Integral

The *Integral method* solves (1) using 3 consecutive current sampled values and 3 consecutive voltage values.

The equations to solve are

$$\int_{t1}^{t2} u\,dt = L(i_2 - i_1) + R\int_{t1}^{t2} i\,dt \tag{18}$$

$$\int_{t0}^{t1} u\,dt = L(i_1 - i_0) + R\int_{t0}^{t1} i\,dt \tag{19}$$

Solving such equations we get:

$$L = \frac{i_{10}dt * u_{21}dt - i_{21}dt * u_{10}dt}{i_{10}dt * (i_2 - i_1) - i_{21}dt * (i_1 - i_0)} \tag{20}$$

$$R = \frac{u_{10}dt - L(i_1 - i_0)}{i_{10}dt} \tag{21}$$

with
$i_{10} = (i_1 - i_0)/2$
$i_{21} = (i_2 - i_1)/2$
$u_{10} = (u_1 - u_0)/2$
$u_{21} = (u_2 - u_1)/2$

1.4.2 Differential

The *Differential method* solves (1) using 3 consecutive current sampled values and 2 consecutive voltage values.

The equations to solve are

$$v_1 \Delta t = R i_1 \Delta t + L(i_1 - i_0) \tag{22}$$

$$v_2 \Delta t = R i_2 \Delta t + L(i_2 - i_1) \tag{23}$$

It leads to:

$$L = \frac{v_2 i_1 - v_1 i_2}{\Delta i_{21} i_1 - \Delta i_{10} i_2} \tag{24}$$

$$R = \frac{v_1 \Delta i_{21} - v_2 \Delta i_{10}}{\Delta i_{21} i_1 - \Delta i_{10} i_2} \tag{25}$$

with

$\Delta i_{10} = i_1 - i_0$
$\Delta i_{21} = i_2 - i_1$

1.4.3 Both

The *Both* method calculates the average value of the results coming from the *Integral* and the *Differential* method.

1.4.4 DFT

The *DFT* method uses the vectors coming from of a Discrete Fourier Filter (DFT) applied to the sampled values. The filter provides two orthogonal values for each voltage or current input. These values are related to the loop impedance according to the formulas:

$$Re(\underline{U}) = R \cdot Re(\underline{I}) + \frac{X}{\omega_0} \frac{\Delta Re(\underline{I})}{\Delta t} \tag{26}$$

$$Im(\underline{U}) = R \cdot Im(\underline{I}) + \frac{X}{\omega_0} \frac{\Delta Im(\underline{I})}{\Delta t} \tag{27}$$

with

$\omega_0 = 2\pi f_0$

Where:
Re represents the real part of an complex number.

Im represents the imaginary part of an complex number.
f_0 represents the rated system frequency

The algorithm calculates *Rm* measured resistance from the equation for the real value of the voltage and substitute it in the equation for the imaginary part. The equation for the *Xm* measured reactance can then be solved. The final result is equal to:

$$R_m = \frac{Im(\underline{U}) * \Delta Re(\underline{I}) - Re(\underline{U}) * \Delta Im(\underline{I})}{\Delta Re(\underline{I}) * Im(\underline{I}) - \Delta Im(\underline{I}) Re(\underline{I})} \tag{28}$$

$$X_m = \omega_0 \Delta t \frac{Re(\underline{U}) * Im(\underline{I}) - Im(\underline{U}) * Re(\underline{I})}{\Delta Re(\underline{I}) * Im(\underline{I}) - \Delta Im(\underline{I}) Re(\underline{I})} \tag{29}$$

1.4.5 RMD

This method based on the calculation of the line reactance at the fault position which is not affected by the fault resistance. It is highly insensitive to the load conditions and to the fault resistance and is offered as alternative impedance calculation method. The mathematical basis of the method are described in the Siemens 7SA8 relay manual and in some the technical conference papers available on line.

Implementation :

The Distance Reactance Method (RMD) has been implemented with the following features:

- ability to select the zero sequence or the negative sequence current as compensation current.
- separated compensations angles for zero sequence and the negative sequence current.

The following formulas have been implemented:

Phase-phase reactance calculation formula

$$X = \frac{Im\{\underline{V}_{BC}[\underline{I}_{comp} * e^{j\delta_{comp}}]^*\}}{Im\{\underline{Z}_L/|Z_L|(\underline{I}_B - \underline{I}_C)[\underline{I}_{comp} * e^{j\delta_{comp}}]^*\}} sin\phi \tag{30}$$

where

$\underline{I}_{comp} = (a - a^2) \cdot \underline{I}_2$ and $a = e^{j120}$

Phase-phase resistance calculation formula

$$\frac{R_F}{2} = \frac{Im\{\underline{V}_{BC}[\underline{Z}_L(\underline{I}_B - \underline{I}_C)]^*\}}{Im\{3\underline{I}_{comp}[\underline{Z}_L(\underline{I}_B - \underline{I}_C)]^*\}} \tag{31}$$

Phase-ground reactance calculation formula

$$X = \frac{Im\{\underline{V}_A[\underline{I}_{Subst} * e^{j\delta_{comp}}]^*\}}{Im\{\underline{Z}_L/|Z_L|(\underline{I}_A - \underline{k}_0\underline{I}_{Gnd})[\underline{I}_{Subst} * e^{j\delta_{comp}}]^*\}} sin\phi \tag{32}$$

Phase-ground resistance calculation formula

$$\frac{R_F}{2} = \frac{Im\{\underline{I}V_A[\underline{Z}_L(\underline{I}_A - \underline{k}_0\underline{I}_{Gnd})]^*\}}{Im\{\underline{I}_F[\underline{Z}_L(\underline{I}_A - \underline{k}_0\underline{I}_{Gnd})]^*\}} \tag{33}$$

3 Phase fault In case of a 3 phase three-pole fault the load decoupling with zero- and negative sequence components is not possible. In this case the superposition principle, in which the contribution of the fault current can be represented in the form of the so called *delta component*, is used:

$$I_F = \Delta I_1 \tag{34}$$

where ΔI_1 is the delta-component as difference between prefault and fault condition.

The full compensation quantity can be expressed as:

$$I_{Cmp(3Ph)} = \Delta\underline{I}_1 e^{j\delta_{Cmp,1}} \tag{35}$$

where $\delta_{Cmp,1}$ is the compensation angle for the positive sequence component.
Generally, this angle is equal to the negative sequence compensation angle $\delta_{comp,2}$.

The impedance calculation is based on following formula:

$$X_F = \frac{sin\phi \cdot Im[\underline{U}_1\underline{I}^*_{Cmp(3Ph)}]}{Im[e^{j\delta} \cdot \underline{I}_1\underline{I}^*_{Cmp(3Ph)}]} \tag{36}$$

$$R_F = \frac{Im[\underline{U}_1 \cdot \underline{Z}^*_1 \cdot \underline{I}^*_1]}{Im[\Delta I_1 \cdot \underline{Z}^*_1 \cdot \underline{I}^*_1]} \tag{37}$$

2 Integration in the relay scheme

The *Polarizing* type class name is *TypZpol*. The *Distance Polarizing Unit* dialogue class name is *RelZpol*. In the relay scheme the *Distance Polarizing* element gets the voltage and the current signals from the measurement element. The signal with the polarizing voltages, the operating current and voltages, and the impedances values are used by the polygonal or the mho trip zones and by the directional distance elements.

A complete connection scheme is showed here below.

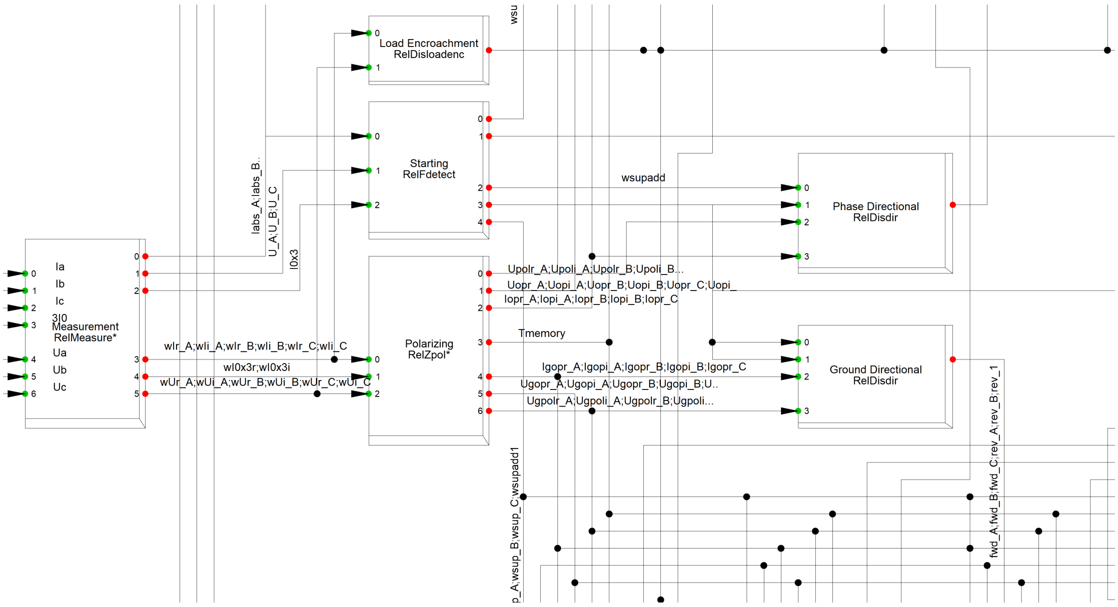

Figure 2.1: *DIgSILENT* Connection scheme of a *Polarizing* block “RelZpol” block.

A Parameter Definitions

A.1 Polarizing Type (TypZpol)

Table A.1: Input parameters of the Polarizing type (*TypZpol*)

Parameter	Description	Unit
loc_name	Name assigned by the user to the block type	Text
itype	The polarization unit type ("Phase-Phase/Phase-Earth", "Phase-Earth:Phase-Phase", "Earth Fault Switching", "Fault Type Switching", "Single-Phase")	Integer
ipol	The first polarizing method ("Self", "Cross (Quadrature)", "Cross (Quad L-L)", "Positive Sequence", "Self", "Ground compensated", "User Configurable")	Integer
ipol2	The second polarizing method ("Self", "Cross (Quadrature)", "Cross (Quad L-L)", "Positive Sequence", "Self", "Ground compensated")	Integer
iImpUnit	Impedance unit ("Secondary Ohm", "sec.Ohm", "sec.Ohm*In")	Integer
iremfloop	Flag to remove the faulted loops voltages from the polarizing voltage calculation(available only for the positive sequence polarizing method)	Integer
iEFactRep	Earth factor representation ("None", "Complex Number (Z0-Z1)/3Z1", "Complex Number (Z0-Z1)/Z1","Complex Number Z0/Z1","Decoupled", "Complex Number or Decoupled", "RAZFE"	Integer
ipoleq	Polarizing equation (*additive* or *relative*)	Integer
rpol2k	Range of the multiplier applied to the value calculated by the 2nd Polarizing method (and also to the value calculated by the 1st Polarizing method with the *Relative* Polarizing equation logic)	Text
izone	The zone at which the polarizing unit is associated ("All", "1", "2", "3", "4", "5", ">1", ">2", ">3")	Integer
iRXsigs	Flag to enable/disable the R,X signals. The R and X calculation is performed only if this flag is on.	Integer
iRXCMethod	R,X Calculation method:Integral:Differential:Both:DFT:Load compensated DFT:Load compensated DFT (Z1 only): RMD	Integer
rk0	Range of the module of earth fault compensation factor using the "Complex Number" representation	Text
rphik0	Range of the angle of the earth fault compensation factor using the "Complex Number" representation	Text
rlineangle	Range of the line angle (used by the models with the "Complex Number or Decoupled" representation)	Text
rReRl	Range of the real part of the earth fault compensation factor using the "Decoupled" representation	Text
rXeXl	Range of the imaginary part of the earth fault compensation factor using the "Decoupled" representation	Text
rk0m	Range of the module of mutual earth fault compensation factor using the "Complex Number" representation	Text
rphik0m	Range of the angle of the mutual earth fault compensation factor using the "Complex Number" representation	Text
rRmRl	Range of the real part of the mutual earth fault compensation factor using the "Decoupled" representation	Text
rXmXl	Range of the imaginary part of the mutual earth fault compensation factor using the "Decoupled" representation	Text
rPcompRatio	Earth current ratio	Text
iPcompDef	Earth current ratio unit (sec.Ampres , pu)	Integer
imem	Flag to enable/disable the voltage memory and to configure its usage ("Only for Polarizing Voltage Signals" or "For all Voltage/Impedance Signals")	Integer
imemtype	Memory Type (*Activated by Threshold*, *Always on (delay memory)*, *Activated by Signal*)	Integer
rmemuse	Range of the maximum voltage value enabling the use of the voltage values stored in the memory	Text
rmemreset	Range of the minimum voltage value disabling the use of the voltage values stored in the memory	Text
rtmem	Range of the memory length	Text
icircularmem	Flag to enable/disable/ make configurable in the RelZpol dialogue the circular memory ("Disabled", "Enabled", "UserConfigurable")	Integer
rCompAngle0	Range of the compensation angle for the zero sequence current (RMD impedance calculation algorithm)	Text
rCompAngle2	Range of the compensation angle for the negative sequence current (RMD impedance calculation algorithm)	Text

A.2 Polarizing Element (RelZpol)

Table A.2: Input parameters of the Polarizing element (*RelZpol*))

Parameter	Description	Unit
loc_name	Name assigned to the user to the block element	Text
typ_id	Pointer to the relevant TypZpol object	Pointer
outserv	Flag to put out of service the block	Integer (Y/N)
k0	Module of earth fault compensation factor using the *Complex Number* representation	Real number
phik0	Angle of the earth fault compensation factor using the *Complex Number* representation	Real number (degree)
lineangle	Line angle (used by the models with the *Complex Number or Decoupled* representation)	Real number (degree)
ReRl	Real part of the earth fault compensation factor using the *Decoupled* representation	Real number (sec.Ohm)
XeXl	Imaginary part of the earth fault compensation factor using the *Decoupled* representation	Real number (sec.Ohm)
k0m	Module of mutual earth fault compensation factor using the *Complex Number* representation	Real number
phik0m	Angle of the mutual earth fault compensation factor using the *Complex Number* representation	Real number (degree)
RmRl	Real part of the mutual earth fault compensation factor using the *Decoupled* representation	Real number (sec.Ohm)
XmXl	Imaginary part of the mutual earth fault compensation factor using the *Decoupled* representation	Real number (sec.Ohm)
PcompRatio	Earth current ratio	Real number (I/I0m)
PcompLtg	Earth current ratio	Real number (% line length)
pol2k	Multiplier applied to the value calculated by the 2nd Polarizing method (and also to the value calculated by the 1st Polarizing method with the *Relative* Polarizing equation logic)	Real number
imem	Flag to enable/disable the voltage memory	Integer (Y/N)
memuse	Maximum voltage value enabling the use of the voltage values stored in the memory	Real number (sec. V)
memreset	Minimum voltage value disabling the use of the voltage values stored in the memory	Real number (sec. V)
tmem	Memory length	Real number (cycles)
iencircmem	Flag to enable/disable the circular memory	Integer
CompAngle0	Compensation angle for the zero sequence current (RMD algorithm)	Real number
CompAngle2	Compensation angle for the negative sequence current (RMD algorithm)	Real number

B Signal Definitions

Table B.1: Input/output signals of the Polarizing element *“Phase-Phase”*, *“Phase-Earth”*, *“Earth fault”* type (*CalZpol3p*)

Name	Description	Unit	Type	Model
wIr_A	Phase A current real part	Secondary Amperes	IN	Any
wIi_A	Phase A current imaginary part	Secondary Amperes	IN	Any
wIr_B	Phase B current real part	Secondary Amperes	IN	Any
wIi_B	Phase B current imaginary part	Secondary Amperes	IN	Any
wIr_C	Phase C current real part	Secondary Amperes	IN	Any
wIi_C	Phase C current imaginary part	Secondary Amperes	IN	Any
wI0x3r	Zero sequence current real part	Secondary Amperes	IN	Any
wI0x3i	Zero sequence current imaginary part	Secondary Amperes	IN	Any
wI0mx3r	Mutual zero sequence current real part	Secondary Amperes	IN	Any
wI0mx3i	Mutual zero sequence current imaginary part	Secondary Amperes	IN	Any
wUr_A	Phase A voltage real part	Secondary Volts	IN	Any
wUi_A	Phase A voltage imaginary part	Secondary Volts	IN	Any
wUr_B	Phase B voltage real part	Secondary Volts	IN	Any
wUi_B	Phase B voltage imaginary part	Secondary Volts	IN	Any
wUr_C	Phase C voltage real part	Secondary Volts	IN	Any
wUi_C	Phase C voltage imaginary part	Secondary Volts	IN	Any
wearth	Supervision earth current	Seconds or Y/N (simulation)	IN	Any
Iopr_A	Operation current AB real part	Secondary Amperes	OUT	Any
Iopi_A	Operation current AB imaginary part	Secondary Amperes	OUT	Any
Iopr_B	Operation current BC real part	Secondary Amperes	OUT	Any
Iopi_B	Operation current BC imaginary part	Secondary Amperes	OUT	Any
Iopr_C	Operation current CA real part	Secondary Amperes	OUT	Any
Iopi_C	Operation current CA imaginary part	Secondary Amperes	OUT	Any
Uopr_A	Operation voltage AB real part	Secondary Volts	OUT	Any
Uopi_A	Operation voltage AB imaginary part	Secondary Volts	OUT	Any
Uopr_B	Operation voltage BC real part	Secondary Volts	OUT	Any
Uopi_B	Operation voltage BC imaginary part	Secondary Volts	OUT	Any
Uopr_C	Operation voltage CA real part	Secondary Volts	OUT	Any
Uopi_C	Operation voltage CA imaginary part	Secondary Volts	OUT	Any
Upolr_A	Polarizing voltage AB real part	Secondary Volts	OUT	Any
Upoli_A	Polarizing voltage AB imaginary part	Secondary Volts	OUT	Any
Upolr_B	Polarizing voltage BC real part	Secondary Volts	OUT	Any
Upoli_B	Polarizing voltage BC imaginary part	Secondary Volts	OUT	Any
Upolr_C	Polarizing voltage CA real part	Secondary Volts	OUT	Any

Table B.2: Input/output signals of the Polarizing element *“Phase-Phase /Phase-Earth”* type (*CalZpol*)

Name	Description	Unit	Type	Model
wIr_A	Loop AE current real part	Secondary Amperes	IN	Any
wIi_A	Loop AE current imaginary part	Secondary Amperes	IN	Any
wIr_B	Loop BE current real part	Secondary Amperes	IN	Any
wIi_B	Loop BE current imaginary part	Secondary Amperes	IN	Any
wIr_C	Loop CE current real part	Secondary Amperes	IN	Any
wIi_C	Loop CE current imaginary part	Secondary Amperes	IN	Any
wIIr_A	Loop AB delta current real part	Secondary Amperes	IN	Any
wIIi_A	Loop AB delta current imaginary part	Secondary Amperes	IN	Any
wIIr_B	Loop BC delta current real part	Secondary Amperes	IN	Any
wIIi_B	Loop BC delta current imaginary part	Secondary Amperes	IN	Any
wIIr_C	Loop CA delta current real part	Secondary Amperes	IN	Any
wIIi_C	Loop CA delta current imaginary part	Secondary Amperes	IN	Any
wI0x3r	Zero sequence current real part	Secondary Amperes	IN	Any
wI0x3i	Zero sequence current imaginary part	Secondary Amperes	IN	Any
wI0mx3r	Mutual zero sequence current real part	Secondary Amperes	IN	Any
wI0mx3i	Mutual zero sequence current imaginary part	Secondary Amperes	IN	Any
wUr_A	Loop AE voltage real part	Secondary Volts	IN	Any
wUi_A	Loop AE voltage imaginary part	Secondary Volts	IN	Any
wUr_B	Loop BE voltage real part	Secondary Volts	IN	Any
wUi_B	Loop BE voltage imaginary part	Secondary Volts	IN	Any
wUr_C	Loop CE voltage real part	Secondary Volts	IN	Any

Table B.2: Input/output signals of the Polarizing element *“Phase-Phase /Phase-Earth”* type (*CalZpol*)

Name	Description	Unit	Type	Model
wUi_C	Loop CE voltage imaginary part	Secondary Volts	IN	Any
wUlr_A	Loop AB delta voltage real part	Secondary Volts	IN	Any
wUli_A	Loop AB delta voltage imaginary part	Secondary Volts	IN	Any
wUlr_B	Loop BC delta voltage real part	Secondary Volts	IN	Any
wUli_B	Loop BC delta voltage imaginary part	Secondary Volts	IN	Any
wUlr_C	Loop CA delta voltage real part	Secondary Volts	IN	Any
wUli_C	Loop CA delta voltage imaginary part	Secondary Volts	IN	Any
wearth	Supervision earth current	Seconds or Y/N (simulation)	IN	Any
wclock	Clock signal (for synchronization with the measurement element)	IN	EMT only	
Iopr_A	Loop AB operation current real part	Secondary Amperes	OUT	Any
Iopi_A	Loop AB operation current imaginary part	Secondary Amperes	OUT	Any
Iopr_B	Loop BC operation current real part	Secondary Amperes	OUT	Any
Iopi_B	Loop BC operation current imaginary part	Secondary Amperes	OUT	Any
Iopr_C	Loop CA operation current real part	Secondary Amperes	OUT	Any
Iopi_C	Loop CA operation current imaginary part	Secondary Amperes	OUT	Any
Igopr_A	Loop AE operation current real part	Secondary Amperes	OUT	Any
Igopi_A	Loop AE operation current imaginary part	Secondary Amperes	OUT	Any
Igopr_B	Loop BE operation current real part	Secondary Amperes	OUT	Any
Igopi_B	Loop BE operation current imaginary part	Secondary Amperes	OUT	Any
Igopr_C	Loop CE operation current real part	Secondary Amperes	OUT	Any
Igopi_C	Loop CE operation current imaginary part	Secondary Amperes	OUT	Any
Uopr_A	Loop AB operation voltage real part	Secondary Volts	OUT	Any
Uopi_A	Lloop AB operation voltage imaginary part	Secondary Volts	OUT	Any
Uopr_B	Loop BC operation voltage real part	Secondary Volts	OUT	Any
Uopi_B	Loop BC operation voltage imaginary part	Secondary Volts	OUT	Any
Uopr_C	Loop CA operation voltage real part	Secondary Volts	OUT	Any
Uopi_C	Loop CA operation voltage imaginary part	Secondary Volts	OUT	Any
Ugopr_A	Operation voltage loop AE real part	Secondary Volts	OUT	Any
Ugopi_A	Operation voltage loop AE imaginary part	Secondary Volts	OUT	Any
Ugopr_B	Operation voltage loop BE real part	Secondary Volts	OUT	Any
Ugopi_B	Operation voltage loop BE imaginary part	Secondary Volts	OUT	Any
Ugopr_C	Operation voltage loop CE real part	Secondary Volts	OUT	Any
Ugopi_C	Operation voltage loop CE imaginary part	Secondary Volts	OUT	Any
Upolr_A	Loop AB polarizing voltage real part	Secondary Volts	OUT	Any
Upoli_A	Loop AB polarizing voltage imaginary part	Secondary Volts	OUT	Any
Upolr_B	Loop BC polarizing voltage real part	Secondary Volts	OUT	Any
Upoli_B	Loop BC polarizing voltage imaginary part	Secondary Volts	OUT	Any
Upolr_C	Loop CA polarizing voltage real part	Secondary Volts	OUT	Any
Upoli_C	Loop CA polarizing voltage imaginary part	Secondary Volts	OUT	Any
Ugpolr_A	Loop AE polarizing voltage real part	Secondary Volts	OUT	Any
Ugpoli_A	Loop AE polarizing voltage imaginary part	Secondary Volts	OUT	Any
Ugpolr_B	Loop BE polarizing voltage real part	Secondary Volts	OUT	Any
Ugpoli_B	Loop BE polarizing voltage imaginary part	Secondary Volts	OUT	Any
Ugpolr_C	Loop CE polarizing voltage real part	Secondary Volts	OUT	Any
Ugpoli_C	Loop CE polarizing voltage imaginary part	Secondary Volts	OUT	Any
Iop_A	Loop AB operation current RMS value	Secondary Amperes	OUT	Any
Iop_B	Loop BC operation current RMS value	Secondary Amperes	OUT	Any
Iop_C	Loop CA operation current RMS value	Secondary Amperes	OUT	Any
Igop_A	Loop AE operation current RMS value	Secondary Amperes	OUT	Any
Igop_B	Loop BE operation current RMS value	Secondary Amperes	OUT	Any
Igop_C	Loop CE operation current RMS value	Secondary Amperes	OUT	Any
Upol_A	Loop AB polarizing voltage RMS value	Secondary Volts	OUT	Any
Upol_B	Loop BC polarizing voltage RMS value	Secondary Volts	OUT	Any
Upol_C	Loop CA polarizing voltage RMS value	Secondary Volts	OUT	Any
Ugpol_A	Loop AE polarizing voltage RMS value	Secondary Volts	OUT	Any
Ugpol_B	Loop BE polarizing voltage RMS value	Secondary Volts	OUT	Any
Ugpol_C	Loop CE polarizing voltage RMS value	Secondary Volts	OUT	Any

When the “Has additional R,X signals” check box is checked inside the “Polarizing” block type dialogue (TypZpol class) the following signals are available:

Table B.3: Input/output signals of the Polarizing element *“Phase-Phase /Phase-Earth”* type with “Has additiona R,X signals” set (*CalZpolSie*)

Name	Description	Unit	Type	Model
wloop	Voltage Buffer active loops		IN	Any
R_A	Loop AE resistance	Secondary Ohms	OUT	Any
X_A	Loop AE reactance	Secondary Ohms	OUT	Any
R_B	Loop BE resistance	Secondary Ohms	OUT	Any
X_B	Loop BE reactance	Secondary Ohms	OUT	Any
R_C	Loop CE resistance	Secondary Ohms	OUT	Any
X_C	Loop CE reactance	Secondary Ohms	OUT	Any
Rl_A	Loop AB resistance	Secondary Ohms	OUT	Any
Xl_A	Loop AB reactance	Secondary Ohms	OUT	Any
Rl_B	Loop BC resistance	Secondary Ohms	OUT	Any
Xl_B	Loop BC reactance	Secondary Ohms	OUT	Any
Rl_C	Loop CA resistance	Secondary Ohms	OUT	Any
Xl_C	Loop CA reactance	Secondary Ohms	OUT	Any
R1_A	Zone 1 loop AE resistance	Secondary Ohms	OUT	Any
X1_A	Zone 1 loop AE reactance	Secondary Ohms	OUT	Any
R1_B	Zone 1 loop BE resistance	Secondary Ohms	OUT	Any
X1_B	Zone 1 loop BE reactance	Secondary Ohms	OUT	Any
R1_C	Zone 1 loop CE resistance	Secondary Ohms	OUT	Any
X1_C	Zone 1 loop CE reactance	Secondary Ohms	OUT	Any
Rl1_A	Zone 1 loop AB resistance	Secondary Ohms	OUT	Any
Xl1_A	Zone 1 loop AB reactance	Secondary Ohms	OUT	Any
Rl1_B	Zone 1 loop BC resistance	Secondary Ohms	OUT	Any
Xl1_B	Zone 1 loop BC reactance	Secondary Ohms	OUT	Any
Rl1_C	Zone 1 loop CA resistance	Secondary Ohms	OUT	Any
Xl1_C	Zone 1 loop CA reactance	Secondary Ohms	OUT	Any

Table B.4: Input/output signals of the Polarizing element *“Single phase”* and *“Fault Type switching”* type (*CalZpol1p*)

Name	Description	Unit	Type	Model
wIr_A	Phase A current real part	Secondary Amperes	IN	Any
wIi_A	Phase A crrent imaginary part	Secondary Amperes	IN	Any
wIr_B	Phase B current real part	Secondary Amperes	IN	Any
wIi_B	Phase B crrent imaginary part	Secondary Amperes	IN	Any
wIr_C	Phase C current real part	Secondary Amperes	IN	Any
wIi_C	Phase C crrent imaginary part	Secondary Amperes	IN	Any
wI0x3r	Zero sequence current real part	Secondary Amperes	IN	Any
wI0x3i	Zero sequence current imaginary part	Secondary Amperes	IN	Any
wI0mx3r	Mutual zero sequence current real part	Secondary Amperes	IN	Any
wI0mx3i	Mutual zero sequence current imaginary part	Secondary Amperes	IN	Any
wUr_A	Phase A voltage real part	Secondary Volts	IN	Any
wUi_A	Phase A voltage imaginary part	Secondary Volts	IN	Any
wUr_B	Phase B voltage real part	Secondary Volts	IN	Any
wUi_B	Phase B voltage imaginary part	Secondary Volts	IN	Any
wUr_C	Phase C voltage real part	Secondary Volts	IN	Any
wUi_C	Phase C voltage imaginary part	Secondary Volts	IN	Any
wearth	Supervision earth current	Seconds or Y/N (simulation)	IN	Any
Wsup_A	Phase A supervision signal	Seconds or 1/0 for the RMS/EMT simulations	IN	Any
Wsup_B	Phase B supervision signal	Seconds or 1/0 for the RMS/EMT simulations	IN	Any
Wsup_C	Phase C supervision signal	Seconds or 1/0 for the RMS/EMT simulations	IN	Any
Iopr	Operation current real part	Secondary Amperes	OUT	Any
Iopi	Operation current imaginary part	Secondary Amperes	OUT	Any
Uopr	Operation voltage real part	Secondary Volts	OUT	Any
Uopi	Operation voltage imaginary part	Secondary Volts	OUT	Any
Upolr	Polarizing voltage real part	Secondary Volts	OUT	Any
Upoli	Polarizing voltage imaginary part	Secondary Volts	OUT	Any

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