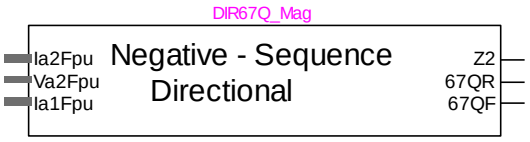
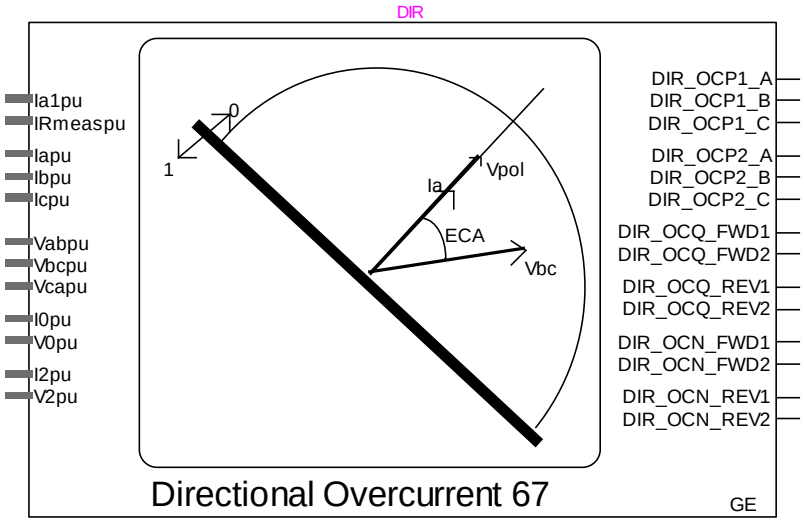
Protection: Directional functions





Henry Gras, Jean Mahseredjian, 8/16/2016 4:50:00 PM

1 Introduction

The inputs are:

1. the (fundamental frequency) phasors of the phase currents
2. the positive-sequence current
3. the zero-sequence current
4. the measured residual current (from the ground)
5. the negative sequence current.
6. the phasors of the line-to-line voltages
7. the zero and negative sequence voltages

Each current has 2 levels of settings.
Table 1-1 presents the signals compared to determine the direction.

Table 1-1 Signals compared to determine the direction for each element plus de comparator.

Phase/Sequence	Operating signal (Op)	Polarizing Signal Vpol	Comparator (C)
A	$\mathbf{I_A}$	$\mathbf{V_{BC}}\angle ECA$	90 deg
B	$\mathbf{I_B}$	$\mathbf{V_{CA}}\angle ECA$	90 deg
C	$\mathbf{I_C}$	$\mathbf{V_{AB}}\angle ECA$	90 deg
Neutral	$\mathbf{I_0}\angle ECA$ or $\mathbf{I_0}$	$-\mathbf{V_0}$ *or* $\mathbf{I_{R_{meas}}}$	User defined
Negative	$\mathbf{I_2}\angle ECA$	$-\mathbf{V_2}$	User defined
Negative	$\mathrm{Re}\left(\frac{\mathbf{V_2}}{\mathbf{I_2}}\angle -MTA\right)$	none	Reverse: Z2F Forward: Z2R

2 Input data of the Polarized Directional functions tab

- **Manufacturer**: In the current version, the directional.
- **Enable directional elements**: If the box is checked, the functions are included in the relay, else they are replaced by null function (empty).

2.1 Phase directional

Two levels of Phase current directional functions are available. The output of the function is 0 if the current is in forward and 1 if it is in reverse direction as illustrated in Figure 2-1. If the current is below 0.05 pu, this function is disabled. The functions are applied identically for the 3 phases. In each case the inputs are:

- **Level *i***: If this box is checked, the level *i* is enabled. If level 1 is unchecked, level 2 is unchecked automatically. The list of output function flags is shown near the level. These flags can be used in the tripping logic specified in the following tab.
- **ECA**: Directional element characteristic angle.
- **Blocked after $\mathbf{V_{MEM}}$ expired**: if checked, when Vpol drops below $\mathbf{V_{min}}$ (defined below) the phase directional element uses the polarized voltage Vpol (see Table 1-1) memorized 3 cycles before and during 1 s. After this delay, the output of the phase directional element is forced to 1 for a period of 1 cycle after the pickup voltage $\mathbf{V_{min}}$ is reached.
- $\mathbf{V_{min}}$: Pickup voltage to use the memorized polarization.

A top level view to the Phase current directional element logic is presented in Figure 2-2.

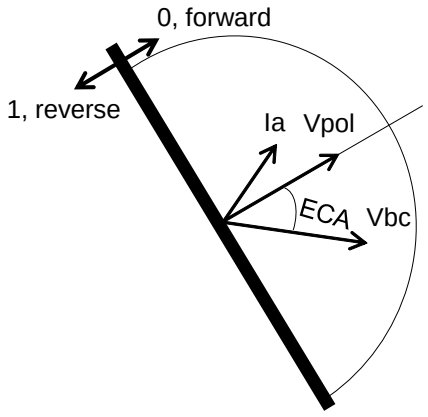


Figure 2-1 Phase current directional element.

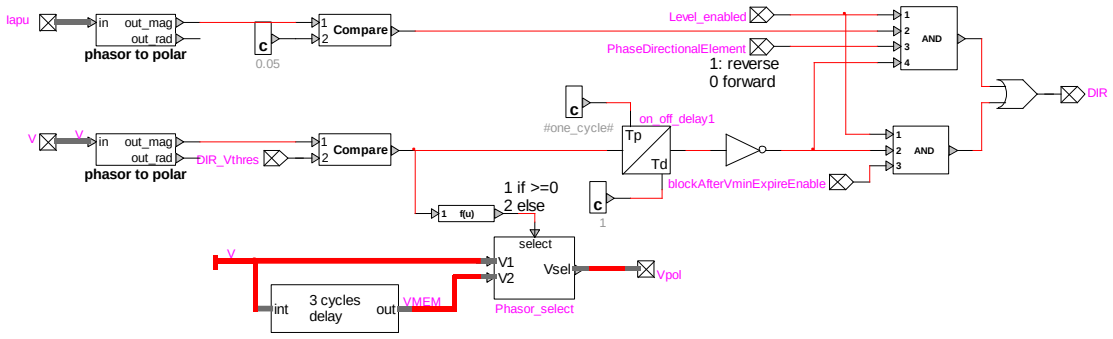


Figure 2-2 Phase current directional element logic.

2.2 Neutral directional

Two levels of neutral current directional functions are available. This element has its own overcurrent supervisors.

For each level, the inputs are:

- **Level *i***: If this box is checked, the level *i* is enabled. If level 1 is unchecked, level 2 is unchecked automatically. The list of output function flags is shown near the level. These flags can be used in the tripping logic specified in the following tab.
- **Polarizing mode**: If "Current" is selected, the polarizing signal (pol in Figure 2-3) is the measured residual current (IRmeaspu pin) from the ground CT. If "Voltage" is selected, the polarizing signal is the inverse of the negative sequence voltage. If "Dual" is selected, both previous options are enabled.
- **ECA**: Directional element characteristic angle.
- **Forward/Reverse limit angle**: Comparator angles between the operation and polarizing signals (see Table 1-1) for detected forward or reverse current.
- $\mathbf{I_{pkpForward/Reverse}}$: Minimum current for the element to be enabled. Below this value, the output of the function is 0.
- **K**: Positive restraint current coefficient. Used to restraint a small portion of the positive sequence current magnitude to the current that is compared to the pickup current $\mathbf{I_{pkpForward/Reverse}}$ for the instantaneous overcurrent supervisor for forward and reverse elements, respectively.
  For the neutral elements, the input current of the IOC is:

$$I_{op} = 3I_0 - KI_1 \quad (1)$$

  K is automatically set to zero if I_1<0.8pu.
  K is common for the two levels.

The Neutral element directional logic is presented in Figure 2-4. If a reverse directional current flow is determined for at least 1.25 cycles and the forward directional current flow is not determined during this time, a reset delay of 1.5 cycles is applied to the forward directional element.

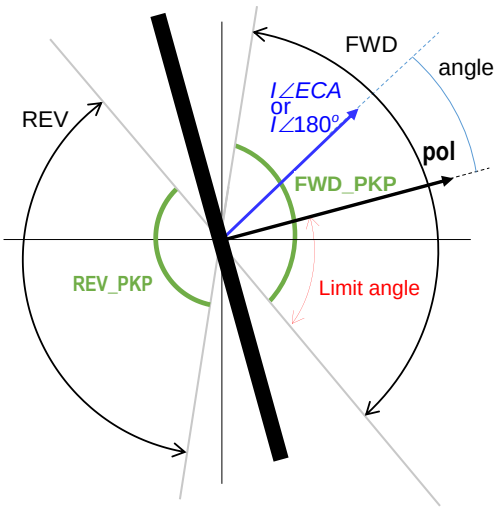


Figure 2-3 Neutral/Negative sequence current directional element.

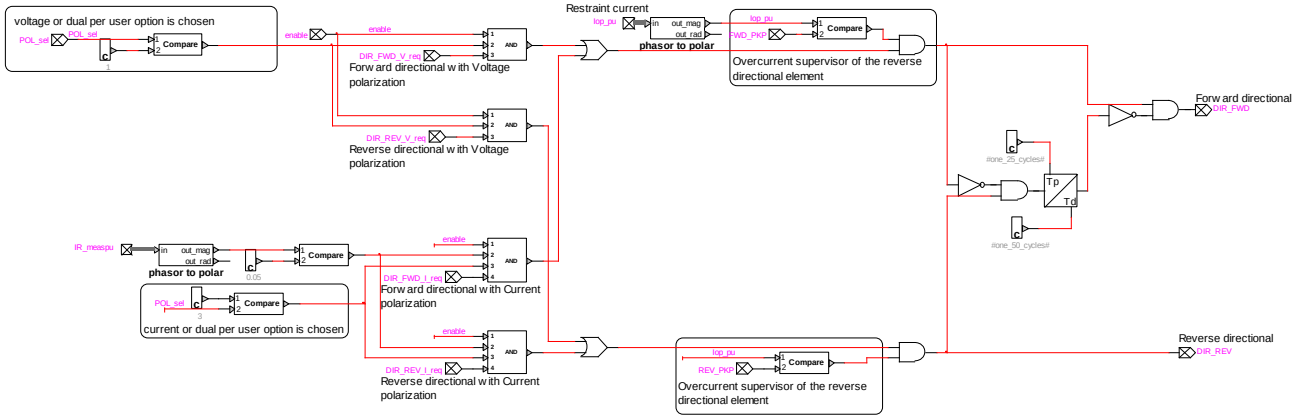


Figure 2-4 Neutral current directional element logic.

2.3 Negative Sequence directional

Two levels of negative-sequence current directional functions are available. For each level, the inputs are similar to the ones of the Neutral directional element. The top level view of this function's logic is shown in Figure 2-5.

This element has its own overcurrent supervisors.

- **Overcurrent supervision type**: Select the input of the overcurrent supervisor of the negative-sequence current directional element.

  If "Neg Sequence" is selected, the operational input current (operating quantity) of the IOC is:

$$I_{op} = 3I_0 - KI_1 \quad (2)$$

  If the "Zero Sequence" is chosen, the operational input current (operating quantity) of the IOC is:

$$I_{op} = I_2 - KI_1 \quad (3)$$

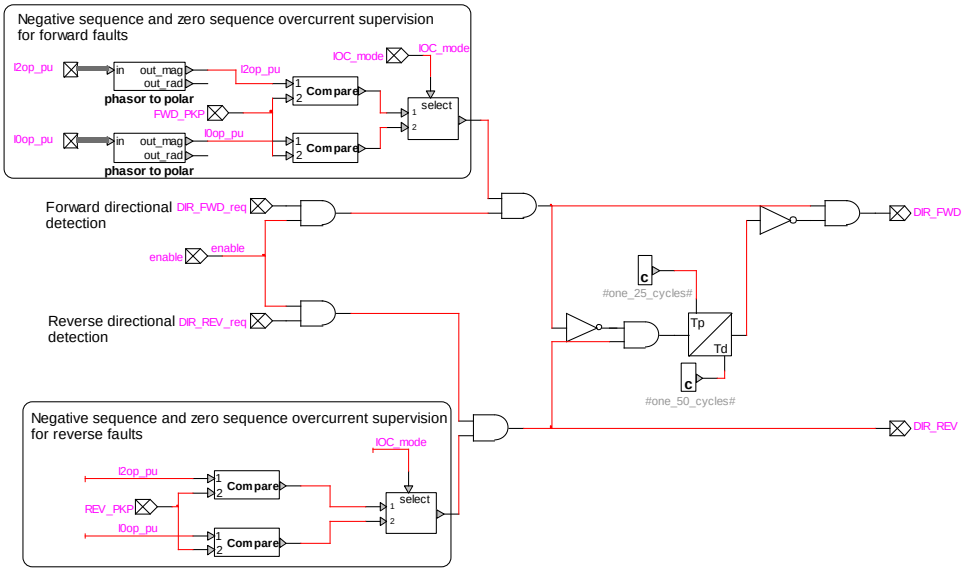


Figure 2-5 Negative sequence current directional element logic.

2.4 Negative Sequence magnitude

Only one level of this element is available. Instead of being based on the angle comparator, the direction of the negative sequence current is determined with the magnitude and sign of the following expression (negative sequence 2):

$$Z_2 = \mathrm{Re}\left(\frac{\mathbf{V_2}}{\mathbf{I_2}} \angle -\mathrm{ECA}\right) \tag{4}$$

If $Z_2 < 0$ and $|Z_2| < Z_{2\mathrm{Forward}}$, the negative sequence current flow is identified as forward.

If $Z_2 > 0$ and $|Z_2| > Z_{2\mathrm{Reverse}}$, the negative sequence current flow is identified as reverse.

This element also has its own overcurrent supervisors.

- **$Z_{2\mathrm{Forward/Reverse}}$**: Pickup values of reverse and forward impedances. In Ohms seen at the secondary of measuring instrument transformers.
- **$I_{\mathrm{pkpForward/Reverse}}$**: Pickup value of the overcurrent supervisor for, respectively, the forward and reverse elements.
- **$(I_2/I_1)_{\mathrm{MAX}}$**: Pickup value of the ratio between negative sequence and the positive sequence currents. Used to identify unbalanced conditions and thus enable the negative sequence element. The Negative Sequence magnitude element is otherwise disabled.
- **ECA**: Directional element characteristic angle.

The logic diagram of this function is shown in Figure 2-6.

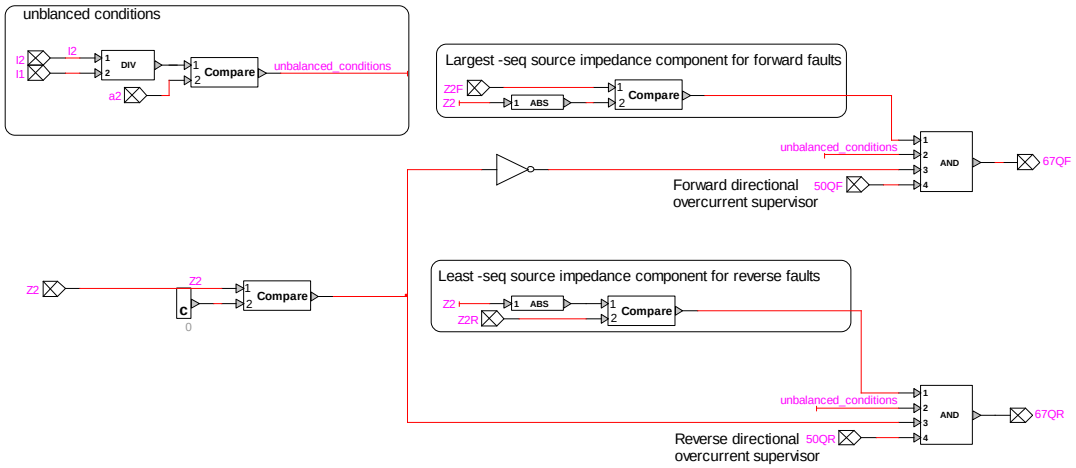


Figure 2-6 Logic of the negative sequence current directional element based on the magnitude.

3 Flags available for Polarized directional functions

The following flags are available.

- 67_LA_1: Reverse directional current on phase A with the setting of level 1
- 67_LA_2: Reverse directional current on phase A with the setting of level 2
- 67_LB_1: Reverse directional current on phase B with the setting of level 1
- 67_LB_2: Reverse directional current on phase B with the setting of level 2
- 67_LC_1: Reverse directional current on phase C with the setting of level 1
- 67_LC_2: Reverse directional current on phase C with the setting of level 2
- 67_NF_1: Forward directional neutral overcurrent with the setting of level 1
- 67_NF_2: Forward directional neutral overcurrent with the setting of level 2
- 67_NR_1: Reverse directional neutral overcurrent with the setting of level 1
- 67_NR_2: Reverse directional neutral overcurrent with the setting of level 2
- 67_QF_1: Forward directional negative-sequence overcurrent with the setting of level 1
- 67_QF_2: Forward directional negative-sequence overcurrent with the setting of level 2
- 67_QR_1: Reverse directional negative-sequence overcurrent with the setting of level 1
- 67_QR_2: Reverse directional negative-sequence overcurrent with the setting of level 2
- 67_QF_SEL: Forward directional negative-sequence overcurrent based on the impedance magnitude with the setting of level 1
- 67_QR_SEL: Forward directional negative-sequence overcurrent based on the impedance magnitude with the setting of level 1

It is noted that for some signals the underscore character is removed in the output bundle.

4 Scopes

The following scopes are found in the subcircuit: *RelayName/Control/Console*:

- 67_L_1: Reverse directional current on each phase with the setting of level 1
- 67_L_2: Reverse directional current on each phase with the setting of level 2
- 67_NF_1: Forward directional neutral overcurrent with the setting of level 1
- 67_NF_2: Forward directional neutral overcurrent with the setting of level 2
- 67_NR_1: Reverse directional neutral overcurrent with the setting of level 1
- 67_NR_2: Reverse directional neutral overcurrent with the setting of level 2
- 67_QF_1: Forward directional negative-sequence overcurrent with the setting of level 1
- 67_QF_2: Forward directional negative-sequence overcurrent with the setting of level 2
- 67_QR_1: Reverse directional negative-sequence overcurrent with the setting of level 1

- 67_QR_2: Reverse directional negative-sequence overcurrent with the setting of level 2
- 67_QF_SEL: Forward directional negative-sequence overcurrent based on the impedance magnitude with the setting of level 1
- 67_QR_SEL: Forward directional negative-sequence overcurrent based on the impedance magnitude with the setting of level 1

5 Modifications

The protection functions are updated automatically. For example, for memory usage and computational speed considerations, if an entire element is disabled, the subcircuits associated to its functions are replaced by empty subcircuits with the same inputs and outputs. The outputs will be forced to zero or one. When enabled, the subcircuits can take different architectures considering the user choices. Some elements can be excluded if not enabled in the mask.

The updates are performed immediately after entering the parameters and clicking the OK button. The user should wait for the completion of tasks.

If the user wants to modify the subcircuit manually (for example, when adding new scopes), using in the GUI, and avoid the automatic updates of contents, the attribute DeviceVersion has to be set to “none” as shown below. To access to this attribute, right click on the desired device, then go to Attributes and select DeviceVersion (see Figure below).

To allow the automatic updates again, just remove the “none” string.

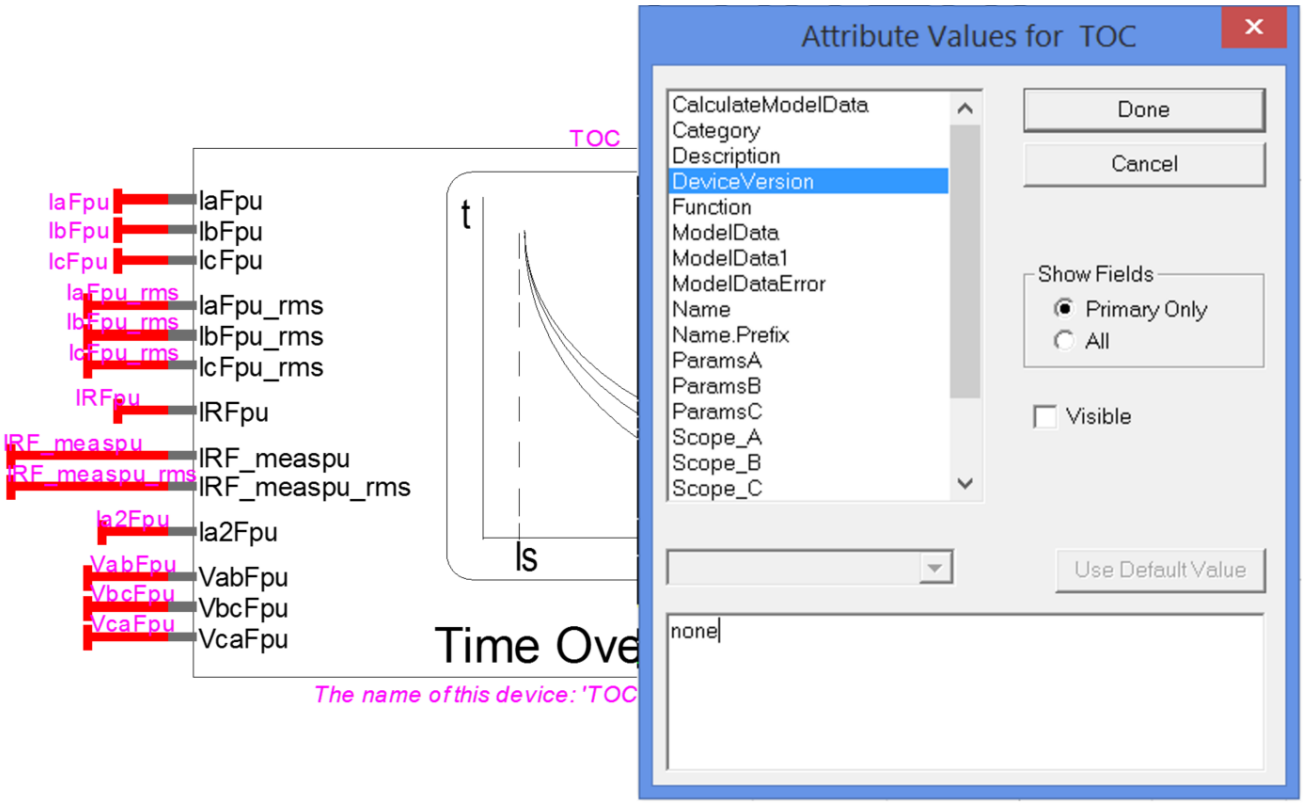


Figure 5-1 How to set the DeviceVersion attribute of the TOC element to allow modifications.

Also, inside the DIR subcircuit, the different directional elements are excluded automatically considering if they are enabled of not. To avoid theses exclusions, repeat the process detailed above for these elements. Do not forget to do it for the parent subcircuit first.

6 References

[1] D60 Line Distance Protection System, chapter 5.6 p5-159, UR Series Instruction Manual, DE Digital Energy, D60 Revision 7.1x