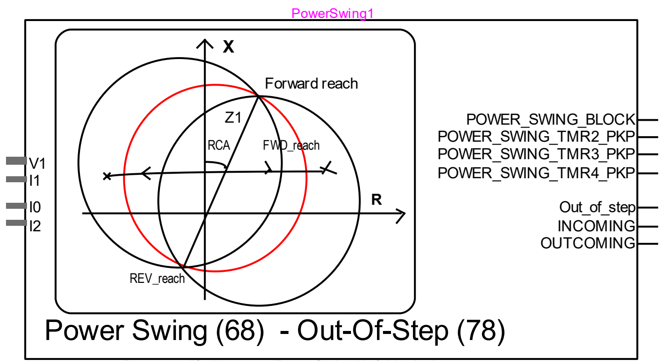
Protection: Power swing / Out-Of-Step functions



Henry Gras, Jean Mahseredjian, 9/26/2017 6:47:00 PM

1 Introduction

This function follows the ANSI standards 68 and 78.
Two algorithms are available: “Operating Characteristic based detection” and “Continuous Impedance Calculation based detection”. These algorithms are running in parallel with an OR gate condition on their power swing blocking and Out-Of-Step detection conditions.
In the “Operating Characteristic based detection” the power swing detection is based on 3 zones: the outer zone (black in Figure 1-1), the middle zone (in red) and the inner zone (in blue). The detection occurs when the measured impedance locus travels through the zones with a certain timing. To accelerate the detection of the Out-Of-Step condition, a two-zone detection can be chosen. In that case, the middle zone can be bypassed.

If the “Continuous Impedance Calculation based detection” is enabled, the power swing detection is based on impedance variation. This is explained below.

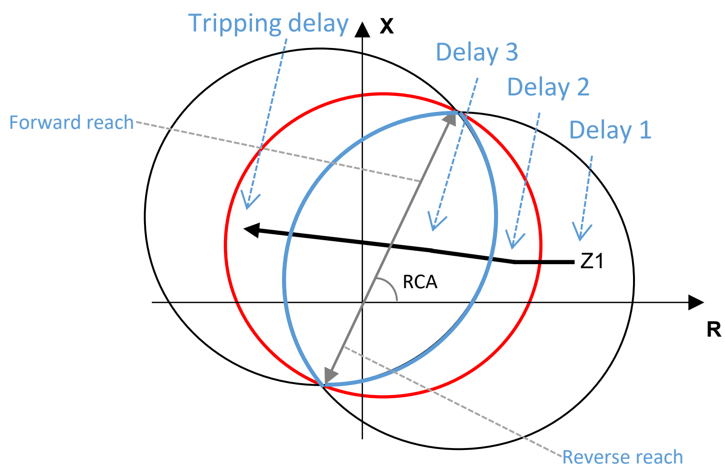


Figure 1-1 Power swing scheme

2 Input data: Power swing data tab

The following data inputs are related to

- **Enable power swing elements**: enables the power swing functions. If unchecked, the functions are disabled and replaced by an empty subcircuit whose outputs are zeros.
- **Shape**: Mho, Quad, Mho with blinders. For the last option, the right and left blinders are enabled as well as the Mho characteristic.
- **Mode**: 3-step or 2-step. Select the number of steps for the detection.
- **The zones have the same reach impedance**: see drawing in the data tab.
- **Trip mode**: Delayed or Instantaneous. If Instantaneous, the delays for 2- or 3-zone detections are zero.
- **I_{1pkp}:** positive sequence pickup current (pu). If the positive sequence current is bellow this value, this element is disabled.
- **I_{2pkp}:** negative sequence supervising current (pu). If the negative sequence current is above this value, the condition is considered unbalanced and the blocking of the power swing is inhibited.
- **Forward reach:** Reach impedance data for the zones, only for Mho and “Mho with blinders” shapes. The variants of input options are self-explanatory on this data tab.
- **Reverse reach:** Reach impedance data for zones, only for Mho and “Mho with blinders” shapes. The variants of input options are self-explanatory on this data tab.
- **Forward RCA:** Forward characteristic impedance angles of the zones.
- **Reverse RCA:** Reverse characteristic impedance angles of the zones.

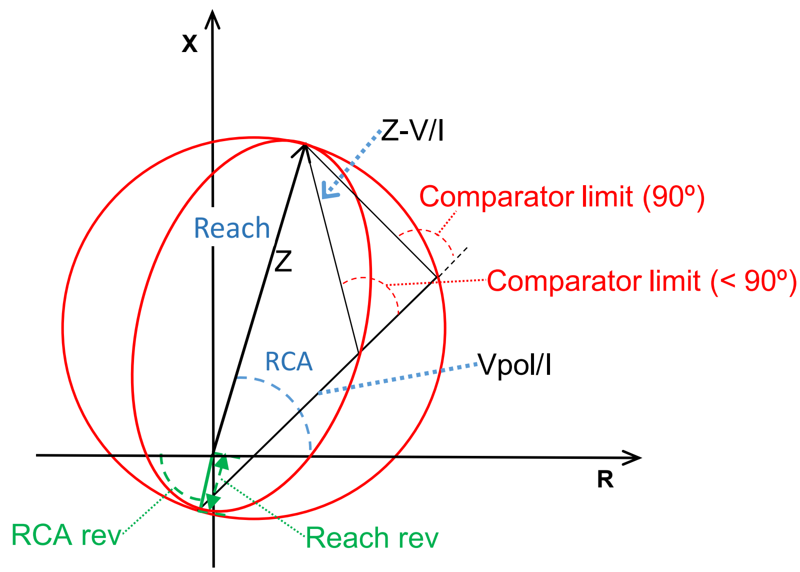


Figure 2-1 Lens and Mho characteristics.

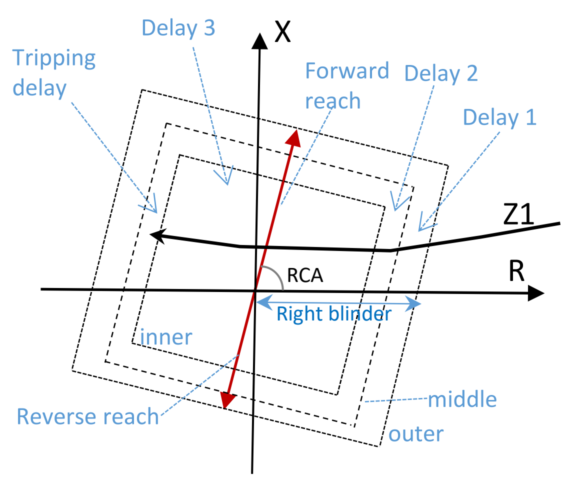


Figure 2-2 Quad shapes.

- **Left blinder outer/inner/middle**: Left blinders of the zones. Only for Quad and "Mho with blinders" shapes.
- **Right blinder outer/inner/middle**: Right blinders of the zones. Only for Quad and "Mho with blinders" shapes.
- **Comparator limit angle outer/middle/inner zone**: Setting options
  - smaller than 90º: the zone is a lens (i.e. inner)
  - equal to 90º: (i.e.: middle zone), it is a Mho shape
  - larger than 90º: the zone is an apple (i.e. outer), only for Mho and "Mho with blinders" shapes.
- **Delay *i:*** Delays in each zone *i* for power swing detection. (See Figure 1-1 and Figure 2-2)
- **Reset delay 1:** See the diagram of Figure 2-5
- **Tripping delay**: See the diagram of Figure 2-5
- **Delay seal in**: See the diagram of Figure 2-5

- **Enable Continuous Impedance Calculation based detection**: If checked this option enables the following data inputs. See also Figure 2-3.
- **Measurement window:** Time between two impedance calculations, variation interval.

- **Continuity DRmin:** Minimum variation of resistance (seen by the relay). During a fault, the impedance value goes into a steady-state point and does not move significantly, whereas during a power swing the impedance value moves continuously.
- **Continuity DXmin:** Minimum variation of reactance (seen by the relay). Same explanation as above.
- **Uniformity DRmax:** Maximum variation of resistance. If above, the variation is considered as more likely due to a fault than a power swing.
- **Uniformity DXmax:** Maximum variation of reactance. If above, the variation is considered as more likely due to a fault than a power swing.

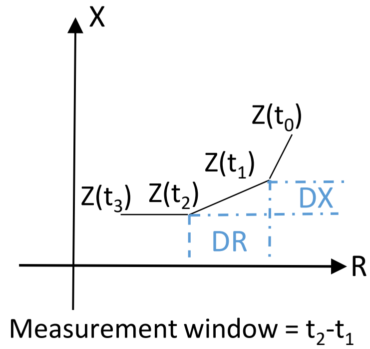


Figure 2-3 Continuous impedance calculation

An Out-Of-Step condition is triggered when:

- when the **Tripping delay** for the “Operating Characteristic based detection” is exceeded or
- if there the resistance exits the inner zone with a sign opposite to the one when entering the zone (see also the device drawing shown in Figure 2-4)

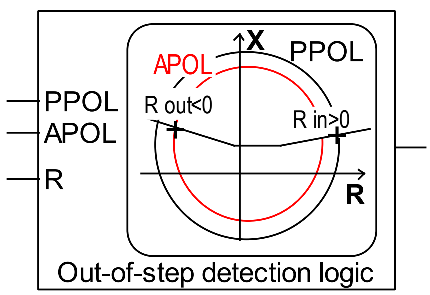


Figure 2-4 Out-of-step detection scheme .

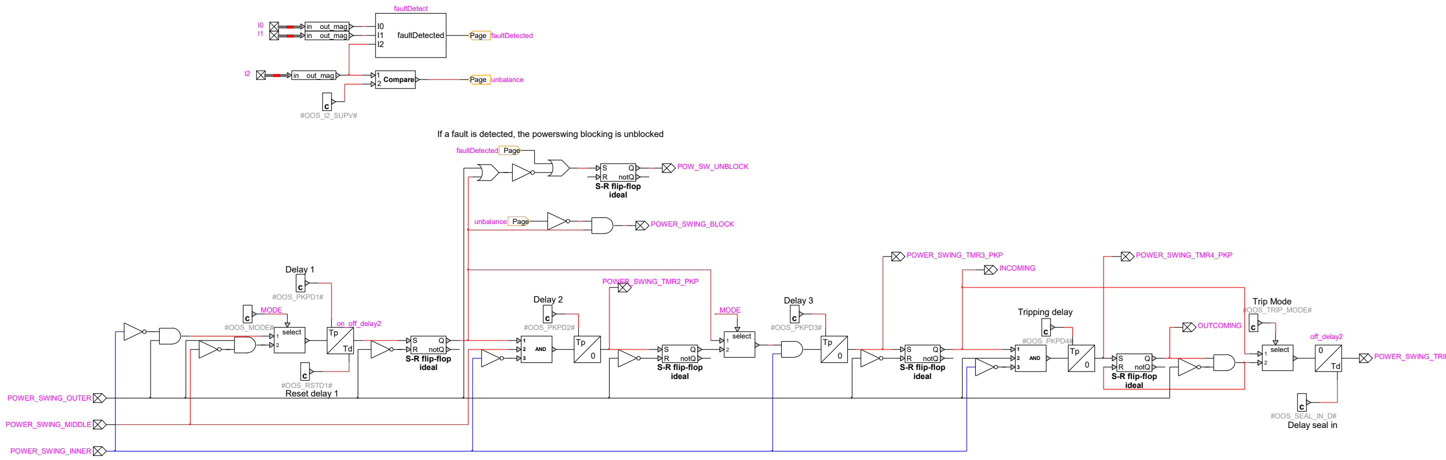


Figure 2-5 Power swing logic (see subcircuit for more details).

3 Flags available in the output bundle of the relay

- POWER_SWING_BLOCK: Outer zone detection (with pickup and reset delay 1).
- POWER_SWING_UNBLOCK: Out of the outer zone or unbalance conditions detected
- POWER_SWING_TMR2_PKP: Middle zone detection (with pickup delay 2). First step.
- POWER_SWING_TMR3_PKP: Inner zone detection (with pickup delay 3). Second step.
- POWER_SWING_TMR4_PKP: Outer zone detection (with tripping delay). Power swing detection with delay.
- OOS: Power swing detection with or without delay and “seal in”. Unstable power swing.

4 Flags available in the tripping function

- PS: Same as POWER_SWING_BLOCK
- PS_UN: Same as POWER_SWING_UNBLOCK
- OOS: Same as OOS

5 Scopes

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

- POWER_SWING_BLOCK: Outer zone detection (with pickup and reset delay 1).
- POWER_SWING_TMR2_PKP: Middle zone detection (with pickup delay 2). First step.
- POWER_SWING_TMR3_PKP: Inner zone detection (with pickup delay 3). Second step.
- POWER_SWING_TMR4_PKP: Outer zone detection (with tripping delay). Power swing detection with delay.
- POWER_SWING_DETECT: Same as OOS.

6 Impedance locus drawing (R-X graph)

- **Locus *k*-zones GND**: Draw the impedance locus and the characteristics of the 3 zones. This option is selectable in the Function Scopes tab.
- **Expansion time**: time in seconds for the locus to reach its maximum value. When the locus does not move in the R-X graph, its size increases until a maximum. The aim is to help the user to differentiate a transient position of the locus with a quasi-steady state one. The size of it can them give an idea on the time the locus stays at this position.
- **Refresh period**: The drawing is refreshed at this period.

6.1 Showing the locus graphs

See the documentation of the “R-X graph plotter” device shown in Figure 6-1.

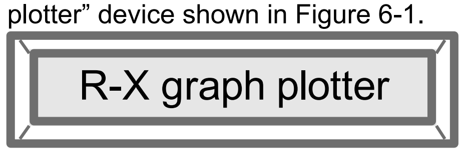


Figure 6-1 R-X graph plotter

7 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.

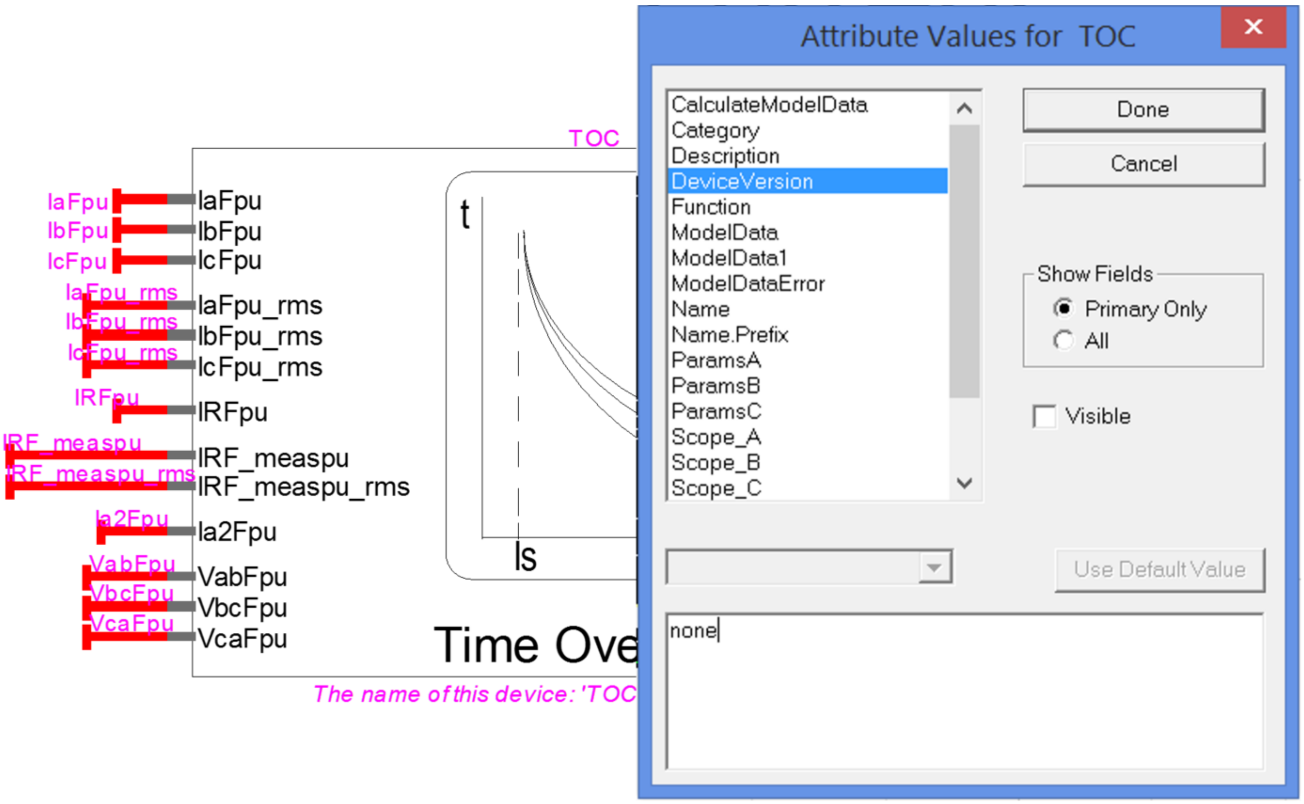


Figure 7-1 How to set the DeviceVersion attribute of the TOC element to allow modifications.

1 References:

[1] D60 Line Distance Protection System, chapter 5.6 p5-159, UR Series Instruction Manual, GE Digital Energy, D60 Revision 7.1x
[2] Edmund O. Schweitzer, New Developments in Distance Relay Polarization and Fault Type Selection, Schweitzer Engineering Laboratories, Inc, March 1991
[3] Siemens, A.G., Infrastructure & Cities Sector (2006) User Manual Distance Protection 7SA522 V4.61. Ordering Nr.C53000-G1176-C155-5. http://www.siprotec.com