

Protection: Signal Acquisition

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1 Introduction

The Signal Acquisition functions are present in all relay models. It is set by the parameters entered in the “Electrical Characteristics” tab and uses the same inputs as the relay device. It samples the inputs from the current (CT) and voltage (VT) transformers, and processes them into phasors and RMS values utilized thereafter by the protection functions. The following scheme (Figure 1-1) describes the processing steps.

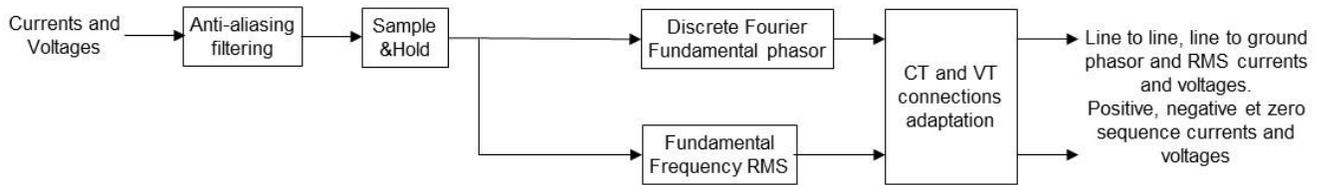


Figure 1-1 Subsystems of the Signal Acquisition function.

An anti-aliasing filter transfer function can be determined by default considering the power frequency and the sampling frequency (see Section 4.1). The quantizer functionality is also optionally simulated in the “Sample & Hold” function.

The CTs for numerical relays are typically star (Wye) connected, as the CT available in EMTP. However, the signal acquisition function has a processing step that determines the output values for delta connected transformers, even if it is not advised to use the CT model in this configuration.

The outputs of the signal acquisition function are converted into per-unit values by the function (subcircuit) named Into_pu1. The conversion base values are entered in the relay mask.

The “Sample & Hold” function is explained in Section 4.2.

Since the relay subcircuit contents are scriptable, the user should not modify those contents without prior knowledge of impact on programmed scripts. Changes are only for advanced scripting needs. The contents and the name of the subcircuit Signals_Acqu1, for example, should not be modified.

2 The relay subcircuit port connections

The following figure presents an example with overcurrent relays. If a protection function (relay) does not use a given pin (input or output), this pin can stay disconnected.

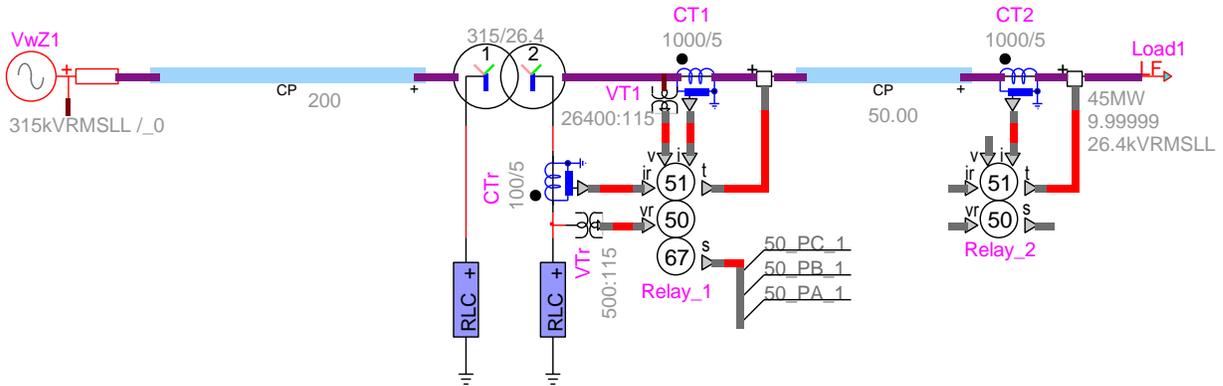


Figure 2-1 Example of overcurrent relays in a network.

The connection pins of relay subcircuits are (see also Figure 2-1):

- ❑ **i**: Input bundle with the 3-phase current signals (inputs a, b and c). It is intended to be connected to the CT control output bundle of the 3-phase CT which contains the currents (a, b and c) at the CT secondary in A.
- ❑ **ir**: Input bundle with the current signal (input a, general signal, 1-wire). It is intended to be connected to the CT control output bundle of the 1-phase CT which contains the current (a) at the CT secondary in A.
- ❑ **v**: Input bundle with the 3-phase voltage signals (inputs a, b and c). It is intended to be connected to the control output bundle of the 3-phase VT (or CVT) which contains the voltages (a, b and c) at the secondary in V.
- ❑ **vr**: Input bundle with the voltage signal (input a, general signal, 1-wire). It is intended to be connected to the control output bundle of the 1-phase VT (or CVT) which contains the voltage (a) at the secondary in V.
- ❑ **t**: Output bundle with the tripping signals of each phase (outputs a, b and c). They are Boolean and equal to 1 when tripping is requested for the phases A, B or C. The output bundle signals are zero when no tripping is requested.
- ❑ **s**: Output bundle that contains all the output signals of the protection functions and/or available in the "Tripping Logic" tab. It gives the possibility to build a tripping logic outside the relay or to create communications between relays.

3 Input data: Electrical characteristics tab

The following data inputs are available in the "Electrical Characteristics" tab of each relay.

- ❑ **Phase CT Connection** type:
 - **Wye**: the CT is star connected. In this case the line currents are directly determined by the input currents connected to the **i**-pin of the relay.
 - **Delta**: the CT is delta connected (the user must define such a CT). In this case, the line currents are calculated as explained in Section 4.5. The CT is normally Wye connected.
- ❑ **Ratio**: Ratio of the CT (current at the primary / current at the secondary)
- ❑ **I_{Rated}**: Rated current units:
 - **A RMS secondary**: it is the value of the RMS current at the secondary of the CT for 1 pu of current at the CT primary.
 - **A RMS primary**: it is directly the rated RMS current of the primary.
- ❑ **Ground CT Ratio**: Ratio of the ground CT (current at the primary / current at the secondary).
- ❑ **Phase VT Connection** type:
 - **Wye**: the VT is star connected. In this case, the line to ground voltages are directly determined by the voltages at the input **v**-pin. The line to line voltages are calculated as explained in Section 4.5.

- **Delta:** the VT is delta connected. If this case, the line to line voltages are directly determined by the voltages at the input. The line to ground voltages are calculated as explained in Section 4.5.
- **Ratio:** Ratio of the VT (primary voltage / secondary voltage)
- **V_{Rated}:** Rated voltage units:
 - V RMSLG secondary: it is the RMS line to ground voltage at the secondary of the VT for a voltage of 1pu at the primary.
 - V RMSLL primary: rated line-to-line voltage at the primary of the VT.
- **Input sampling:** Number of samples per power cycle.
Warning: The simulation time-step has to be at least twice the value of the sampling frequency of the relay.
- **Simulate sampling quantizers:** If selected, a quantizer is added to each input. In that case, set each quantizer by selecting the “**Setting for input**” dropdown menu and setting the **Resolution** and “**Maximum value**” parameters. The value in pu of the “Resolution” is calculated accordingly.
- **Anti-Aliasing filter transfer function:** The parameters of the anti-aliasing filter are entered in this section. It is possible to generate a 2nd-order transfer function with the **Default Transfer Function** button (see Section 4.1 for more information).

4 Processing steps description

4.1 Anti-aliasing

Anti-aliasing filters are commonly used to reduce the bandwidth of the signal before sampling and thus, avoid high frequencies to be interpreted as sub-frequency signals after the sampling step.

A default transfer function (button) calculator is available in the mask of the relay. It fills the data inputs of the anti-aliasing filter with the coefficients of two-stage RC filter with a cutoff frequency of half of the sampling frequency and a quality factor of 0.7. The sampling frequency is determined with the number of samples per cycle multiplied by the power frequency.

4.2 Sample & Hold function

The sampling frequency is determined with the number of samples per cycle and the power frequency specified in the mask. The Figure 4-1 shows a signal sampled at a rate of 16 samples per cycle.

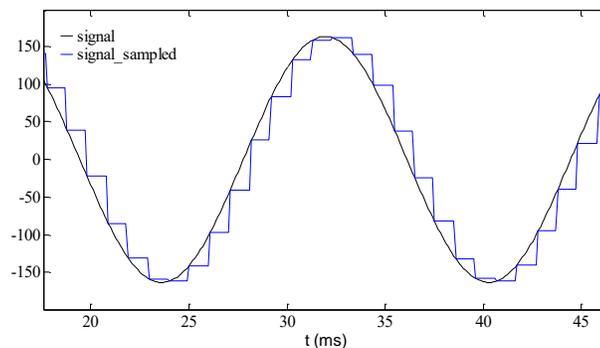


Figure 4-1 Example, signal sampled at a rate of 16 samples per cycle.

If the sampling instant occurs between two simulation time points, an interpolation is performed.

If the quantizer option is enabled, the sampled signal can only take a discrete number of values according to the “Resolution” and “Maximum value” parameters.

4.3 Discrete Fourier Fundamental Phasor

This block is shown in Figure 1-1. The phasors of the inputs for the fundamental frequencies are calculated by a cosine filter. The phasor values are held between two sampling times.

The functions that calculate the phasors are located in the subcircuit: Control/Signals_Acq1/Inst_to_phasor1. The inputs of these functions are the sampling period defined by the user in the mask and the number of samples per window of DFT computation.

The window is set to one cycle in the current version, thus the number of samples per window is the same as the number of samples per cycle. The user can modify the inputs of the DFT function manually in the GUI.

4.4 Discrete RMS Fundamental Phasor

This block is shown in Figure 1-1 (Fundamental Frequency RMS).

The RMS values of the inputs are calculated with the values sampled following the DFT theory. These values are held between two sampling times.

The functions that calculate the RMS phasors are located in the subcircuit: Control/Signals_Acq1. The inputs of these functions are the sampling period defined by the user in the mask and the number of samples per window of RMS computation. The window is set to one cycle in the current version, so the number of samples per window is the same as the number of samples per cycle. The user can modify the inputs of the RMS function manually in the GUI.

Warning: The DFT magnitude is the peak value whereas the RMS is the peak divided by $\sqrt{2}$. In order to have a common base when converting into pu, the RMS values are multiplied by $\sqrt{2}$. Thus, the base values calculated with the input data are the peak values.

4.5 CT and VT connections adaptation

This block is shown in Figure 1-1.

Wye (star) connected: When wye connected, the line (phase-to-ground voltage and phase current) values are determined with the inputs connected to the CTs and VTs. The line-to-line values are calculated from the line values. The sequence currents and voltages are calculated with the line currents and voltages.

Delta connected: When delta connected, the line-to-line values are determined with the inputs connected to the CTs (when a Delta CT is used) and VTs (when Delta connection is selected).

The sequence phasors are calculated with the line-to-line phasors as follows:

$$\begin{aligned} X_1 &= \frac{1\angle-30^\circ}{3\sqrt{3}} (X_{AB} + aX_{BC} + a^2X_{CA}) \\ X_2 &= \frac{1\angle-30^\circ}{3\sqrt{3}} (X_{AB} + a^2X_{BC} + aX_{CA}) \end{aligned} \quad (1)$$

where $a = 1\angle 120^\circ$, X_1 and X_2 are respectively the positive and negative sequence phasors of X (voltage or current). The phasors X_{AB} , X_{BC} and X_{CA} are the line-to-line phasors of X .

The zero sequence voltage is one third of the residual voltage provided as a control input (**vr**-pin).

The zero sequence current is one third of the residual current provided as a control input (**ir**-pin).

The line-to-ground phasors are calculated from the sequence phasors as follows:

$$\begin{aligned} X_A &= X_1 + X_2 + X_0 \\ X_B &= a^2X_1 + aX_2 + X_0 \\ X_C &= aX_1 + a^2X_2 + X_0 \end{aligned} \quad (2)$$

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.

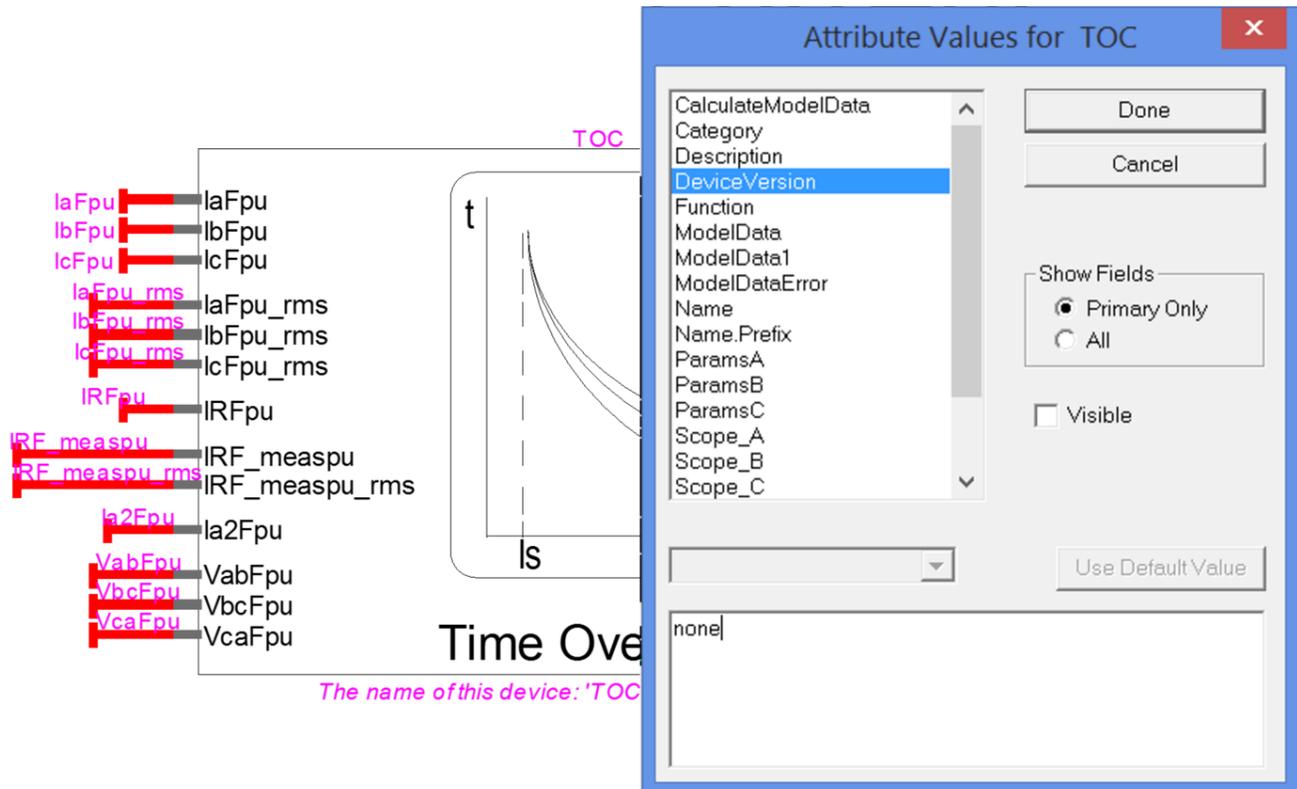


Figure 5-1 How to set the DeviceVersion attribute of the TOC element to allow modifications.