Protection: Signal acquisition

Henry Gras, Jean Mahseredjian, 2015/04/15

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.

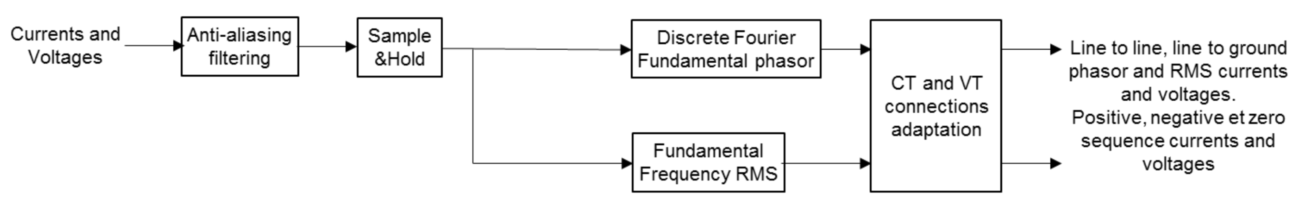

Figure 1-1 Subsystems of the signals acquisition function.

According to the manufacturer selection, the "CT and VT connections adaptation block", also called "in-zone transformer adapter", can be placed before the DFT blocks (see Section 4.3).
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 outputs of the signal acquisition function are converted to per-unit values. The base values are calculated according to data entered in the mask.

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 Sign_acq, for example, should not modified.

2 The relay subcircuit port connections

The following Figure 2-1 presents the available relay pins. If no protection function uses a given pin, this pin can stay disconnected. Figure 2-2 presents an interfacing example with the relay 87.

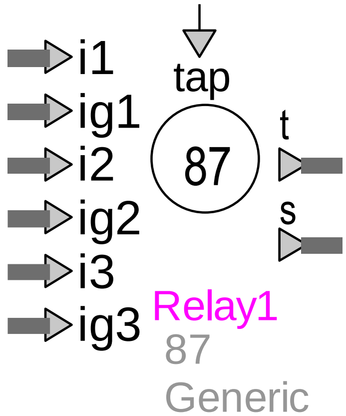

Figure 2-1 The relay 87 device

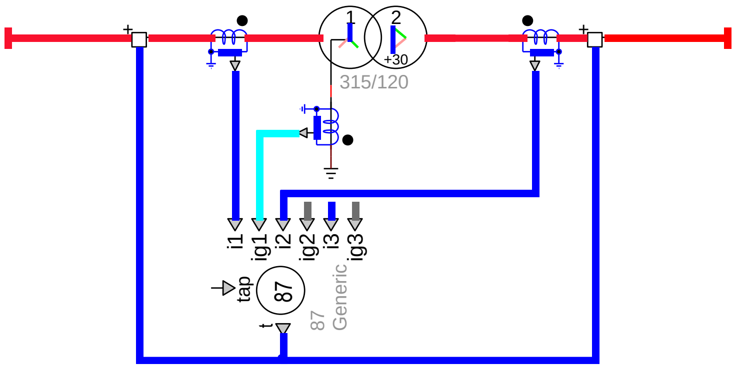

Figure 2-2 The relay 87 interface with CTs and controlled breakers

- **i***j*: Input bundle with the 3-phase current signals (inputs a, b and c of terminal *j*). 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.
- **ig***j*: Input bundle with the current signal (input a, general signal, 1-wire, terminal *j*). 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.
    - **tap**: is the tap position number
- **s**: output signals bundle. See protection functions documentation for more information.
- **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.

3 Input data: Electrical characteristics tab

- **Frequency**: fundamental frequency.
- **Number of inputs**: 2 or 3. Number of CTs connected to the relay.
- **Connection type (1/2, 1/3)**: Transformer connection type between windings 1-2, and 1-3. Determines the in-zone transformer magnitude and phase correction.

3.1 Tap changer

- **Winding with tap changer**: Indicates the winding with the tap changer.
- **Number of positions**: total number of position of the tap.
- **Voltage at the minimum position**: in kVRMSLL
- **Voltage increment per tap**: percentage increment of the **Voltage at the minimum position** per tap change

3.2 Winding data

- **Winding *i* voltage**: Rated voltage of the winding *i*.
- **Nominal power winding** *i*: Nominal power of winding *i.*
- **CT ratio winding** *i*: Ratio of the current at the primary divided by the one at the secondary if the CT is connected to winding *i.*
- **Rated current:** rated current (A secondary) of the CT of winding *i*.
- **TAP:** Normalization factor that converts current values from ampere to per unit. For SEL only. The value suggested is:

  $$TAP = \frac{MVA * 1000}{\sqrt{3} * KV * CTratio} \quad (1)$$

  Where MVA is the winding nominal power in MVA, KV is the winding line-to-line voltage in KV, CTratio is the winding CT ratio.
- **Ground CT input on this winding**: Must be checked if a ground differential element is applied on winding *i*.

3.3 Sampling

- **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.

3.4 Anti-Aliasing filter transfer function

- **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.

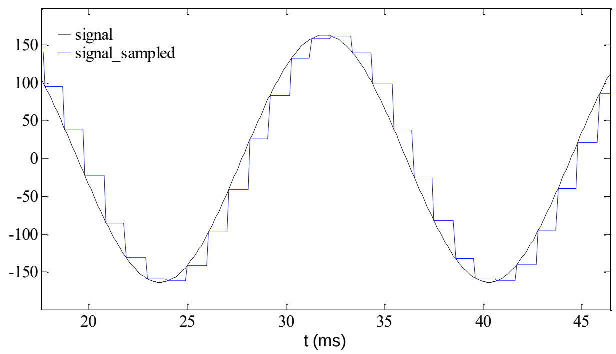

Figure 4-1 Example, signal sampled at a rate of 16 samples per cycle.

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 connections adaptation

The magnitudes and angles of the currents from the CTs are corrected according to the winding connections. The Lag angles are in degrees.

For 2-winding transformers:

Conn.	**Lag 1**	**Transformation winding 1**	**Lag 2**	**Transformation winding 2**
YY0	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$

DY1	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	330	$Va_{adapted} = (Va - Vb) / \sqrt{3}$ $Vb_{adapted} = (Vb - Vc) / \sqrt{3}$ $Vc_{adapted} = (Vc - Va) / \sqrt{3}$
YD1	30	$Va_{adapted} = (Va - Vc) / \sqrt{3}$ $Vb_{adapted} = (Vb - Va) / \sqrt{3}$ $Vc_{adapted} = (Vc - Vb) / \sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
DY11	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	30	$Va_{adapted} = (Va - Vc) / \sqrt{3}$ $Vb_{adapted} = (Vb - Va) / \sqrt{3}$ $Vc_{adapted} = (Vc - Vb) / \sqrt{3}$
YD11	330	$Va_{adapted} = (Va - Vb) / \sqrt{3}$ $Vb_{adapted} = (Vb - Vc) / \sqrt{3}$ $Vc_{adapted} = (Vc - Va) / \sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
DD0	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
YY6	180	$Va_{adapted} = -Va$ $Vb_{adapted} = -Vb$ $Vc_{adapted} = -Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
DY7	210	$Va_{adapted} = (Vc - Va) / \sqrt{3}$ $Vb_{adapted} = (Va - Vb) / \sqrt{3}$ $Vc_{adapted} = (Vb - Vc) / \sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
YD5	150	$Va_{adapted} = (Vb - Va) / \sqrt{3}$ $Vb_{adapted} = (Vc - Vb) / \sqrt{3}$ $Vc_{adapted} = (Va - Vc) / \sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$

For 3-winding transformers:

Conn.	**Lag 1**	**Transformation winding 1**	**Lag 2**	**Transformation winding 2**	**Lag 3**	**Transformation winding 3**
YY0Y0	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
YY0D1	30	$Va_{adapted} = (Va - Vc) / \sqrt{3}$ $Vb_{adapted} = (Vb - Va) / \sqrt{3}$ $Vc_{adapted} = (Vc - Vb) / \sqrt{3}$	30	$Va_{adapted} = (Va - Vc) / \sqrt{3}$ $Vb_{adapted} = (Vb - Va) / \sqrt{3}$ $Vc_{adapted} = (Vc - Vb) / \sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$

YY0D11	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
YY0Y6	180	$Va_{adapted} = -Va$ $Vb_{adapted} = -Vb$ $Vc_{adapted} = -Vc$	180	$Va_{adapted} = -Va$ $Vb_{adapted} = -Vb$ $Vc_{adapted} = -Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
Y0Y0D5	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
DY1Y1	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$
DY1Y11	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$
DY1D0	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
DY1Y7	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$
YD1Y0	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$
YD1D1	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
YD1D11	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	60	$Va_{adapted} = -Vc$ $Vb_{adapted} = -Va$ $Vc_{adapted} = -Vb$

YD1Y6	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	210	$Va_{adapted} = (Vc - Va)/\sqrt{3}$ $Vb_{adapted} = (Va - Vb)/\sqrt{3}$ $Vc_{adapted} = (Vb - Vc)/\sqrt{3}$
YD1D5	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	240	$Va_{adapted} = Vc$ $Vb_{adapted} = Va$ $Vc_{adapted} = Vb$
DY11Y1	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$
DY11Y11	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$
DY11D0	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
DY11Y7	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$
YD11Y0	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$
YD11D1	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$
YD11D11	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$

YD11Y6	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$
YD11D5	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	180	$Va_{adapted} = -Va$ $Vb_{adapted} = -Vb$ $Vc_{adapted} = -Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
DD0Y1	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$
DD0Y11	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$
DD0D0	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
DD0Y7	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$
YY6Y0	180	$Va_{adapted} = -Va$ $Vb_{adapted} = -Vb$ $Vc_{adapted} = -Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	180	$Va_{adapted} = -Va$ $Vb_{adapted} = -Vb$ $Vc_{adapted} = -Vc$
YY6D1	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	210	$Va_{adapted} = (Vc - Va)/\sqrt{3}$ $Vb_{adapted} = (Va - Vb)/\sqrt{3}$ $Vc_{adapted} = (Vb - Vc)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
YY6D11	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
YY6Y6	180	$Va_{adapted} = -Va$ $Vb_{adapted} = -Vb$ $Vc_{adapted} = -Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$

YY6D5	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
DY7Y1	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$
DY7Y11	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$
DY7D0	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
DY7Y7	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$
YD5Y0	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$
YD5D1	30	$Va_{adapted} = (Va - Vc)/\sqrt{3}$ $Vb_{adapted} = (Vb - Va)/\sqrt{3}$ $Vc_{adapted} = (Vc - Vb)/\sqrt{3}$	240	$Va_{adapted} = Vc$ $Vb_{adapted} = Va$ $Vc_{adapted} = Vb$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$
YD5D11	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	180	$Va_{adapted} = -Va$ $Vb_{adapted} = -Vb$ $Vc_{adapted} = -Vc$
YD5D6	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	330	$Va_{adapted} = (Va - Vb)/\sqrt{3}$ $Vb_{adapted} = (Vb - Vc)/\sqrt{3}$ $Vc_{adapted} = (Vc - Va)/\sqrt{3}$
YD5D5	150	$Va_{adapted} = (Vb - Va)/\sqrt{3}$ $Vb_{adapted} = (Vc - Vb)/\sqrt{3}$ $Vc_{adapted} = (Va - Vc)/\sqrt{3}$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$	0	$Va_{adapted} = Va$ $Vb_{adapted} = Vb$ $Vc_{adapted} = Vc$

5 Manufacturer architectures

There are the different signal acquisition architectures according to the manufacturer selection. The manufacturer is selected on a relay tab.

5.1 Generic and General Electric

The in-zone transformer adaptation (see Section 4.5) is performed after sampling, before the phasor calculation (see Figure 5-1).

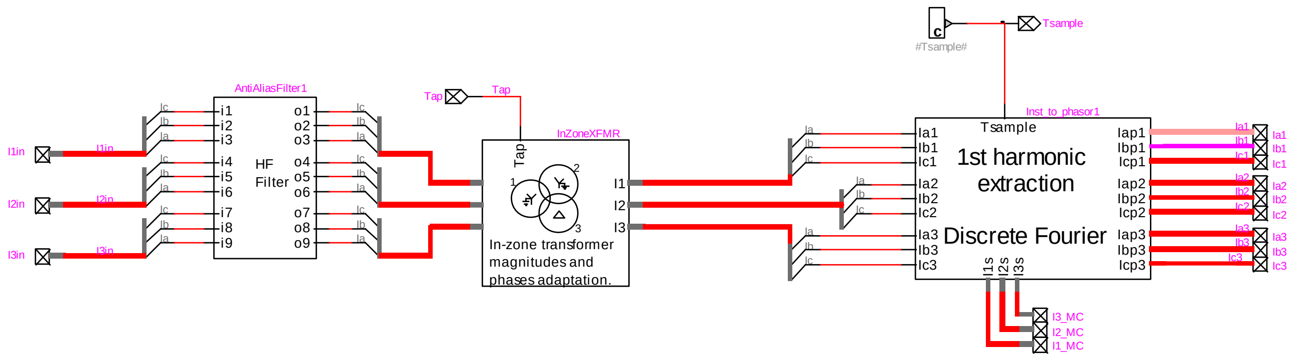

Figure 5-1 Signal acquisition: generic and General Electric.

5.2 General Electric (GE745)

Same as Generic.

5.3 SEL (Relay 487E)

Two kinds of output are provided. The first one (top path) is the same as the Generic signal acquisition. For the second one, with the suffix CFC, the DFT calculation is performed before the in-zone transformer adaptations, as shown in Figure 5-2.

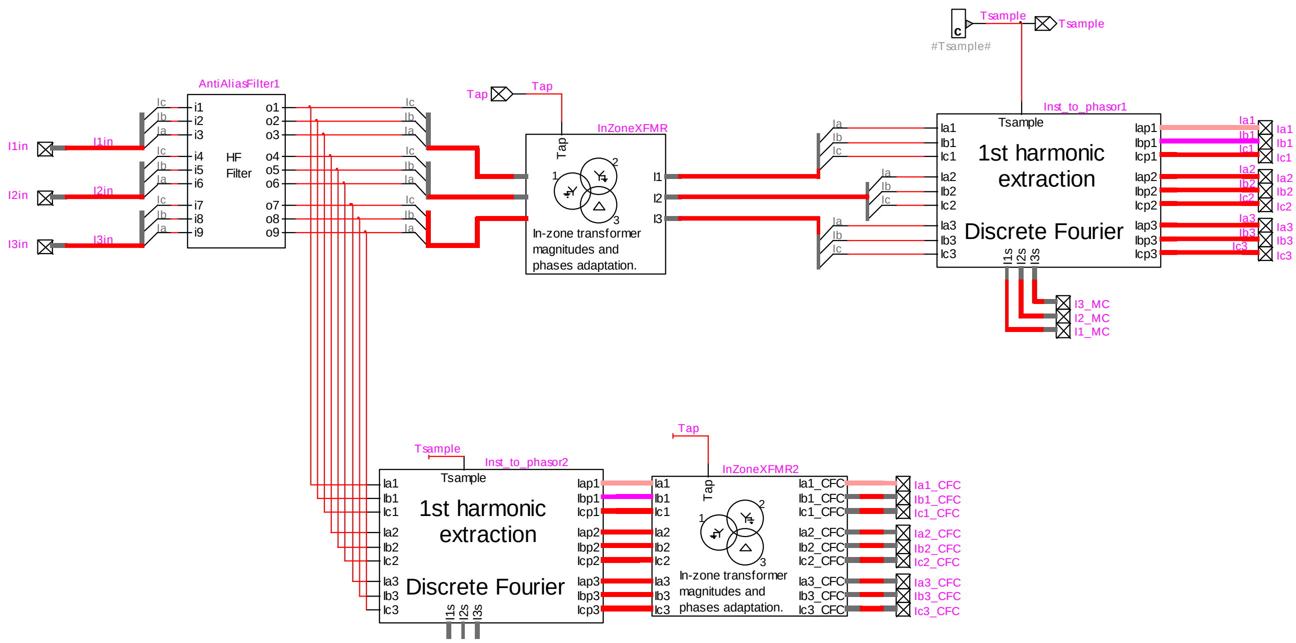

Figure 5-2 Signal acquisition: SEL

6 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.

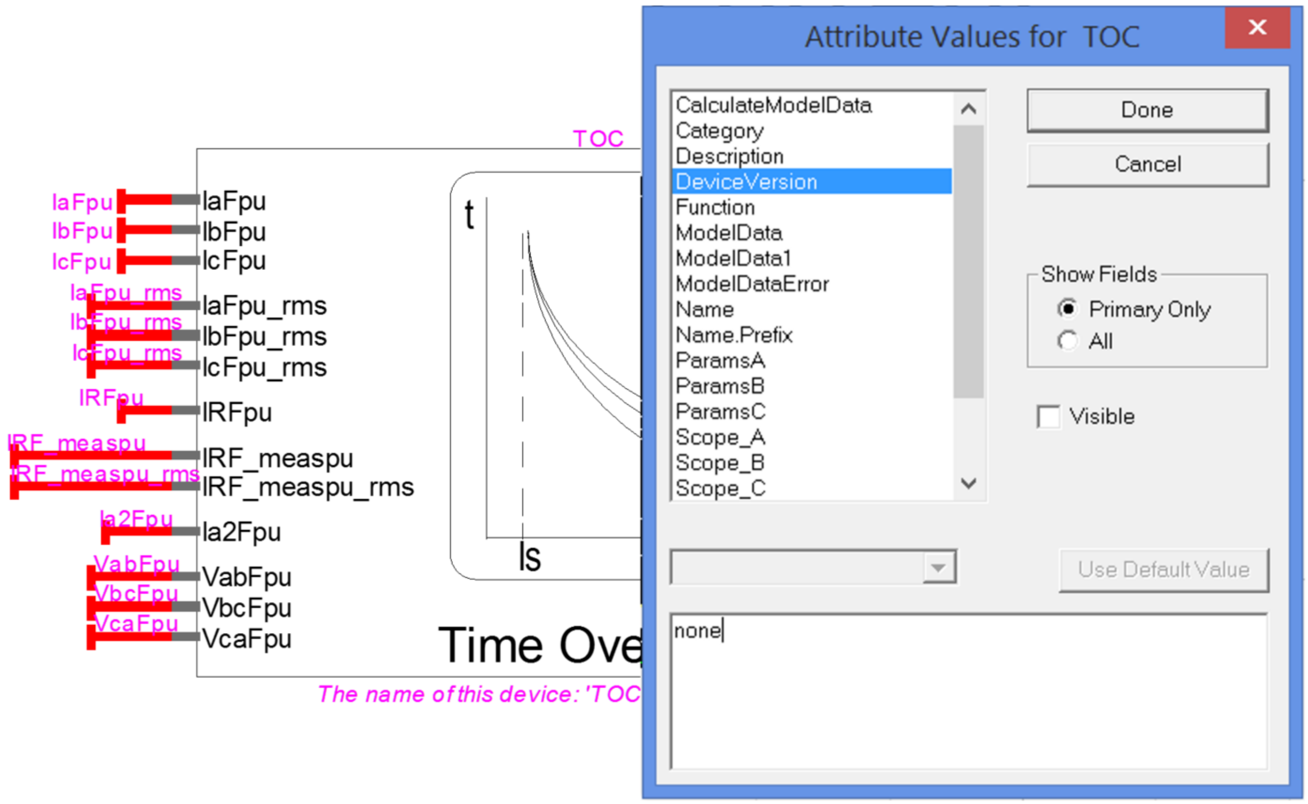

Figure 6-1 How to set the DeviceVersion attribute of the TOC element to allow modifications.