Protection: Signal acquisition

Henry Gras, 2017/07/17

1 Introduction

The Signal Acquisition functions is specific to the line-differential applications. 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.

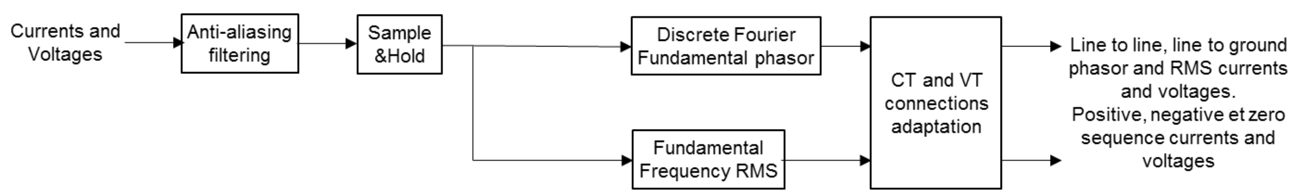

Figure 1-1 Subsystems of the signals acquisition function.

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 87L.

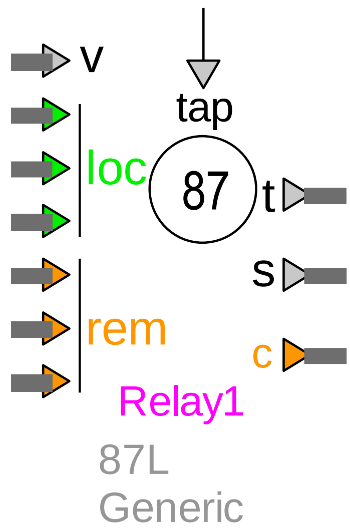

Figure 2-1 The relay 87L device

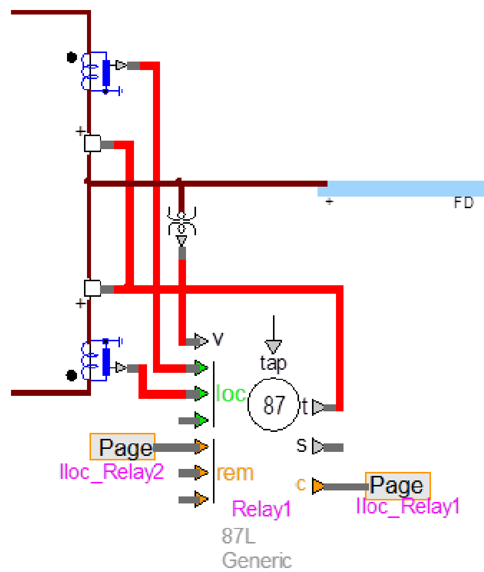

Figure 2-2 The relay 87L interface with CTs and controlled breakers in a breaker-and-half application.

- **v**: input bundle with the 3-phase local voltage signals (inputs a, b, c). It is intended to be connected to the local voltage transformer output bundle (see Figure 2-2) and is used in order to evaluate the charging current of the line to compensate the differential current.
  This bundle also contains the input pin VT_off which is a flag stopping the charging current compensation based on the local voltage measurement. It can be used to indicate that the voltage transformer is not connected to the line anymore.
- **loc**: Input bundles with the 3-phase current signals (a, b and c). It is intended to be connected to the local CTs control output bundles which contain the currents (a, b and c) at the CTs secondary in A.
- **rem**: input bundles receiving the signals from the line remote relays. It is intended to be connected to the output bundle **c** of the remote relays. See **c** definition for the detail of each pin.
- **c:** output bundle sending local signals to the line remote ends relays. It is intended to be connected to one of the input bundles **rem** of the remote relays.
  - **a, b, c**: instantaneous value of each phase local differential current after charging current compensation (if applicable), in ampere at the CTs secondary.

- **Amag, Bmag, Cmag**: phasor magnitude of each phase local differential current after charging current and zero-sequence compensation (if applicable), in ampere at the CTs secondary.
- **Aang, Bang, Cang**: phasor angle of each phase local differential current after charging current and zero-sequence compensation (if applicable), in radian.
- **I0mag, I0rad, I1mag, I1rad, I2mag, I2rad**: magnitude and angle of the sequence local differential currents in amperes at the secondary and radian.
- **Irest_a, Irest_b, Irest_c**: local restraint currents in ampere at the CTs secondary. According to the user selection in the differential protection tab, it can be the sum or the maximum of the local currents absolute value.
- **Irest_negSeq, Irest_zero:** local negative-sequence and zero-sequence currents in ampere at the CTs secondary. According to the user selection in the differential protection tab, it can be the sum or the maximum of the local negative-sequence and zero-sequence currents absolute value.
- **signal*i:*** extra signals which can be passed through the communication channel. According to the manufacturer selection, they can be unused.
  - For **Generic:** none of the **signal*i*** are used.
  - For **SEL:** signal1 is EFD, the local external fault detection flag. The other **signal*i*** are not used.

- **tap**: is the tap position number. Not used if **Winding with tap changer** is set to *none*.
- **s**: output signals bundle. See protection functions documentation for more information.
- **t**: Output bundle with the tripping signal of each phase (outputs a, b and c). They are Boolean and equal to 1 when tripping is requested. The output bundle signals are zero when no tripping is requested.

3 Input data: Electrical characteristics tab

3.1 Line system

- **Frequency**: fundamental frequency.
- **Number of inputs**: 2 or 3. Number of local CTs connected to the relay.
- **Number of remote terminals:** number of line terminals (without counting the local terminal).
- **Enable charging current compensation**: Enable charging current compensation using a local voltage measure. When enabled, the local differential current is calculated as follow:

$$\mathbf{i}_{\mathbf{Loc}} = \mathbf{i}_{\mathbf{MEASURED}} - \frac{1}{n}\mathbf{C}_{\mathbf{LINE}}\frac{d}{dt}\mathbf{v}_{\mathbf{MEASURED}} \tag{1}$$

Where $\mathbf{i}_{\mathbf{MEASURED}}$ is the sum of local currents measured, $\mathbf{v}_{\mathbf{MEASURED}}$ is the local voltage measured, n is the number of terminals where VTs are connected and used for the charging current compensation and $\mathbf{C}_{\mathbf{LINE}}$ is:

$$\mathbf{C}_{\mathbf{LINE}} = \begin{bmatrix} C_s & C_m & C_m \\ C_m & C_s & C_m \\ C_m & C_m & C_s \end{bmatrix} \tag{2}$$

Where C_s is the self-phase capacitance and C_m the mutual capacitance:

$$C_s = \frac{1}{3\omega}\left(B_0 + 2B_1\right) \tag{3}$$

$$C_s = \frac{1}{3\omega}\left(B_0 - B_1\right) \tag{4}$$

ω is the frequency in radian, B_0 is the line zero-sequence susceptance and B_1 the line positive-sequence susceptance.

- **Number of terminals with a VT**: number of line terminals equipped with a VT and where the local relay performs the line charging current compensation. Parameter n in (1).
- **Line length**: used to calculate the total line positive and zero-sequence susceptances using the susceptances given per unit length.

- **Pos-seq susceptance**: positive-sequence line susceptance in per unit length.
- **Zero-seq susceptance**: zero-sequence line susceptance in per unit length.

3.2 In-zone transformer

- **Winding with tap changer**: Indicate 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 per tap change

3.3 Local inputs data

- **Local terminal rated voltage/Rated voltage**: Rated voltage of the local terminal. For in-zone transformer applications, it is used to rescale the remote differential currents according to the transformer ratios.
- **VT ratio**: optional input. If **Enable charging current compensation** is checked, the voltage measured by the local VT is used to estimate the charging current (see (1)). If this feature is disabled, the **VT ratio** data is not used.
- **Winding nominal power**: Nominal power of the transformer winding connected to the local terminal.
- **Rated current:** rated current at the secondary of the local CTs. Used as base for per unit current quantities. If CTs with different rated currents are used, enter the rated current of CT connected to the relay first local input bundle.
- **CT ratio *i***: Ratio of the current at the primary divided by the one at the secondary of the CT connected to the relay local input bundle *i*.

3.4 Local inputs data

- **Transformer connection with local**: Vector group of the transformer between local and remote terminals, the reference being the local terminal. The correction explained in chapter 4.4 is applied according to the vector group selected. Applied only for in-zone transformer applications.
- **Rated voltage**: Rated voltage of the remote terminal. For in-zone transformer applications, it is used to rescale the remote differential currents according to the transformer ratios.
- **Winding nominal power**: Nominal power of the transformer winding connected to the remote terminal.
- **CT ratio**: Ratio of the current at the primary divided by the one at the secondary of the remote terminal CT. If several CTs are connected to a given remote terminal, enter the ratio of CT connected to the relay first local input bundle as the currents measured by the other CTs are locally rescaled accordingly.

3.5 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.

3.6 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. Figure 4-1 shows a signal sampled at a rate of 16 samples per cycle.

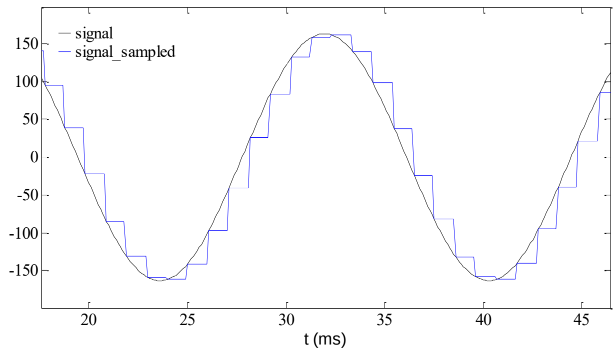

Figure 4-1 Example, signal sampled at a rate of 16 samples per cycle.

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 In-zone transformer vector group compensation

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

For 2-winding transformers:

Connection	**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 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.

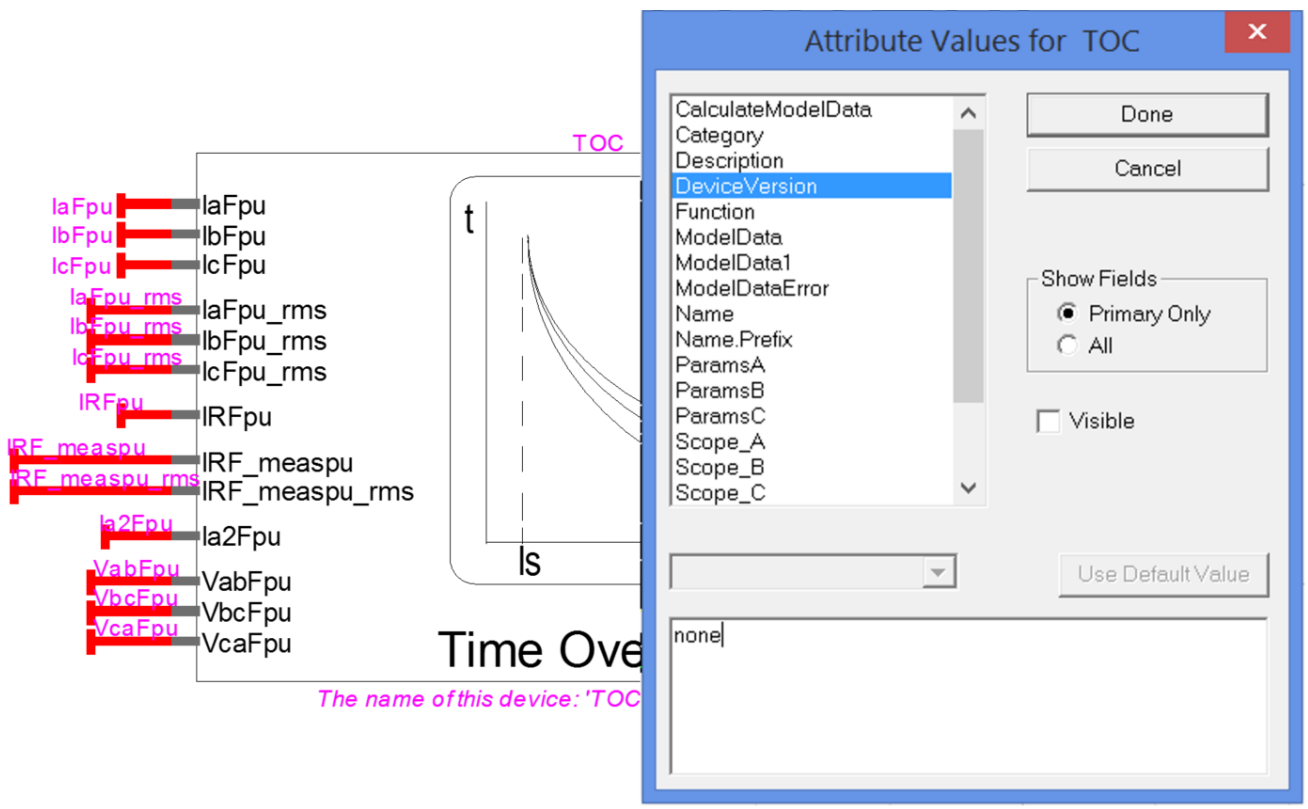

Figure 5-1 How to set the DeviceVersion attribute of the TOC element to allow modifications.