Breaker (TRV)

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1. Available versions

This device is 3-phase. The 3-phase version of this device is the equivalent of 3 independent 1-phase devices with separate data.

2. Description

This device is a breaker modelled by ideal gaps. It has a zero resistance and zero voltage drop when closed and infinite resistance when open.

3. Parameters and rules

3.1 Data tab

The first tab is used to enter the standard switch data:

- t_{close} is the breaker closing time. The breaker will start closing if the simulation time t is greater or equal to t_{close}. Any negative value means that the switch is closed in steady-state. If restrikes/prestrikes and re-ignitions are not considered, the closing is instantaneous. If they are, the closing time depends on the data of the TRV tab.
- t_{open} is the breaker opening time. The breaker start opening if $t \geq t_{open}$ and its current falls below I_{margin} or when its current crosses zero when $I_{margin} = 0$. If restrikes/prestrikes and re-ignitions are not considered, the opening is instantaneous. If they are, the opening time depends on the data of the TRV tab.
- I_{margin} is the absolute current margin.

By definition $t_{open} > 0$ and the switch will not close if $t_{open} \leq t_{close}$. If it is desired to make a breaker closed in steady-state but opened in time-domain, then t_{close} must be any negative value and t_{open} must be given a very small value (smaller than the time-step), such as 1e15.

3.2 Random tab

- **Random data law**: Selects the random data law for this breaker. This is the method used for generating random numbers. There are three options: Uniform, Gaussian and Systematic. More explanations are given below.

- **Dependency** is used to create random data dependency. If the breaker has slaves, in addition of the path of the device, '/t/1' has to be added. For example, in the design of the Figure 3-1, brk1 is the slave of brk2. Figure 3-2 shows how to set the dependency of the phase A of brk1 to be slave of the phase A of brk2.

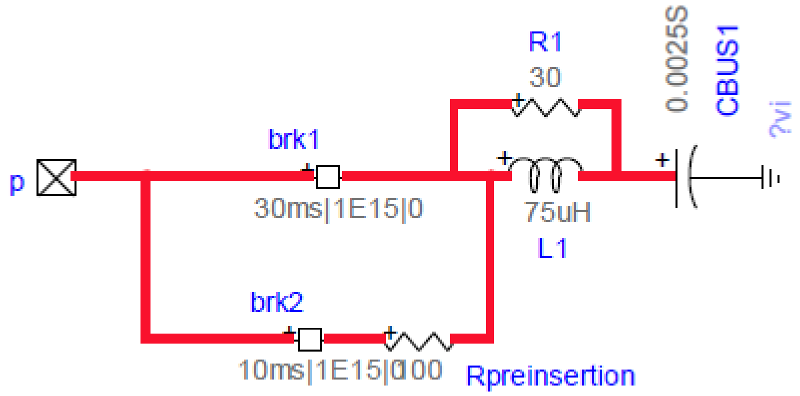

Figure 3-1: Master/Slave between breaker

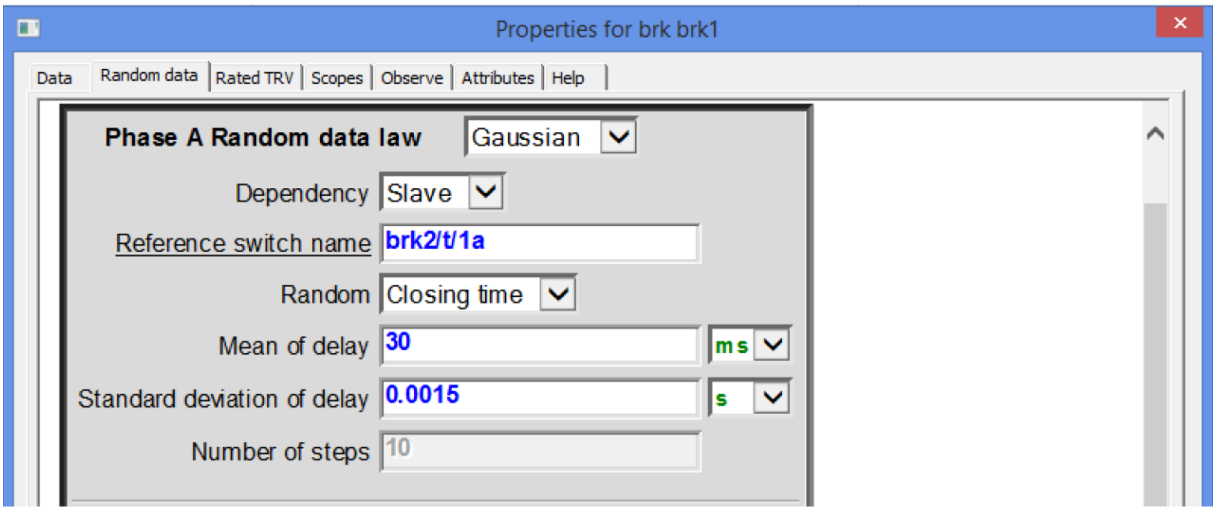

Figure 3-2: Random data tab of brk1, slave of brk2

- **Reference switch name** is the breaker on which the current breaker depends when it is not a Master breaker. Clicking on the hyperlink provides rules for naming the reference breaker. It is noticed that if the switch is 3-phase, then it is allowed to refer from one phase to the other.
  - It is not allowed to refer to a non-random data switch or to any other non-random data based device.
- **Random Closing** time or **Random Opening** time.
  - When **Random Closing** time is selected, then the breaker closing time t_{close} becomes a random variable. The switch is initialized as being open. The breaker opening time t_{open} is not changed and remains active. The breaker may open after t_{open}. The user must also check that $t_{open} > t_{close}$ if desired.
  - When **Random Opening** time is selected, then the breaker opening time t_{open} becomes a random variable. The breaker opening rules described above remain applicable. The breaker is initialized as closed and t_{close} is set to -1.
- **Mean:** This field has different definitions depending on the selections above.
  - The mean (µ) of the Gaussian or Uniform law when this breaker is a Master.
  - The mean (µ) of delay of the Gaussian or Uniform law when this breaker is a Slave.
  - The Start time of the Systematic law when this breaker is a Master.
  - The Start time delay of the Systematic law when this breaker is a Slave.
- **Standard deviation**: This field has different definitions depending on the selections above.

   - The Standard deviation (σ) of the Gaussian or Uniform law when this breaker is a Master.
   - The Standard deviation of delay (σ) of the Gaussian or Uniform law when this breaker is a Slave.
   - The Step size (ΔT) of the Systematic law when this breaker is a Master or Slave.
- **Number of steps**: This field is only used for the Systematic law. It indicates the number of steps performed for this breaker in the Systematic switching process.

In the 3-phase case there are 3 Random data tables, one for each phase. The phases can be interdependent and depend on other switches. It is however illegal to create dependency loops and will result in an error message on EMTP side.

3.2.1. Gaussian and Uniform laws

For a Master breaker the random data generator calculates the random data T_{master} (t_{close} or t_{open}) using the specified Mean μ and Standard deviation σ entries.

For a Slave breaker, the random data generator first generates the random data T_{slave}^{delay} for the slave breaker and then adds it to the master breaker. The following relation is established for an arbitrary pair of Slave and Master breakers:

$T_{slave} = T_{master} + T_{slave\ delay}$

It is allowed to have a negative T_{slave}^{delay} and it is allowed to specify a negative Mean for the Slave breaker. It is noticed however that the Mean of a Master breaker cannot be negative since it will step into the steady-state solution domain. Generally speaking, the calculated random time T of any breaker (Slave or Master) should be bounded to make a significant event:

$t_{dice} < T < t_{max}$ (1)

The t_{max} is the maximum simulation time and t_{dice} is the "Time of dice roll" which is set in the "Stat Options" device. The t_{dice} is the starting time of all random simulations (energizations) in a case. It is greater or equal to zero. More information on the setting of this parameter can be found in the Help section of "Stat Options". For a random closing breaker the random time T corresponds to the actual (real switching time T_{real}) closing time. For a random opening breaker the random time T is the time after which the breaker is allowed to open based on its current I_{margin} condition, thus the real switching time may be different and fall outside the interval given by equation (1).

If the Uniform law is used, the user can pre-calculate the random data interval by using the following formulas:

$$T_{min} = \mu - \sqrt{3} * \sigma$$

$$T_{max} = \mu + \sqrt{3} * \sigma$$

When the T_{real} of a breaker falls outside the interval of equation (1), EMTP still performs the simulation. For a random closing breaker, there will be no actual closing, but the breaker may open based on t_{open} and I_{margin}. For a random opening breaker, there will be no opening and the breaker will remain closed for the given random simulation.

3.2.2. Systematic law

In this case the breaker random time T_{master} (becomes t_{close} or t_{open}) for each breaker is computed from the following equation for an arbitrary Master breaker:

$T_{master} = T_{masterstart} + (n_{master} - 1)\Delta T_{master}$ where T_{master} start is the Start time, n_{master} is the Number of steps and ΔT_{master} is the step size. The minimum value of n_{master} is 1. All these numbers are positive for a Master breaker.

ΔTmaster can be zero and nmaster can be 1.

If there are several systematic breakers in a design, then EMTP must perform all switching combinations and the maximum number of systematic simulations is given by the following formula:

$$N_{systsimulation} = \prod_{i=1}^{n_{syst}} n_i$$

where n_{syst} is the number of systematic breakers (Master or Slave) and n_i is the Number of steps for each systematic breaker. This number can become very high and the user must be careful with selections. More options are available through the “Stat Options” device.

For a Slave systematic breaker, the Tslave is calculated as follows:

Tslave = $T_{master} + T_{slavedelay} + (n_{slave} - 1)\Delta T_{slave}$

It is now allowed to use a negative T_{slave}^{delay} . In most cases it is just required to specify a simple delay by setting n_{slave} to 1.

The rules indicated by equation (1) remain applicable.

3.2.3. Base Case

The Base Case option that can be selected in the “Stat Options” device is for performing a standard simulation before starting random simulations (random data based simulations).

This “Breaker” device does not calculate any random data in the Base Case simulation. The following settings are automatically applied for a Gaussian or Uniform law switch:

- If the breaker is a closing breaker: $t_{close} = \mu$, the breaker is initialized as open, but t_{open} remains active.
- If the breaker is an opening breaker: $t_{open} = \mu$, the breaker is initialized as closed and t_{close} is set to -1.

When the breaker is using a Systematic law, then the Mean time μ above is replaced by the Start time. All dependency rules are maintained.

4. Rated TRV Tab

This tab contains the options to display the rating Transient Recovery Voltage (TRV) of the breaker, to enable restrikes/prestrikes and re-ignitions and to include stray capacitances.

❑ **Draw rating TRV**: enables the rated TRV drawing.
If **Draw rating TRV** is on, the other tabs are displayed.

❑ **Enable Restrikes/prestrikes and re-ignitions**: enables the gap conduction when its voltage withstand is reached. When the breaker is opened, closing or opening, if the voltage at the terminal of the breaker reaches the envelope of the voltage withstand, the gap is closed and opened again with the current goes bellow I_{margin}.

❑ **Envelope**: choose **Standard IEC 62271-100** for predefined data or **User-defined** to use your own data.

❑ **Rated voltage**: Rated voltage of the circuit breaker in kVRMS line to line. Value predefined in the standard [1]

❑ **Short-circuit current**: Current in kA RMS that goes through the breaker before opening. Can be determined by simulating the event without opening the switch or in steady state and looking at the current through the breaker. Used to interpolate the parameter from T10, T30, T60 and T100. Has to be between 10 and 100% of the **Rated short-circuit current.**

❑ **Rated short-circuit current**: Rated short-circuit current of the circuit breaker in kA RMS.

❑ **Calculate Short-Circuit current while closing this box**: if this checkbox is checked, the calculation of Short-Circuit Current will be done after closing the HTML window. The calculated value will be then set in the field “Short-Circuit Current”.

❑ **Class**: **Class S1** for cables and **Class S2** for lines with a rated voltage below 100kV. **>100k effectively earthed** for breakers with a rated voltage bigger than 100kV in an effectively earthed system and **>100kV non-effectively earthed** for breakers with a rated voltage bigger than 100kV in a non-effectively earthed system.

- **Include stray capacitances**: when enabled, two stray capacitances, one on each side of each pole of the circuit breaker, are added.

The second table can be modified only if **Envelope** is set to **User-defined**. Else, it only displays the parameters predefined.

- **TRV shape**: Select the shape of the TRV envelope. 2 options: **2-parameter** or **4-parameter** as defined in [1].
- **First Voltage Reference U1**: four-parameter TRVs only. Value of the withstand voltage of the circuit breaker at **t1** after the beginning of the opening. (kV peak)
- **TRV peak value Uc**: Maximum value of the withstand voltage of the circuit breaker. Reached at **t2** for 4-parameter envelopes and at **t3** for 2-parameter envelopes. (kV peak)
- **Time t3**: used for **2-parameter** TRVs only. (us)
- **Time t1**: used for **4-parameter** TRVs only. (us)
- **Time t2**: used for **4-parameter** TRVs only. (us)
- **RRRV1**: Rate of rise of recovery voltage. Used for **4-parameter** TRVs. It is the first slope of the rated TRV. It is calculated with **U1** and **t1**. (kV/us)
- **RRRV2**: Rate of rise of recovery voltage. Used for **2 and 4-parameter** TRVs. It is the second or only slope of the rated TRV. It is calculated with **Uc** and **t3** (or Time **t2** for four parameters TRV). (kV/us)
- **td**: Delay time between the opening of the breaker and the occurrence of the reflection.
- **U’**: reference voltage of the delayed part of the curve
- **t’**: End time of the reflected part of the standard, i.e. time to reach U’

The next options are only showed if the "Include stray capacitances" is checked.

- **Breaker type**: Type of breakers. Defined in [2].
- **Stray capacitance +**: stray capacitance at the pin k (+) of the breaker.
- **Stray capacitance -**: stray capacitance at the end of the breaker