**Report –** PSCAD component “statistical breaker close”



Statistical Breaker Close

Shan Jiang

**Manitoba HVDC Research Centre,** a division of

Manitoba Hydro International Ltd**.**

211 Commerce Drive

Winnipeg,MB R3P 1A3

CANADA

[www.hvdc.ca](http://www.hvdc.ca)

File: 20-250-80013

Rev:

Date: Jan 21, 2013

|  |  |  |
| --- | --- | --- |
| **Rev** | **Description** | **Date** |
| **0** | First Issue Report | Jan-21-2013 |
| **1** | Second Issue Report |  |
|  |  |  |
|  |  |  |

# Executive Summary

This report presents the study of the PSCAD component “statistical breaker close”.

In PSCAD, the breaker is assumed to be able to close at any (voltage) point on wave (POW), and the three phase contacts may close with different time delays. The delay time is consistent with normal distribution in statistics.

The component “statistical breaker close” is developed to simulate the normal distributed closing delays of breaker main contracts and the pre-insertion contacts. It, together with PSCAD components “multiple run” and “breaker”, can be used to study following aspects of breaker close:

1. the switching transients due to the different closing point on (voltage) wave (POW),
2. the impact of pre-insertion on the switching transients.

This report introduces the “statistical breaker close” component, presents the validation results and gives the application examples for the component.

Contents

[1. Executive Summary 2](#_Toc346542327)

[2. Introduction 4](#_Toc346542328)

[2.1. The breaker operation in PSCAD/EMTDC 4](#_Toc346542329)

[2.2. Normal distribution 7](#_Toc346542330)

[3. The “statistical breaker close” 9](#_Toc346542331)

[4. Validation of “statistical breaker close” 11](#_Toc346542332)

[5. Examples 13](#_Toc346542333)

[5.1. The impact of different closing time on the switching voltage (case “statistic\_singlepole.pscx”) 13](#_Toc346542334)

[5.2. The impact of the pre-insertion resistor (case “statistic\_preinsertion.pscx”) 15](#_Toc346542335)

[6. Appendix 18](#_Toc346542336)

[6.1. Case1: “validation.pscx” 18](#_Toc346542337)

[6.2. Case2: “statistic\_singlepole.pscx” 19](#_Toc346542338)

[6.3. Case3: “statistic\_preinsertion.pscx” 20](#_Toc346542339)

# Introduction

In PSCAD, the breaker is assumed to be able to close at any (voltage) point on wave (POW), and the three phase contacts may close with different time delays. The delay time is consistent with normal distribution in statistics.

The component “statistical breaker close” is developed to simulate the normal distributed closing delays of breaker main contracts and the pre-insertion contacts. It, together with components “multiple run” and “breaker”, can be used to study following aspects of breaker close:

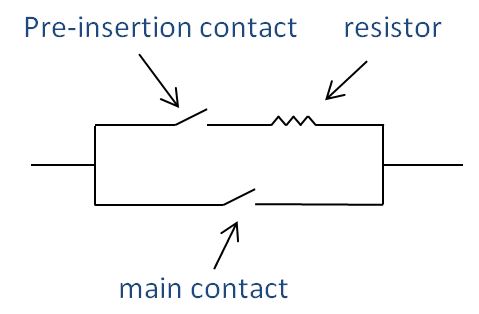
1. The switching transients due to the different closing point on (voltage) wave (POW),
2. The impact of pre-insertion on the switching transients.

This report includes following sections:

1. A brief description of the breaker operation (standard PSCAD/EMTDC model in the Master Library).
2. An introduction of the PSCAD component “statistical breaker close”.
3. Validation of the component by comparing the simulation results with the mathematical calculation results.
4. Examples for the component application.

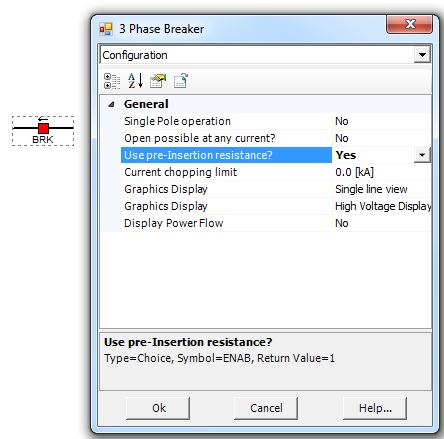
## The breaker operation in PSCAD/EMTDC

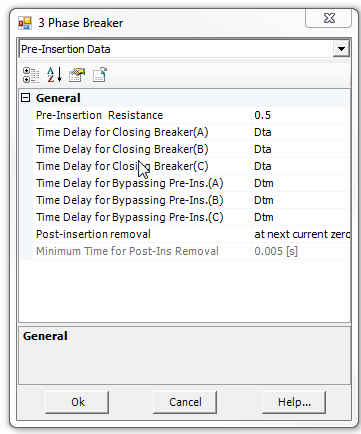
The breaker model contains three phases. As shown in *Figure 1*, each phase of the PSCAD (three phase) breaker model consists of a main contact and a pre-insertion circuit. The pre-insertion circuit contains resistor contact and a resistor. It is designed to protect the main contact from arc strike during closing operation. During the closing operation, the resistor contacts closes prior to the main contact (about 10-15 msec). It can reduce and damp the switching transients. If the actual breaker under study does not have the pre-insertion circuit, then this path can be ‘disabled’ in the model to represent only the main contact.



*Figure 1 breaker with pre-insertion resistor*

Several options and features of the standard breaker model (*Figure 2*) are discussed below.



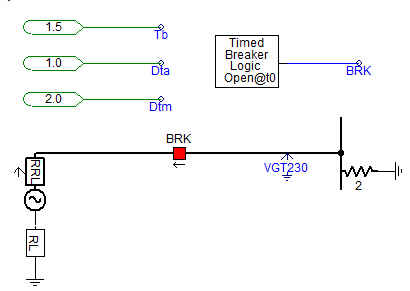


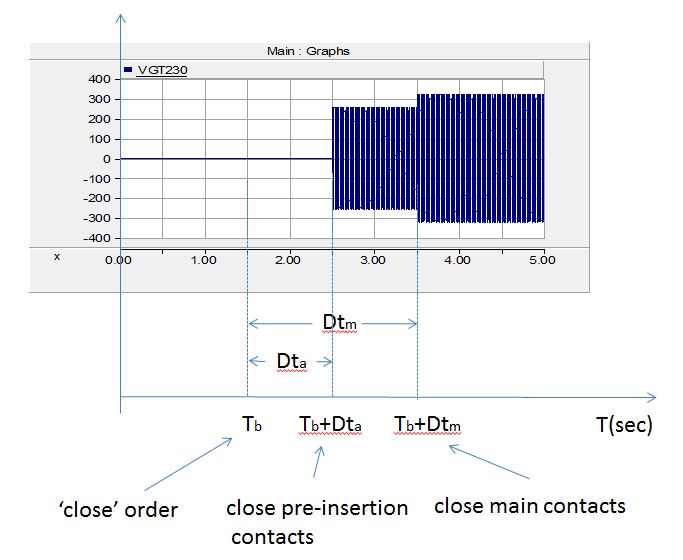
*Figure 2 breaker settings in PSCAD*

**Single Pole Operation**: Select **Yes** or **No**. If ***Yes*** is selected, all three breaker phases will operate independent of each other. Therefore, three input control signals are required.

**Use Pre-Insertion Resistance?:** If ***Yes*** is selected, the pre-insertion circuits are included. Then the corresponding resistor (**Pre-insertion resistance**), the time delay to close the pre-insertion contact (**Time Delay for Closing Breaker - Dta)** and the time delay to close the main contact (**Time Delay for Bypassing Pre-Ins. - Dtm**) need to be specified.

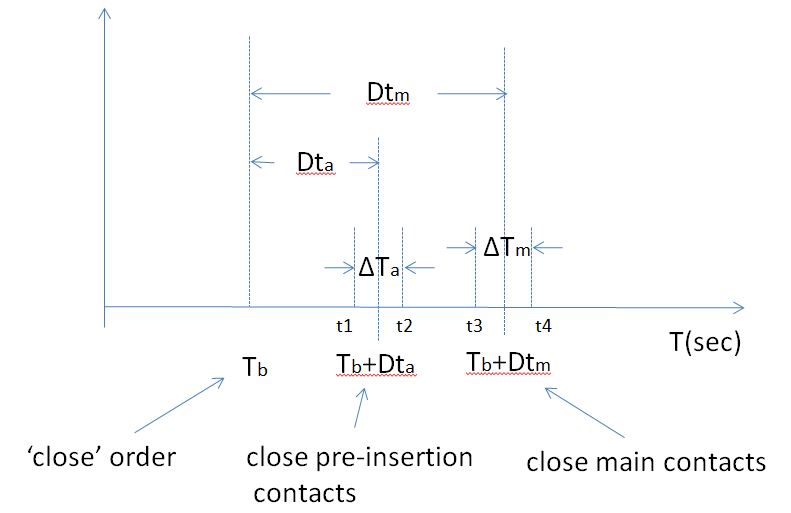
With above model, PSCAD is able to simulate the split closes of the main contacts, as well as the pre-insertion contacts.





*Figure 3 Closing time of the breaker with pre-insertion contacts and main contacts*

*Figure 3* shows the closing times of the breaker contacts. The breaker receives the “close” signal at time Tb. After a time delay Dta, the pre-insertion contacts close first, and then after a time delay Dtm, the main contacts close. Note that the closing time delay Dta and Dtm are the ‘mean closing time’. The contacts may close at any time in the intervals t1 to t2 and t3 to t4 as shown in Figure 4 (see the PSCAD case corresponding t*o Figure 3).*



*Figure 4 Closing time of the breaker with statistical deviation accounted*

The exact closing time of each pole is normal distributed in nature.These natures (time delays Dta, Dtm and normal deviation time ΔTa, ΔTm) can be simulated using the ‘Statistical Breaker Close’ model or the Random (number) Generator component. Examples are presented and discussed in the later section.

## Normal distribution

In [probability theory](http://en.wikipedia.org/wiki/Probability_theory), the normal (or Gaussian) distribution is a [continuous probability distribution](http://en.wikipedia.org/wiki/Continuous_probability_distribution), defined by the formula

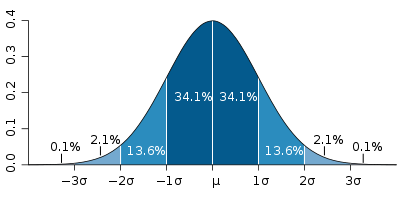

f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{ -\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2 }


Where:

μ: the [mean](http://en.wikipedia.org/wiki/Mean) of the distribution.

σ: the [standard deviation](http://en.wikipedia.org/wiki/Standard_deviation).

The normal distribution is an important statistical distribution which is often used to describe, at least approximately, any variable that tends to cluster around the mean. Figure 5 shows the normal distribution curve. The Y-axis is the probability, and the X-axis is the value generated randomly around the mean.

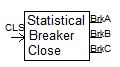
[](http://upload.wikimedia.org/wikipedia/commons/8/8c/Standard_deviation_diagram)

*Figure 5 Probability density curve of the normal distribution*

The mean μ shows the peak of the probability occurs, and the standard deviation σ shows how much variation or "[dispersion](http://en.wikipedia.org/wiki/Statistical_dispersion)" exists from the average ([mean](http://en.wikipedia.org/wiki/Mean)). A low standard deviation indicates that the data points tend to be very close to the [mean](http://en.wikipedia.org/wiki/Mean); high standard deviation indicates that the data points are spread out over a large range of values. The number of standard deviation σ indicates the probability of the values drawn from a normal distribution lying in. For an example, 68% of values draws from normal distribution are within area (μ-σ, μ+σ), 95% are within (μ-2σ, μ+2σ) and 99.7% are within (μ-3σ, μ+3σ).

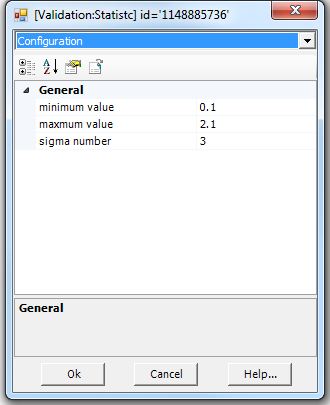
# The “statistical breaker close”

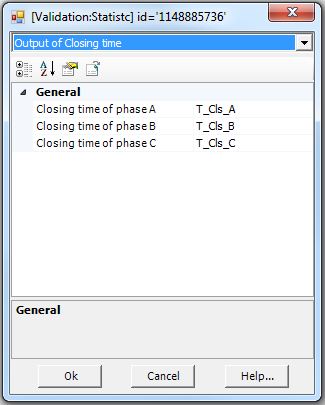
This component is designed based on normal distribution theory. The purpose is to generate normal distributed switching signals for breaker close operation.



*Figure 6 the “statistical breaker close”*

*Figure 6* shows the component “statistical breaker close”. The input “Cls” (real) gives the time to issue the “close” directive. The outputs (BrkA, BrkB and BrkC) (integer) are signals to control the breaker operation (“1”=breaker open, “0”=breaker close).





*Figure 7 “statistical breaker close” input parameters*

**Input parameters:**

Configuration

Minimum value: the minimum value of normal distribution.

Maximum value: the maximum value of normal distribution.

Sigma number: the number of standard deviation (σ).

**Output of closing time:**

Closing time of phase A: name for the closing time of phase A

Closing time of phase B: name for the closing time of phase B

Closing time of phase C: name for the closing time of phase C

The normal distributed time delay is defined by the input parameters:

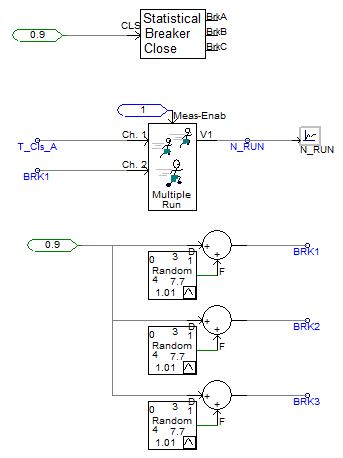
Mean: μ = (min+max)/2

Number of standard deviation: nσ = (max-min)/2 (n is the sigma number)

If the “Cls” = 0.9, min = 0.1, max = 2.1, then the closing time of phase A,B,C lie in area (Cls+min, Cls+max) = (1, 3).

# ****Validation of “statistical breaker close”****

To examine whether the “**statistical breaker close**” works correctly and to better understand its setting (mean μ and standard deviation), a test is carried out on PSCAD.



*Figure 8 validation of “statistical breaker close”*

See *Figure 8*, in this test, there are total 5000 runs and in each run a normal distributed number “T\_Cls\_A” (an internal output of “**statistical breaker close**”) is generated. The statistical distribution of these 5000 values is calculated by the Multiple Run component. As a comparison an output from a random generator is also input to the “Multiple Run”. The simulation results from the “**statistical breaker close**” and “Multiple Run” are compared with mathematical calculation. See *Figure 9*, the results from “**statistical breaker close**” show a close agreement with the mathematical calculation and “random generator” (details see PSCAD case1 ‘validation.pscx’).

.

*Figure 9 Validation of “statistical breaker close”-the probability curve* *with different number of standard deviation (2, 3 and 4)*

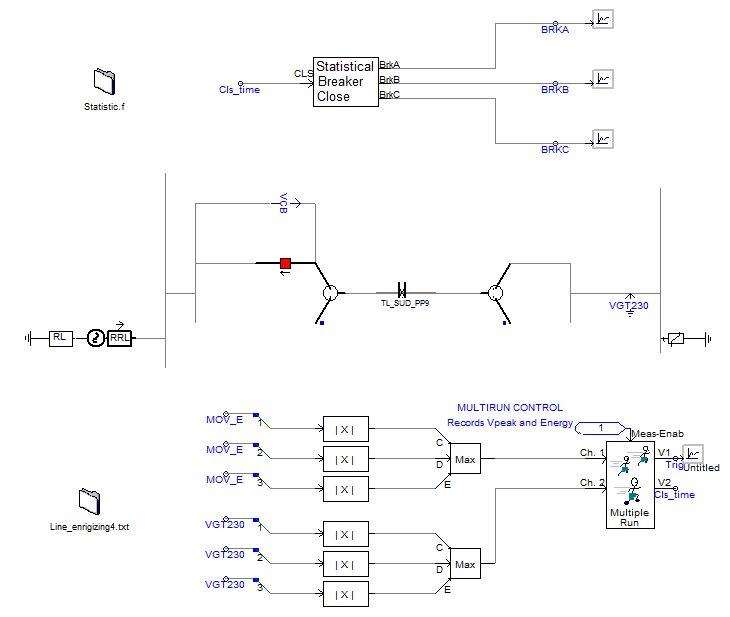
# Examples

Two examples are created to illustrate the component applications in breaker switching study.

## The impact of different closing time on the switching voltage (case “statistic\_singlepole.pscx”)

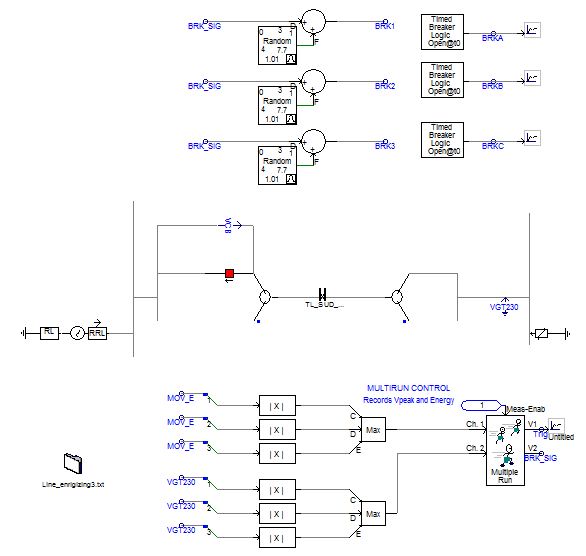
This case is to examine the impact of different closing time on the switching voltage during transmission line energizing.

A simple circuit was used in the example (*Figure 10*). A 380 kV AC source is connected to a bus via a transmission line (T\_line). Closing the breaker from the source end will energize the line. The closing instant is controlled by the Multiple Run which is set so that the breaker closes at 50 incremental points on a single cycle. At each point (set by the Multiple Run), there are 20 further runs with the poles closing around a mean with a statistical distribution. Thus, a total of 1000 closing operations ensure the credibility of the test. The closing signal for the breaker is given by the “statistical breaker close” which randomly generates the closing signals for the three contacts of the breaker.



*Figure 10* Circuit to test the impact of different breaker closing time on switching vlotage(Case: “statistic\_singlepole.pscx”)

To examine the credibility of this case, a similar case is also created by replacing the“statistical breaker close” with three random generators (*Figure 11*).



*Figure 11 validation* circuit using random generators

The distribution of the maximum switching overvoltage under different switching instants (POW) is shown in *Figure 12*. The following are the observations:

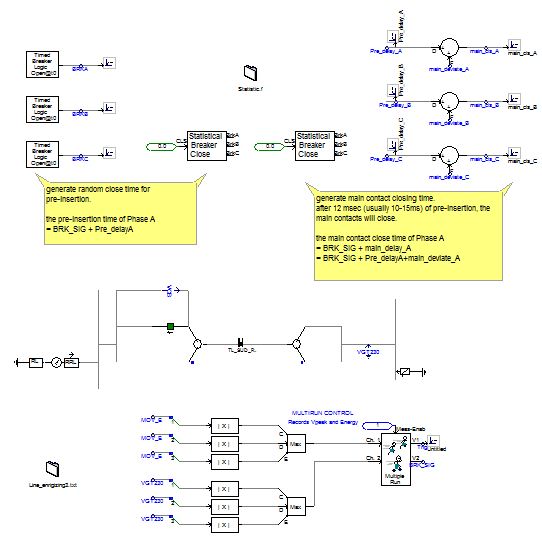
1. The closing voltages range from 430KV to 630KV. This shows that the different closing time will result different closing voltage.
2. The results from using “statistical breaker close” and random generator are identical.

*Figure 12 impact of different closing time on line voltage*

## The impact of the pre-insertion resistor (case “statistic\_preinsertion.pscx”)

This case is to examine the impact of the pre-insertion resistor on the switching voltage during transmission line energizing.

The circuit is shown in *Figure 13*. Similar with last example, a validation case is also created by replacing the“statistical breaker close” with three random generators.



*Figure 13* Circuit to test the impacts of pre-insertion resistor (Case: “statistic\_preinsertion.pscx”)

*Figure 14*  the impacts of pre-insertion resistor on the switching voltage (Case: “statistic\_singlepole.pscx”)

Simulation results (*Figure 14*) shows that

1. The closing voltages range from 350KV to 460KV. The pre-insertion resistor largely reduces the switching voltage.
2. The results from using “statistical breaker close” and random generator are identical.

# ****Appendix****

## Case1: “validation.pscx”

This case examine whether the “**statistical breaker close**” output signals are consistent with normal distribution.

The settings of main components in the PSCAD case “**singlepole.pscx**” are shown in Table 1.

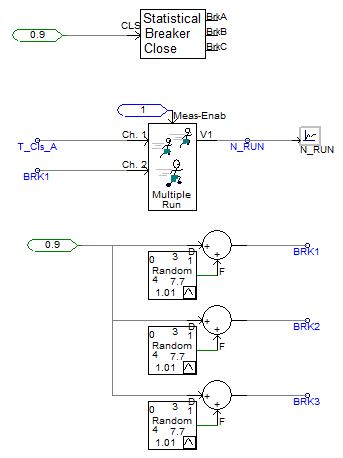
Cls =0.9

μ = (min +max)/2+Cls = 2.0

n\_sigma\*σ = (max-min)/2 (n\_sigma is the sigma number)

Table 1 Settings of the main components in Case1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **# of Runs** | | | |
| Multiple Run | 50 points in 1 cycle, each point 20 runs. Total runs: 1000 times | | | |
| Statistical breaker close | **Input (Cls)** | **Minimum value** | **Maximum value** | **# of standard deviations (n\_sigma)** |
| 0.9 | 0.1 | 2.1 | 2,3,4 respecitively |



*Figure 15*  the circuit of case1 “validation.pscx”

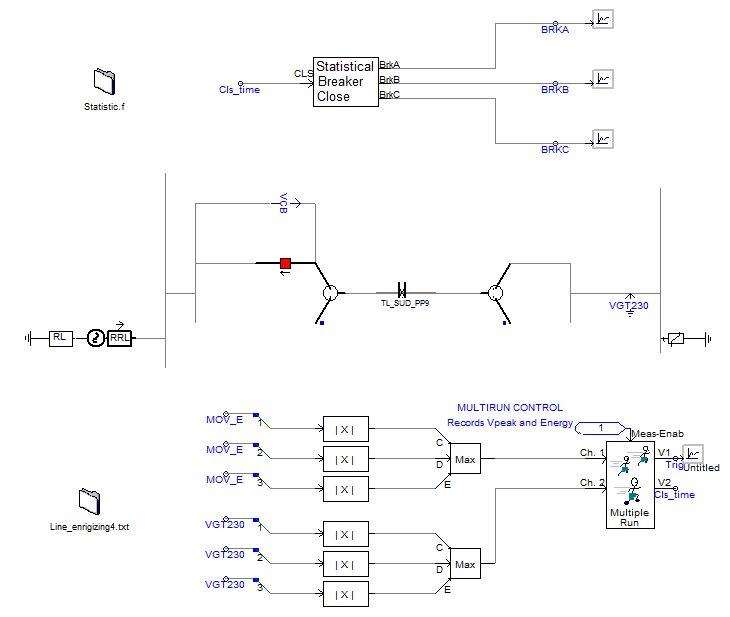
## Case2: “statistic\_singlepole.pscx”

This case examine the impact of different closing time on the switching voltage.

The settings of main components in the PSCAD case “**singlepole.pscx**” are shown in Table 2.

Table 2 Settings of the main components in Case2

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **# of Runs** | | |
| Multiple Run | 50 points in 1 cycle, each point 20 runs. Total runs: 1000 times | | |
| Statistical breaker close | **Minimum value** | **Maximum value** | **# of standard deviations (n\_sigma)** |
| 0.008 | 0.015 | 3 |



*Figure 16*  the circuit of case1 “statistic\_singlepole pscx”

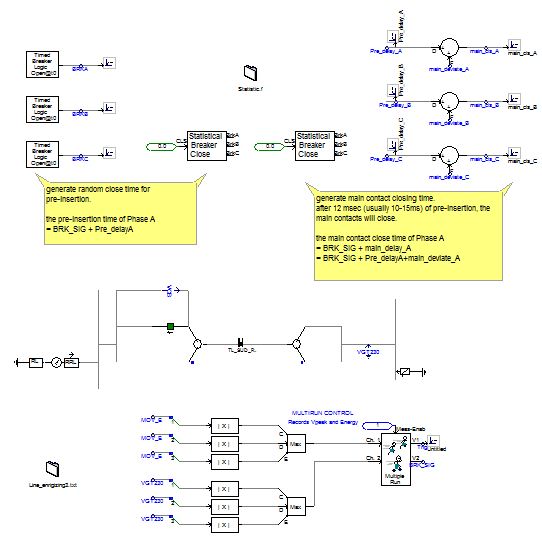
## Case3: “statistic\_preinsertion.pscx”

This case examine the impact of different closing time on the switching voltage.

The settings of main components in the PSCAD case “**singlepole.pscx**” are shown in Table 3.

Table 3 Settings of the main components in Case3

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **# of Runs** | | |
| Multiple Run | 50 points in 1 cycle, each point 20 runs. Total runs: 1000 times | | |
|  | **Minimum value** | **Maximum value** | **# of standard deviations (n\_sigma)** |
| Statistical breaker close 1 to generate delay time for pre-insertion contacts | 0.008 | 0.015 | 3 |
| Statistical breaker close 1 to generate delay time for main contacts | 0.010 | 0.014 | 3 |



*Figure 17*  the circuit of case1 “statistic\_preinsertion pscx”