Statistical Breaker

Written for PSCAD v4.5 and v4.6.

In this document we learn the theory of normal distribution and the functionality of the statistical breaker through some examples.

1. Normal Distribution

In probability theory, the normal (or Gaussian) distribution is a 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 of the distribution

σ: the 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 1 shows the normal distribution curve. The Y-axis is the probability, and the X-axis is the samples generated randomly (closing time for the breaker) around the mean.

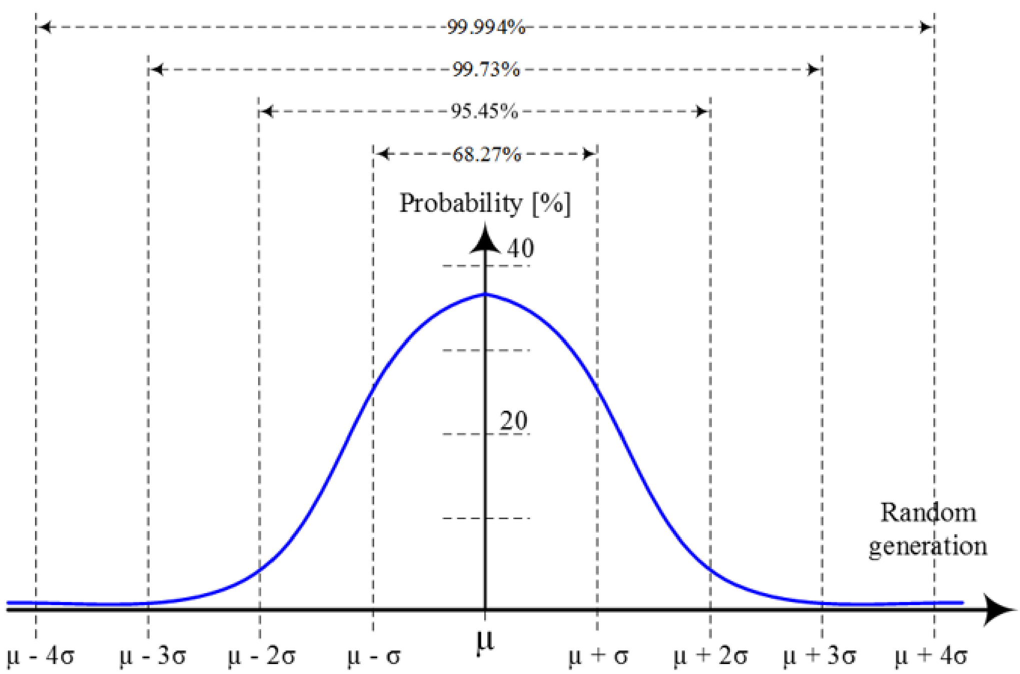

Figure 1:Normal Statistical generation of sample closing time for breaker

Notes

The statistical breaker always generates samples within a normal distribution. The number of standard deviations indicates the probability of the values being drawn from a normal distribution. If the number of standard deviations is 1, then about 68.27% of samples are within the area (μ-σ, μ+σ). If it is 2 (μ-2σ, μ+2σ), then 95.45% are within. If it is 3, then 99.73% are within (μ-3σ, μ+3σ). If it is 4, 99.994% are within (μ-4σ, μ+4σ) (See Figure 1).

The larger the standard deviation number, the more computation time is needed.

2. Statistical Breaker

The statistical breaker is designed based on normal distribution theory. The purpose is to generate three individual breaker close status signals within a user-defined delay time interval.

Notes

If the input signal changes to open status, all three individual signals will change to open status immediately (no single-pole operation).

This component is used to simulate the normal distributed closing delay of breaker main contacts. It is usually used together with master library components Multiple-Run and Three-Phase Breaker.

<u>Example 1: Statistical breaker operation</u>

Figure 2 shows the component “statistical breaker close”. The input “Cls” is breaker closing command signal (which is initiated at 0.1 sec in this example), gives the time to issue the “close” directive. The outputs (BrkA, BrkB and BrkC) are signals to control the breaker operation (“1”= breaker open, “0” = breaker closed).

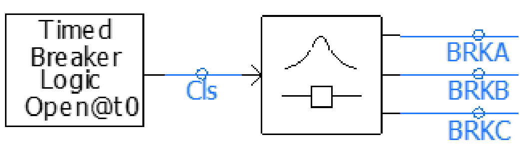

Figure 2:The statistical breaker is closed

The statistical breaker is meant to be used in the single-pole operation of a 3-phase breaker, in a statistically distributed manner.

Once a breaker closing command signal (Cls) is received on its input, the statistical breaker will generate three individual breaker close status signals within a minimum and maximum time delay.

In this example, the number of standard deviation is varied to 4 and 1 respectively as shown in the following cases to show its impact on the sample generation.

Case1: The number of standard deviations in the half interval is 4

Figure 3 shows the minimum time delay (MinTD) is zero and maximum time delay (MaxTD) is 0.0.004 sec. Therefore the user-defined delay time interval is 0.004 – 0 = 0.004 sec.

The number of standard deviations in the half interval is 4. Therefore the mean (μ) is close to 0. 0.002 sec and the standard deviation (σ) of the breaker is 0.0005 sec (as the number of samples goes to infinity).

Therefore the statistical-breaker generates random closing time for breaker in between 0.1 sec and 0.104 sec around 0.102 sec (mean +0.1 sec).

As shown in Figure 3 the number of standard deviations is 4 and about 99.994% of samples must be within the area (μ-4σ, μ+4σ).

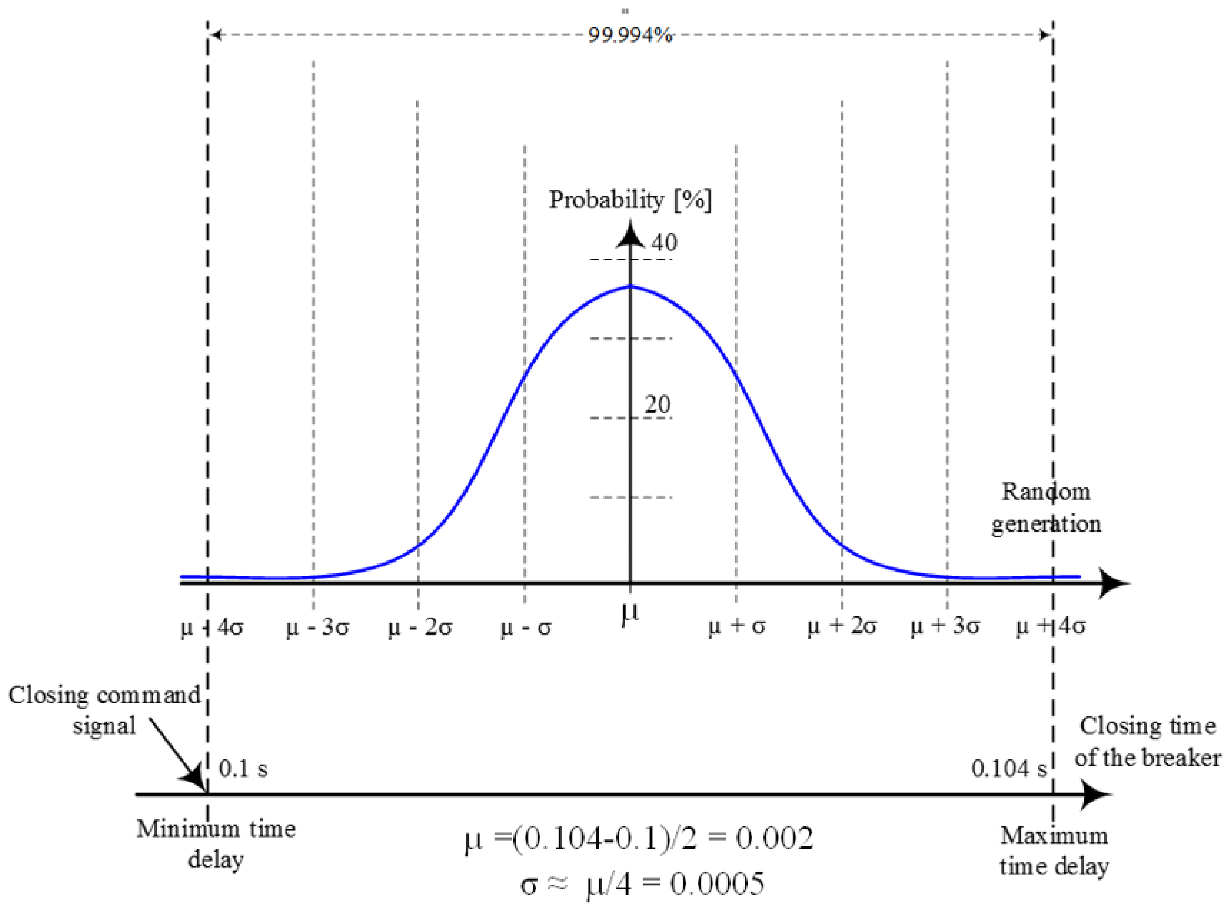

Figure 3:Normal statistical distribution of sample closing time when the number of standard deviations is 4

Figure 4 shows the simulation results for 1000 random sample closing times with the number of standard deviations in the half interval set to 4. As shown in Figure 4, the closing signal of each phase is grouped closer to the mean. The distribution curve is sharp and there is less breaker operations closer to MinTD and MaxTD.

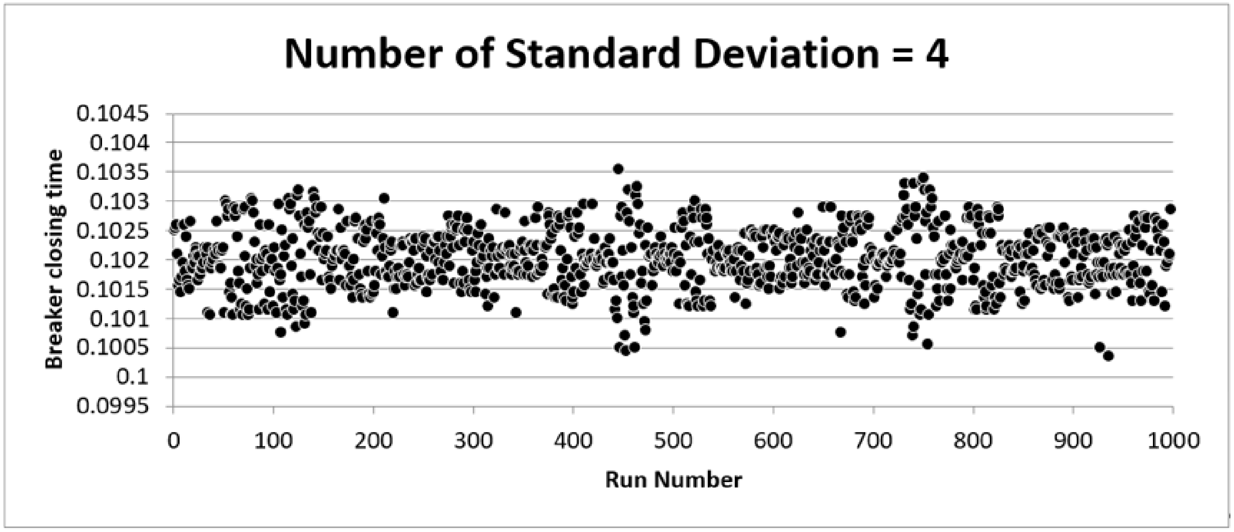

Figure 4:Normal distribution of 1000 sample closing time generated by statistical breaker when the number of standard deviations is 1

Case2: The number of standard deviations in the half interval is 1

Figure 5 shows the MinTD is zero and MaxTD is0.004 sec. Therefore, the mean (μ) is close to 0.002 sec and the standard deviation (σ) of the breaker is around0.0005 sec. Consequently, the statistical-breaker generates random closing time for breaker in between 0.1 sec and 0.104 sec around 0.102 sec (mean +0.1 sec).

As shown in Figure 5, the number of standard deviations is 1 and about 68.27 % of samples are within the area (μ-σ, μ+σ). During the determination of switching instances by the random number generator any number that is generated which falls outside the range of 1 standard deviation is discarded and a new number is drawn until one is found in the specified range.

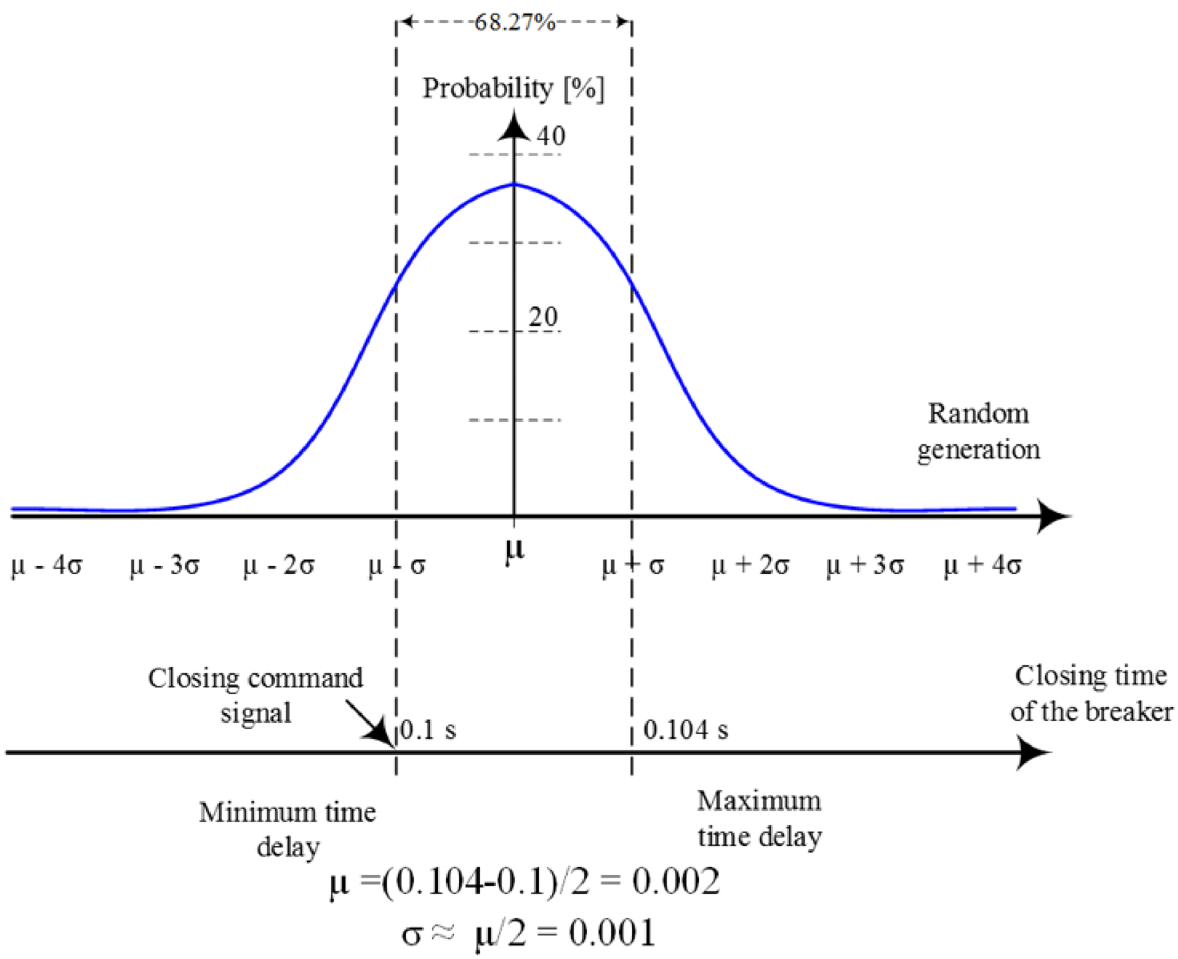

Figure 5:Normal statistical distribution of sample closing time when the number of standard deviations is 1

Figure 6 shows the simulation results for 1000 random sample closing times when the number of standard deviations in the half interval is 1. The slope of the distribution curve is more flat compared to case 1 (where standard deviation in 4) and there is a more “uniform” distribution of close signals between MinTD and MaxTD.

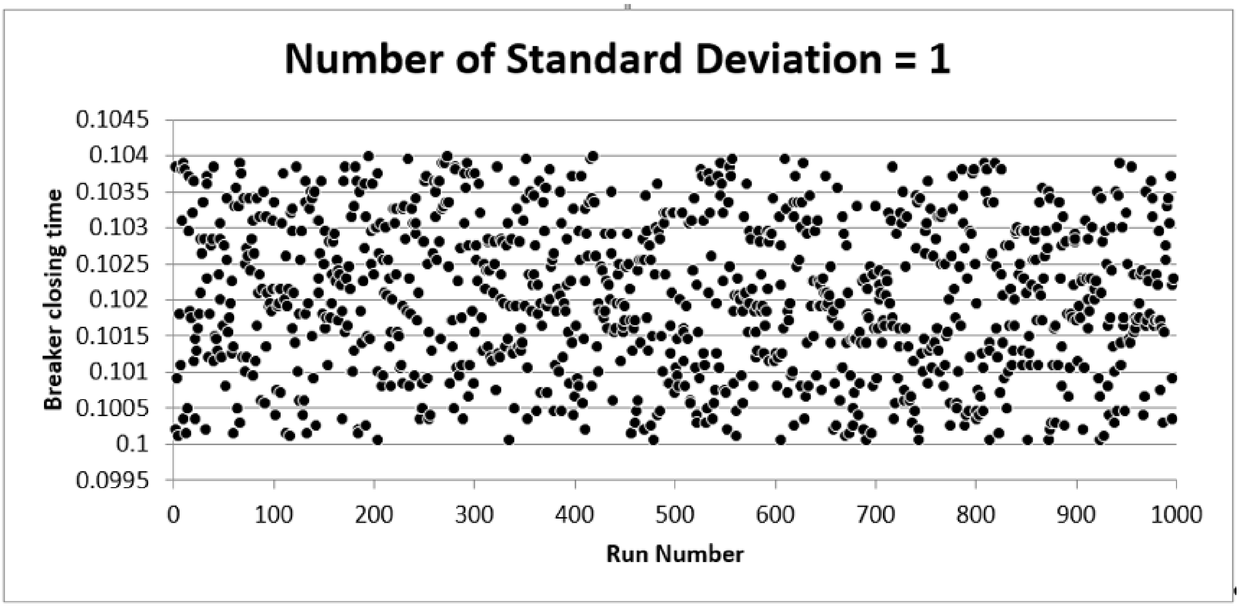

Figure 6:Normal distribution of 1000 sample closing time generated by statistical breaker when the number of standard deviations is 1

<u>Example2: Impact of Closing Time on Switching Voltage</u>

The impact of varying breaker closing times on the switching voltage, during transmission line energization, is examined in this example.

The simple circuit used in this example is shown in Figure 7. A 380 kV, AC source is connected to a bus via a transmission line (TL). Closing the breaker from the source end will energize the line. The closing instant is controlled by the Multiple Run component, 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, which randomly generates the closing signals for the three contacts.

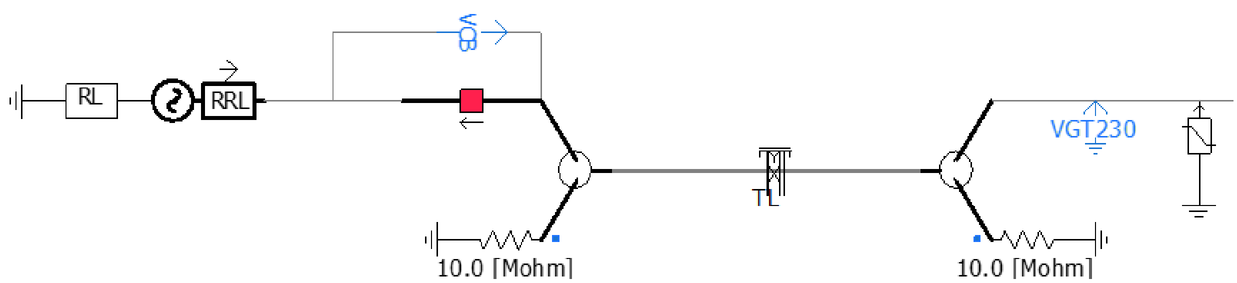

Figure 7:Transmission line energization circuit; the transmission line consist of double circuit

Settings for multiple run component are shown in Figure 8 where the files are saved in Line_energizing.txt.

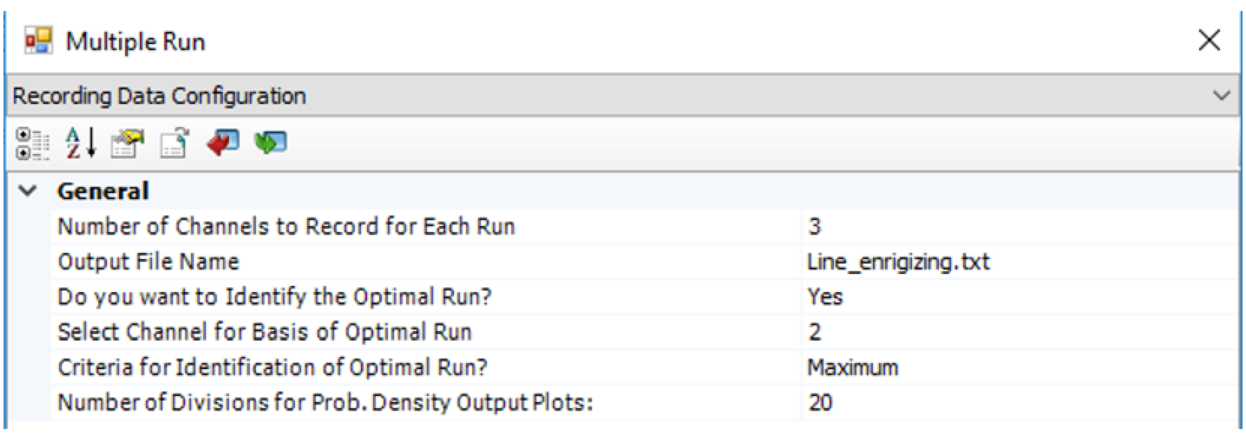

Figure 8:Settings for multiple run components

Simulation procedures:

1. Disable Multiple-Run, run 0.2 sec and get the snapshot file.
2. Change project setting:
    - Duration of run is changed as 0.06 sec (to save simulation time),
3. Start from snapshot. Then each run starts from 0.198 sec.
4. Enable Multiple-Run.
5. When simulation finishes, open file reference to check the switching voltage at different runs.