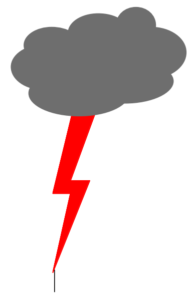
Lightning stroke



Henry Gras, 6/2/2023 3:16 PM

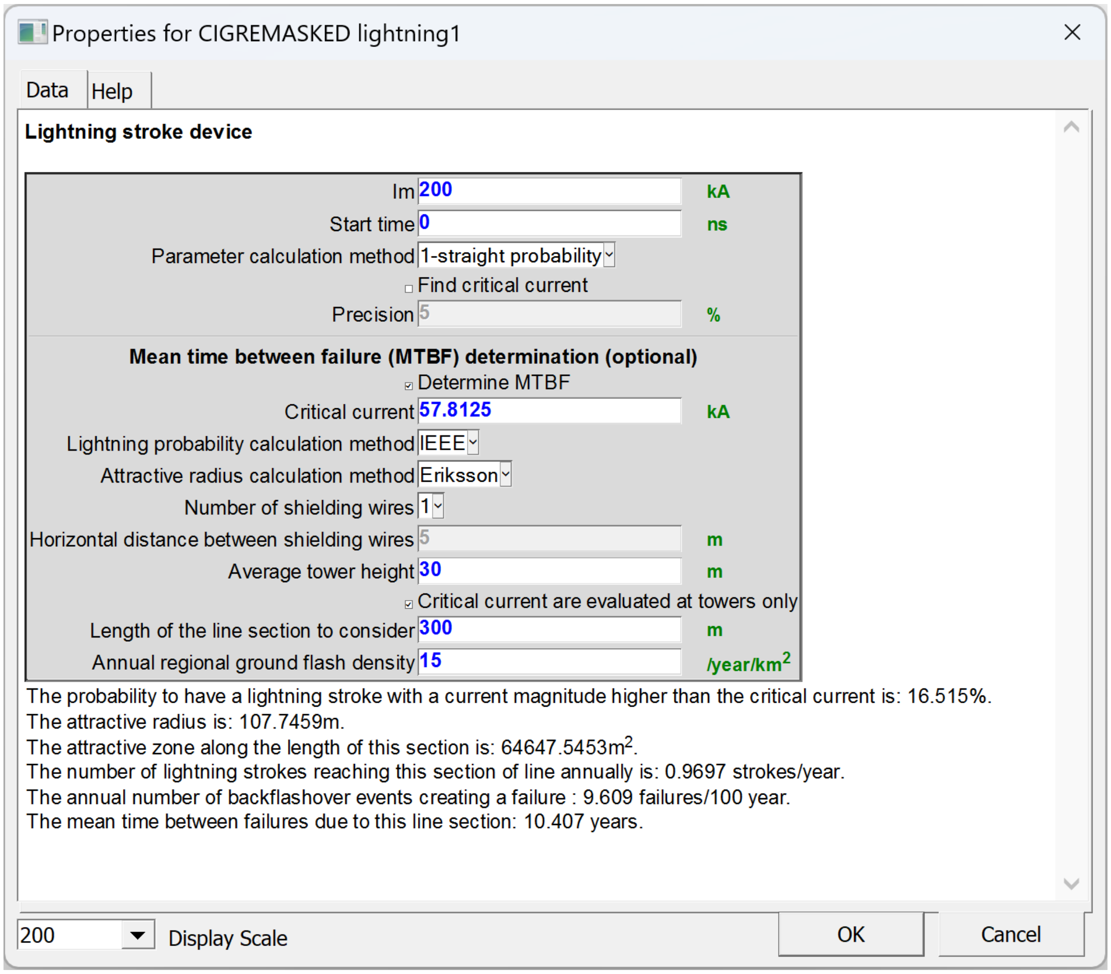
1 Introduction

This device is a lightning stroke CIGRE waveshape [1] modeled as a current source in parallel of a resistance and must be connected at the node where the lightning strikes is simulated. It may be used to simulate a lightning stroke or to determine the critical lightning current at a location for flashover determination or main-time-between-failure (MTBF) analysis.

- To simulate a particular lightning stroke, simply set the lightning stroke magnitude I_m, the *start time* and a method of parameter calculation and start the simulation normally. Several of these devices may be connected to the same node to simulate subsequent strokes.
- To automatically determine the critical current, check the *Find critical current* checkbox and click on the OK button. Several simulations will be automatically started with different lightning stroke parameters until the critical current is found with the precision requested.

The model parameters are determined using an approximation to the CIGRE cumulative distributions for peak current and maximum steepness. A joint correlation between the two quantifies is used.
See the CIGRE current source device for more information on the CIGRE model.

2 Parameters



- **Im**: Lightning stroke peak current. The maximum value is 200kA. This value is sued
- **Start time**: time when the lightning stroke is applied.
- **Parameter calculation method**:
  For the following equations, P is the probability, Sm is the steepness of the CIGRE model, $TD30$ is an intermediate time, Th is the time of half value, tf is the rise time to maximum current and Z_{stroke} is the Norton resistance of the lightning stroke model.
  - **Conditional**:
    $P \ = \ 1/(1 + pow(Im/31, 2.6))$
    $if \ (Im \ <= \ 20) \ \{$
    $\qquad Sm = 12.* \ pow(Im, 0.171)$
    $\qquad TD30 = 1.77 * pow(Im, 0.188)$
    $\}$
    $if \ (Im \ > \ 20) \ \ \{$
    $\qquad Sm = 6.5 * pow(Im, 0.376)$
    $\qquad TD30 = 0.906 * pow(Im, 0.411)$
    $\}$
    $th = 77.5 * Math.pow(10, (log((1 - P)/P)/3.42)/2.303) * 1e^{-6}$
    $tf = Im/(.6 * Im/TD30) * 1e^{-6}$
  - **1-straight probability**:
    $P \ = \ 1/(1 + pow(Im/31, 2.6))$
    $Sm = 24 * pow(10, (log((1 - P)/P)/4)/2.303);$
    $TD30 = 3.83 * pow(10, (log((1 - P)/P)/3.72)/2.303)$
    $th = 77.5 * pow(10, (log((1 - P)/P)/3.42)/2.303) * 1e^{-6}$

$tf = Im/(.6 * Im/TD30) * 1e^{-6}$

- **2-sebsequent**

  $P = 1/(1 + pow(Im/12.3, 2.7))$

  $Sm = 39.9 * pow(10, (log((1 - P)/P)/2.1)/2.303);$

  $TD30 = 0.67 * pow(10, (log((1 - P)/P)/1.855)/2.303)$

  $th = 30.2 * pow(10, (log((1 - P)/P)/2.014)/2.303) * 1e^{-6}$

  $$tf = \frac{Im}{\left(.6 * \frac{Im}{TD30}\right)9} * 1e^{-6}$$

$Z_{stroke} = max(6987. - 158.45 * Im, 2000)$

- **Find critical current:** if checked, the critical current will be determined after clicking the OK button. The critical current is the lowest lightning intensity creating a voltage higher than thresholds defined in either an *Insulation coordination longitudinal voltage probe* or an *insulation coordination voltage probe.* The thresholds are:
  - $\frac{BIL}{1+\text{Safety Coefficient}/100}$ for phase-to-ground voltages,
  - $\frac{Phase-to-phase\ BIL}{1+\text{Safety Coefficient}/100}$ for phase-to-phase voltages.

  These probe devices are from the Switching and Lightning library. They must be placed in the circuit where the voltage is to be monitored before starting the critical current determination.

  During the process, several simulations are automatically started.

  If the critical current is over 200kA, it is assumed the lightning cannot create any failure.

Mean time between failures (MTBF) determination.

This section is optional and used to calculate:

- attractive radiuses of line conductors above)
- probability to have a lightning stroke striking a line
- the attractive zone area over a section of line
- The number of lightning strokes reaching this section of line annually
- The annual number of backflashover events creating a failure
- The mean time between failures at the probes due to this line section

- **Determine MTBF**: Check this box to calculate the number of failures per year due to this section of line and the mean time between failures. The critical current must be determined first. For this, check the *Find critical current* box and click on the OK button. Once the process is completed, reopen this form and check this box.
- **Critical current:** Peak of the critical lightning stroke current. It is automatically determined and overwritten when *Find critical current* is checked and the action associated with this checkbox is completed (see above)**.**
- **Lightning probability calculation method**: Calculation method used to determine the probability to have a lightning intensity of higher magnitude than the critical current.
  - IEEE: $P(i) = \frac{1}{\left(1 + \left(\frac{i}{31}\right)^{2.6}\right)}$ (Anderson's distribution)

    Where i is the lightning current peak in kA.
- **Attractive radius calculation method:** Calculation method used to determine the attractive radius.
  - Erikson: $Ra = 14 * Ht^{0.6}$
  - Rizk: $Ra = 19.1 * Ht^{0.45}$

  where Ra is the attractive radius and Ht is the average shielding wire height.
- **Number of shielding wires:** Used to calculate the attractive radius.
- **Horizontal distance between shielding wires:** Used to calculate the attractive radius.
- **Average tower height:** Used to calculate the attractive radius.
- **Critical currents are evaluated at towers only:** Check this box if the critical current is evaluated at towers only. In this case, the span effect is considered and the annual number of backflashovers events is multiplied by a correction coefficient of 60%.

- **Length of the line section to consider**: Used to calculate the attractive radius. Length of line section which is considered for calculation.
  For example, if the lightning simulations are performed at each tower, the length is the span length. If the simulations are performed at towers and at mid spans, the length is half the line length.
- **Annual regional ground flash density:** Number of lightning strokes per area and per year.

3 Probes parameters

For lightning analysis, only the following parameters of the *Insulation coordination longitudinal voltage probes* and *insulation coordination voltage probes* are considered:

- Safety coefficient: product of the safety coefficient, the pollution factor, the altitude correction factor, the atmospheric factor, etc. It is used to define a threshold used to discriminate if a failure occurs during the Find Critical current procedure. See 2.
- BIL: Phase-to-ground basic Impulse Level

4 References

[1]. "Guide to procedures for estimating the lightning performance of transmission lines", Working Group 01 (Lightning) of Study Committee 33 (Overvoltages and Insulation Co-ordination), October 1991, CIGRÉ.
[2]. IEC 60071-2018, Insulation co-ordination
[3]. IEEE Std 1313.2.2-1999, IEEE Guide for the Application of Insulation Coordination
[4]. Douglas Mader, Simulation and Analysis of Power System Transients Using EMTP-RV, Lightning Overvoltages Modeling and Analysis, November 3-7, 2014