**OpenETran**

**An Open-Source Electromagnetic Transient Program**

During the period from 1990 through 2002, EPRI funded the development of a Lightning Protection Design Workstation (LPDW), which was used by many utilities to assess the lightning performance of distribution lines. Since about 2002, this program has not been available. EPRI decided to release the simulation kernel of LPDW under the name OpenETran, with an open-source license (GPL v3), so it may be incorporated into IEEE Flash and other projects.

OpenETran can presently simulate multi-conductor power lines, insulators, surge arresters, non-linear grounds, and lightning strokes. It efficiently calculates energy and charge duty on surge arresters, and iterates to find the critical lightning current causing flashover on one or more phases. It is also suitable for use in substation insulation coordination. Capacitor switching, TRV, and other applications may be added.

EPRI originally had permission to use code from the Numerical Recipes book in LPDW. These routines have been removed in favor of the GNU Scientific Library (GSL), which also uses the GPL v3 license. As a result, the OpenETran package can be freely used and modified, but not commercialized.

This document presents tutorials for using OpenETran’s new graphical user interface (GUI), which was funded by members of CEATI’s Grounding and Lightning Interest Group (GLIG).

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# Revie0wer Notes

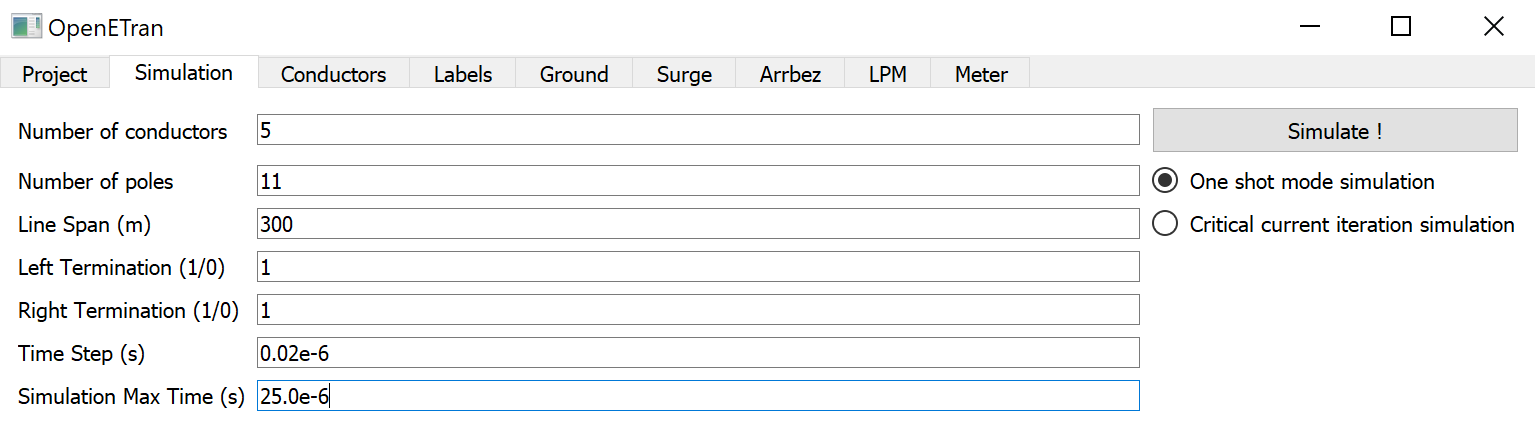
In this pre-release phase, GLIG reviewers should please add comments and changes to those already listed below.

1. File open and save dialogs should remember the last location used
2. If the user has saved project to a specific name, that one should be used instead of *home*
3. Project should save the nearby object, ground slope, flash density and line length data from the Phase View
4. Add Resistor tab to the Simplified interface; it’s commonly used to connect shield wires
5. Pre-fill the default LPM parameters for KI and E0
6. Pre-fill the default Ground parameters for E0
7. In the setup for critical current iterations, the prompts for first tower, last tower, and wire flags need to remain visible
8. On the ground tab, the formula behind ***Get R60*** should update to Dwight’s formula, because we changed the counterpoise ladder assembly.
   1. Dwight 
   2. Note: Sunde’s is used in [1]: 
9. Add guidance for determining tower inductance.

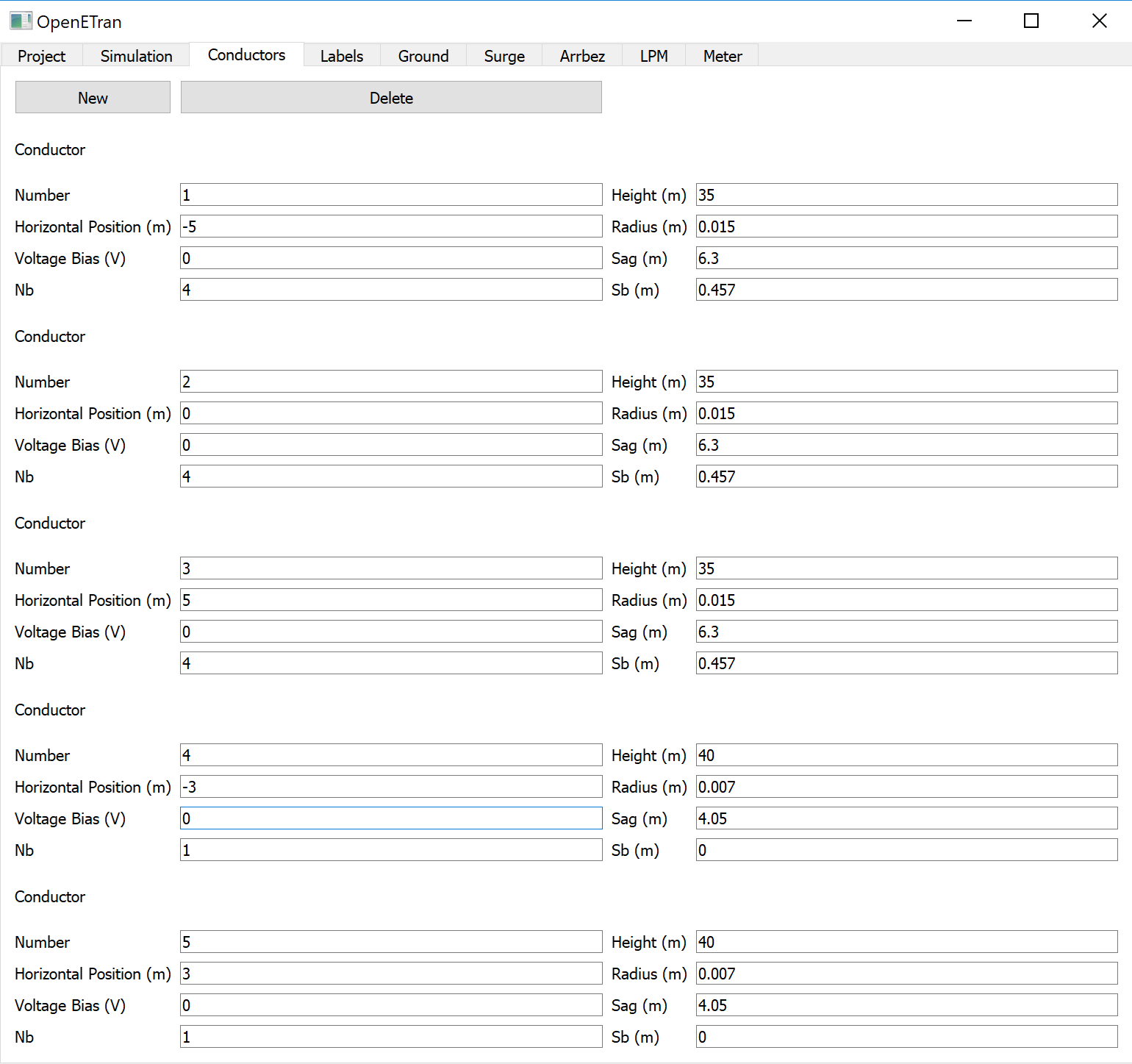
# 500-kV Horizontal Line

This example is based on pp. 27-32 in Annex B of [1]. When you start the GUI, two windows appear. One is the main component panel called ***OpenETran***, and the other is the ***Phase View***.

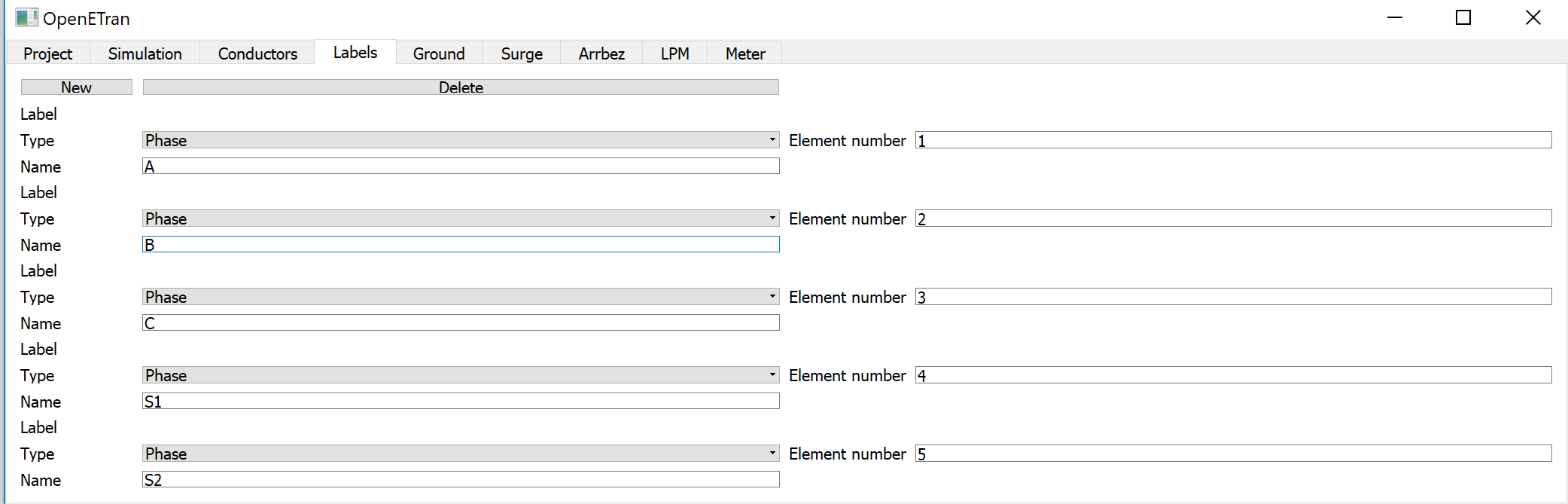
Click the ***Simulation*** tab on the main window and fill it out as follows. This creates a framework of 11 towers, each separated by 300 m. There are 5 conductors, to be labeled A, B, C, S1 and S2.



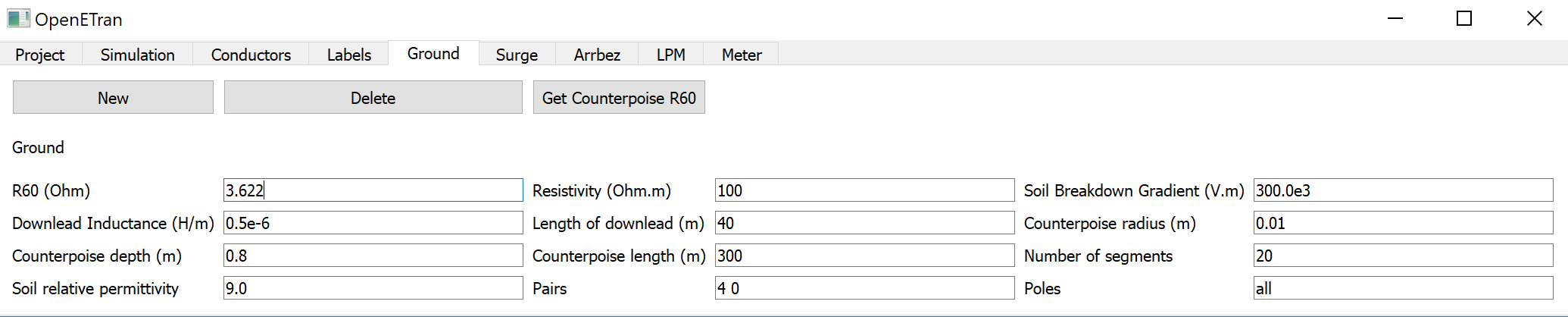
Click the ***Conductors*** tab, then click ***New*** four times, and fill it out as follows:



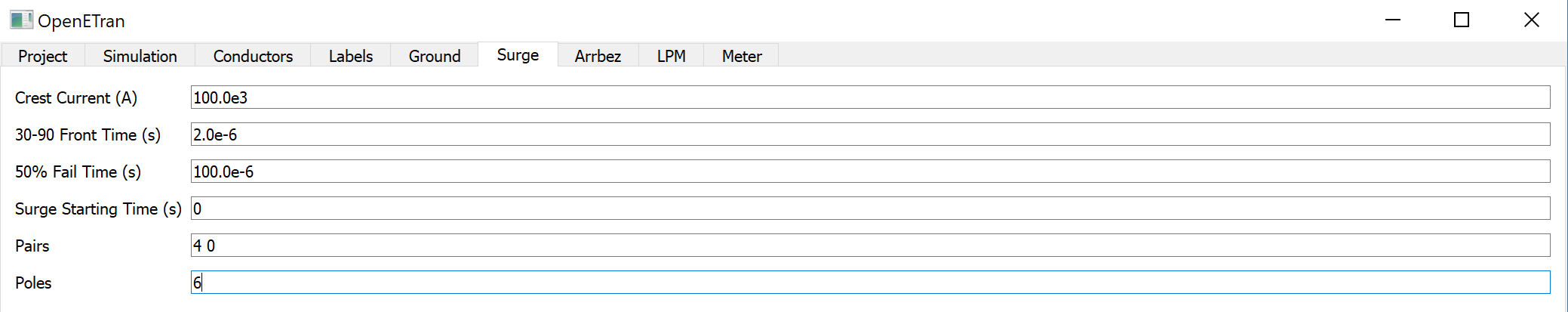
Click the ***Labels*** tab, then click ***New*** four times, and fill it out as follows:



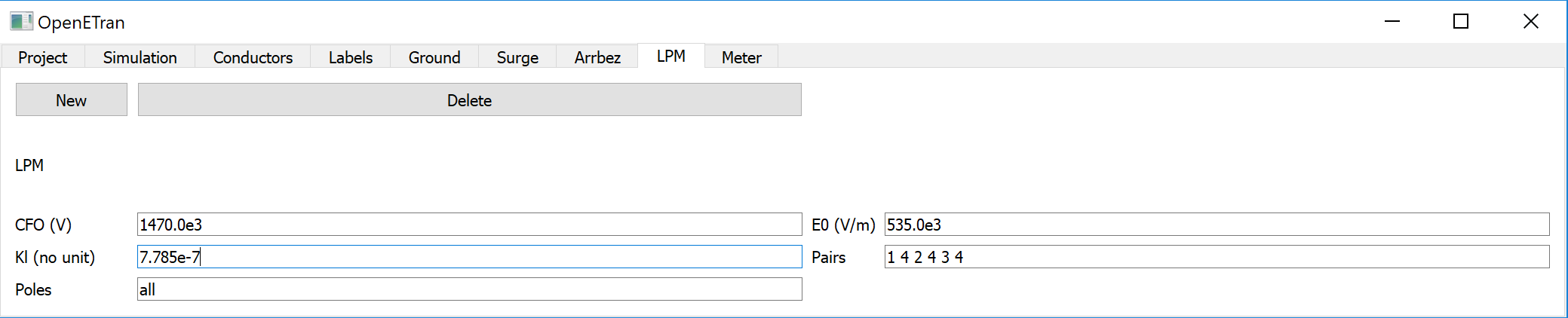
Click the ***Ground*** tab, and fill it out as follows. This puts a counterpoise and tower inductance on the first shield wire, S1, at every tower. We’ll connect S2 to ground later.



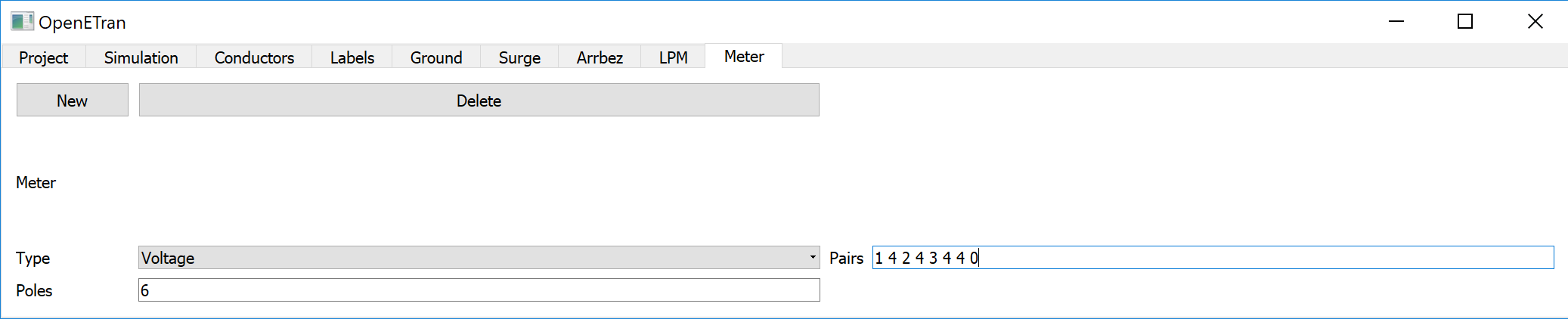
Click the ***Surge*** tab, and fill it out as follows. This puts a stroke to S1 of the middle tower.



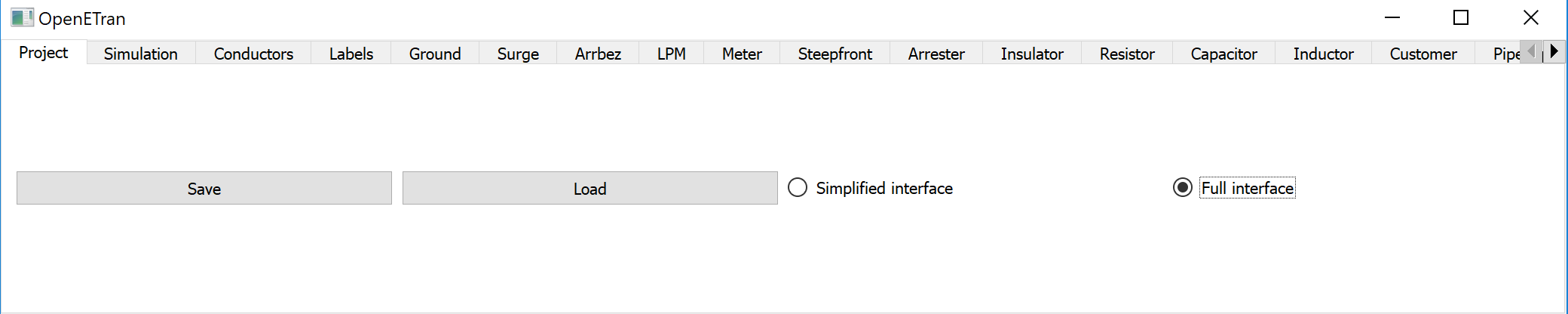
Click the ***LPM*** tab, and fill it out as follows. This puts insulation of 1470-kV CFO (i.e. strike distance over insulators of 3 m) on each phase. Time-dependence is represented in default parameters for the leader progression model.



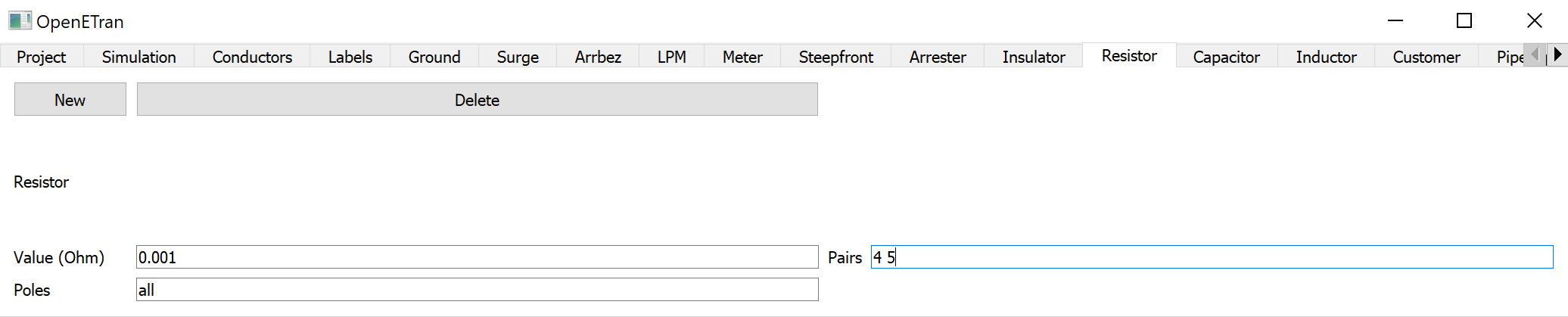
Click the ***Meter*** tab, and fill it out as follows. This requests voltage plots across each phase insulator, and from tower top to remote ground, just at the struck tower #6, which is the middle one of 11 towers.



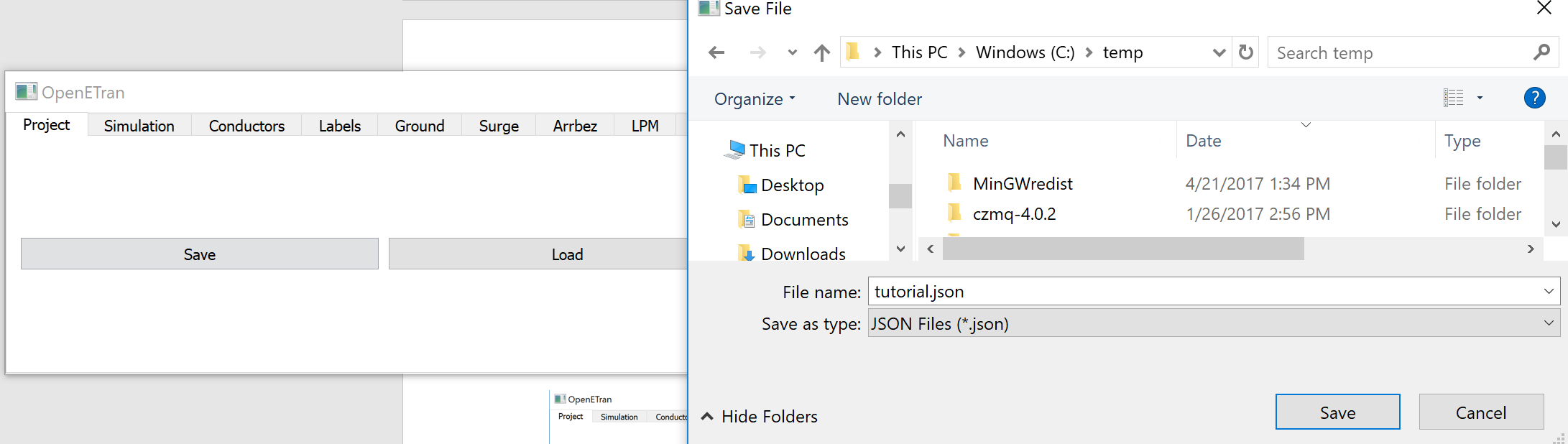
We’re not using line arresters now, but we still need to connect S1 and S2 at all towers. Go back to the ***Project*** tab and request the ***Full Interface*** by clicking the radio button.



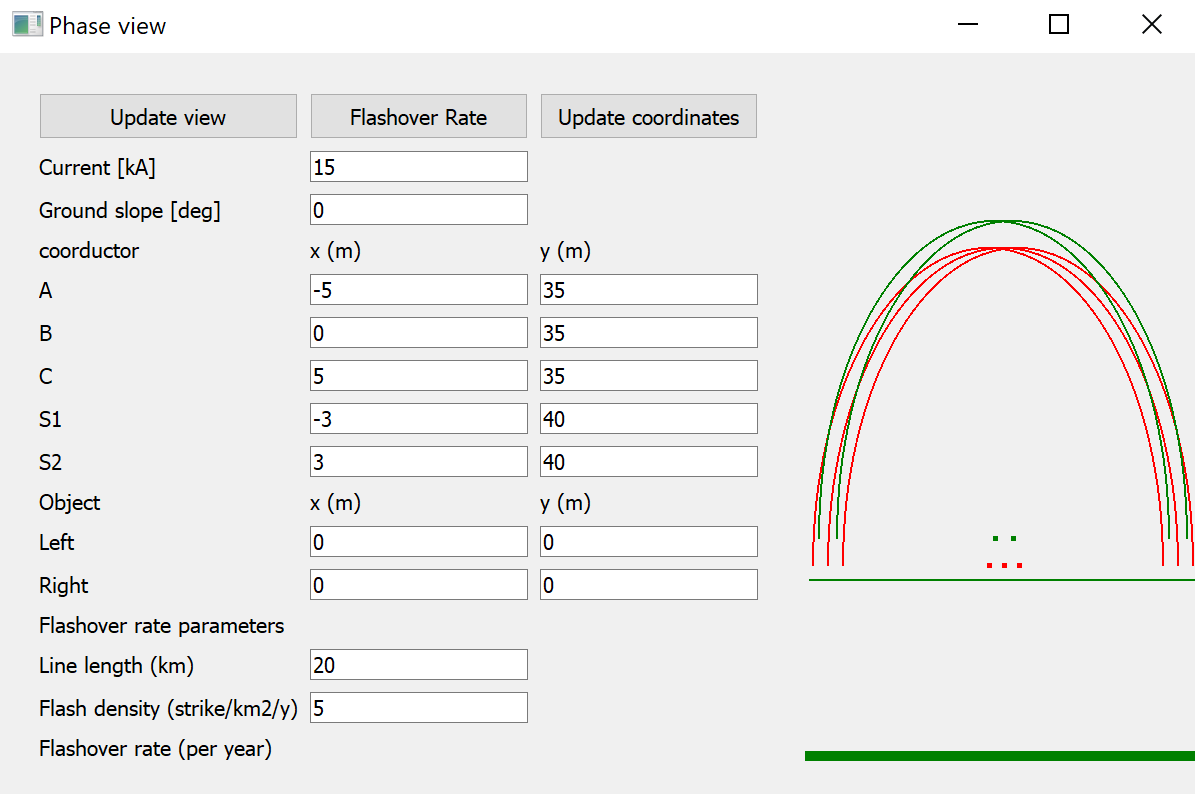
Click the ***Resistor*** tab and fill it out as follows. This 1-m resistor connects S1 and S2.



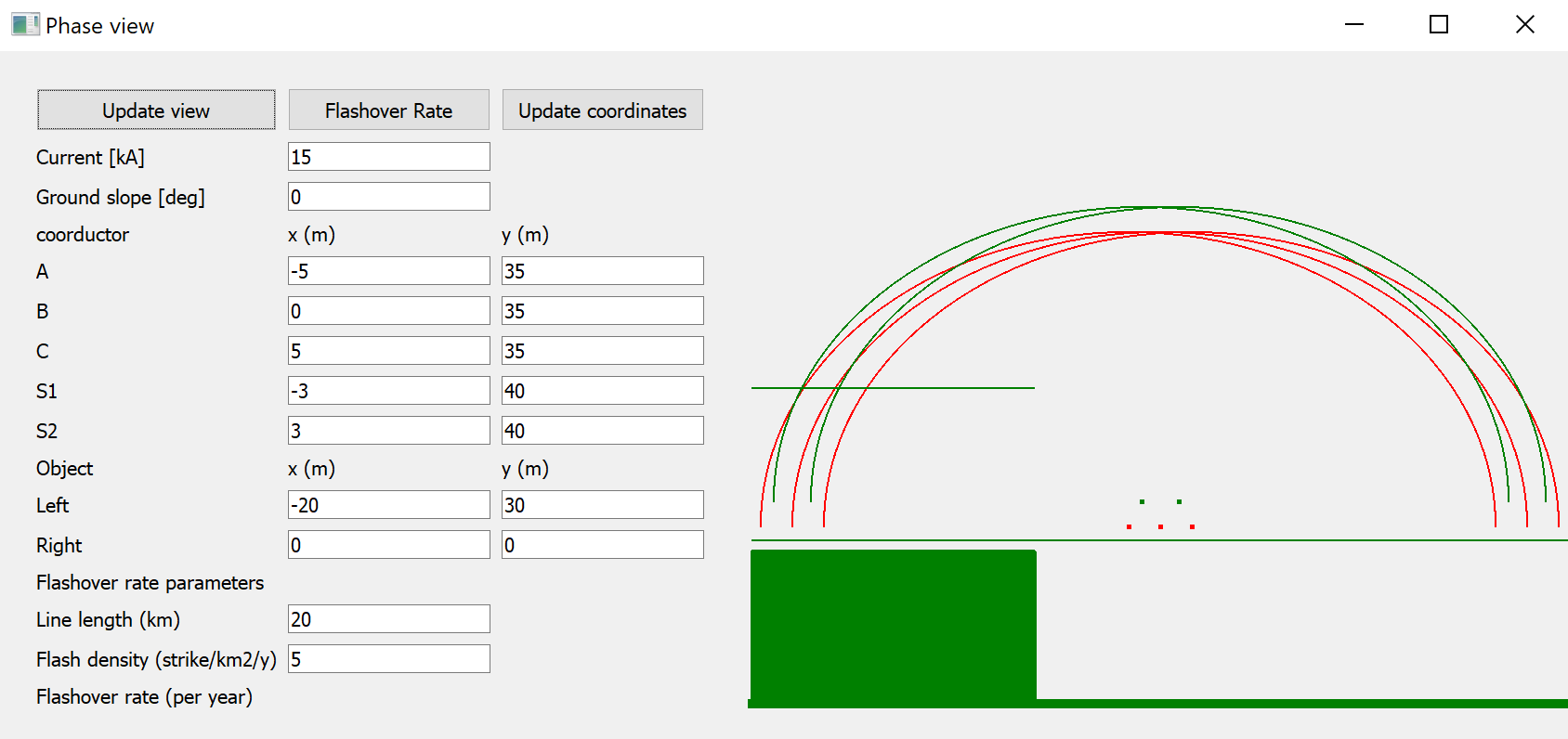
This is a good time to save your work, i.e. before attempting your first simulation. Click the ***Project*** tab again, Click the ***Save*** button and save the project to a file name and path of your choice.



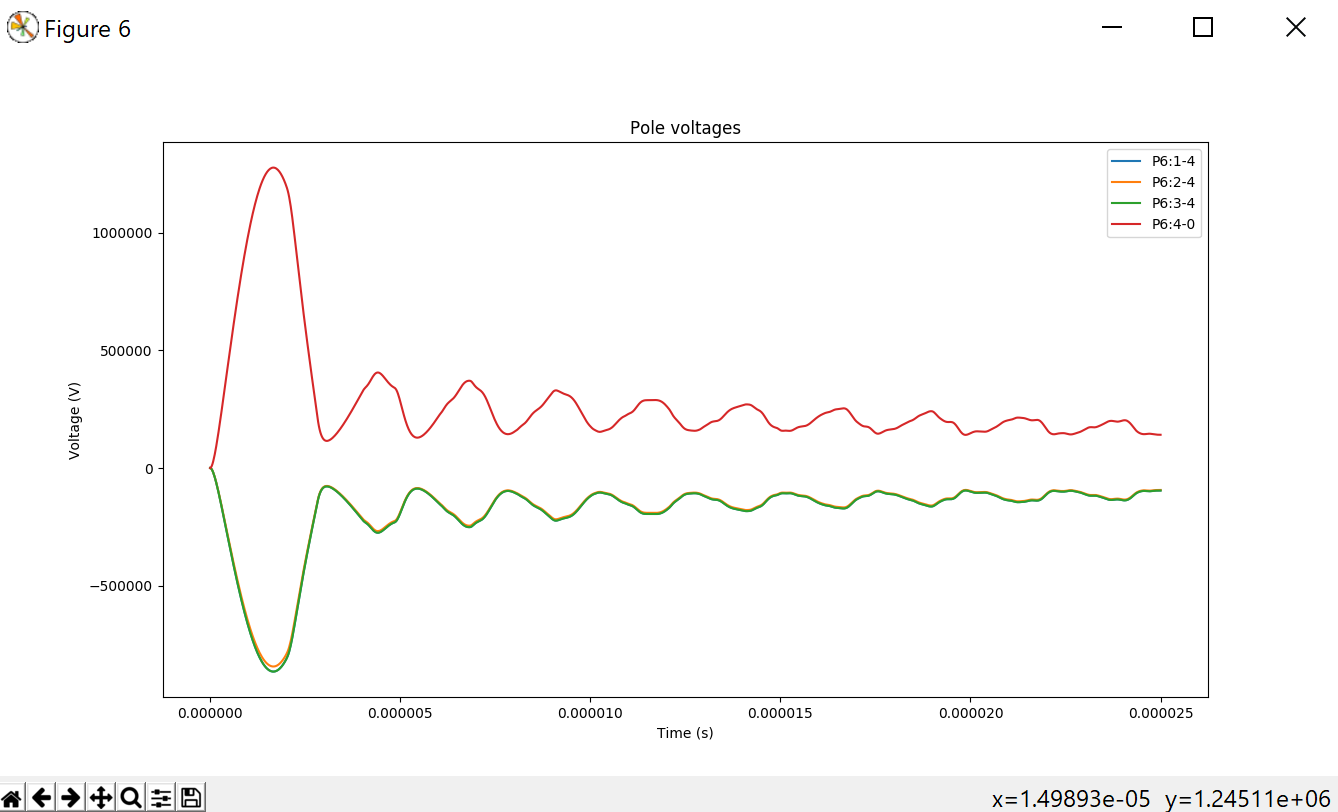
Now find the ***Phase View*** window and click ***Update Coordinates***. It should now show your input conductor coordinates at the tower. This line is not perfectly shielded at 15 kA, as indicated by some exposure of the red arcs outside the green shielding envelope. Our critical current for shielding failures is yet to be determined; it may not be 15 kA.



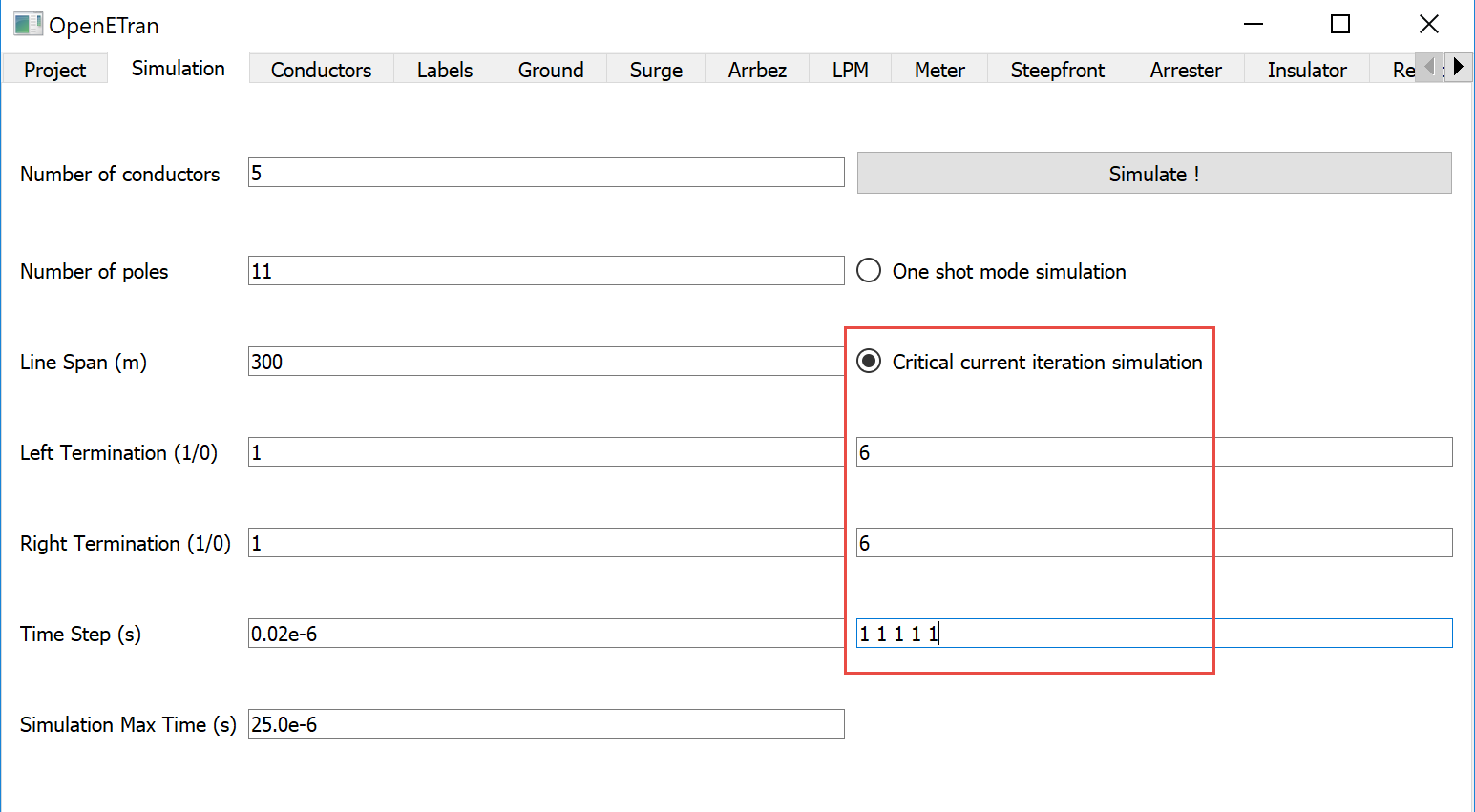
For illustrative purposes, put a tree line on the left-hand side of the line. Change the ***Object Left*** x and y coordinates to -20 and 30, respectively, then click ***Update view****.* Now the left side is shielded from strokes 15 kA or greater.



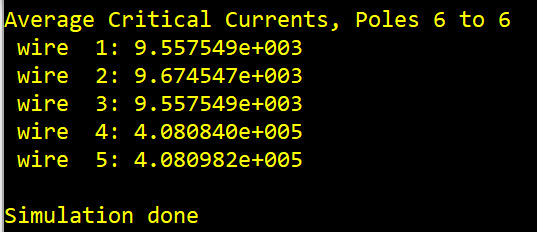
Back on the ***OpenETran*** window, click ***Simulate*** and then the ***Simulate!*** Button. After a couple of seconds, you see the following requested voltage plots at tower 6 for a 100-kA stroke. The peak tower voltage is about 1280 kV. It’s higher than 3.622  x 100 kA, due to tower inductance and nonlinear frequency dependence in the counterpoise. However, the worst peak insulator votlages are -865 kV on the two outer phases, less than the 1470-kV CFO, so flashover would not be expected. Plot data was saved in a CSV file if you wish to do further processing in a program like Excel or MATLAB.



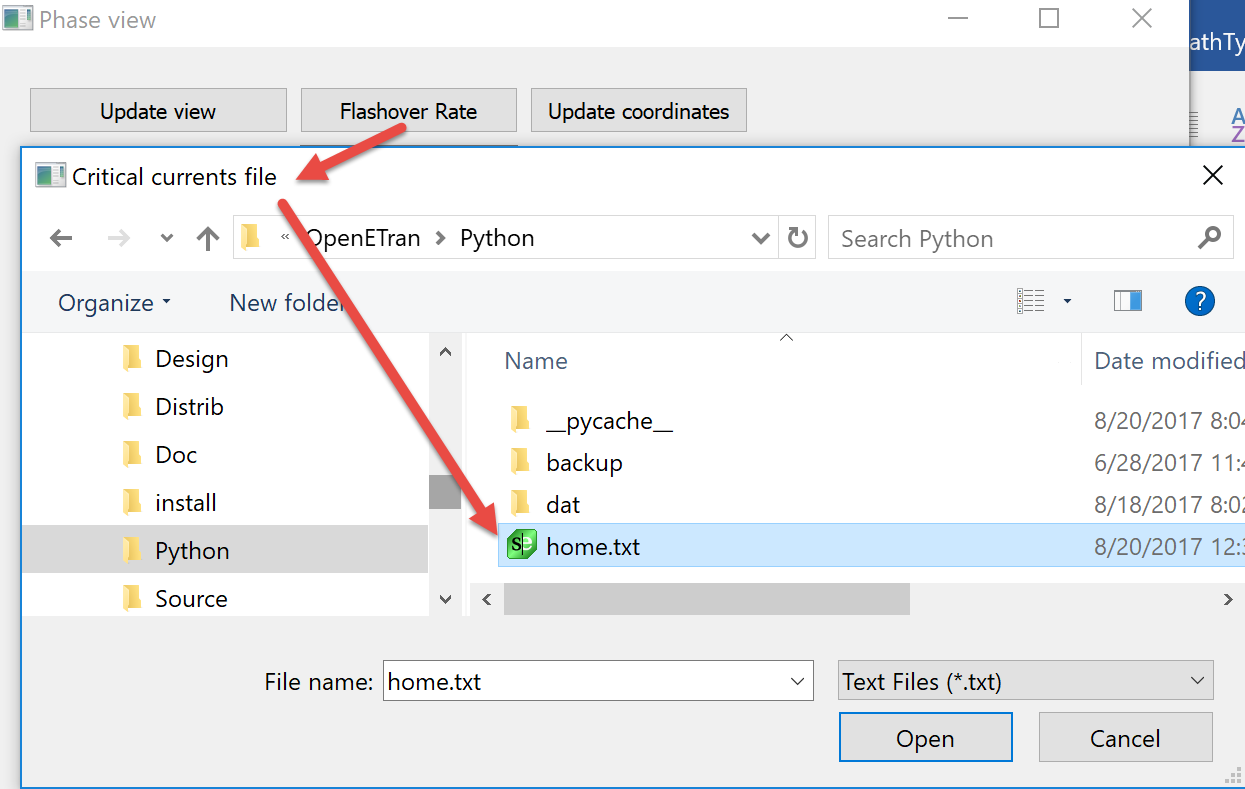
Close the plot window using the ***X*** in its upper right corner. Back ***OpenETran*** window, change the simulation control parameters as shown in the **red** highlighted area. This will run the program to determine critical currents, which just barely cause flashover, to any of the five conductors if struck at tower 6. You need to click the radio button for “Critical current iteration simulation” to see three additional input fields, each of which contains an input prompt. When ready, click the ***Simulate!*** Button.



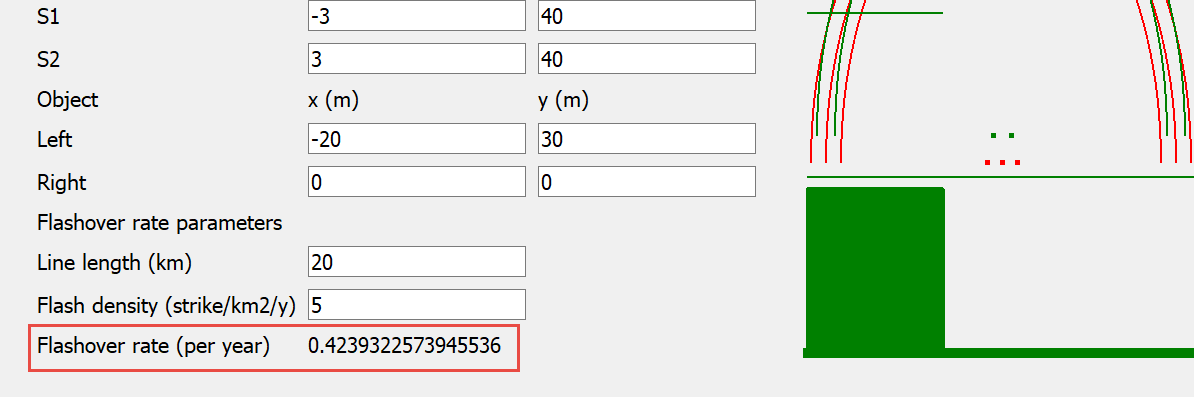
Within a few seconds, you’ll see the critical currents displayed in the Python output console, as shown below. These are all approximately 96 kA for the three phase conductors, because they have the same CFO and similar coupling factors. The critical currents are nearly equal, at 408 kA, for the two shield wires that are connected together. These critical currents are written to a text file, so you don’t need to copy them down. However, the Python output console is where any error messages from the transient simulation engine will appear, so please check it if a simulation fails to produce results.



Back at the ***Phase View*** window, we can use the critical currents to calculation line flashover rate. Click the ***Flashover Rate*** button, and then navigate to your critical current file, as shown below.



Click ***Open*** in the file open dialog, and then see an estimated flashover rate of 0.42 per year for the given parameters.



# 15-kV Distribution Line

To be completed, based on [2], with CFO-added.

# 35-kV Distribution Line

To be completed, based on [2], with CFO-added.

# Double-Circuit Transmission Line

To be completed, with shielding design of a double-circuit line in the GUI, extended to transient analysis in console mode.

# References

1. IEEE Std. 1243-1997, IEEE Guide for Improving the Lightning Performance of Transmission Lines.
2. IEEE Std. 1410-2010, IEEE Guide for Improving the Lightning Performance of Electric Power Overhead Distribution Lines.