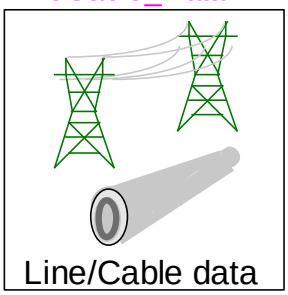
LineCable Data

LineCable_Data



Jesus Morales, 09-Oct-19 6:43:00 PM

1 Theoretical background MoM-SO

LineCable Data device computes line and cable models based on the Method of Moments and Surface admittance Operator (MoM-SO) technique [1-8]. The MoM-SO approach has several advantages for calculating the per-unit-length series impedance and shunt admittance matrices for overhead lines and underground cables compared to traditional approaches. With MoM-SO, skin and proximity effects of conductors can be considered, a stratified earth with arbitrary earth parameters (permeability, permittivity and conductivity) can be properly represented, also, arbitrary cable configurations, such as tunnel installed and submarine cables, can be modeled. Furthermore, MoM-SO provides better computational efficiency than finite element method (FEM) approach.

2 Conductors tab

The default layout of the Line/Cable data device is shown in Figure 1. This figure shows the Conductors tab where the user can enter the number of conductors for overhead lines, as either single-wire or bundle conductors, the number of single-core cables and/or the number of pipe-type cables to be modeled. After entering these data, different tables are generated for entering physical and geometrical data of conductors at the bottom of the page. The white box to the right-side of the conductors table in Figure 1 is for drawing the cross-section geometry of the line/cable model.

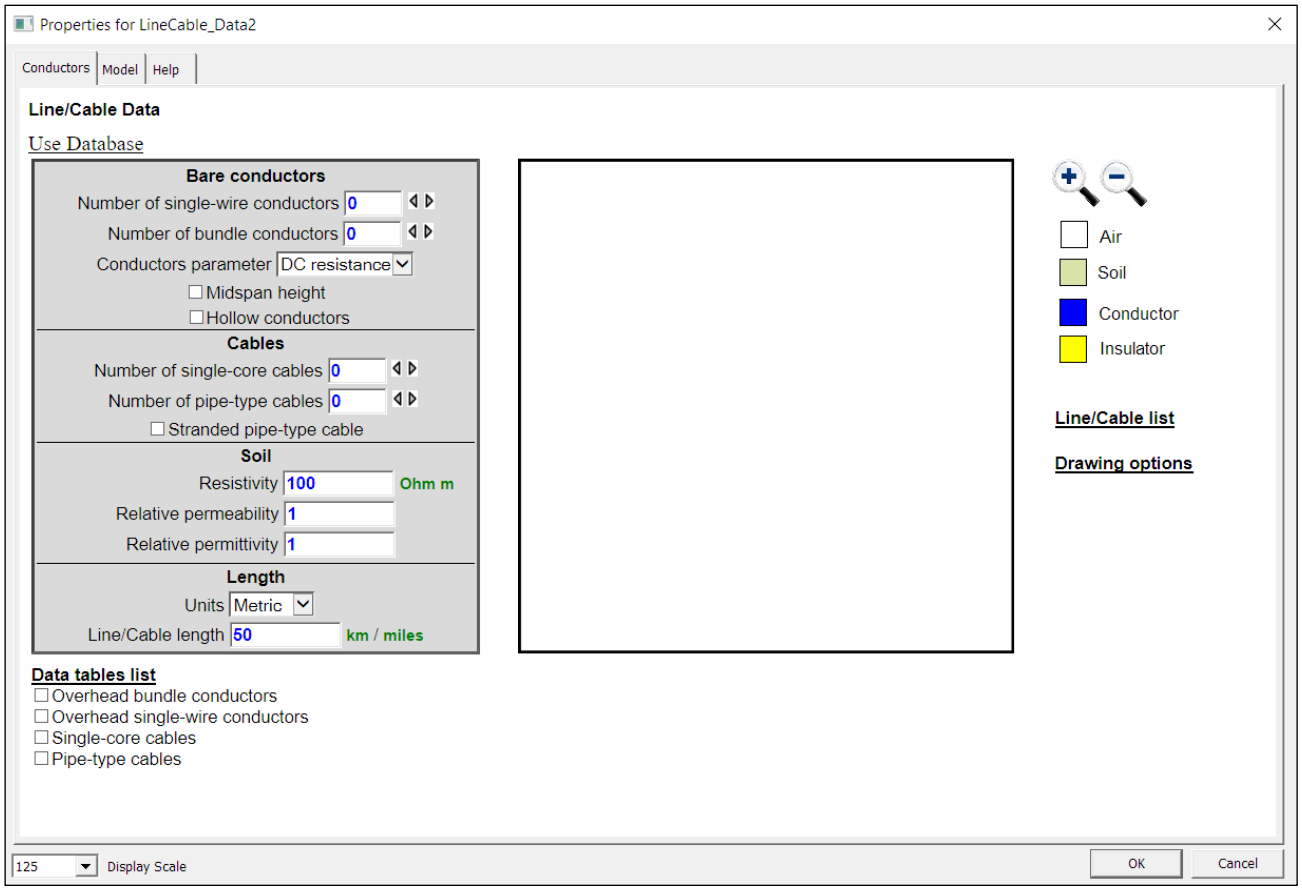


Figure 1 Default layout of LineCable Data device.

2.1 Overhead transmission lines

2.1.1 Single-wire conductors

For a three-phase overhead transmission line with one conductor per phase and two ground wires as illustrated in Figure 2, the LineCable Data device must be filled-in as shown in Figure 3. Note that the LineCable Data device can account for the midspan conductors' height as well as for hollow conductors by checking the corresponding checkboxes in the section of bare conductors. These options modify the data tables to allow the user entering the necessary data. Additionally, the user can select between the conductors' resistivity or DC resistance to represent the conductor material. Finally, the system of units (Metric or English) can be selected. Note that ground wires are given a zero value in the column *Phase*, this allows the correct reduction of conductors in the model. For this example, the resulting model will consider the effect of ground-wires, however, only three pins will be given.

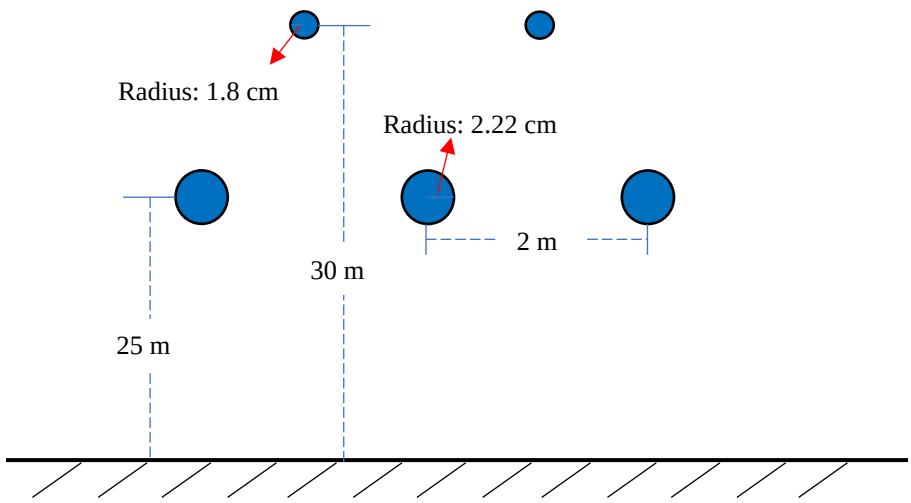


Figure 2 Three-phase overhead line example.

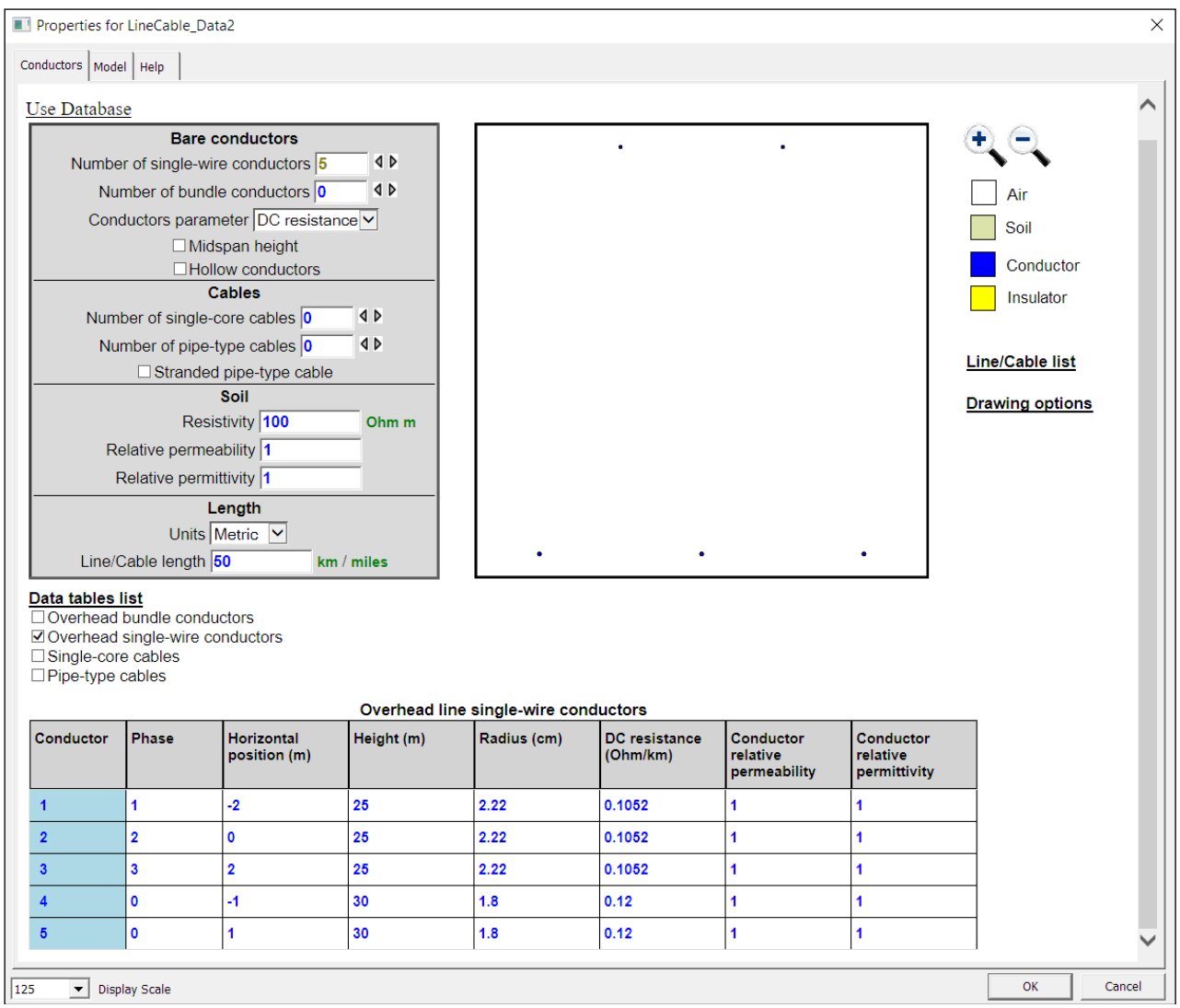


Figure 3 LineCable Data device for modeling the three-phase overhead line of Figure 2.

2.1.2 Bundle conductors

In the case of overhead transmission lines with bundle conductors, the user must enter the number of conductors for each bundle and the angle of reference for the first conductor in the bundle. See an example in Figure 4. Note that the drawing box can be clicked for visualizing specific conductors. For example, if the user clicks on one of the bundle conductors, the drawing box will show the clicked bundle zoomed-in, see Figure 5. Figure 5 also shows that the row containing the data of the clicked bundle conductor is highlighted in the corresponding table at the bottom of the page. This feature allows the user to identify erroneous entered data. Additional drawing options are available at the right side of the drawing box, see Figure 5.

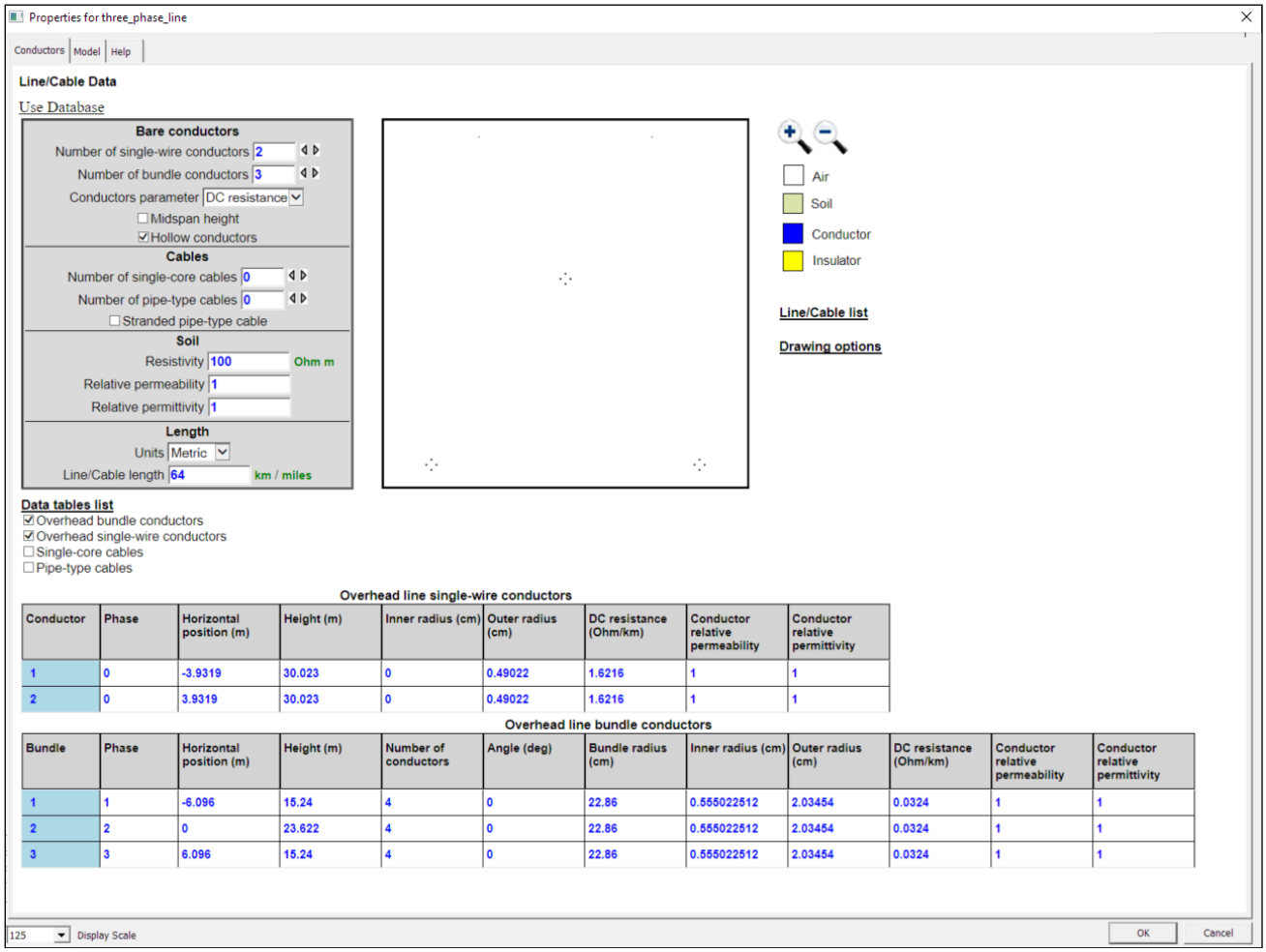


Figure 4 LineCable Data device for a three-phase overhead line with bundle conductors.

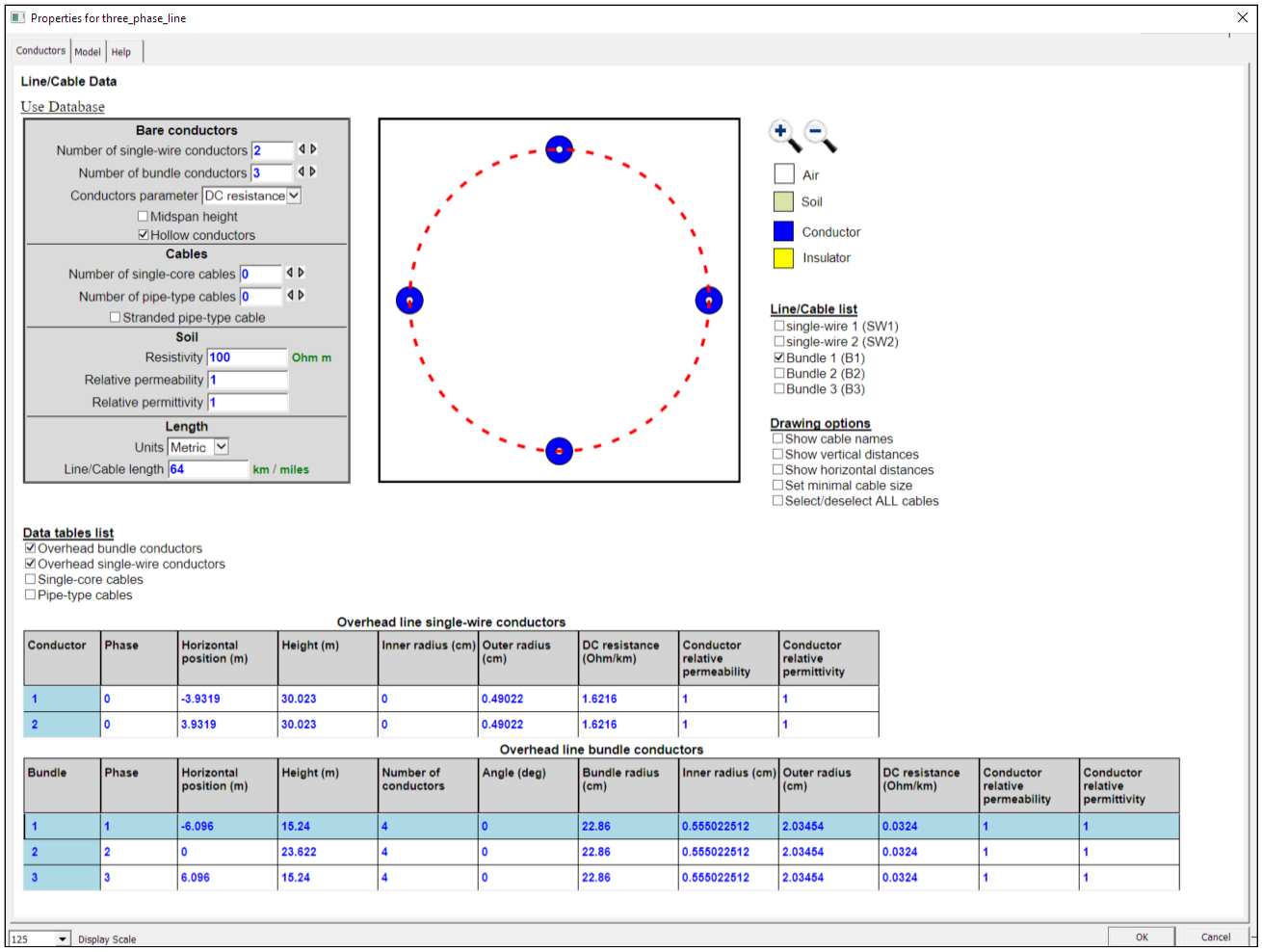


Figure 5 LineCable Data device drawing capabilities.

2.2 Single-core cables

A set of three identical single-core cables buried 1.1 meters underground as illustrated in Figure 6, can be modeled using the LineCable Data device as shown in Figure 7. Note that the modeling of single-core cables requires filling-in two tables as follows: the table entitled Single-core cable main data is generated depending on the number of single-core cables entered; on the other hand, the table entitled Single-core cable conductors/insulators data is generated depending on the number of conductors given to each cable. Note that negative values are required in the column *ground depth* for underground cables, however, it is possible to model cables above the ground by entering positive values.

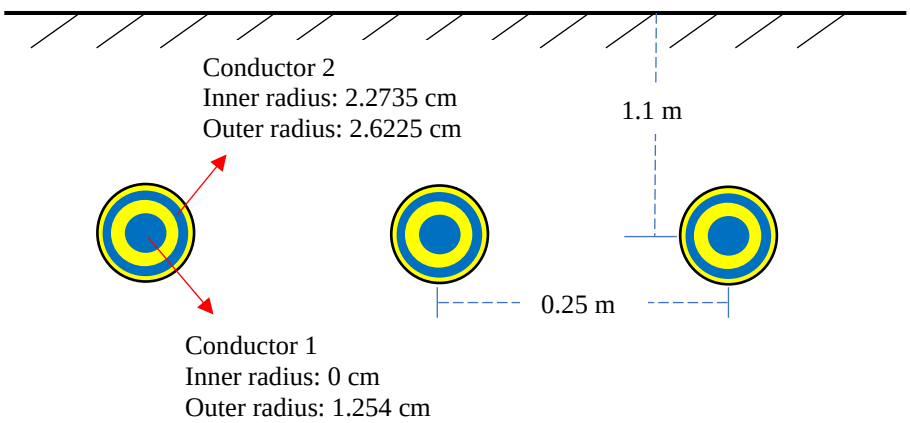


Figure 6 Example of three underground single-core cables.

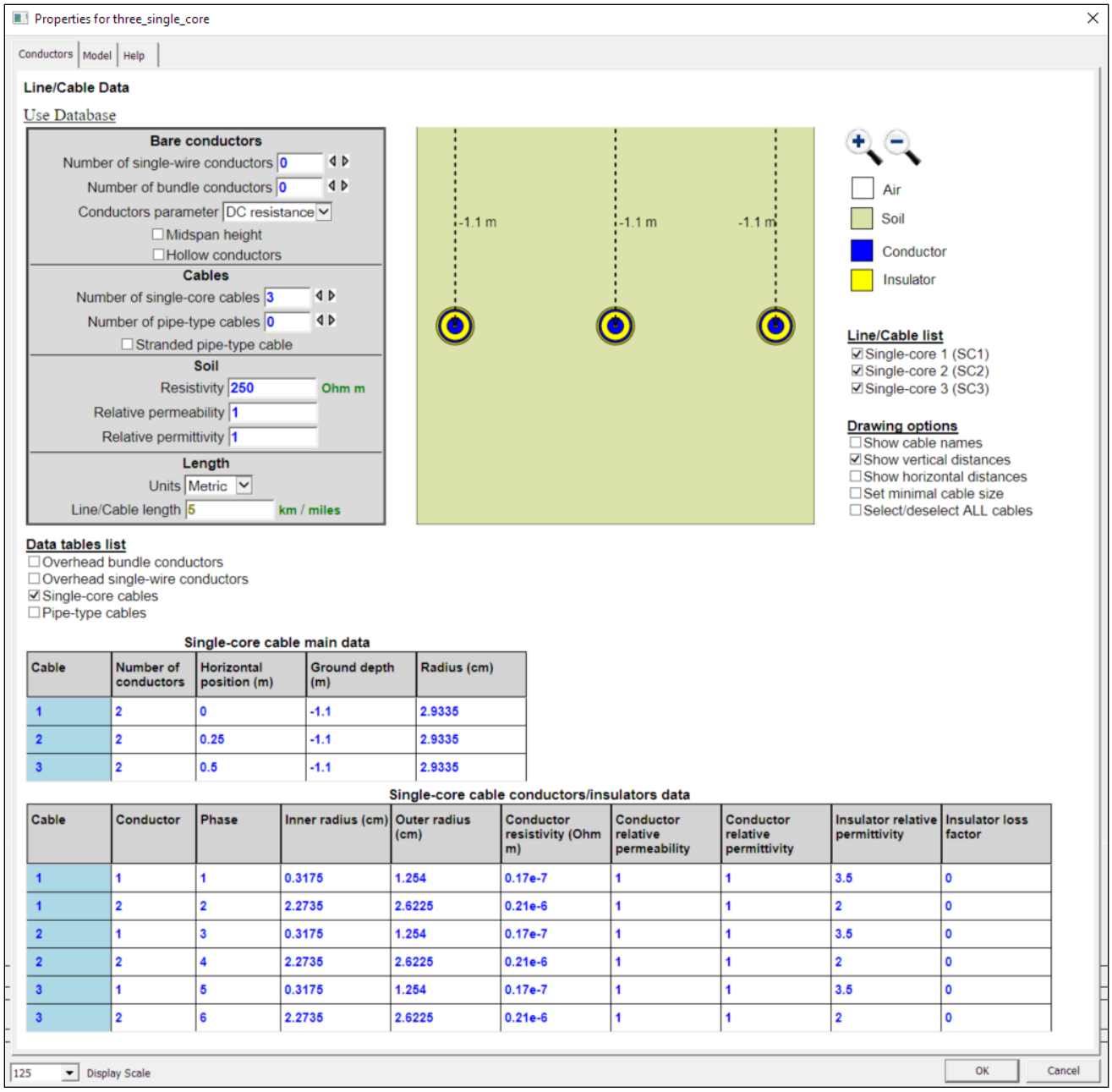
2.2.1 Insulator and semiconductor layers

For modeling of cables with the LineCable Data device, each conductor is supposed to have an insulator layer covering it. The thickness of the nth insulator layer is defined by the difference between the outer radius of the nth conductor and the inner radius of the $(n+1)^{th}$ conductor, such that it is implicitly specified. Insulator layers are represented by its relative permittivity, which is in general larger than 1 for insulator materials. For representing semiconductor layers, a loss factor larger than 0 must be entered, this value corresponds to the value $\tan\delta$ given by manufacturers in cable data sheets. The value $\tan\delta$ is related to the material's relative permittivity as follows:

$$\tan\delta = \frac{\varepsilon_r'}{\varepsilon_r''}$$

where ε_r' and ε_r'' are the real and imaginary parts of the material's relative permittivity.
Then, the relative permittivity for semiconductor materials is given as

$$\varepsilon_r = \varepsilon_r' - j\varepsilon_r''$$



Single-core cable main data

Cable	Number of conductors	Horizontal position (m)	Ground depth (m)	Radius (cm)
1	2	0	-1.1	2.9335
2	2	0.25	-1.1	2.9335
3	2	0.5	-1.1	2.9335

Single-core cable conductors/insulators data

Cable	Conductor	Phase	Inner radius (cm)	Outer radius (cm)	Conductor resistivity (Ohm m)	Conductor relative permeability	Conductor relative permittivity	Insulator relative permittivity	Insulator loss factor
1	1	1	0.3175	1.254	0.17e-7	1	1	3.5	0
1	2	2	2.2735	2.6225	0.21e-6	1	1	2	0
2	1	3	0.3175	1.254	0.17e-7	1	1	3.5	0
2	2	4	2.2735	2.6225	0.21e-6	1	1	2	0
3	1	5	0.3175	1.254	0.17e-7	1	1	3.5	0
3	2	6	2.2735	2.6225	0.21e-6	1	1	2	0

Figure 7 LineCable Data device for three underground single-core cables.

2.3 Pipe-type cables

A pipe-type cable example is given in Figure 8. This cable can be modeled using the LineCable Data device as shown in Figure 9. Note that as for single-core cables, two tables are required. Also, positive ground depth values can be given for the modeling pipe-type cables above ground. Numeration of conductors in Figure 9 is indicated in Figure 8.

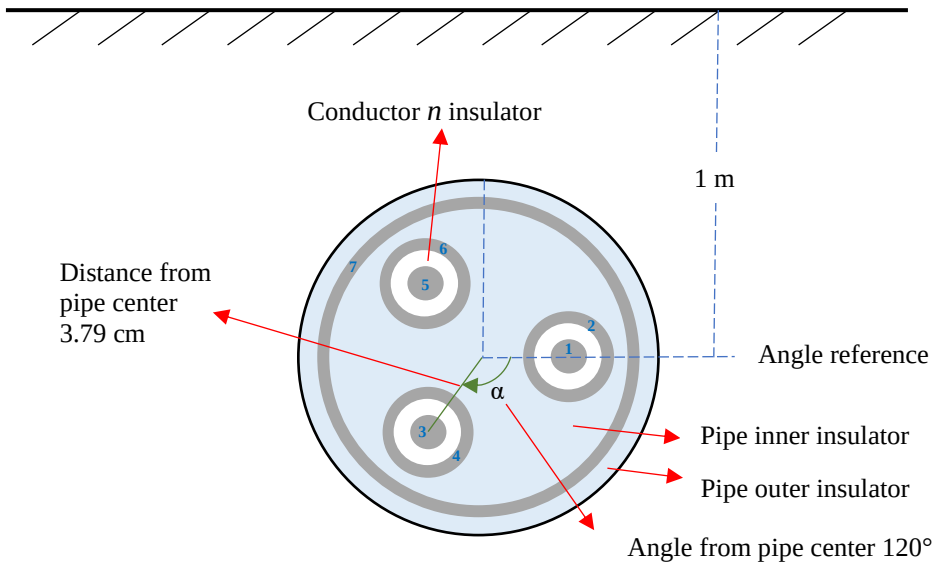
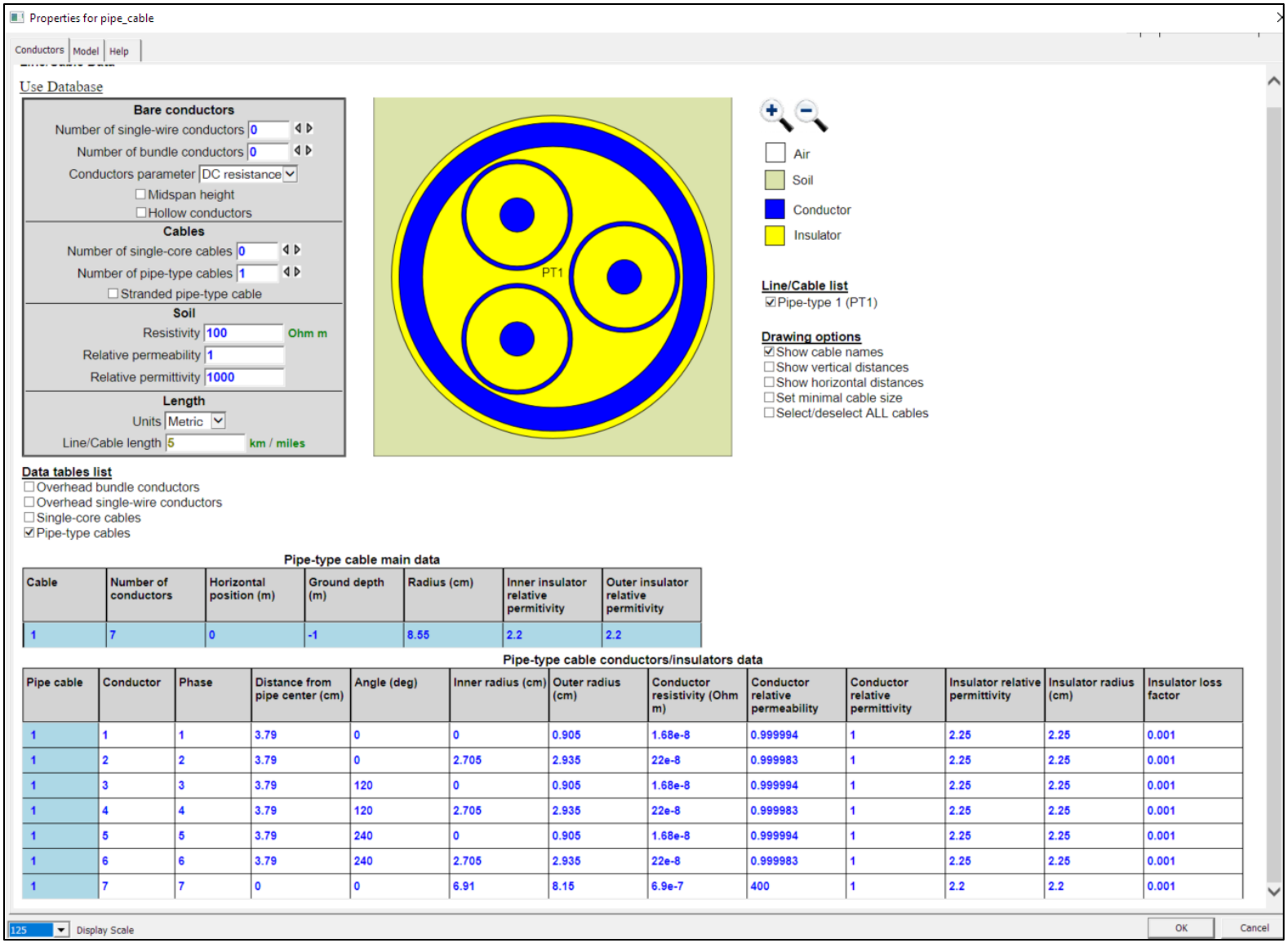


Figure 8 Underground pipe-type cable.



Pipe-type cable main data

Cable	Number of conductors	Horizontal position (m)	Ground depth (m)	Radius (cm)	Inner insulator relative permitivity	Outer insulator relative permitivity
1	7	0	-1	8.55	2.2	2.2

Pipe-type cable conductors/insulators data

Pipe cable	Conductor	Phase	Distance from pipe center (cm)	Angle (deg)	Inner radius (cm)	Outer radius (cm)	Conductor resistivity (Ohm m)	Conductor relative permeability	Conductor relative permittivity	Insulator relative permittivity	Insulator radius (cm)	Insulator loss factor
1	1	1	3.79	0	0	0.905	1.68e-8	0.999994	1	2.25	2.25	0.001
1	2	2	3.79	0	2.705	2.935	22e-8	0.999983	1	2.25	2.25	0.001
1	3	3	3.79	120	0	0.905	1.68e-8	0.999994	1	2.25	2.25	0.001
1	4	4	3.79	120	2.705	2.935	22e-8	0.999983	1	2.25	2.25	0.001
1	5	5	3.79	240	0	0.905	1.68e-8	0.999994	1	2.25	2.25	0.001
1	6	6	3.79	240	2.705	2.935	22e-8	0.999983	1	2.25	2.25	0.001
1	7	7	0	0	6.91	8.15	6.9e-7	400	1	2.2	2.2	0.001

Figure 9 LineCable Data device for a pipe-type cable.

3 Model tab

After setting the parameters of conductors in the conductors tab, the user can proceed to select the model, the following options are available.

3.1 Constant Parameters (CP) model

This is a time-domain model, characteristic admittance and propagation function are calculated at a single frequency. For multiphase lines/cables, the user can use the option balanced line/cable for considering symmetrical models.

3.2 Wideband (WB) model

This is the most accurate model for time domain simulations. The LineCable Data device generates the parameters of propagation function and characteristic admittance as function of frequency. Fitting is required as a post-processing step for obtaining the final time-domain model.

3.3 Exact PI model

This model is used in steady-state solutions and frequency scan. It is necessary that the model is calculated for the same frequency of the steady-state solution to be perform or the same frequency range to the frequency scan to be performed. To load the generated model the FD model must be used.

3.4 Nominal PI model

The Nominal PI model is a short approximation not valid for electrically long lines. The resulting model can be used in the PI multiphase device in EMTP-v3.

Depending on the selected model, and the line/cable configuration different additional options can be available, such as the frequency for the model, considering proximity effect, among others. An example of the Model tab page is shown in Figure 10 for the modeling of a cable with the CP model selection.

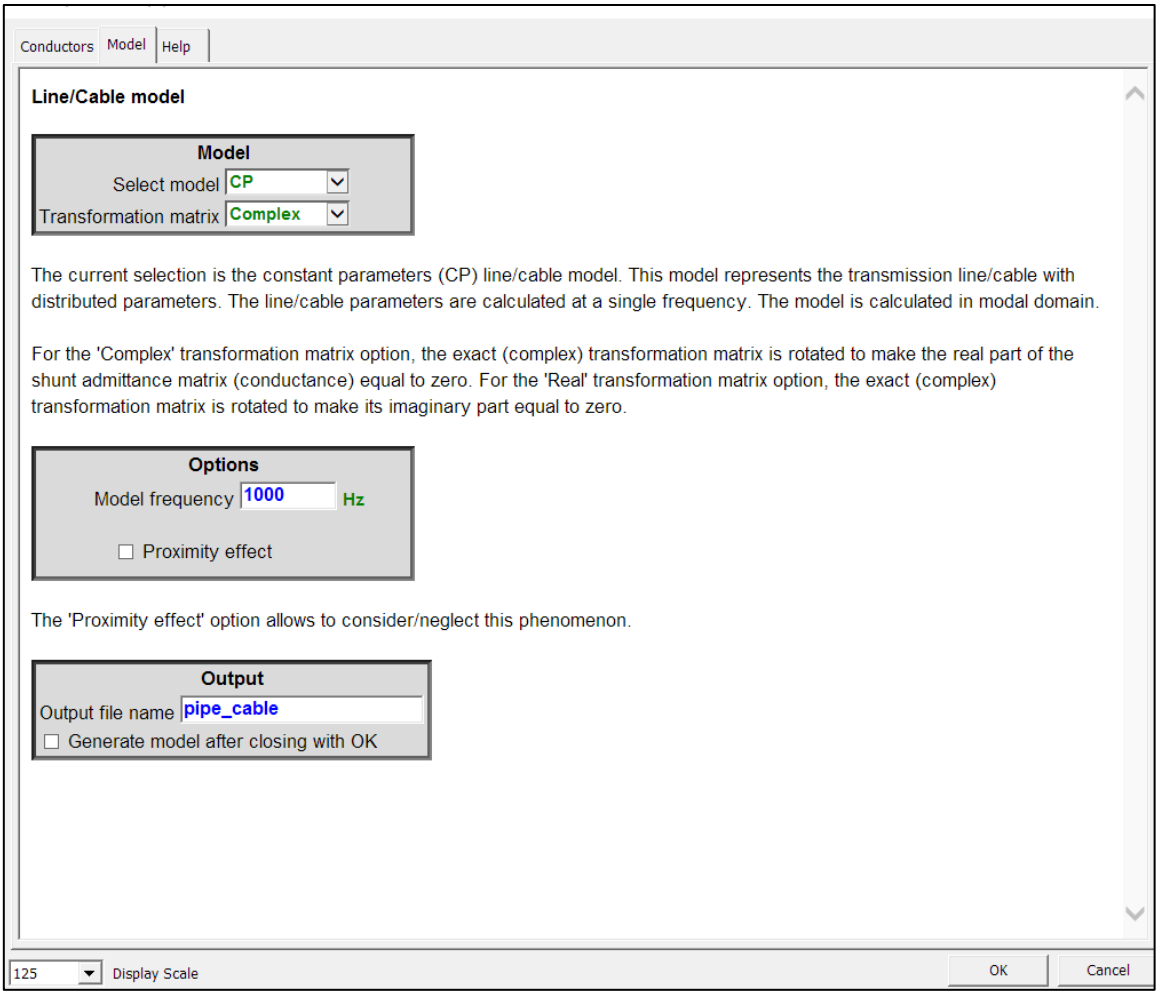


Figure 10 Model tab page example.

4 References

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[6] H. Xue, A. Ametani, J. Mahseredjian, Y. Baba, F. Rachidi, and I. Kocar, "Transient responses of overhead cables due to mode transition in high frequencies," *IEEE Trans. Electromag. Compat,* vol. 60, no. 3, pp. 785-794, 2018.

[7] H. Xue, A. Ametani, J. Mahseredjian, and I. Kocar, "Generalized formulation of earth-return impedance / admittance and surge analysis on underground cables," *IEEE Trans. Power Delivery,* vol. 33, no. 6, pp. 2654 - 2663, 2018.

[8] H. Xue, A. Ametani, J. Mahseredjian, and I. Kocar, "Computation of overhead line / underground cable parameters with improved MoM-So method," *Power Systems Computation Conference (PSCC),* 2018.