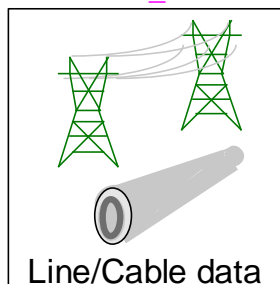


LineCable Data

LineCable_Data



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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.

Properties for LineCable_Data2

Conductors | Model | Help

Line/Cable Data

Use Database

Bare conductors

Number of single-wire conductors: 0

Number of bundle conductors: 0

Conductors parameter: DC resistance

☐ Midspan height

☐ Hollow conductors

Cables

Number of single-core cables: 0

Number of pipe-type cables: 0

☐ Stranded pipe-type cable

Soil

Resistivity: 100 Ohm m

Relative permeability: 1

Relative permittivity: 1

Length

Units: Metric

Line/Cable length: 50 km / miles

Data tables list

☐ Overhead bundle conductors

☐ Overhead single-wire conductors

☐ Single-core cables

☐ Pipe-type cables

Legend:

- Air
- Soil
- Conductor
- Insulator

[Line/Cable list](#)

[Drawing options](#)

125 Display Scale

OK Cancel

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.

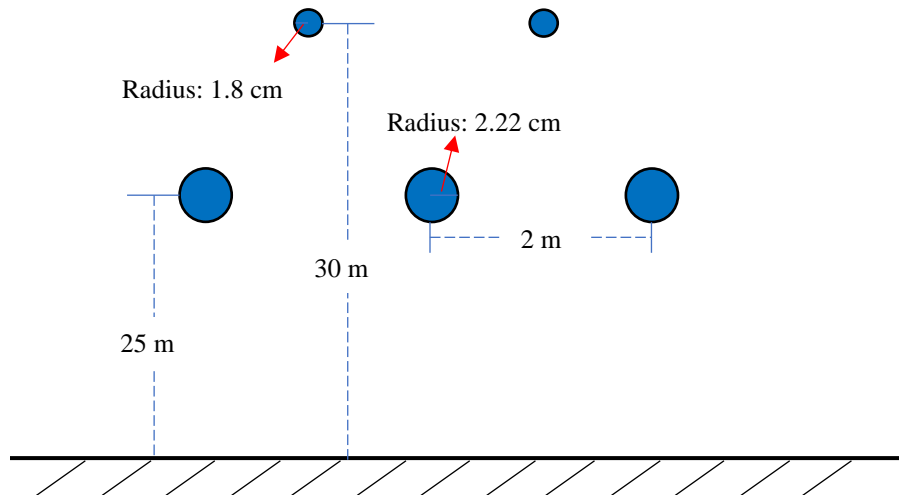


Figure 2 Three-phase overhead line example.

Properties for LineCable_Data2

Conductors | Model | Help

Use Database

Bare conductors

Number of single-wire conductors: 5

Number of bundle conductors: 0

Conductors parameter: DC resistance

☐ Midspan height

☐ Hollow conductors

Cables

Number of single-core cables: 0

Number of pipe-type cables: 0

☐ Stranded pipe-type cable

Soil

Resistivity: 100 Ohm m

Relative permeability: 1

Relative permittivity: 1

Length

Units: Metric

Line/Cable length: 50 km / miles

Data tables list

☐ Overhead bundle conductors

☒ Overhead single-wire conductors

☐ Single-core cables

☐ Pipe-type cables

Overhead line single-wire conductors

Conductor	Phase	Horizontal position (m)	Height (m)	Radius (cm)	DC resistance (Ohm/km)	Conductor relative permeability	Conductor relative permittivity
1	1	-2	25	2.22	0.1052	1	1
2	2	0	25	2.22	0.1052	1	1
3	3	2	25	2.22	0.1052	1	1
4	0	-1	30	1.8	0.12	1	1
5	0	1	30	1.8	0.12	1	1

125 Display Scale

OK Cancel

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.

Properties for three_phase_line

Conductors | Model | Help

Line/Cable Data

[Use Database](#)

Bare conductors

Number of single-wire conductors: 2

Number of bundle conductors: 3

Conductors parameter: DC resistance

☐ Midspan height

☒ Hollow conductors

Cables

Number of single-core cables: 0

Number of pipe-type cables: 0

☐ Stranded pipe-type cable

Soil

Resistivity: 100 Ohm m

Relative permeability: 1

Relative permittivity: 1

Length

Units: Metric

Line/Cable length: 64 km / miles

Data tables list

☒ Overhead bundle conductors

☒ Overhead single-wire conductors

☐ Single-core cables

☐ Pipe-type cables

Overhead line single-wire conductors

Conductor	Phase	Horizontal position (m)	Height (m)	Inner radius (cm)	Outer radius (cm)	DC resistance (Ohm/km)	Conductor relative permeability	Conductor relative permittivity
1	0	-3.9319	30.023	0	0.49022	1.6216	1	1
2	0	3.9319	30.023	0	0.49022	1.6216	1	1

Overhead line bundle conductors

Bundle	Phase	Horizontal position (m)	Height (m)	Number of conductors	Angle (deg)	Bundle radius (cm)	Inner radius (cm)	Outer radius (cm)	DC resistance (Ohm/km)	Conductor relative permeability	Conductor relative permittivity
1	1	-6.096	15.24	4	0	22.86	0.555022512	2.03454	0.0324	1	1
2	2	0	23.622	4	0	22.86	0.555022512	2.03454	0.0324	1	1
3	3	6.096	15.24	4	0	22.86	0.555022512	2.03454	0.0324	1	1

125 Display Scale

OK Cancel

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

Properties for three_phase_line

Conductors

Model

Help

Line/Cable Data

Use Database

Bare conductors

Number of single-wire conductors

2

Number of bundle conductors

3

Conductors parameter

DC resistance

Midspan height

☐

Hollow conductors

☒

Cables

Number of single-core cables

0

Number of pipe-type cables

0

Stranded pipe-type cable

☐

Soil

Resistivity

100

Ohm m

Relative permeability

1

Relative permittivity

1

Length

Units

Metric

Line/Cable length

64

km / miles

+

-

Air

Soil

Conductor

Insulator

Line/Cable list

☐ single-wire 1 (SW1)

☐ single-wire 2 (SW2)

☒ Bundle 1 (B1)

☐ Bundle 2 (B2)

☐ Bundle 3 (B3)

Drawing options

☐ Show cable names

☐ Show vertical distances

☐ Show horizontal distances

☐ Set minimal cable size

☐ Select/deselect ALL cables

125

Display Scale

OK

Cancel

Data tables list

☒ Overhead bundle conductors

☒ Overhead single-wire conductors

☐ Single-core cables

☐ Pipe-type cables

Overhead line single-wire conductors

Conductor	Phase	Horizontal position (m)	Height (m)	Inner radius (cm)	Outer radius (cm)	DC resistance (Ohm/km)	Conductor relative permeability	Conductor relative permittivity
1	0	-3.9319	30.023	0	0.49022	1.6216	1	1
2	0	3.9319	30.023	0	0.49022	1.6216	1	1

Overhead line bundle conductors

Bundle	Phase	Horizontal position (m)	Height (m)	Number of conductors	Angle (deg)	Bundle radius (cm)	Inner radius (cm)	Outer radius (cm)	DC resistance (Ohm/km)	Conductor relative permeability	Conductor relative permittivity
1	1	-6.096	15.24	4	0	22.86	0.555022512	2.03454	0.0324	1	1
2	2	0	23.622	4	0	22.86	0.555022512	2.03454	0.0324	1	1
3	3	6.096	15.24	4	0	22.86	0.555022512	2.03454	0.0324	1	1

Figure 5 LineCable Data device drawing capabilities.

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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.

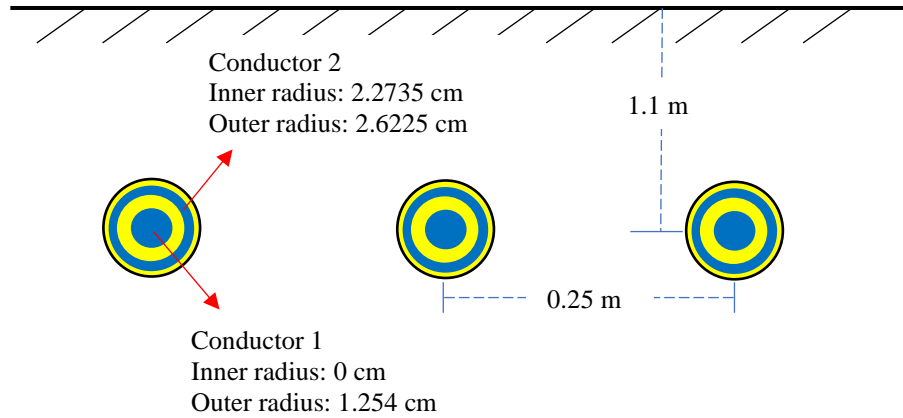


Figure 6 Example of three underground single-core cables.

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 n^{th} insulator layer is defined by the difference between the outer radius of the n^{th} conductor and the inner radius of the $(n+1)^{\text{th}}$ 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

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

Properties for three_single_core

Conductors | Model | Help

Line/Cable Data

Use Database

Bare conductors

Number of single-wire conductors: 0

Number of bundle conductors: 0

Conductors parameter: DC resistance

☐ Midspan height

☐ Hollow conductors

Cables

Number of single-core cables: 3

Number of pipe-type cables: 0

☐ Stranded pipe-type cable

Soil

Resistivity: 250 Ohm m

Relative permeability: 1

Relative permittivity: 1

Length

Units: Metric

Line/Cable length: 5 km / miles

Legend

- Air
- Soil
- Conductor
- Insulator

Line/Cable list

- ☒ Single-core 1 (SC1)
- ☒ Single-core 2 (SC2)
- ☒ Single-core 3 (SC3)

Drawing options

- ☐ Show cable names
- ☒ Show vertical distances
- ☐ Show horizontal distances
- ☐ Set minimal cable size
- ☐ Select/deselect ALL cables

Data tables list

- ☐ Overhead bundle conductors
- ☐ Overhead single-wire conductors
- ☒ Single-core cables
- ☐ Pipe-type cables

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

125 Display Scale

OK Cancel

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.

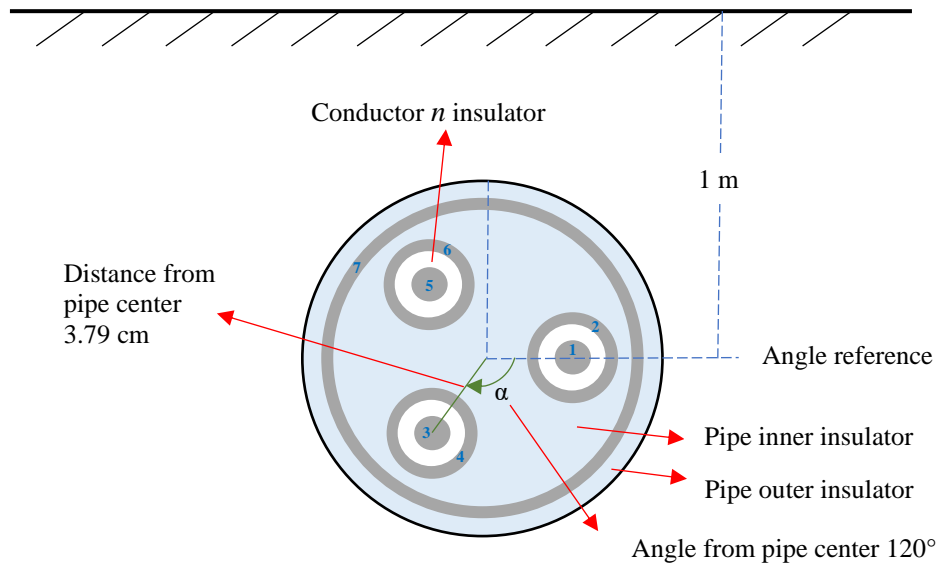


Figure 8 Underground pipe-type cable.

Properties for pipe_cable

Conductors | Model | Help

Use Database

Bare conductors

Number of single-wire conductors

Number of bundle conductors

Conductors parameter

☐ Midspan height

☐ Hollow conductors

Cables

Number of single-core cables

Number of pipe-type cables

☐ Stranded pipe-type cable

Soil

Resistivity Ohm m

Relative permeability

Relative permittivity

Length

Units

Line/Cable length km / miles

☐ Air

☐ Soil

☐ Conductor

☐ Insulator

Line/Cable list

☒ Pipe-type 1 (PT1)

Drawing options

☒ Show cable names

☐ Show vertical distances

☐ Show horizontal distances

☐ Set minimal cable size

☐ Select/deselect ALL cables

Data tables list

☐ Overhead bundle conductors

☐ Overhead single-wire conductors

☐ Single-core cables

☒ Pipe-type cables

Pipe-type cable main data

Cable	Number of conductors	Horizontal position (m)	Ground depth (m)	Radius (cm)	Inner insulator relative permittivity	Outer insulator relative permittivity
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

125 Display Scale

OK Cancel

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 performed 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.

Conductors Model Help

Line/Cable model

Model

Select model **CP**

Transformation matrix **Complex**

The current selection is the constant parameters (CP) line/cable model. This model represents the transmission line/cable with distributed parameters. The line/cable parameters are calculated at a single frequency. The model is calculated in modal domain.

For the 'Complex' transformation matrix option, the exact (complex) transformation matrix is rotated to make the real part of the shunt admittance matrix (conductance) equal to zero. For the 'Real' transformation matrix option, the exact (complex) transformation matrix is rotated to make its imaginary part equal to zero.

Options

Model frequency **1000** Hz

☐ Proximity effect

The 'Proximity effect' option allows to consider/neglect this phenomenon.

Output

Output file name **pipe_cable**

☐ Generate model after closing with OK

125 Display Scale OK Cancel

Figure 10 Model tab page example.

4 References

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- [2] U. R. Patel, B. Gustavsen, and P. Triverio, "An equivalent surface current approach for the computation of the series impedance of power cables with inclusion of skin and proximity effects.," *IEEE Trans. Power Delivery*, vol. 28, no. 4, pp. 2474-2482, 2013.
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