PowerWorld Transmission Line Parameter Calculator

Introduction

The PowerWorld Transmission Line Parameter Calculator is a tool designed to compute characteristic line parameters given the type of the conductor and the tower configuration of a three-phase overhead transmission line.
The parameters computed are the resistance R, reactance X, susceptance B, and conductance G. These values are computed as distributed (per unit of distance), lumped or total (for a specific line distance), and in per-unit.

Calculations

The following controls are part of the calculations section:

Parameters Calculation

This section is to enter the necessary data to compute the characteristic line parameters that are shown in the Results panel.

Input Data

Conductor Type: This is the combo box that lists all the conductor types available in the Conductors table. To add, remove or edit a specific conductor and its characteristics, see Conductor Type section below.

Tower Configuration: This combo box lists all the tower configurations available in the Tower Configurations table. To add, remove or edit a specific tower configuration, please go to the Tower Configuration section below.

Line Length: This is the value of the distance of the transmission line. The units are miles when using English system, or kilometers when using the Metric (SI) system.

Line Length Units: The line length units specify the measurement system to use when entering the line length. The options are English system or Metric (SI) system. The final and intermediate results will also be shown in the system specified here.

Power Base:	The system voltampere base in MVA.
Voltage Base:	The line-line voltage base in KV.
Impedance Base:	The impedance base in Ohms. This value is automatically computed when the power base and the voltage base are entered or modified.
Admittance Base:	The admittance base in Siemens. It is also automatically computed as the inverse of the impedance base.

Final Results

When all the input data is entered, the results automatically will be displayed. The values for R, X, B and G are shown in three different sections, each section corresponding to Distributed, Lumped or Total, and Per Unit values, respectively. The Power Surge Impedance Loading is calculated only for the lumped section.

Intermediate Results

The intermediate values calculated to compute the R, X, B, and G values are displayed here. The computed geometric mean radius and geometric mean distance are shown in the Distributed values section. The characteristic impedance and propagation factor are displayed in the Lumped values section.

Note: To see the specific calculations used in this program, see the Calculations section, at the end of this document.

Ampere to MVA Limit Conversion

This section converts the limits of the transmission line from Amperes to MVAs, given the voltage base, and vice versa.

Conductor Type

This section is used to add, remove, rename, and edit the information related to the conductor types. This can be done in two ways: using the form for an individual conductor type, or using the table for all the conductor types available.

Edit By Form

Conductors are identified by a unique code word. All the available conductors are listed in the Conductor Code Word combo box. By selecting one conductor, all its properties are displayed in the form. There, the user is able to modify any of those values. After modification of any value, the user has to save the changes by clicking on the button **Save** before changing tabs, otherwise the changes will be lost.

By clicking on **New**, a message prompting for a name for a new conductor will be shown. By clicking on **Rename**, a new name for the current conductor type is required. In order to save the current conductor type with a different name is necessary to click on **Save As**. Finally, to remove the current conductor the user can do so by clicking on the **Delete** button.

Edit By Table

In this tab, all the conductor types are shown as records in a table, where every field is a characteristic of the conductor. In order to edit the records in this table, use the Database button described in the Database section. While editing the table, the user can not change of tab until changes are posted or discarded.

Conductor Properties

The available properties of the conductors are the following:

Code Word:	Code name for the type of conductor. The names of bird species are typically used. Code Word has to be unique.
Area:	The area of aluminum conductor in circular mils. A circular mil is the cross-sectional area of a circular conductor having a diameter of 1 mil. One mil is one thousandth of an inch (0.001").
Aluminum strands:	Number of aluminum strands.
Steel layers:	Number of steel strands.

Aluminum layers: Number of aluminum layers.

External diameter: Outside diameter of the conductor in inches.

GMR: Geometric Mean Radius in feet.

DC Resistance: DC resistance of the conductor at 20°C per 1 mile in Ohms.

AC Resistance 25:   AC resistance of the conductor at 60 Hz and 25°C per 1 mile in Ohms.

AC Resistance 50:   AC resistance of the conductor at 60 Hz and 50°C per 1 mile in Ohms.

AC Resistance 75:   AC resistance of the conductor at 60 Hz and 75°C per 1 mile in Ohms.

Inductive Reactance: Inductive reactance per conductor at 1 foot spacing at 60 Hz in Ohms/mile.

Capacitive Reactance: Capacitive reactance per conductor at 1 foot spacing at 60 Hz in MegaOhms/mile.

Tower Configuration

This part is used to add, remove, rename, and edit the information related to the tower configurations. This can be done in two ways: using the form for an individual tower configuration, or using the table for all the tower configurations available.

Edit By Form

Tower configurations are identified by a unique name. All the available tower configurations are listed in the Tower Configuration Name combo box. By selecting one specific tower configuration, all its characteristics are displayed in the form. There, the user can modify any of those characteristics. After modification of any value, the user has to save the changes by clicking on the button **Save** before changing tabs, otherwise the changes will be lost.

By clicking on **New**, a message prompting for a name for a new tower configuration will be shown. By clicking on **Rename**, a new name for the current tower configuration is required. In order to save the current tower configuration with a different name is necessary to click on **Save As**. Finally, to remove the current tower configuration the user can do so by clicking on the **Delete** button.

Edit By Table

In this tab, all the tower configurations are shown as records in a table, where every field is a value of the tower configuration. In order to edit the records in this table, use the Database button described in the Database section. While editing the table, the user can not change of tab until changes are posted or discarded.

Tower Configuration Values

The values of the tower configuration are the following:

Name: Name for the tower configuration. Name has to be unique.

Phase spacing: x and y coordinates of phases A, B and C positions. Values are in feet for English system and meters for Metric (SI) system. When these values are modified, the phase spacing graph is automatically updated. **Draw axis** has to be checked for x and y axis to be drawn in the graph.

Conductors per bundle: This section specifies the number of conductors (either single conductor or a bundle of conductors) per phase. The maximum number of conductors per bundle allowed is 4.

Use regular spacing: When using a bundle of conductors, checking the **Use Regular Spacing of** check box will use the specified value as a regular spacing among the conductors. If the **Use Regular Spacing of** check box is not checked, then the custom conductors spacing section has to be used.

Conductors spacing: x and y coordinates of the conductors in the bundle. Values are in feet for English system and meters for Metric (SI) system. When these values are modified, the bundle spacing graph is automatically updated. **Draw axis** has to be checked for x and y axis to be drawn in the graph.

Temperature: Assumed temperature in Fahrenheit degrees for English system and Celsius degrees for Metric (SI) system.

Frequency: Frequency of the system in Hertz.

System of units: The system of units used to specify the values of the tower configuration. The options are English system or Metric (SI) system. The units specified here not necessarily have to math the units specified in the **Input Data** section.

Database

The conductor type and tower configurations tables are read by default from the file **conductors.mbd**, which is a MS Access® database. This database can be read from another *.mdb file by clicking on the **Select Conductors and Configurations Database** button.

Note: The conductors.mdb file can also be viewed and edited in MS Access®.

In order to edit a record in the database tables, the user can use the toolbar designed to do that. Following there is a figure showing this toolbar:

First   Prior   Next   Last   Insert   Delete   Edit   Post edit   Cancel edit   Refresh data
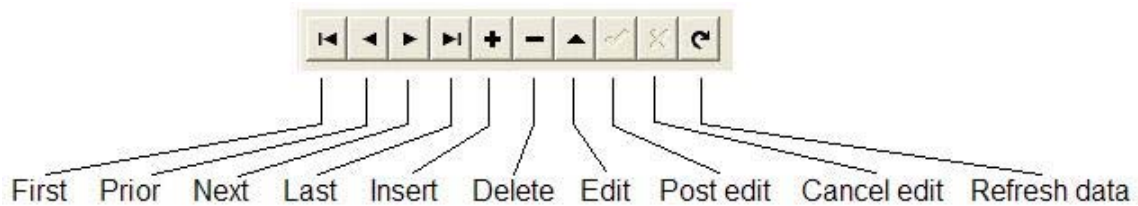
The **First**, **Prior**, **Next**, and **Last** buttons are used to move among records. The **Insert**, **Delete** and **Edit** buttons are used to insert, delete or edit the current record, respectively. While editing a record, the user can not change of tab until modifications are posted through the **Post edit** button or canceled with the **Cancel edit** button. The **Refresh data** button just refreshed the data of the entire table.

Calculations

Distributed Parameters

Resistance

$$R_t = \frac{\left(R_{25} + \left(\frac{R_{25} - R_{50}}{25 - 50}\right)(t - 25)\right)}{N} \qquad 0 \le t \le 50$$

$$R_t = \frac{\left(R_{50} + \left(\frac{R_{50} - R_{75}}{50 - 75}\right)(t - 50)\right)}{N} \qquad 50 \le t$$

Where:

- R_t AC resistance at temperature *t* per phase per 1 mile in Ohms
- t Assumed temperature in Celsius degrees
- R_{25} AC resistance of the conductor at 60 Hz and 25°C per 1 mile in Ohms
- R_{50} AC resistance of the conductor at 60 Hz and 50°C per 1 mile in Ohms
- R_{75} AC resistance of the conductor at 60 Hz and 75°C per 1 mile in Ohms
- N Number of conductors per phase

Inductive Reactance

$$X_L = 4\pi f \times 10^{-7} \ln \frac{D_{eq}}{D_{SL}}$$

Where:

- X_L Inductive reactance in Ohms/meter
- f Frequency of the system in Hertz
- D_{eq} Geometric mean distance between phases in meters
- D_{SL} Geometric mean radius between conductors of one phase in meters

The **geometric mean distance** between phases is defined as:

$$D_{eq} = \sqrt[3]{d_{ab} d_{bc} d_{ca}}$$

Where:

d_{ab}, d_{bc}, d_{ca} Distances between phases a-b, b-c, c-a, respectively in meters

The **geometric mean radius** between conductors of one phase is defined as:

$$D_{SL} = GMR \qquad\qquad \text{For 1 stranded conductor}$$

$$D_{SL} = e^{-1/4}r \qquad\qquad \text{For 1 solid cylindrical conductor}$$

$$D_{SL} = \left(\prod_{k=1}^{N} \prod_{m=1}^{N} d_{km} \right)^{\frac{1}{N^2}} \qquad \text{For more then 1 conductor bundle}$$

Where:

D_{SL} Geometric mean radius in meters

r External radius of conductor in meters

GMR Geometric mean radius given in tables for one stranded conductor

d_{km} Distance between conductors k and m in meters.

Note: If $k = m$, then $d_{km} = D_{SL}$ for one stranded or solid cylindrical conductor.

Susceptance

$$B = 2\pi f \left(\frac{2\pi\varepsilon}{\ln\left(\dfrac{D_{eq}}{D_{SC}}\right)} \right)$$

Where:

B Susceptance in Siemens/meter

f Frequency of the system in Hertz

ε Constant permittivity = 8.85418×10^{-12}

D_{eq} Geometric mean distance between phases, defined as above

D_{SC} Geometric mean radius between conductors of one phase using external radius in meters

The geometric mean radius between conductors of one phase using external radius is defined as:

$$D_{SC} = r \qquad\qquad \text{For 1 conductor}$$

$$D_{SC} = \left(\prod_{k=1}^{N} \prod_{m=1}^{N} d_{km} \right)^{\frac{1}{N^2}} \qquad \text{For more then 1 conductor bundle}$$

Where:

D_{SC} Geometric mean radius in meters

r External radius of conductor in meters

d_{km} Distance between conductors k and m in meters.

       Note: If $k = m$, then $d_{km} = r$.

Conductance

$$\text{Assumed } G = 0$$

Where:

G Conductance in Siemens/meter

Lumped (Total) Parameters

Resistance, Inductive Reactance, Conductance and Susceptance, using the equivalent π circuit (long line)

$$Z' = R' + jX' = Z_c \sinh \gamma \ell$$

$$Y' = G' + jB' = \frac{2}{Z_c} \tanh \frac{\gamma \ell}{2}$$

Where:

Z' Total series impedance of line in Ohms

Y' Total series admittance of line in Siemens

R' Total series resistance of line in Ohms

X' Total series inductive reactance of line in Ohms

G' Total series conductance of line in Siemens

B' Total series susceptance of line in Siemens

Z_c Characteristic impedance in Ohms

γ Propagation constant in meters^{-1}

ℓ Line length in meters

The **characteristic impedance** and **propagation constant** are defined as:

$$Z_c = \sqrt{\frac{z}{y}}$$

$$\gamma = \sqrt{zy}$$

Where:
  z Distributed series impedance in Ohms/meter
  y   Distributed series admittance in Siemens/meter

The **distributed series impedance** and **distributed series admittance** are defined as:

$$z = R + jX$$

$$y = G + jB$$

Where:
  R Distributed series resistance in Ohms/meter
  X Distributed series inductive reactance in Ohms/meter
  G Distributed series conductance in Siemens/meter
  B Distributed series susceptance in Siemens/meter

Surge Impedance Loading

The surge impedance loading is defined as the power delivered by a lossless line to a load resistance equal to the surge (or characteristic) impedance Z_c, and is given by:

$$P_{SIL} = \frac{|V_N|^2}{Z_C}$$

Where:
  P_{SIL} Total surge impedance loading in a three-phase line in VA
  V_N Line-line nominal voltage in Volts

Base Values

Impedance Base

$$Z_B = \frac{(V_B^{ll})^2}{S_B^{3\phi}}$$

Where:

Z_B Impedance base in Ohms

$S_B^{3\phi}$ Power base in VA

V_B^{ll} Line-line voltage base in Volts

Admittance Base

$$Y_B = \frac{1}{Z_B}$$

Where:

Y_B Admittance base in Siemens

Z_B Impedance base in Ohms

Per Unit (PU) Parameters

Resistance, Inductive Reactance, Conductance, Susceptance

$$R_{PU} = \frac{R'}{Z_B}$$

$$X_{PU} = \frac{X'}{Z_B}$$

$$G_{PU} = \frac{G'}{Y_B}$$

$$B_{PU} = \frac{B'}{Y_B}$$

Where:

R_{PU} Per unit resistance

R' Total series resistance in Ohms

X_{PU} Per unit Inductive reactance

X' Total series inductive reactance in Ohms
X_{PU} Per unit conductance
G' Total series conductance in Siemens
B_{PU} Per unit susceptance
B' Total series susceptance in Siemens
Z_B Impedance base in Ohms
Y_B Admittance base in Siemens

MVA To Ampere and Ampere To MVA Limits Conversion

MVA to Ampere Limit Conversion

$$Lim_{Amp} = \frac{Lim_{MVA} \times 10^6}{\sqrt{3}|V_N|}$$

Where:
   Lim_{Amp} Limit in Amperes
   Lim_{MVA} Limit in MVAs
   V_N Nominal voltage in Volts

Ampere to MVA Limit Conversion

$$Lim_{MVA} = Lim_{Amp} \frac{\sqrt{3}|V_N|}{10^6}$$

Where:
   Lim_{Amp} Limit in Amperes
   Lim_{MVA} Limit in MVAs
   V_N Nominal voltage in Volts

References

[1]   J. D. Glover and M. S. Sarma, *Power Systems analysis and design*, Brooks/Cole, 3rd edition, 2002.

[2]   A. R. Bergen and V. Vittal, *Power System Analysis*, Prentice Hall, 2nd edition, 2000.