PowerWorld Transmission Line Parameter Calculator Version 2

Introduction

The PowerWorld Transmission Line Parameter Calculator (TransLineCalc) 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.

PowerWorld provides TransLineCalc as a stand-alone program (.exe file) and also as an automation server that can run from PowerWorld Simulator directly or from an external application (.dll file).

PowerWorld Corporation
2001 South First Street
Champaign, IL 61820, USA
(217) 384-6330
www.powerworld.com
support@powerworld.com

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1 Features

1.1 Calculations

The following controls are part of the calculations section:

1.1.1 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.

Lumped 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 two different sections, one for actual total values per phase, and one for Per Unit values. The Power Surge Impedance Loading is also calculated.

Distributed Results

The values in this section will be displayed automatically too when all the input data is entered. The values for R, X, B and G are shown in actual values per distance units per phase.

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.

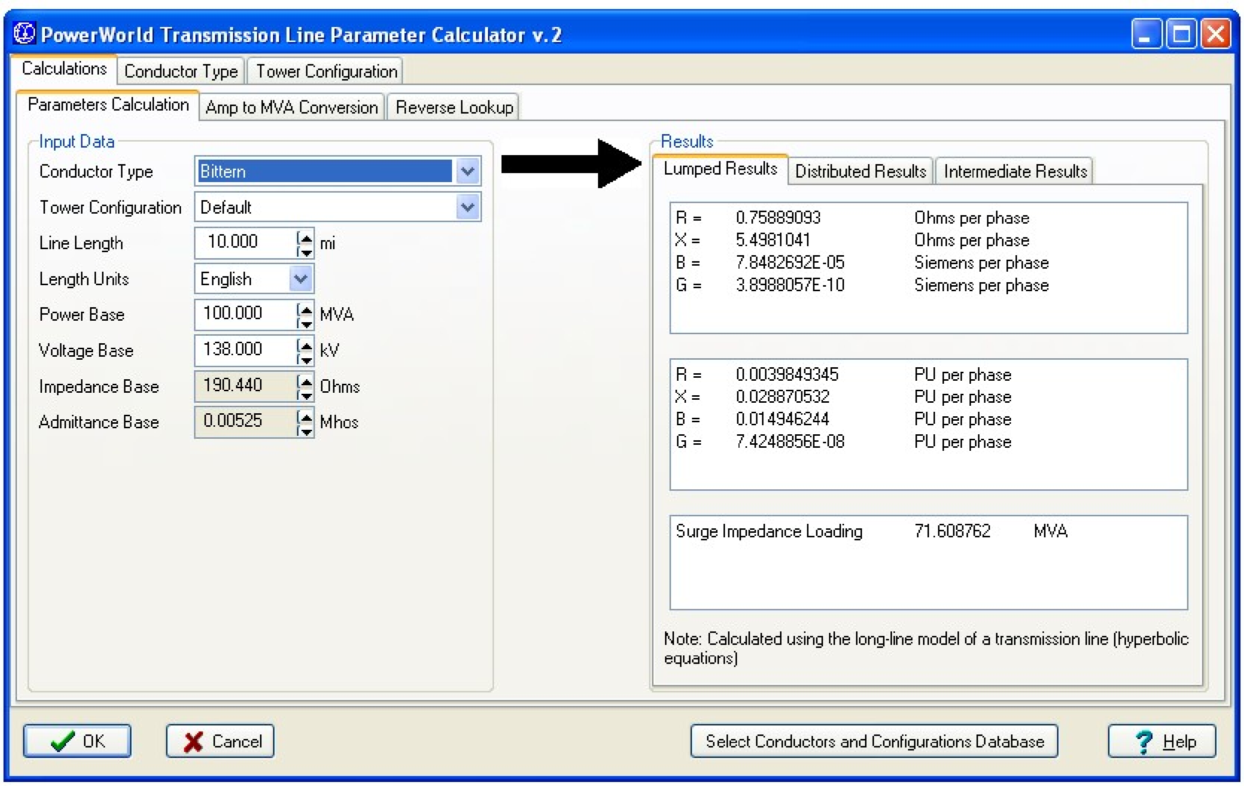


Figure 1: Calculations Tab

1.1.2 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.

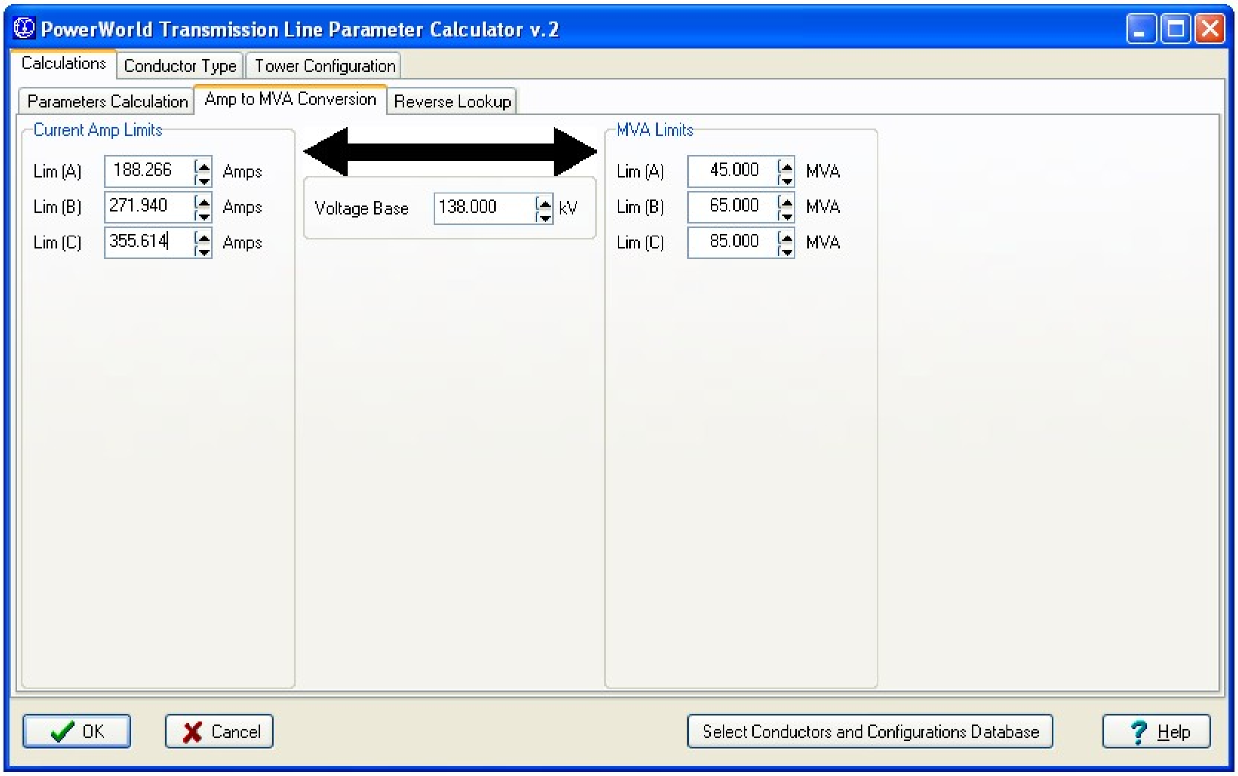


Figure 2: Amp to MVA Conversion

1.1.3 Reverse Lookup

Use this section to do a reverse lookup of the conductor, given a tower configuration and the characteristic line parameters in per unit.

Input Data

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.

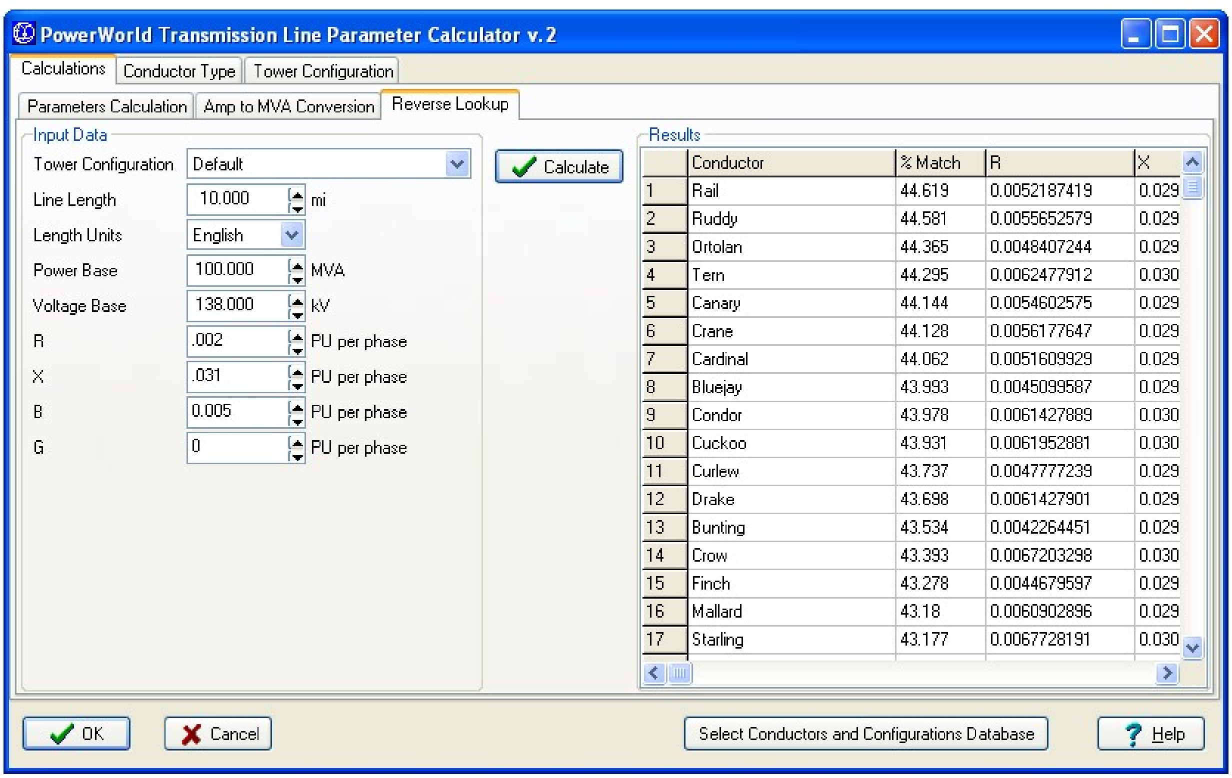
Line Length: This is the value of the distance of the transmission line. The units are miles when using English system, or kilometers when using the Metric (SI) system.

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.
R:	Resistance in per unit per phase.
X:	Reactance in per unit per phase.
B:	Susceptance in per unit per phase.
G:	Conductance in per unit per phase.

Results

When all the input data is entered, click on the **Calculate** button to display the results in the table on the right. This table will compute the characteristic line parameters for each of the conductors in the data base, using the input tower configuration. The conductors will be sorted according to the match of their characteristics line parameters results with the input characteristic line parameters.



1.2 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.

1.2.1 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.

1.2.2 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.

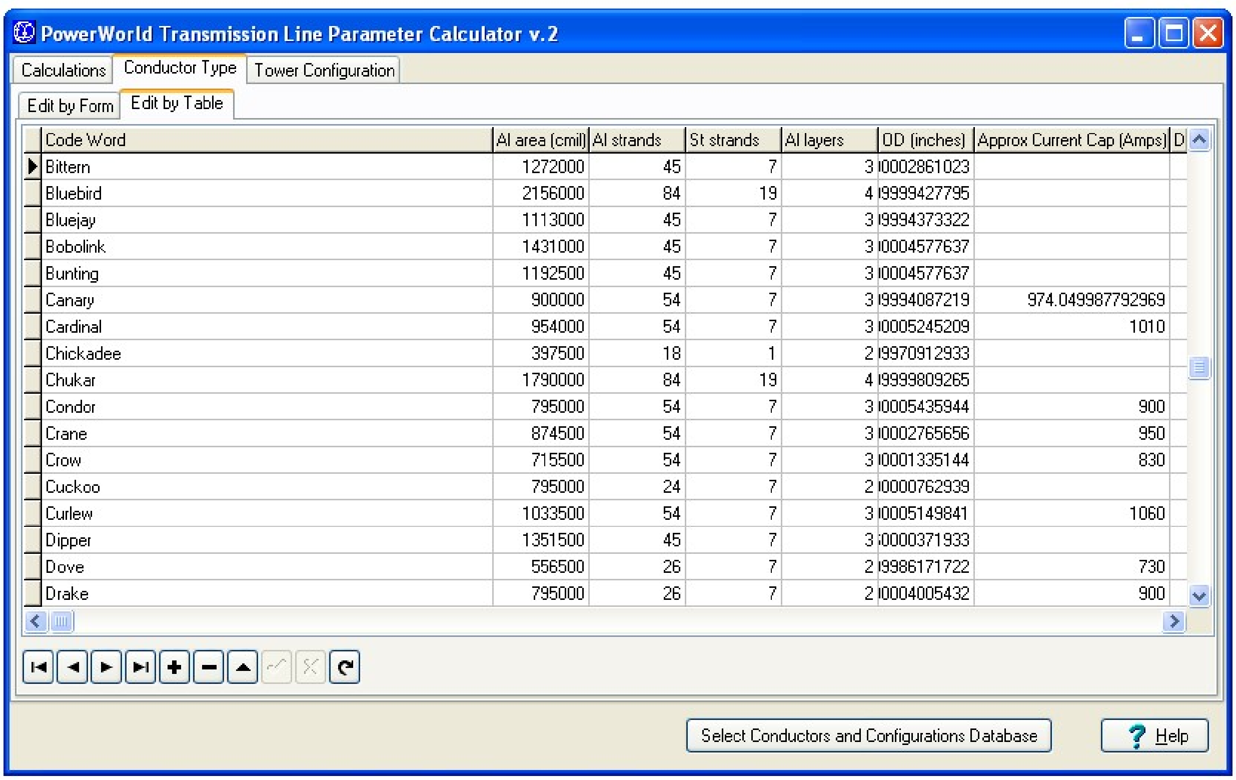


Figure 3: Conductors Tab (Editing by Table)

1.3 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.

1.3.1 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.

1.3.2 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:	The temperature is in Celsius degrees regardless of the System of units that is selected.
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.

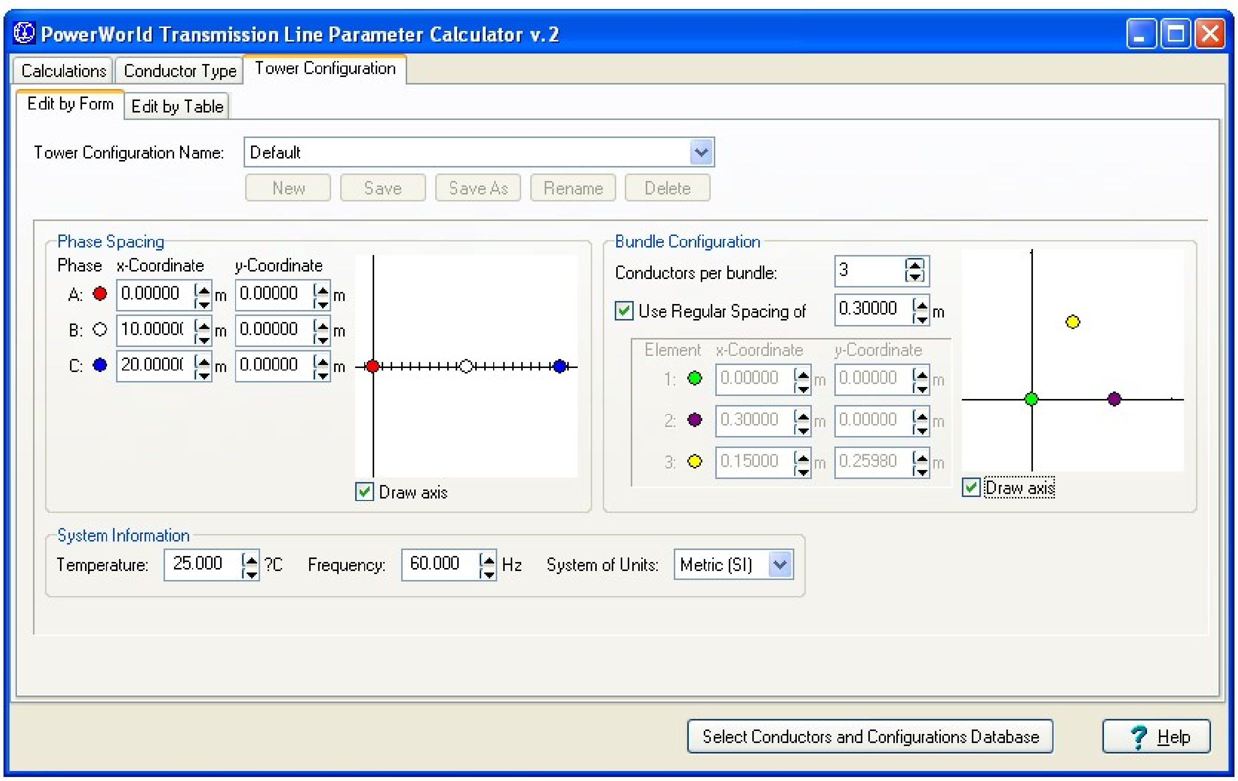


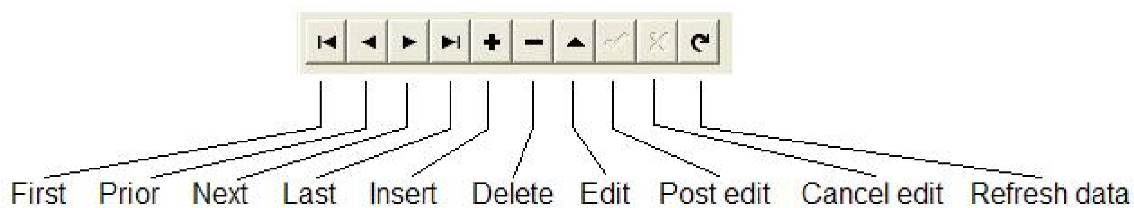
Figure 4: Tower Configuration (Editing by Form)

1.4 Database Controls

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:



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.

2 Automation Server

The following automation server is useful for take advantage of the TransLineCalc functionality from an external application. Note that we also have included a script command in Simulator that is designed to run TransLineCalc and compute the characteristics parameters of a set of transmission lines, without the need of an external application: CalculateRXBGFromLengthConfigCondType(filtername);

CalculateRXBGFromLengthConfigCondType takes the set of lines specified by the filtername, and computes the characteristic parameters for each of them, using the existing fields ConductorName and TowerConfiguration fields. If these fields are empty or can not be found within the TransLineCalc conductors database, no computations are performed or modified. The filtername is optional. See the Simulator Help for more information.

2.1 COM Object Initialization and Destruction

To initialize the TransLineCalc COM object, see the documentation for the particular programming environment being used. Sample code for initialization and destruction is provided for VB for Applications (which should easily port to VB 6). The calls for initialization and destruction are provided below. If for some reason the COM initialization code fails, be sure you have the TransLineCalc add-on for Simulator and you have either run the application on the computer where the COM object is being created or run the command regsvr32 "c:\path\TransLineCalcSvr.dll" at the command line. Also, some programming languages (e.g. Visual Basic) require an explicit reference to the COM object when using "early binding". "Late binding", on the other hand, requires no explicit reference.
If, for some reason, you would like SimAuto to unregister itself as a COM object, run the command `regsvr32 /u "c:\path\TransLineCalcSvr.dll"` at the command line.

TransLineCalc Initialization Code Samples

VB for Applications

```
Dim TransAuto As New PWTransLineCalcAuto
```
←Early binding

-or-

```
Dim TransAuto As Object
Set TransAuto = CreateObject("PWTransLineCalcSvr.PWTransLineCalcAuto")
```
←Late binding

2.2 Methods of the SimAuto Object

2.2.1 SetParameters

Function Prototype: SetParameters(ConductorName as String, TowerConfiguration as String, LineLength as Single, Units as Integer, VoltageBase as Single, PowerBase as Single)

SetParameters is used to set the initial configuration of a transmission line. This input data will be used to compute the parameters of the transmission line.

SetParameters takes six arguments:

- The first and second arguments correspond directly to the conductor and the tower configuration names of the transmission line. These names should be present in the TransLineCalc conductor's database.
- The third and fourth arguments correspond to the transmission line length and the units for that value. The options for units are 0 for English units or 1 for Metric (SI) units.
- The fifth and sixth arguments correspond to the voltage and power bases.

SetParameters returns only one element in Output—any errors which may have occurred when attempting to setting the initial input data.

Sample Implementation

VB for Applications

```
Output = TransAuto.SetParameters("Bluebird", "Default", 25, 0, 138, 100)
```

2.2.2 GetParametersPU

Function Prototype: GetParametersPU(Rpu, Xpu, Bpu, Gpu as Single)

GetParametersPU is used to return the characteristic per-unit parameters of a transmission line.

GetParametersPU takes fourth variant arguments:

- The resistance R, reactance X, susceptance B, and conductance G will return the calculated parameters.

GetParametersPU returns only one element in Output—any errors which may have occurred when attempting to setting the initial input data.

Sample Implementation

VB for Applications

```
Output = TransAuto.GetParametersPU(Rpu, Xpu, Bpu, Gpu)
```

2.2.3 GetParametersLumped

Function Prototype: GetParametersLumped(Rpu, Xpu, Bpu, Gpu as Single)

GetParametersLumped is used to return the characteristic total parameters of a transmission line. The units of these values will be in Ohms/ length unit. The length unit will be the one entered in the SetParameters method.

GetParametersLumped takes fourth variant arguments:

- The resistance R, reactance X, susceptance B, and conductance G will return the calculated parameters.

GetParametersLumped returns only one element in Output—any errors which may have occurred when attempting to setting the initial input data.

Sample Implementation

VB for Applications

```
Output = TransAuto.GetParametersLumped(Rt, Xt, Bt, Gt)
```

3 Calculations

3.1 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:

$D_{SL} = GMR$	For 1 stranded conductor
$D_{SL} = e^{-1/4} r$	For 1 solid cylindrical conductor
$D_{SL} = \left(\prod_{k=1}^{N} \prod_{m=1}^{N} d_{km} \right)^{\frac{1}{N^2}}$	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

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

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:

$D_{SC} = r$	For 1 conductor
$D_{SC} = \left(\prod_{k=1}^{N} \prod_{m=1}^{N} d_{km} \right)^{\frac{1}{N^2}}$	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

Assumed $G = 0$

Where:

G Conductance in Siemens/meter

3.2 Lumped (Total) Parameters

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

$$Z' = R' + jX' = Z_c \sinh \gamma \ell \qquad Y' = G' + jB' = \frac{2}{Z_c} \tanh \frac{\gamma \ell}{2}$$

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:

$$Z_c = \sqrt{\frac{z}{y}} \qquad \gamma = \sqrt{zy}$$

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

3.3 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

3.4 Per Unit (PU) Parameters

Resistance, Inductive Reactance, Conductance, Susceptance

$$R_{PU} = \frac{R'}{Z_B} \qquad X_{PU} = \frac{X'}{Z_B} \qquad G_{PU} = \frac{G'}{Y_B} \qquad B_{PU} = \frac{B'}{Y_B}$$

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

3.5 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

4 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.