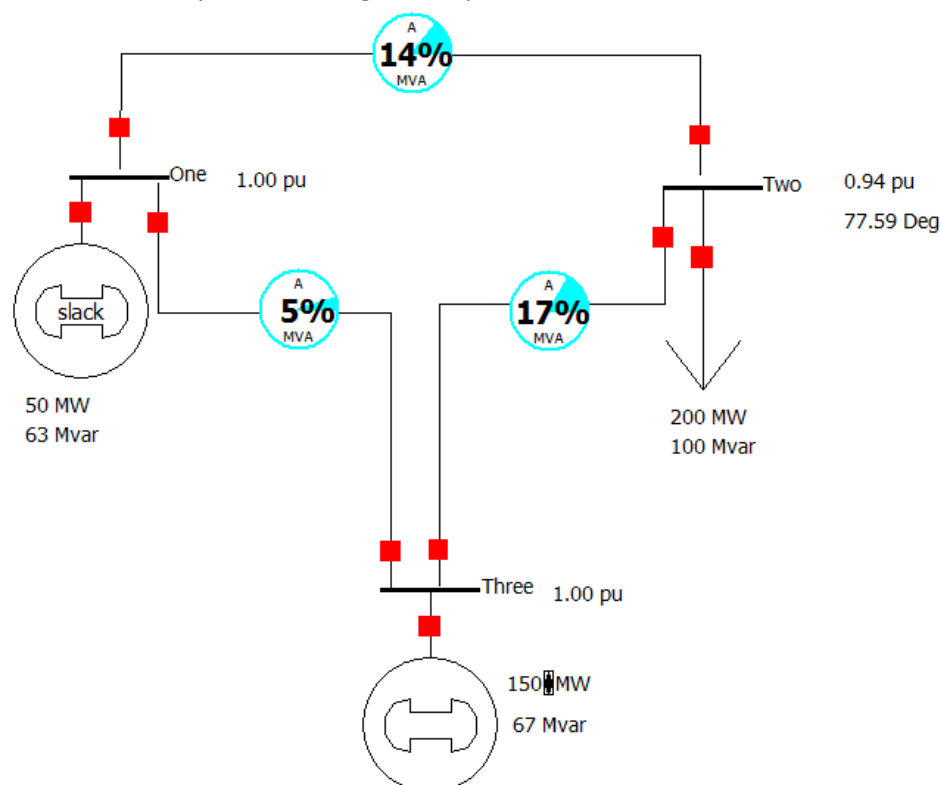


Introduction to PowerWorld Tutorial

*Created by the University of Illinois at Urbana-Champaign
TCIPG PMU Research Group¹*

INTRO:

In this tutorial, we will modify the following 3-bus system.

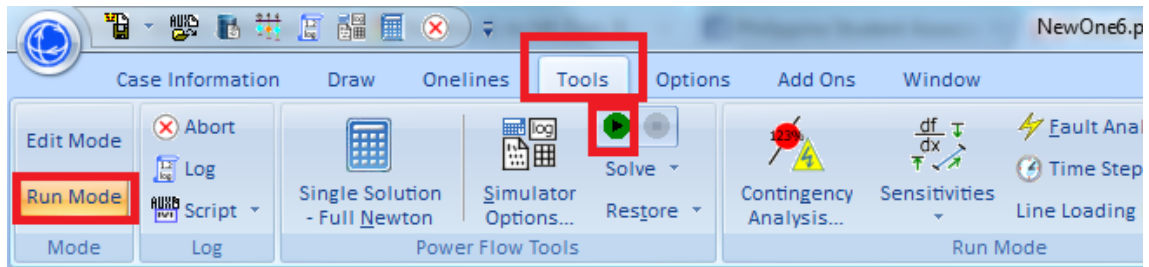


In this system, there are two generators and one load. The first generator (slack) is producing 50 MW of real power and 63 Mvar of reactive power. The real power produced by the second generator can be adjusted with the corresponding “up” and “down” arrows. In our case, the load consumes constant 200 MW and 100 Mvar.

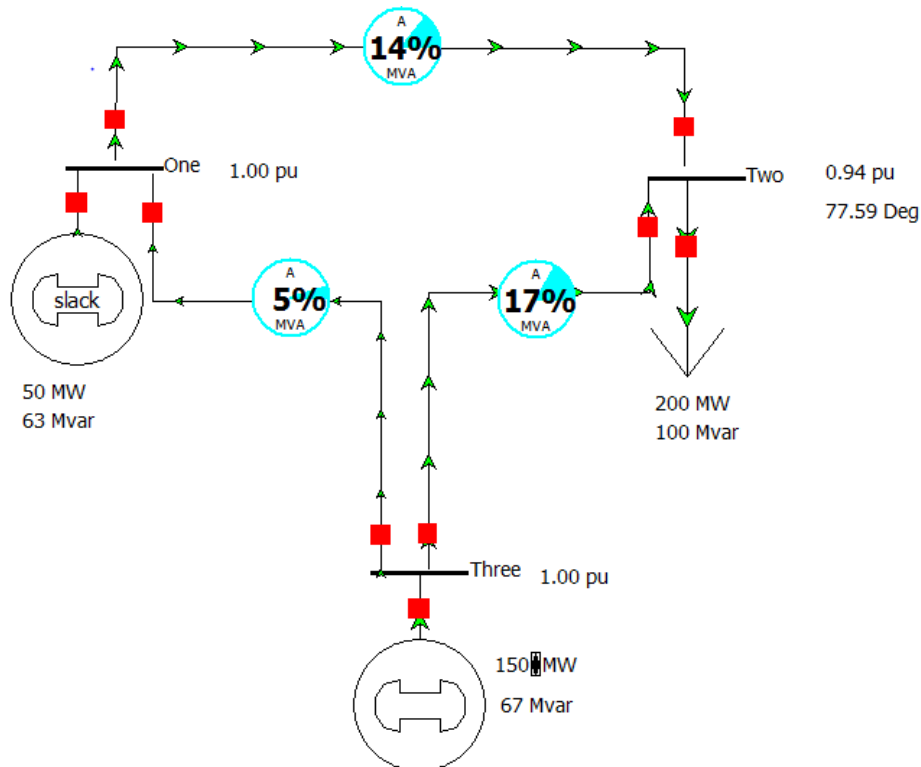
TUTORIAL:

1. To see the power flow from the generators to the load, press **Run Mode->Tools->Solve->[Green Button]**

¹ Credit given to Mark Alipala, Kenta Kiriara and Bogdan Pinte.

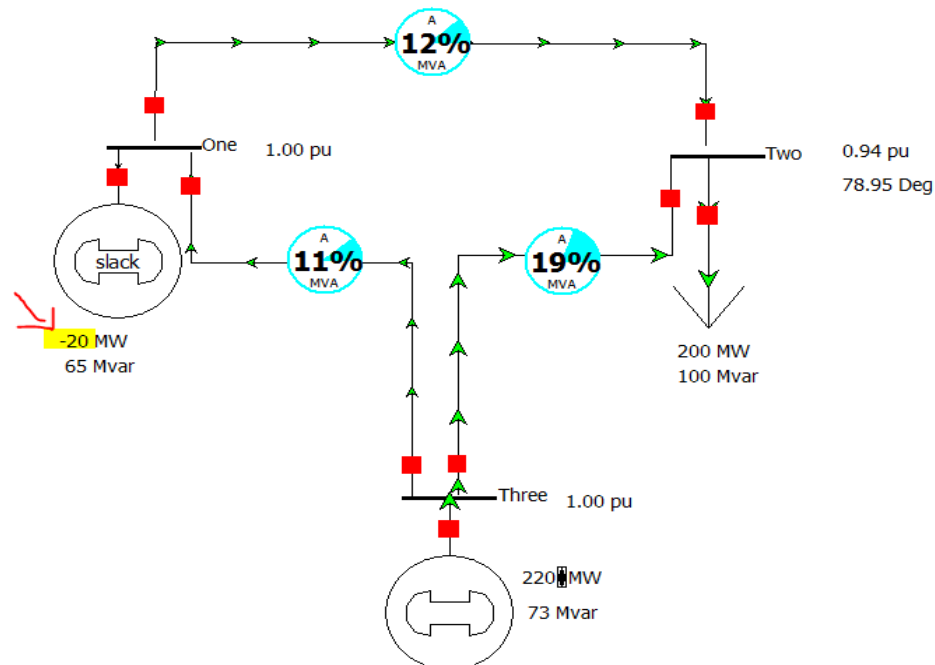


2. The program will then calculate the Power flow equations and would look like the following:



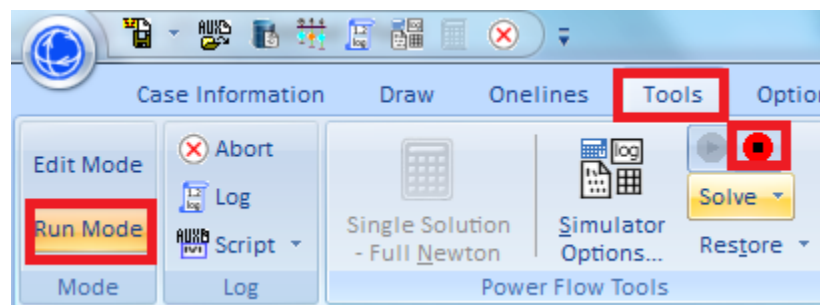
The green arrows indicate the direction of power flow.

- While it is running, increase the power generated by the bottom generator to 180 MW. What will happen to power provided by the other generator?
- Keep increasing the power until 220 MW is provided by the bottom generator. The system will look like this:

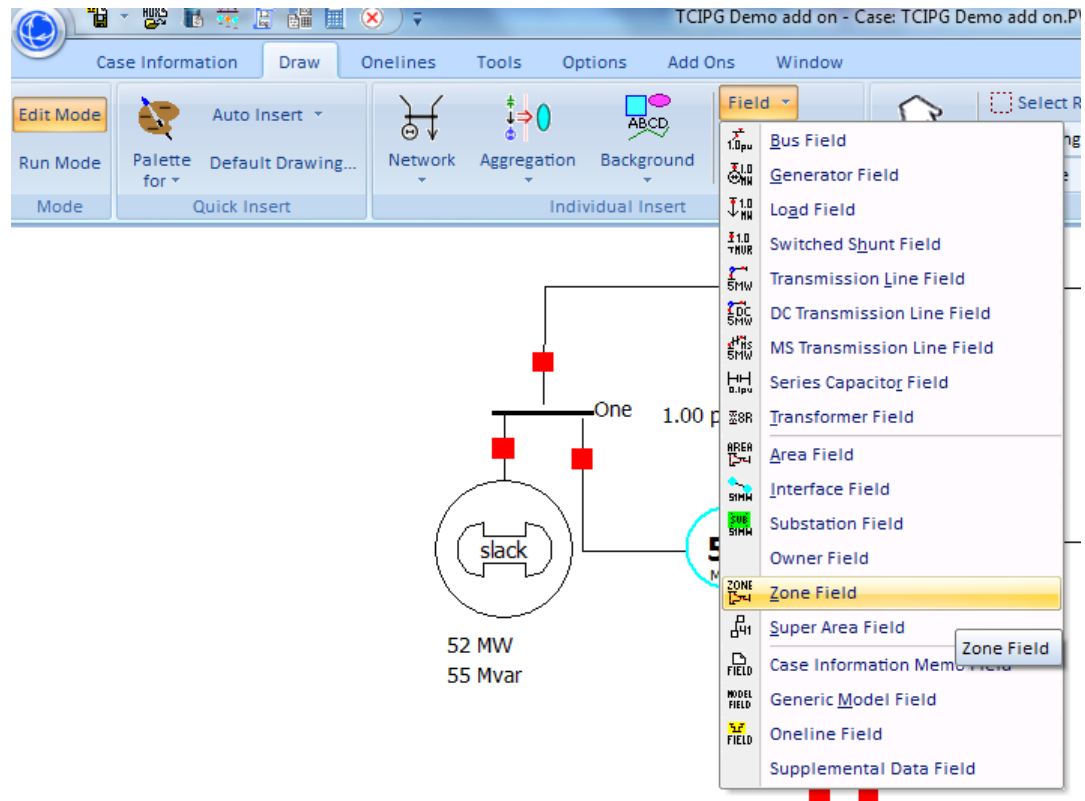


Note: Generator 1 becomes a motor (it consumes power). This is similar to what we observed in the power-flow lab 2 weeks ago.

5. Change power generated back to 150 MW.
6. Stop the simulation: press **Run Mode->Tools->Solve->[Red Button]**



7. Press **Edit Mode**.
8. Observe that there is 130 Mvar of Reactive Power generated, but only 100 Mvar is consumed by the load. It means that 30 Mvar is stored in the transmission lines.
9. Display Real and Reactive Power lost in the system:
Stop the simulation, go to **Edit Mode->Draw->Field->Zone Field**



Left Click below the load and to the right of the bottom generator. The following window will be displayed:

Zone Field Options

Zone Number: 0 (Entire Case) Find ...

Total Digits in Field: 4 Other Zone Number: 0

Digits to Right of Decimal: 2 Delta per Mouse Click: 0.000

Rotation Angle in Degrees: 0 Field Value: 0.00 MW

Field Prefix (e.g., field name): MW Losses

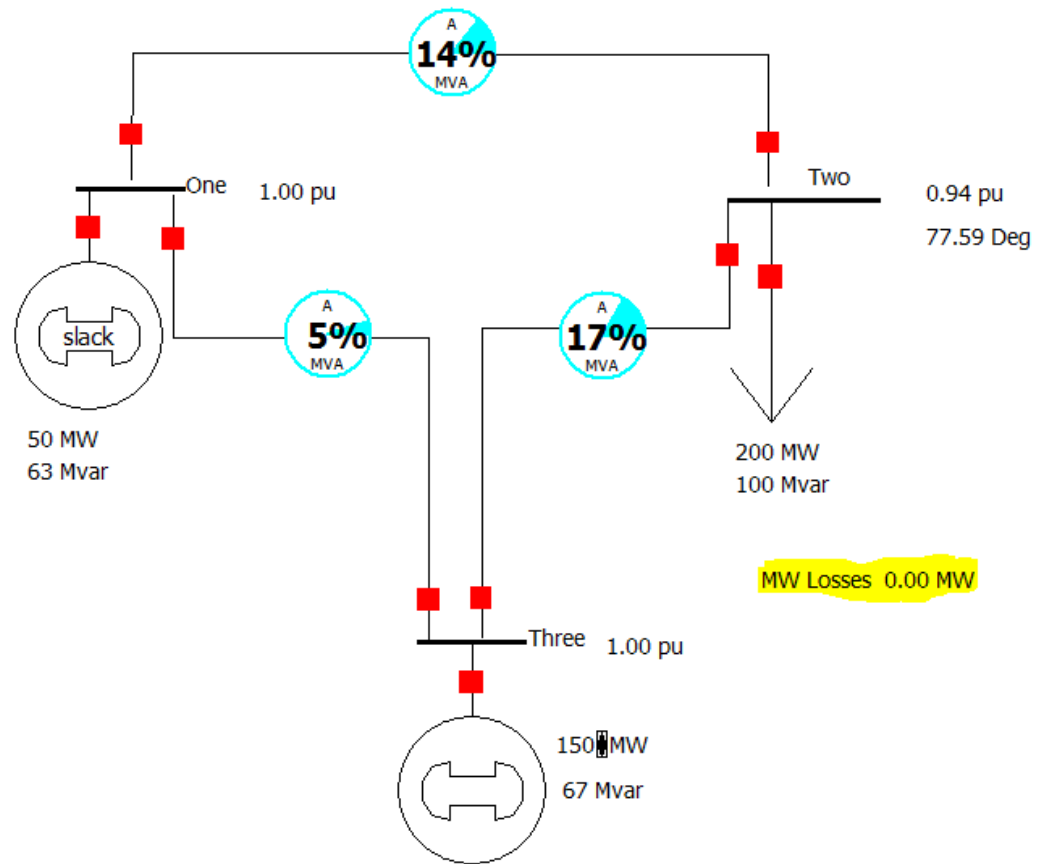
☒ Anchored ☒ Include Suffix

Type of Field

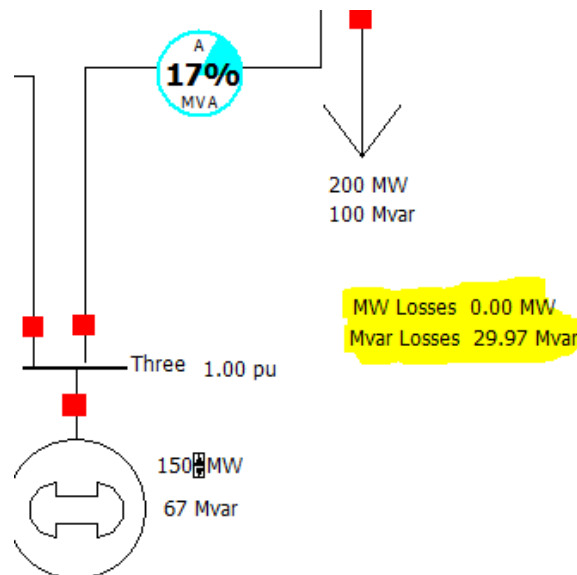
- ☐ Name
- ☐ Number
- ☐ MW Load
- ☐ Mvar Load
- ☐ MW Generation
- ☐ Mvar Generation
- ☐ MW Shunts
- ☐ Mvar Shunts
- ☐ MW Flow to Other Zone
- ☐ Mvar Flow to Other Zone
- ☒ MW Losses
- ☐ Mvar Losses
- ☐ Load Schedule Multiplier
- Select a Field: Find Field ...

OK Cancel Help

Select **0 (Entire Case)** for the **Zone Number** field. Type **MW Losses** follow by 2 spaces in the **Field Prefix (e.g., field name)** box and select **MW Losses** bullet under **Type of Field**. Press **OK**. The following should be displayed:



10. Follow similar steps to display **Mvar Losses** and position it under **MW Losses**:



11. Double-click the transmission line between Bus 1 and Bus 2. The following window appears:

Branch Options

Line: From Bus 1 To Bus 2 Circuit 1

Name: One Two

Area Name: 1 (1) 1 (1)

Nominal kV: 138.0 138.0

Labels ... no labels

☒ From End Metered

☒ Default Owner (Same as From Bus)

Display Parameters Fault Info Owner, Area, Zone, Sub Custom Stability

Status: ☐ Open ☒ Closed

Branch Device Type: Line

☐ Allow Consolidation

Length: 0.00

Calculate Impedances >

Convert Line to Transformer

Per Unit Impedance Parameters

Series Resistance (R)	0.00000
Series Reactance (X)	0.10000
Shunt Charging (B)	0.00000
Shunt Conductance (G)	0.00000

☐ Has Line Shunts

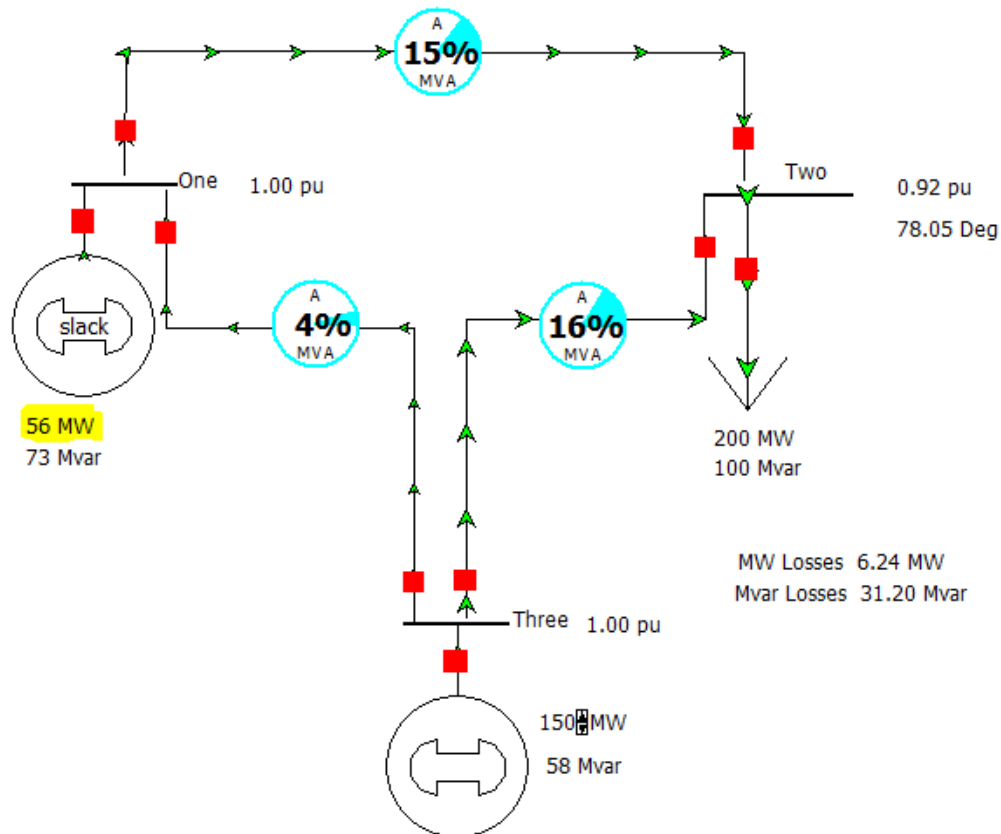
MVA Limits

Limit A	750.000
Limit B	750.000
Limit C	750.000
Limit D	0.000
Limit E	0.000
Limit F	0.000
Limit G	0.000
Limit H	0.000

OK Save Cancel Help

Notice that the transmission line is modeled as having a reactance, but no resistance. Reactance stores reactive power (Mvar), while resistance dissipates real power (MW). Since there is no resistance in the lines, there is no real power dissipated.

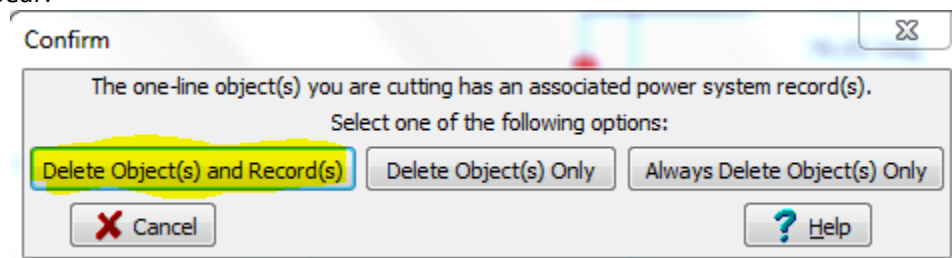
12. Realistically, transmission lines have both resistance (R) and reactance (X) associated with them. Input **0.02** in the **Series Resistance (R)** field. Press **OK**. Do this for the remaining two transmission lines.
13. Run the simulation again: **Run Mode->Tools->Solve->[Green Button]**. The system should look like this:



Generator 1 increased the Real Power production in order to compensate for Real Power lost in the transmission lines.

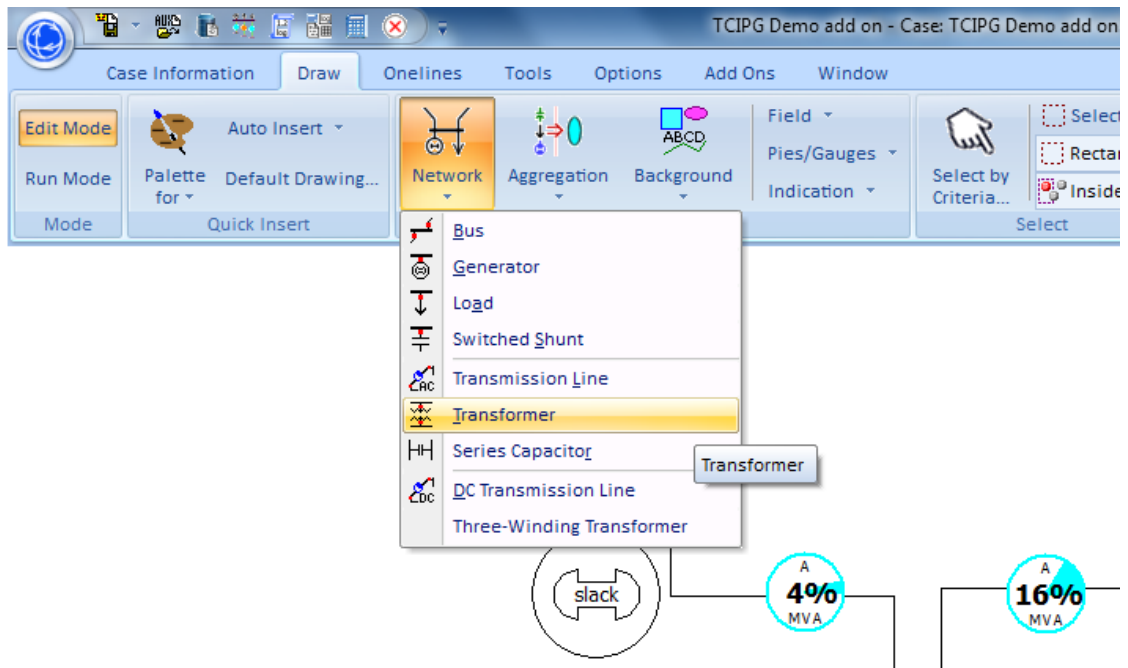
14. Add a transformer between the left generator and bus 2. To do so, first delete the transmission line connecting the two.

Go to **Edit Mode**, click anywhere on the transmission line. Press **Delete**. The following window will appear:

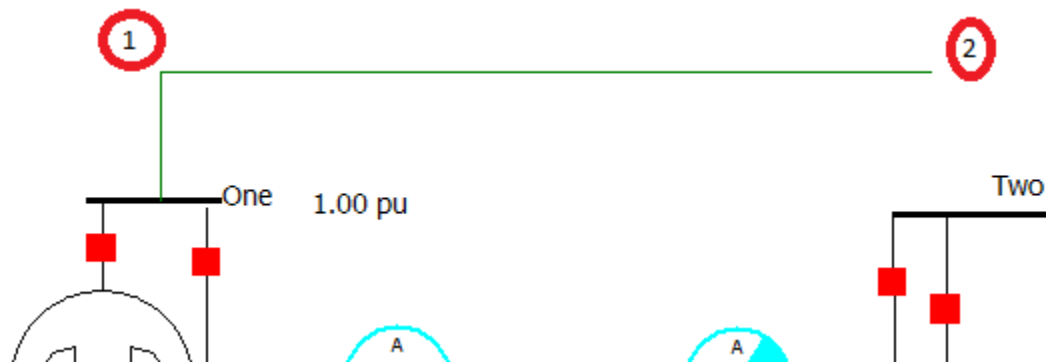


Choose the highlighted option.

15. To add a transformer go to **Edit Mode->Draw->Network->Transformer**, as illustrated below:



16. The cursor now turned into a crosshair. With it, click **once** on bus 1. Then move it up to point **1** and click once again. Then move it to point **2** and click once. Lastly, move the cursor to bus 2 and **Double Click**.



After double clicking on bus 2, the following window shows up:

Branch Options

From Bus: 1 To Bus: 2 Circuit: 1

Number: 1 Name: One Area Name: 1 (1) Nominal kV: 138.0

Find By Numbers Find By Names Find ...

☒ From End Metered ☒ Default Owner (Same as From Bus)

Labels ...

Display Parameters Transformer Control Series Capacitor Fault Info Owner, Area, Zone, Sub Custom

Status: ☐ Open ☒ Closed

Branch Device Type:

☒ Allow Consolidation Length: 0.00

Calculate Impedances >

Per Unit Impedance Parameters

Series Resistance (R): 0.00000

Series Reactance (X): 0.1

Shunt Charging (B): 0.00000

Shunt Conductance (G): 0.00000

Magnetizing Conductance: 0.000000

Magnetizing Susceptance: 0.000000

☐ Has Line Shunts Line Shunts

MVA Limits

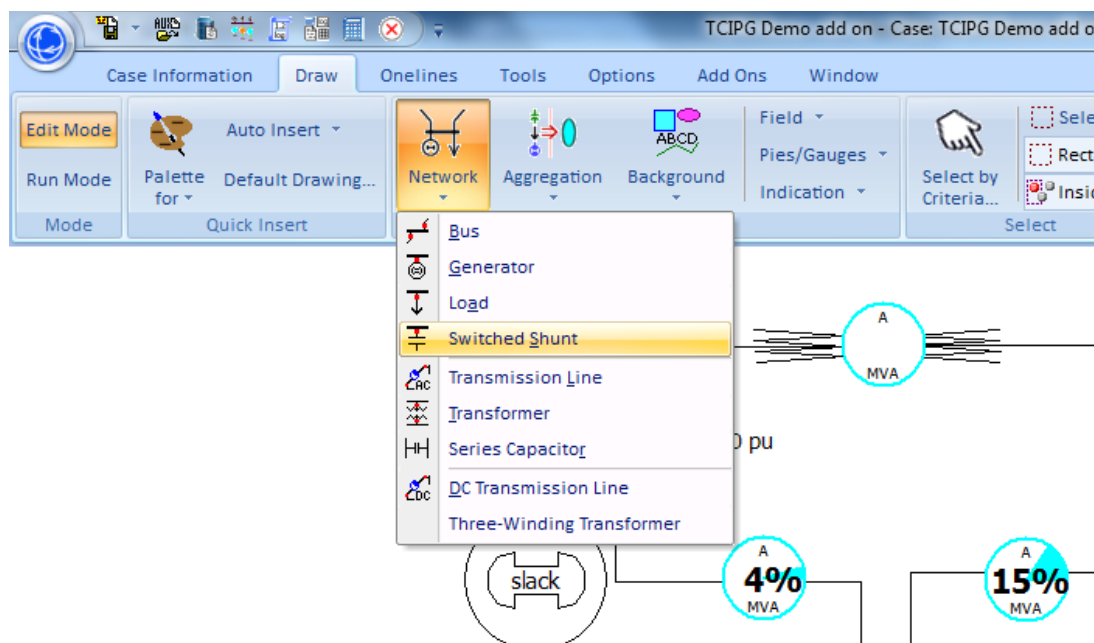
Limit A	0.000
Limit B	0.000
Limit C	0.000
Limit D	0.000
Limit E	0.000
Limit F	0.000
Limit G	0.000
Limit H	0.000

Convert Transformer to Line

OK Save Cancel Help

Input **0.1** in the **Series Reactance (X)** field. Also, make sure the transformer is connected from Bus 1 to Bus 2, as illustrated above. Click **OK**.

17. Now we will add a capacitor, which will decrease losses.
To do so, go to **Edit Mode->Draw->Network->Switched Shunt**.



Place the crosshair cursor on Bus 2 and click once. This will appear:

Switched Shunt Options

Bus Number: 2 Find By Number

Bus Name: Two Find By Name

Shunt ID: 1 Find ...

Labels ...

	Number	Name
Area	1	1
Zone	1	1
Substation		

Display Parameters Control Parameters Fault Parameters Custom

Nominal Mvar: **70**

Control Mode:

- ☒ Fixed
- ☐ Discrete
- ☐ Continuous
- ☐ Bus Shunt (Fixed)

Control Regulation Settings:

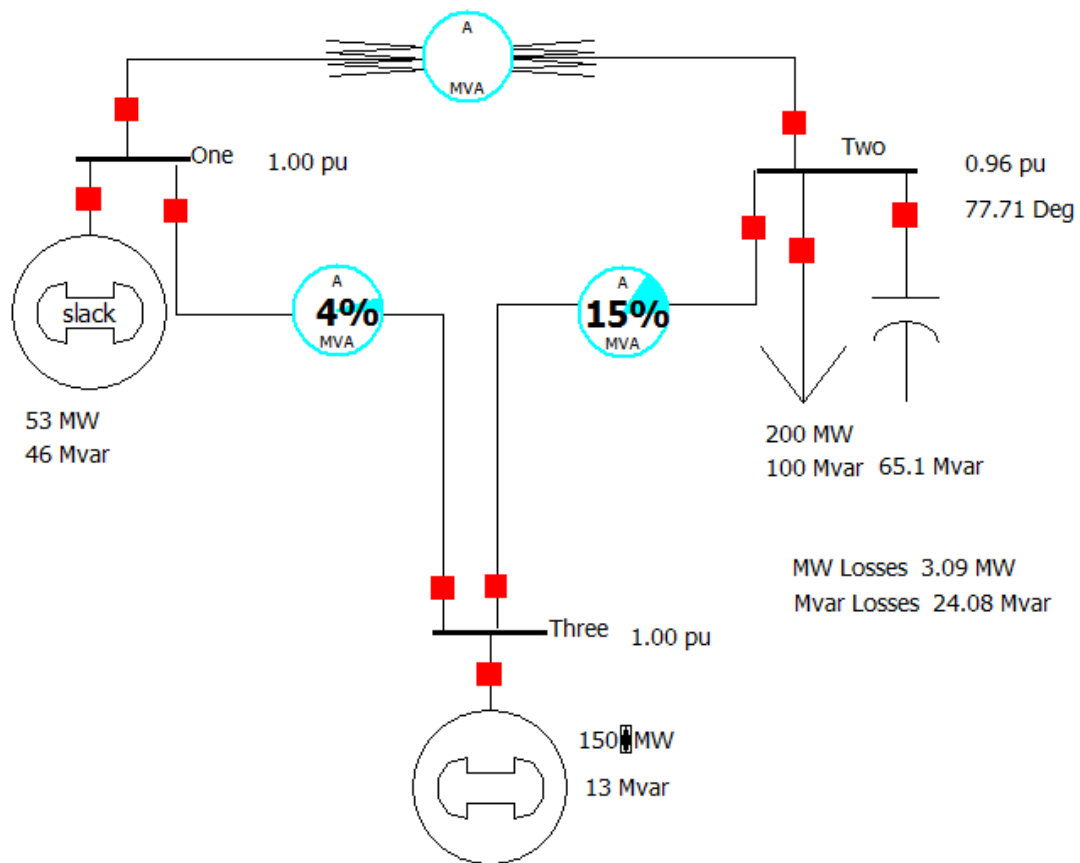
- ☒ Voltage: High Value 1.00000, Low Value 0.99000, Target Value 1.00000, Reg. Bus #
- ☐ Generator Mvar
- ☐ Wind Mvar

Switched Shunts Blocks:

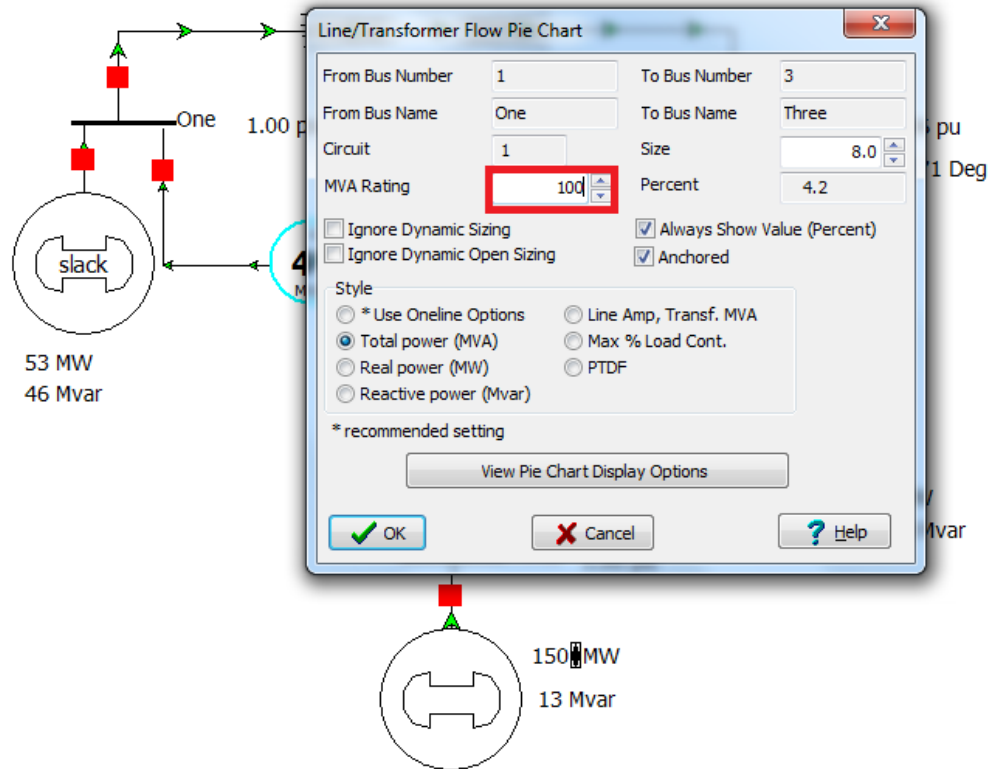
Number of Steps	Mvars per Step

OK Save Cancel Help

Input **70** in the **Nominal Mvar** field. Under **Display** tab choose **Down** under **Orientation** section and click **OK**. You can move the capacitor to the right, so that text does not overlap. The case will look like this:



18. Simulate the circuit again.
19. While running, click the red square above the capacitor to disconnect it from the rest of the circuit. Watch what happens to power losses.
20. Double click the pie-display on the transmission line connecting Bus 1 to Bus 3. Input **100** in the **MVA Rating** box as illustrated below.



21. Click **OK**.
22. Give the transformer a **70 MVA Rating**.
23. Give the transmission line connecting Bus 3 and Bus 2 **125 MVA Rating**.
24. While running the simulation, increase the Real Power output of the bottom generator to 260 MWA, while watching the pie chart between Bus 1 and Bus 3.
In reality, the Transmission Line will give up if its rating it's exceeded.
25. To disconnect the transmission line connecting Bus 1 and Bus 3, click the red square connecting it to either Bus 1 or Bus 3. That is how you obtain a blackout.
26. Connect the transmission lines back in the circuit.
27. Simulate the circuit and bring the bottom generator back to **150 MW**.
28. To add another bus go to **Edit Mode->Draw->Network->Bus**.
29. Click to the left of Bus One. The following window will appear:

Bus Options

Bus Number: 4

Bus Name: Four

Nominal Voltage: 0.1 kV

Labels ...: no labels

Area: Change 1 1

Zone: Change 1 1

Owner: Change 1 1

Substation: Change

Bus Information: Display Attached Devices Geography Custom

Bus Voltage: Voltage (p.u.) 1.0000

Angle (degrees): 0.000

☐ System Slack Bus

OK Save Cancel

30. Enter **Four** in the **Bus Name** field and **0.1** in the **Nominal Voltage** field. Click **OK**.
31. Under **Display** tab choose, select **Right** for **Orientation**.
32. Connect a transformer between **Bus One** and **Bus Four**.
33. Give it a **0.1** Series Reactance (X).
34. To add a load to **Bus Four** go to **Edit Mode->Draw->Network->Load** and click on **Bus Four**.
35. Input **130** and **20** for **MW Value** and **Mvar Value** respectively. Also, choose **Down** under **Orientation**.

Load Options

Bus Number: 4
 Bus Name: Four
 ID: 1
 Labels ...

Find By Number
 Find By Name
 Find ...

Status:
☐ Open
☒ Closed

Area: Change
 Zone: Change
 Substation:
 Owner: Change

Number: 1
 Name: 1

☒ Same Owner as Terminal Bus

Load Information: OPF Load Dispatch | Custom

Constant Power
 MW Value: 130
 Mvar Value: 20

Constant Current: 0.000
 Constant Impedance: 0.000

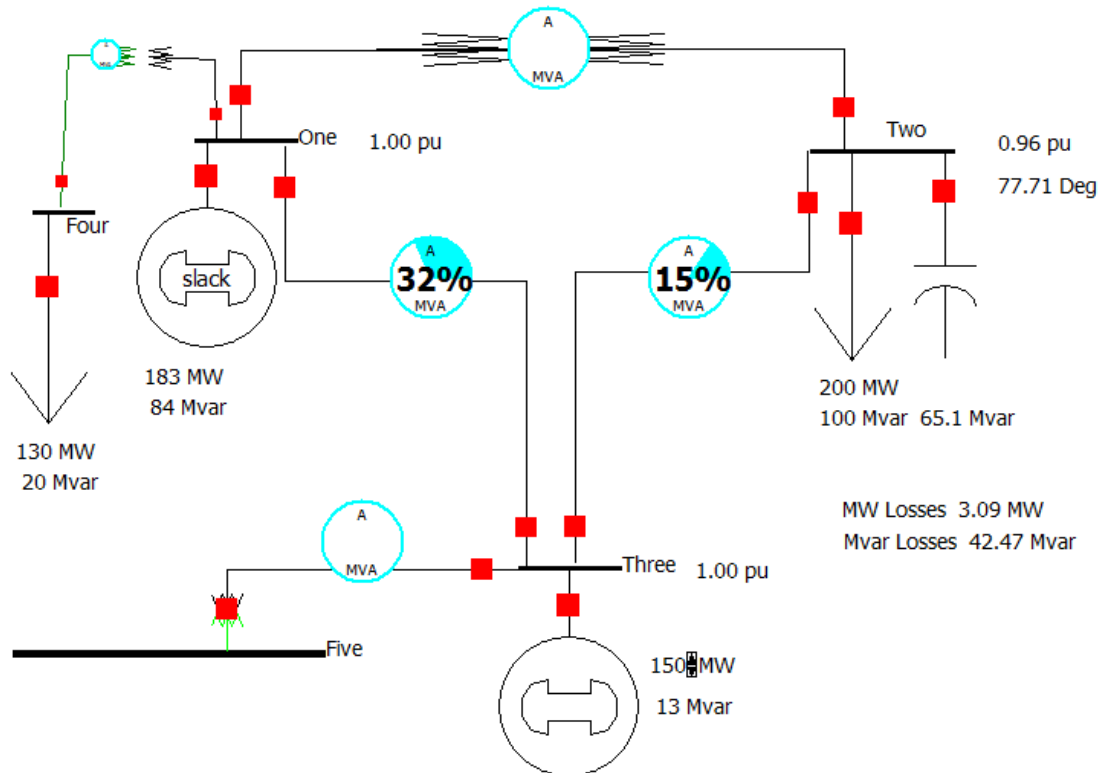
Display Information
 Display Size: 10.00
☒ Scale Width with Size
 Display Width: 3.75
 Pixel Thickness: 1

Orientation:
☐ Right
☐ Left
☐ Up
☒ Down

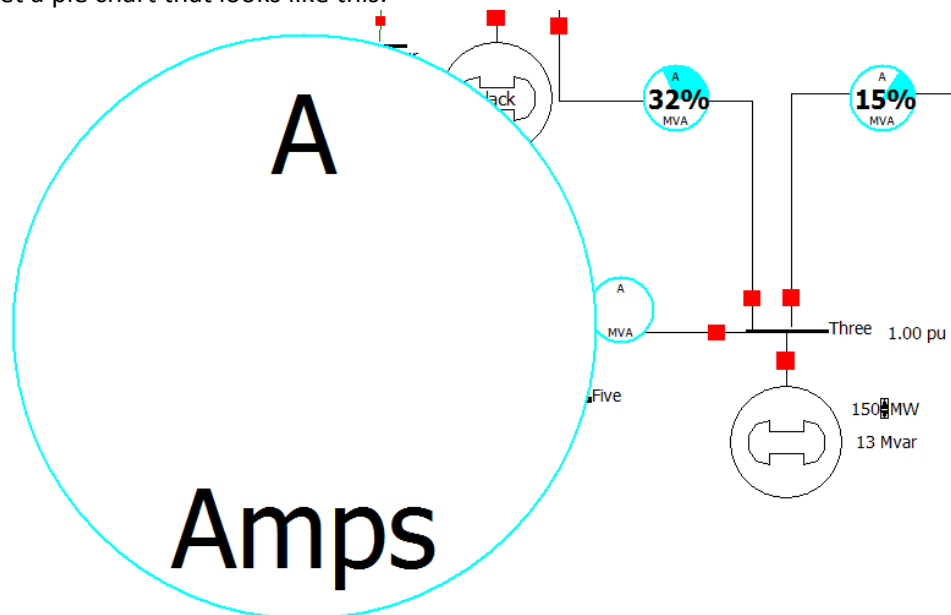
☒ Anchored
 Link To New Load

OK Save Cancel Help

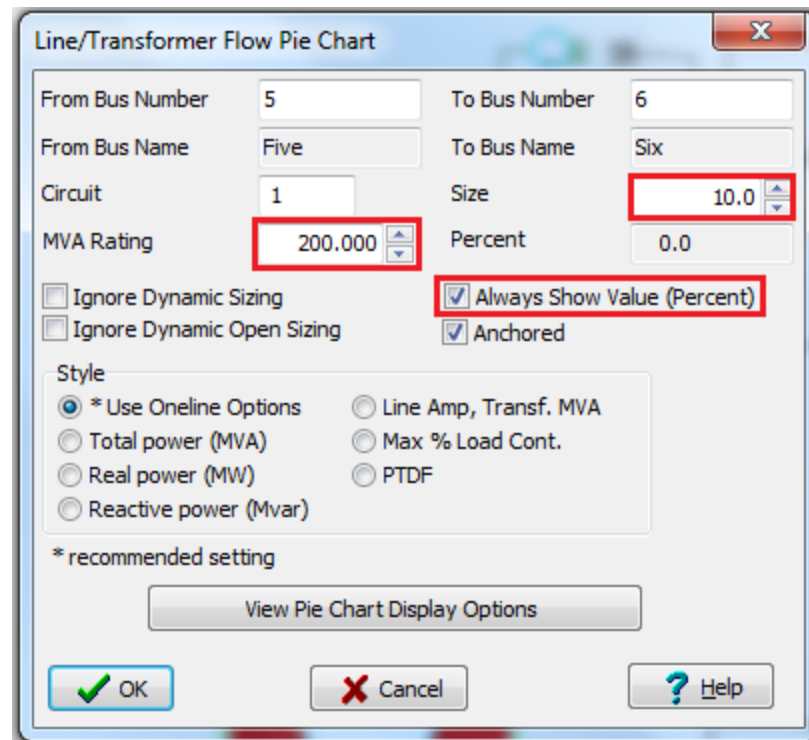
36. Click **OK**.
37. Insert a new **Bus Five** to the left of **Bus Three** , with a **750 kV Nominal Voltage**. By now, you should be able to do this without step-by-step instruction.
38. Connect a **Transformer** with **0.1 Series Reactance (X)** between **Bus Three** and **Bus Five**.
39. The system should look like this:



40. Next, add **Bus Six** to the left of **Bus Five**, with a **750 kV Nominal Voltage**.
41. Connect **Bus Five** to **Bus Six** using a transmission line with **0.02 Series Resistance (R)** and **0.1 Series Reactance (X)**.
42. You will get a pie chart that looks like this:



43. To decrease its size, double click on it and change **Size** to **10**, check **Always Show Value (Percent)** and give it a **200 MVA Rating**, like below.



The image shows a software dialog box titled "Line/Transformer Flow Pie Chart". It contains several input fields and checkboxes. The "From Bus Number" is 5, "To Bus Number" is 6, "From Bus Name" is Five, and "To Bus Name" is Six. The "Circuit" is 1, "Size" is 10.0, "MVA Rating" is 200.000, and "Percent" is 0.0. There are checkboxes for "Ignore Dynamic Sizing", "Ignore Dynamic Open Sizing", "Always Show Value (Percent)", and "Anchored". The "Style" section has radio buttons for "* Use Online Options", "Line Amp, Transf. MVA", "Total power (MVA)", "Max % Load Cont.", "Real power (MW)", "PTDF", and "Reactive power (Mvar)". A button "View Pie Chart Display Options" is at the bottom. The "OK", "Cancel", and "Help" buttons are at the very bottom.

From Bus Number	5	To Bus Number	6
From Bus Name	Five	To Bus Name	Six
Circuit	1	Size	10.0
MVA Rating	200.000	Percent	0.0
<input type="checkbox"/> Ignore Dynamic Sizing		<input checked="" type="checkbox"/> Always Show Value (Percent)	
<input type="checkbox"/> Ignore Dynamic Open Sizing		<input checked="" type="checkbox"/> Anchored	

Style

☒ * Use Online Options ☐ Line Amp, Transf. MVA

☐ Total power (MVA) ☐ Max % Load Cont.

☐ Real power (MW) ☐ PTDF

☐ Reactive power (Mvar)

* recommended setting

View Pie Chart Display Options

OK Cancel Help

44. Click **OK**.

45. Add **Bus Seven** up and to the left of **Bus Six** with the following options:

Bus Options

This will insert a new bus in the power system data model

Bus Number

Bus Name

Nominal Voltage kV

	Number	Name
Area	<input type="text" value="1"/>	<input type="text" value="1"/>
Zone	<input type="text" value="1"/>	<input type="text" value="1"/>
Owner	<input type="text" value="1"/>	<input type="text" value="1"/>
Substation	<input type="text"/>	<input type="text"/>

Bus Information **Display** **Attached Devices** **Geography** **Custom**

Orientation

☒ Right

☐ Up

☐ Left

☐ Down

Shape

☒ Rectangle

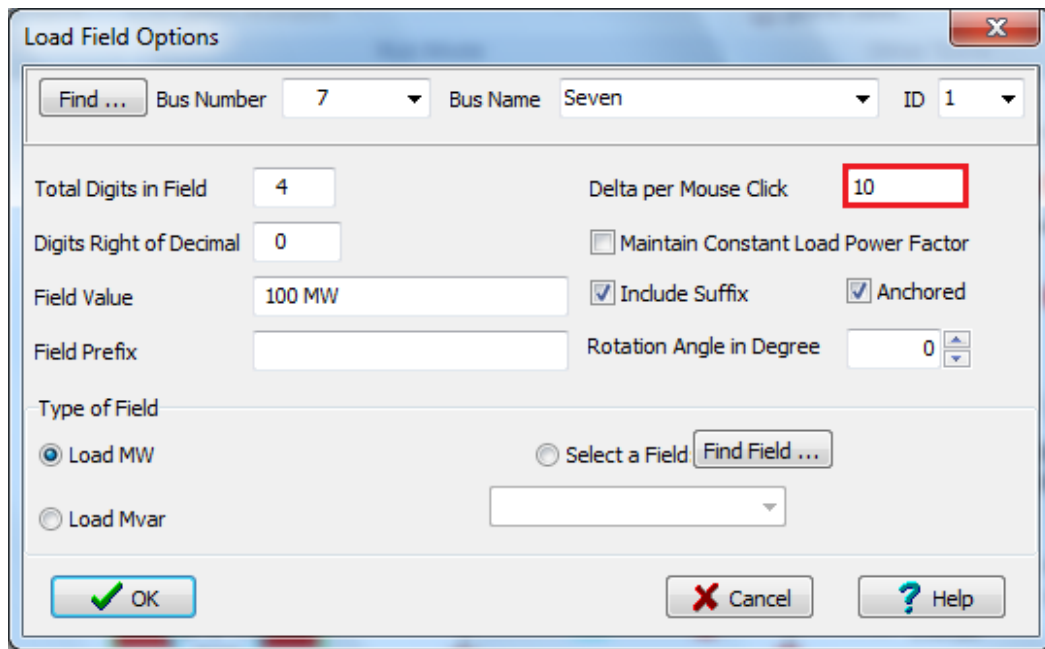
☐ Ellipse

Size

Width

☐ Scale Width with Size

46. Add a **0.1 Series Reactance (X)** between **Bus Six** and **Bus Seven**.
47. Add a **100 MW Constant Power** load to **Bus Seven**.
48. Double Click the **100 MW** displayed under the load, and make the following change:



The image shows a 'Load Field Options' dialog box. At the top, there is a search bar with 'Find ...' and three dropdown menus: 'Bus Number' (7), 'Bus Name' (Seven), and 'ID' (1). Below this, there are several input fields and checkboxes. 'Total Digits in Field' is 4, 'Digits Right of Decimal' is 0, 'Field Value' is '100 MW', and 'Field Prefix' is empty. 'Delta per Mouse Click' is 10, which is highlighted with a red rectangle. There are checkboxes for 'Maintain Constant Load Power Factor' (unchecked), 'Include Suffix' (checked), and 'Anchored' (checked). 'Rotation Angle in Degree' is 0. Under 'Type of Field', 'Load MW' is selected with a radio button, and 'Load Mvar' is unselected. There is a 'Select a Field' radio button and a 'Find Field ...' button. At the bottom, there are 'OK', 'Cancel', and 'Help' buttons.

Field	Value
Find ...	Find ...
Bus Number	7
Bus Name	Seven
ID	1
Total Digits in Field	4
Delta per Mouse Click	10
Digits Right of Decimal	0
Field Value	100 MW
Field Prefix	
Rotation Angle in Degree	0
Type of Field	Load MW
Include Suffix	Checked
Anchored	Checked
Maintain Constant Load Power Factor	Unchecked

49. Run the simulation and increase the power generated by the generator connected to **Bus 3**.
50. Observe that this does not change power flow to the load connected to **Bus 7**.
51. Now increase power absorbed by **Bus 7 Load**.