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The PowerWorld program includes a production quality and highly interactive power-flow program which will be used in Assignment #1.

The information in this guide complements the PowerWorld Tutorial from the Collaborative Power Engineering Centres of Excellence, by Prof. Syed Islam. Please, note that there may be other ways of obtaining the same information, and only some of the most needed actions are presented here. Students are encouraged to explore the different tabs, options and settings to find the most effective approach for themselves.

PowerWorld **help** can be called by clicking the small question mark "**?**" on the top right of the screen. Also, initiating Google searches will show a diverse source of available information on specific topics.

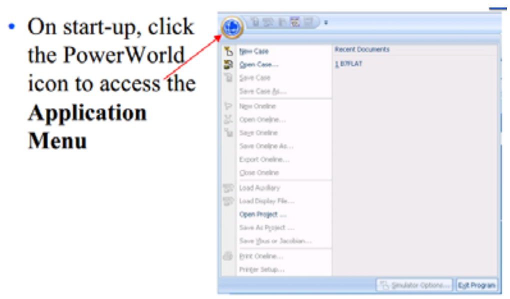
<u>Typical Power-Flow Study Sequence</u>

1. Start PowerWorld.
2. Load an *existing case* into memory.
3. Solve the case.
4. View / export and assess the results.
5. Modify the case to represent a different operating condition or add new equipment.
6. Save the modified case.
   (It is safest to save a modified case before attempting to solve it.)
7. Repeat from (3) above.
8. Edit the annotations on the network one line diagram.

1. Starting PowerWorld

From the **Start** menu select:
PowerWorld > Simulator Educational-Evaluation 19

If the program does not appear in the **Start** Menu, in a file Explorer navigate to:
c:\program files (x86)\PowerWorld\Simulator Education-Evaluation 19
and double click on *pwrworld.exe*



<u>Figure 1</u>: Application Menu. PowerWorld Corporation

<u>Figure 2</u>: Ribbon Interface. PowerWorld Corporation

2. Loading an existing case

 Date: 12 August 2017

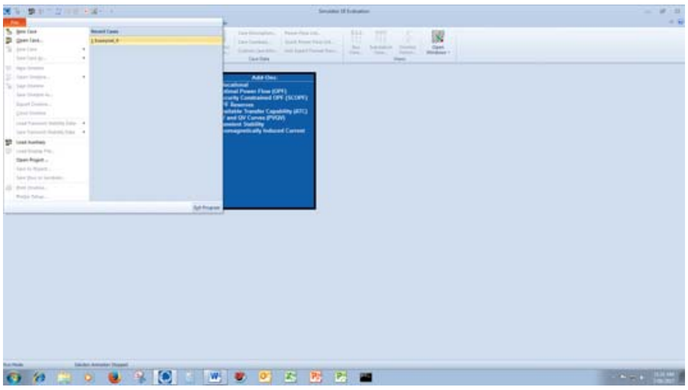


Figure 3: Load an existing case. From the main menu ribbon select **File** > **Open Case** …, and then select the file to be opened.

3. *Solving the case*

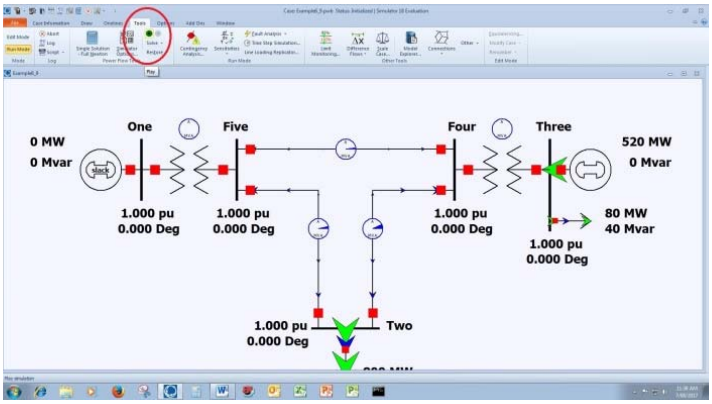


Figure 4: Run/solve power-flow.
Ensure **Run Mode** (main menu) is selected and then select the **Tools** tab, and click on **Solve** (green arrow), as highlighted by the red circle (left).

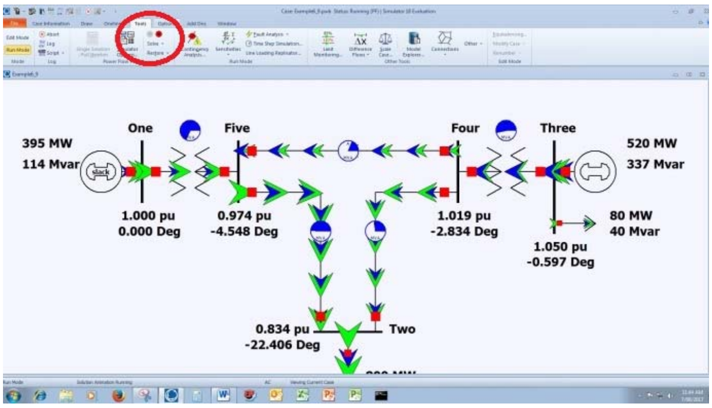


Figure 5: Stopping the simulation.
Once the case is solved, the simulation can be stopped by pressing the red button next to the now greyed **Solve** button, as highlighted by the red circle (left).

Note: Even though not required, it is highly recommended that you save your edited case before attempting to solve it. Otherwise, if the solution is poor you may not be able to backtrack to the system state that existed before attempting the solution.

4. *Viewing and Extracting Data*

After solving and stopping the simulation, select the **Case Information** tab to access a comprehensive set of power-flow data and solution results.
A summary of the overall system results is accessed by the **Case Summary …** item on the main menu ribbon. The summary includes totals of system generation, load and losses. The loss information is very useful when attempting to optimize voltage control.

Data and results of individual buses and equipment (e.g. transmission lines, loads, etc.) is accessible as shown below.

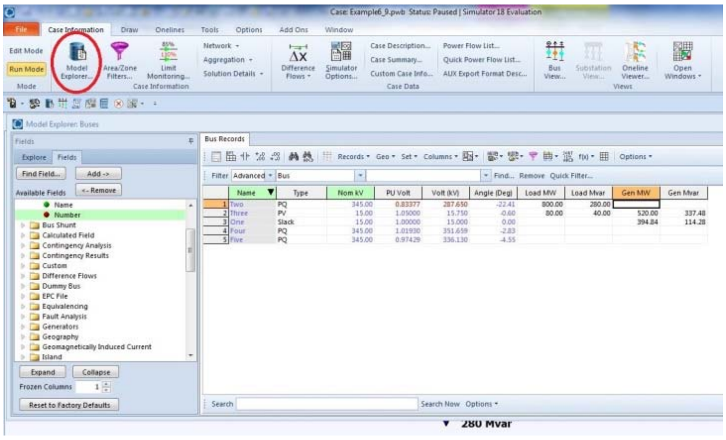


Figure 6: After selecting the **Case Information** tab, select the **Model Explorer** icon. This displays the **Model Explorer** window.

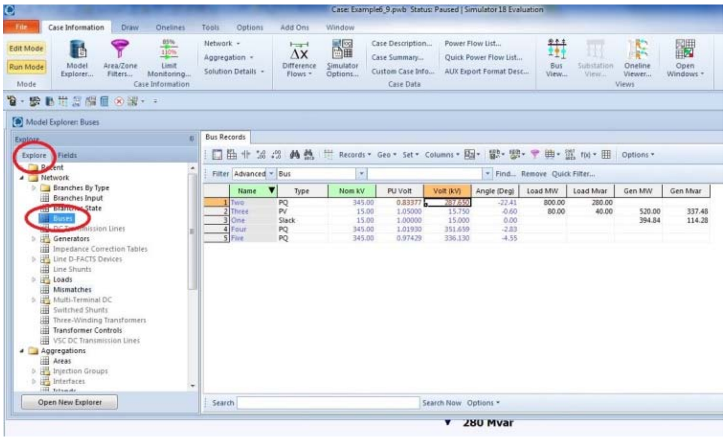


Figure 7: Select the data set to display.
From the tree view, in the left pane, select the data that you wish to view. They will then be displayed in the right pane.

Useful data sets are:
Network> Branches Input (Transformer / transmission line data)
Network>Branches State (Transformer / transmission line power flows)
Network>Buses (Bus voltages)
Network>Loads (Value of loads)
Network >Generators (Generator outputs and voltage set-points), etc.

Under the Solution Details folder you can access the network admittance matrix (Ybus) and the power-flow Jacobian matrix.

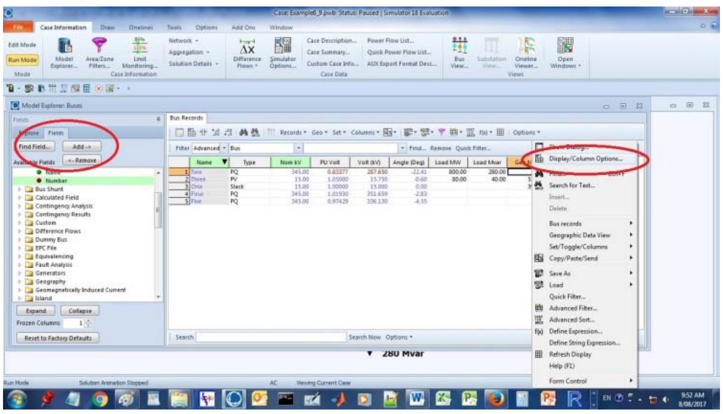


Figure 8: Changing data displayed in tables.
With the mouse pointer within the data table, right-click. From the pop up menu select **Display / Column Options…** From here you can add new columns of data, remove existing ones, or change their

order. This can also be done from the **Fields** tab.

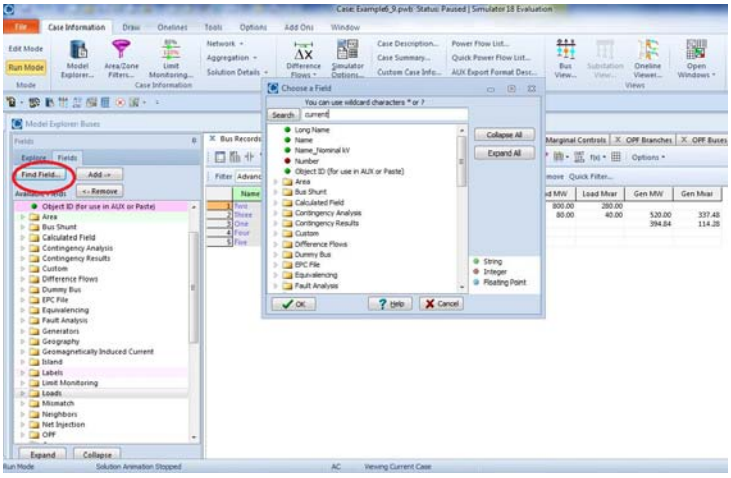


Figure 9: Finding fields. Specific fields to be added to a data table can be found by selecting **Fields** > **Find Field…** in the left pane.

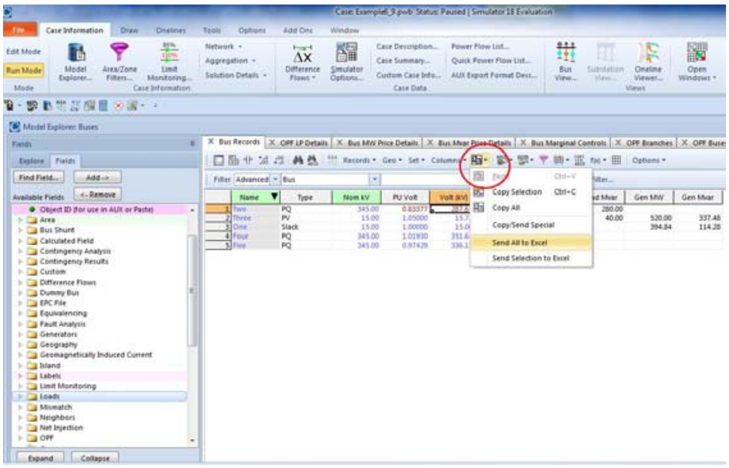


Figure 10: Exporting case information. The selected data set can be transferred to Excel for further processing by clicking the **Copy, Paste and Send to Spreadsheet options** button (red circle). Then choose **Send All to Excel** from the drop down menu.

5. Network Configuration Change

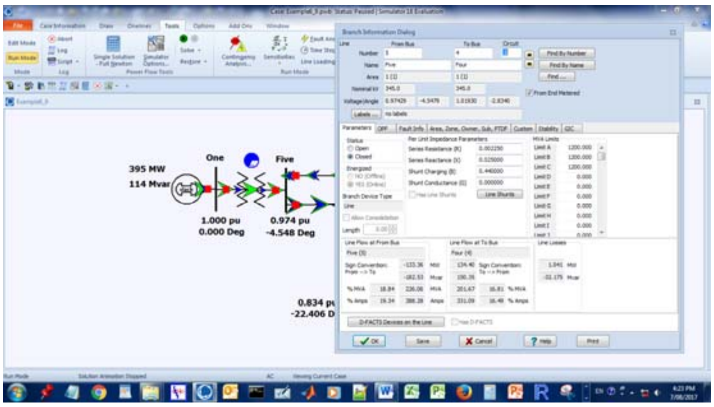


Figure 11: Editing parameters. Changes to parts of the system can be made by double clicking the item of interest on the network diagram. This displays a dialog box containing the item parameters which can be edited, as shown in the example at left.

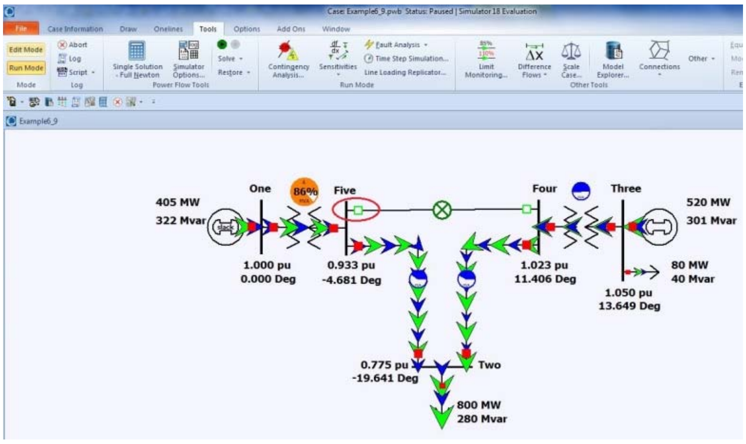


Figure 12: Configuration change.

A line can be switched by activating one of its circuit breakers. (The case can be running when you switch a circuit breaker). A line is energized when the circuit breaker icons at the ends of the line are coloured red (i.e. CB's closed) and is de-energized when the circuit breaker icons are coloured green (i.e. CB's open). A generator or other device can be similarly switched. This configuration change will produce a new solution One possibility is a blackout, in this case reload the system with a working configuration without saving the existing case.

NOTE: For details on creating new cases, inserting network items, building a new case from an existing case, refer to: "Introduction to Commercial Power Flow Software – PowerWorld", by Prof. Syed Islam, Collaborative Power Engineering Centres of Excellence, The Australian Power Institute (API), Department of Electrical and Computer Engineering, CURTIN 2009.

Annotation of the network diagram

The network diagram can be annotated with network solution data so that pertinent power-flow results can be seen immediately.

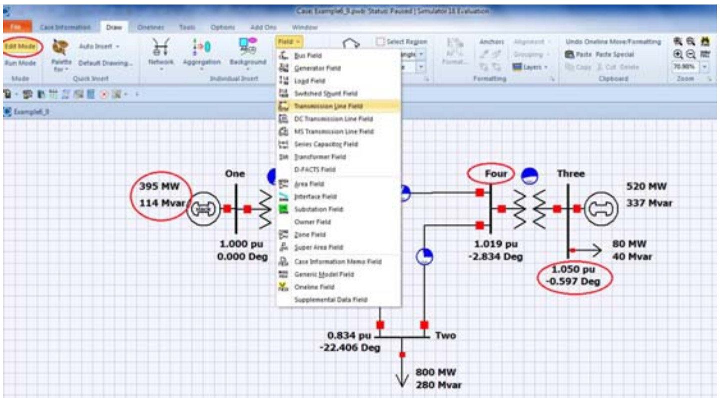


Figure 13: Annotation with solution data.
With the case in **Edit Mode**, select the **Draw** tab. Then select Field> to choose the data field that you want to add to the diagram. The pointer becomes a cross, which is then clicked on the item whose annotation you want to add or modify.

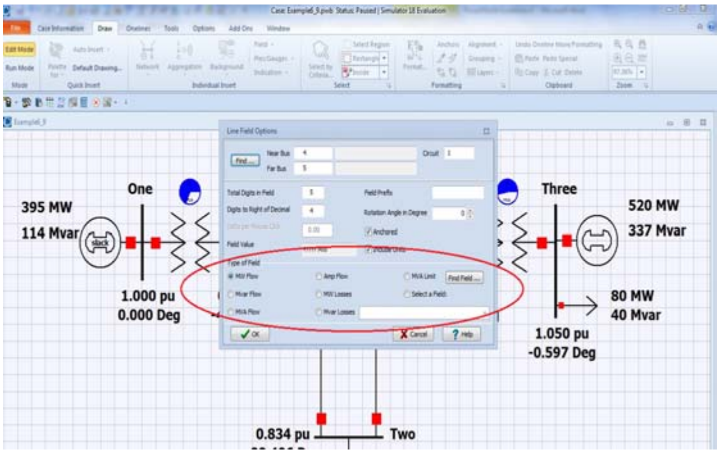


Figure 14: Selection of annotation. Circled in red at left are the standard set of annotations (for a line) that can be specified for the device. A **Field Prefix** can also be added to show its nature, e.g. "P = ", "**Q** = ", etc. The number of digits can also be chosen to ensure that a meaningful value will be displayed.

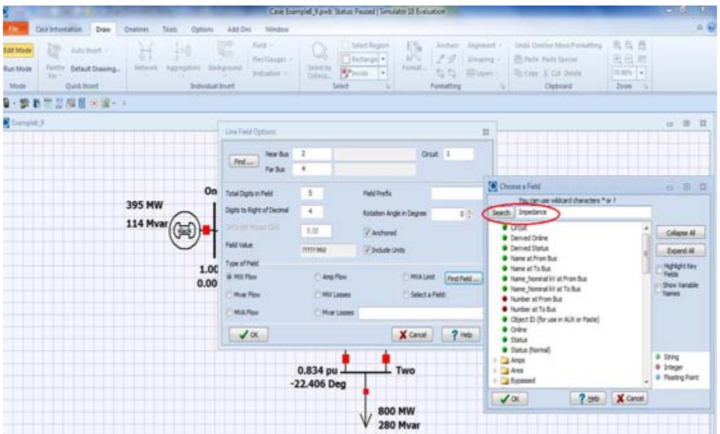


Figure 15: Customized Annotation.
In addition to the standard annotations available for each type of device a number of other parameters can also be displayed. Select the Find Field … button to display a list of additional parameters that can be selected to annotate the network diagram.

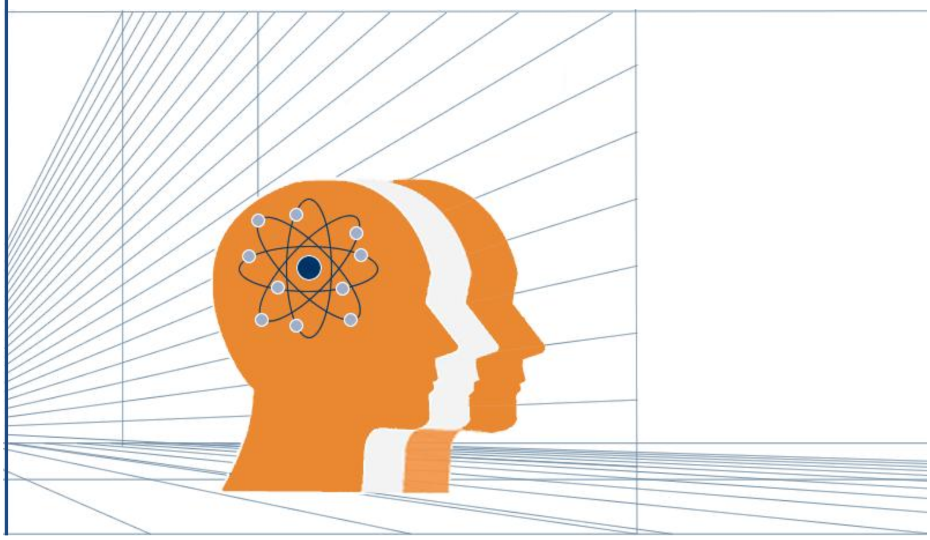
COLLABORATIVE POWER ENGINEERING
CENTRES OF EXCELLENCE

INTRODUCTION TO COMMERCIAL POWER FLOW SOFTWARES – POWERWORLD

REAL AND REACTIVE POWER AND LOAD FLOW ANALYSIS

PROF. SYED ISLAM
Department of Electrical & Computer Engineering
Curtin University of Technology
Perth, WA

Tutorial



About the Activity

PowerWorld Simulator is a power system simulation package designed from the ground up to be user-friendly and highly interactive. This commercial-grade power system analysis and simulation package accompanies the text book to provide computer solution to some examples is the text. Simulator has the power for serious engineering analysis, but it is also so interactive and graphical that it can be used to explain power system operations to non-technical audiences. At its core, PowerWorld is a comprehensive, robust Power Flow Solution engine capable of efficiently solving systems of up to 100,000 buses. This makes Simulator quite useful as a stand-alone power flow analysis package. Unlike other commercially available power flow packages, however, Simulator allows the user to visualize the system through the use of full-color animated single-line diagrams complete with zooming and panning capability [1-2].

This tutorial is targeted to aid you to learn the basic features of PowerWorld. However, it is not intended to cover all the capabilities of PowerWorld, and it only helps you in your first steps of using the simulator [3].

What You Will Learn

For this tutorial you will learn various steps necessary to interface with a software to perform power flow calculations.

What You Will Need

You are provided with the following resource for this tutorial:

- Powerworld software [1-3]

Relevant Resources

Course Notes and References

- Real and Reactive Power and Load Flow Analysis

Presentation Packs

- Introduction to Real and Reactive Power (2 hrs)
- Power Flow Fundamentals (2 hrs)
- Power Flow – Additional Techniques (2 hrs)
- Power Flow Applications - Transmission System Planning (2 hrs)

Activities

- Tutorial: Per Unit Conversion and Reactance Diagram (1 hr)

- Tutorial: Newton Raphson Power Flow (1 hr)
- Tutorial: Introduction to Commercial Power Flow Softwares – ETAP
- Tutorial: Introduction to Commercial Power Flow Softwares – PowerWorld (1 hr)
- Tutorial: Load Flow Modeling (1 hr)
- Practical: Effect of Power Angle on Power Flow in an AC circuit (2 hr)
- Assignment: Solving Power-Flow for a Real Power System Using ETAP

YOUR TASK

Follow the steps outlined below:

1. CREATING A NEW CASE

Assume that we plan to simulate a system with single-line diagram shown below. The system has the following parameters:

Generator: Rated voltage 66 kV, maximum active power generation: 350 MW, reactive power limits ±90 MVAr

Transmission line: R = 0.01 p.u., X = 0.06 p.u, B = 0.10 p.u.

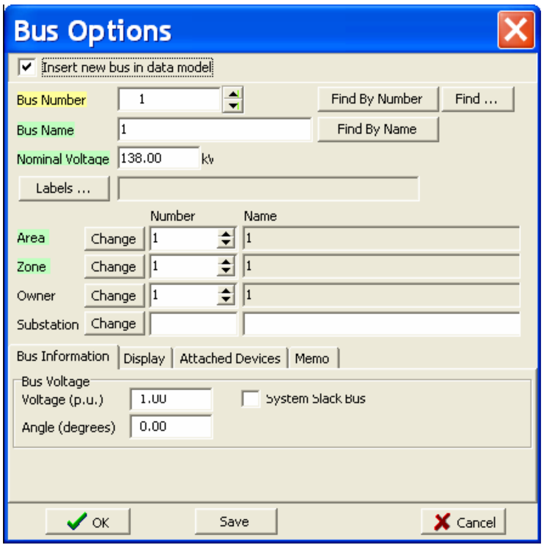
Transformer: 66/11 kV, X = 0.05 p.u.

Load: 100 MW, 45 MVAr

From the **File** menu select **New Case**. At any point of the development of this case, you can save your work by selecting **Save Case** (or **Save Case as …**) from the **File** menu.

(a) Inserting a bus

From the Insert menu select Bus or click on the  button in the "Insert" toolbar. (If you cannot see this toolbar, you can add it from Window → Toolbars and the selecting "Insert." Click anywhere in the drawing and the following dialog box should appear:



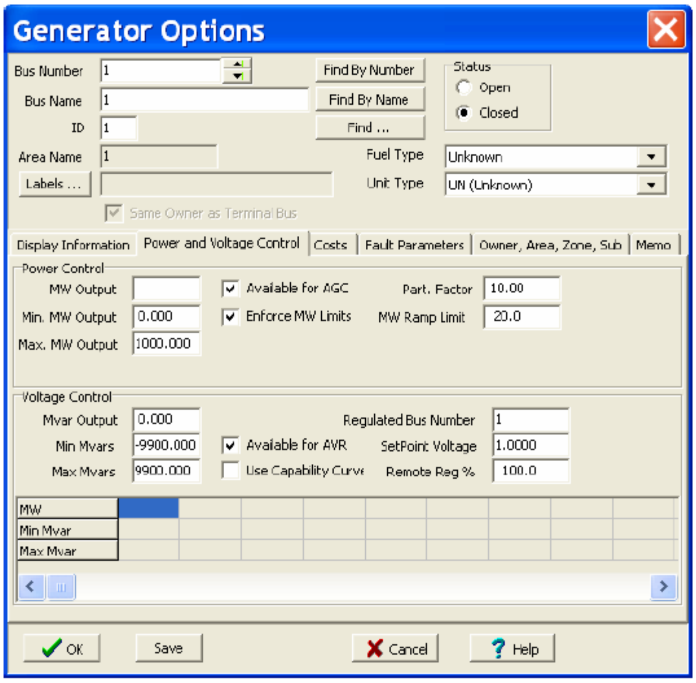
You can choose the bus number and the bus name. For now, leave them unchanged. Use 66 kV for the nominal voltage of the bus. Check the system slack bus box because we want this bus to be our slack bus. On the display tab, select up (or down) for the orientation so that the bus is vertical. Then click the OK button.

Insert two more buses in the same way as shown in Fig. 1. Make sure that the System Slack Bus option is not checked. Bus 2 has a nominal voltage of 66 kV, while bus 3 has a nominal voltage of 11 kV.

Note that right-clicking on any component and selecting the first option (Component Information Dialog, where “Component” is the name of the component, e.g., bus or line) allows you to change the settings and parameters of each component.

(b) Inserting a generator

From the Insert menu select Generator or click on the  button in the “Insert” toolbar. Then, click on bus 1 that we have just inserted (so that the generator is associated to the bus). The following dialog box should appear:



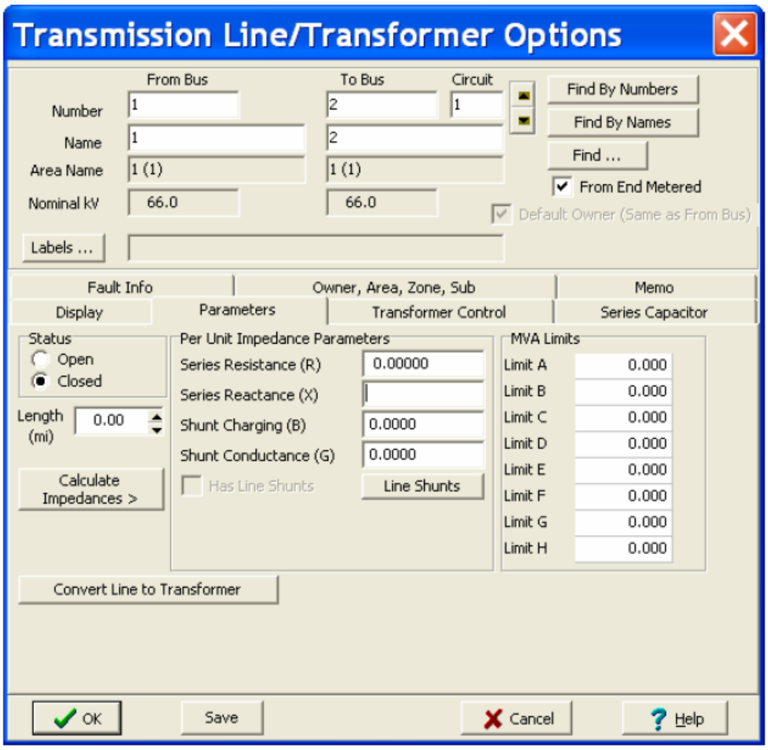
Since it is a slack bus, the actual MW output will be determined by the Simulator through solving the load flow. However, we must insert a value, e.g. 350 MW which is the maximum MW output of the generator (so this value needs to be inserted in the Max. MW Output field as well). Since the generator has MVAr limits, insert -90 and 90 in the Min MVArs and Max MVArs fields respectively.

In the Display Information tab select left orientation. Then click OK.

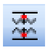
(c) Inserting a transmission line

From the Insert menu select Transmission Line or click on the  button in the "Insert" toolbar. Click on bus 1 and then double-click on bus 2. The following dialog should appear:

Insert the parameters *R*, *X*, and *B* in p.u. Insert 1000 as the MVA limit of the transmission line in Limit A. Click OK. A transmission line with two circuit breakers on each side and a line flow pie chart in the middle should appear in the single-line diagram.

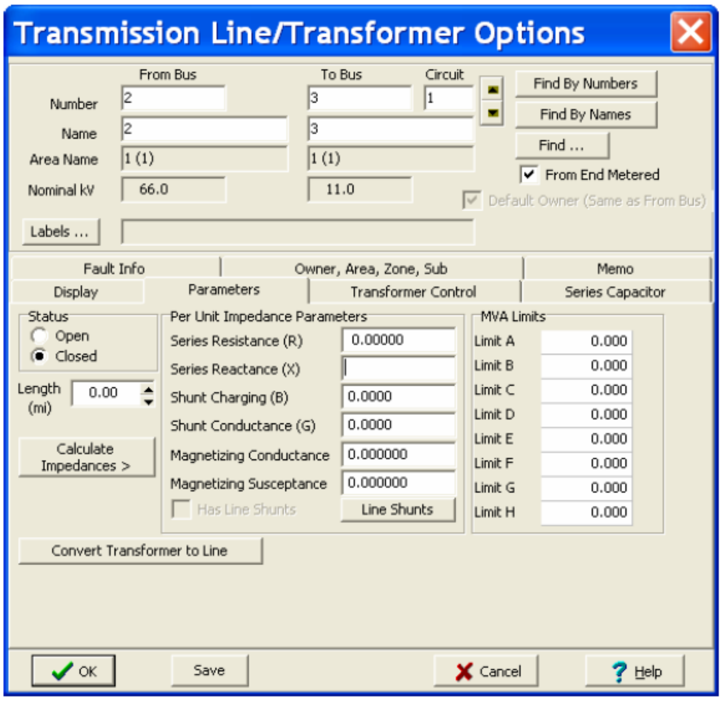


(d) Inserting a transformer

From the Insert menu select Transformer or click on the  button in the "Insert" toolbar. Click on bus 2 and then double-click on bus 3. The following dialog should appear:

Insert the series reactance of the transformer in p.u. Insert 1000 as the MVA limit of the transmission line in Limit A. Click OK.

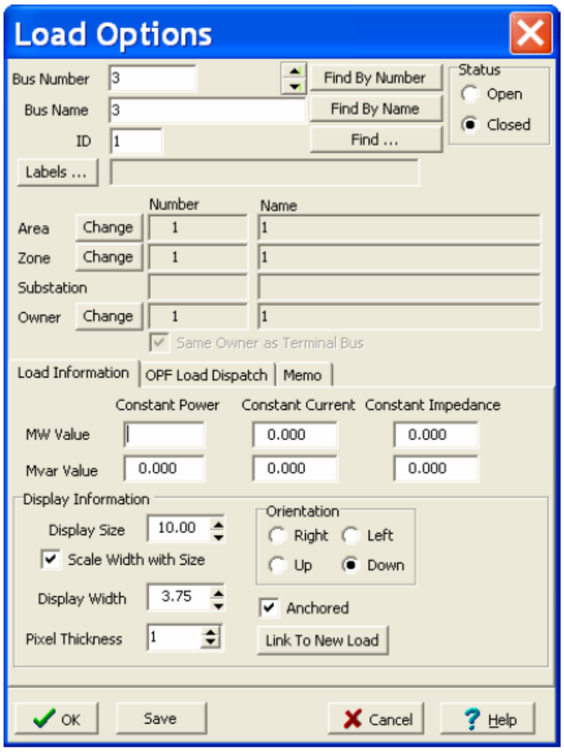
There is also an option for simulating the tap changes in the transformer. You can insert an off-nominal ratio in the Transformer Control tab (don't select the Automatic Control Enabled option). You can also indicate the phase shift between primary and secondary.



(e) Inserting a load

From the Insert menu select Load or click on the button in the "Insert" toolbar. Click on bus 3. The following dialog should appear:

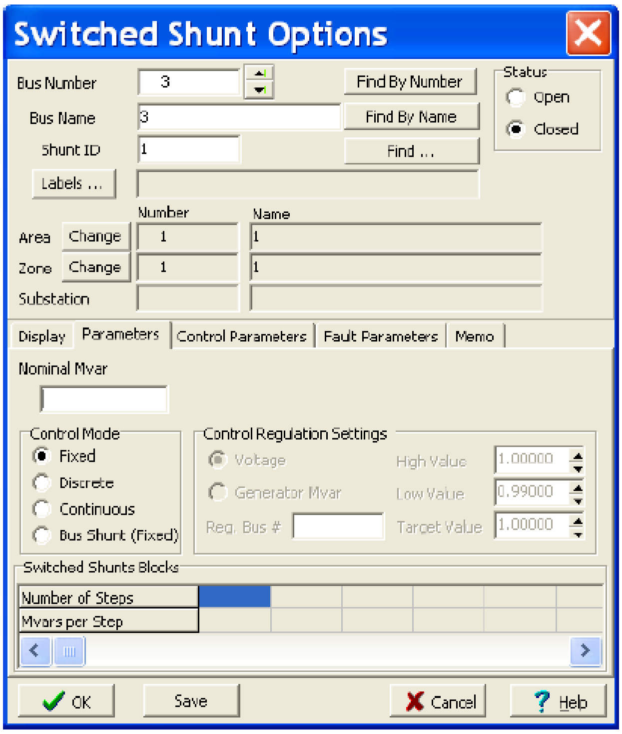
In the Constant Power column insert 100 in the MW Value field and 45 in the MVAr Value field. Select right orientation and click OK.



(f) Inserting a shunt component

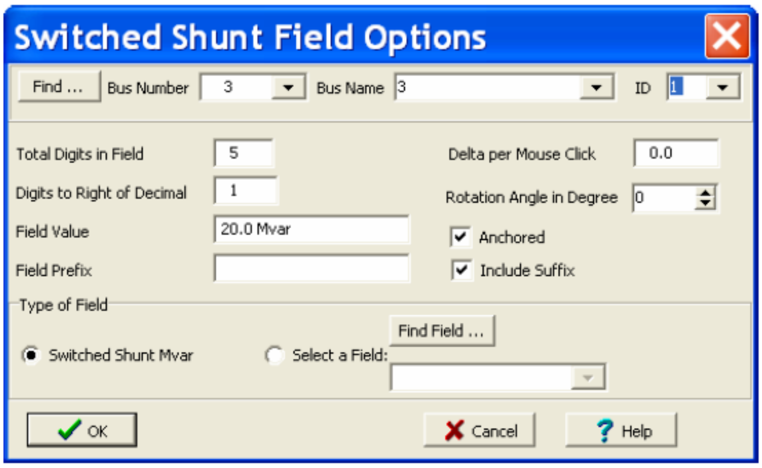
Often, it is necessary to add shunt components such as capacitors and reactors to selected power systems to maintain the voltage level within prescribed boundaries. Let us insert a shunt capacitor to maintain the voltage at bus 3 at 1 p.u.

From the Insert menu select Switched Shunt or click on the button in the "Insert" toolbar. Click on bus 3. The following dialog should appear:



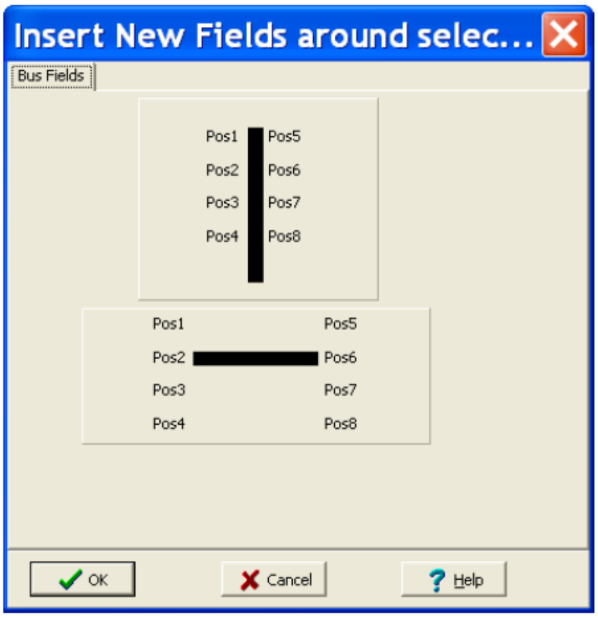
Insert 20 in the Nominal MVAr field (this is the initial value of the reactive compensation). Select down in the orientation field. We don't know how much shunt compensation we will need, and therefore we would like to have a variable MVAr compensation. Click the Discrete button in the Control Mode so that the dialog box allows you to insert a number of steps and MVArs per step. Insert 120 and 0.5 in each field respectively. Then click Fixed since we do not want the MVAr value to change on its own. Click OK. Right-click on the 20 MVAr value in the single-line drawing and the following dialog should appear:

Insert 0.5 in the Delta per Mouse Click option. This is the number of MVArs that the reactive power of the shunt component will increase or decrease at every click on the up or down button which will appear when we click OK in this dialog box. Please note that the 0.5 MVAr value is at rated (i.e. 1 p.u.) voltage.

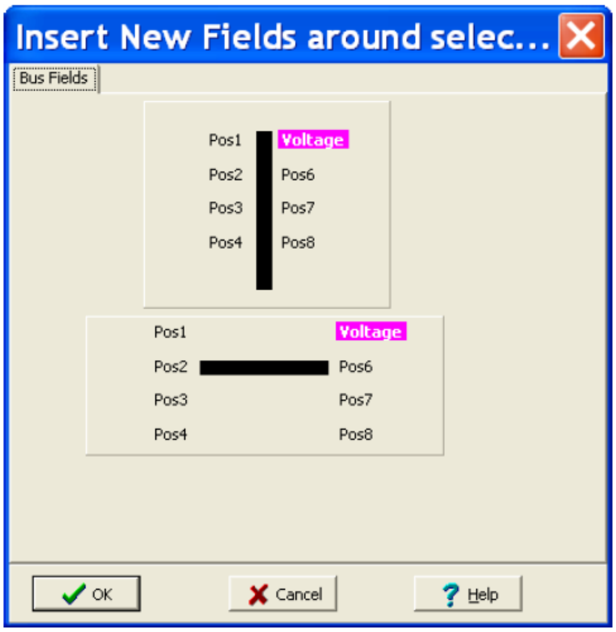


2. ADDING BUS INFORMATION

If you want to add labels and useful information on the buses (the same can be achieved with other system components), right click on a bus and select **Add New Fields Around Bus**. The dialog box should appear:

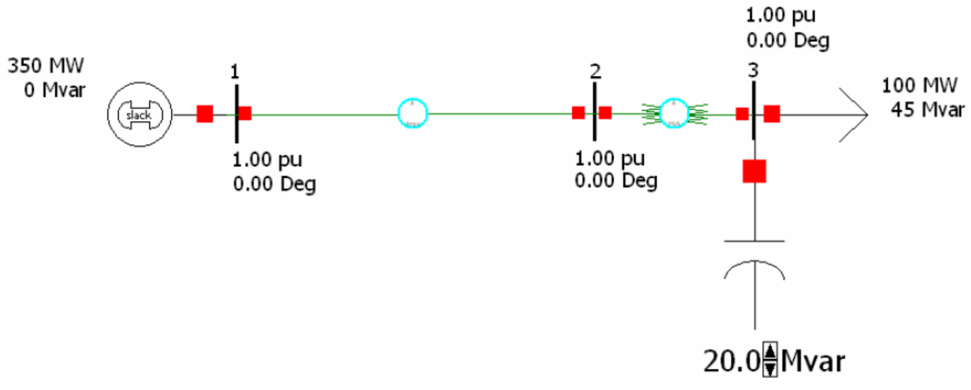


Let's add bus voltage for bus 1 at position 5. Click **Pos5** in the dialog box. Click **Bus voltage** in the new dialog box that appears and click **OK**. The **Bus Fields** dialog box should now appear as:



Now, let's add the bus angle below the bus voltage, i.e. at position 6. Click **Pos6** and select **Bus Angle**. Click **OK** twice and both the bus voltage and bus angle appear at the requested positions next to bus 1. We can drag these fields to other positions around the bus. We can add descriptive measures for other buses in the same way.

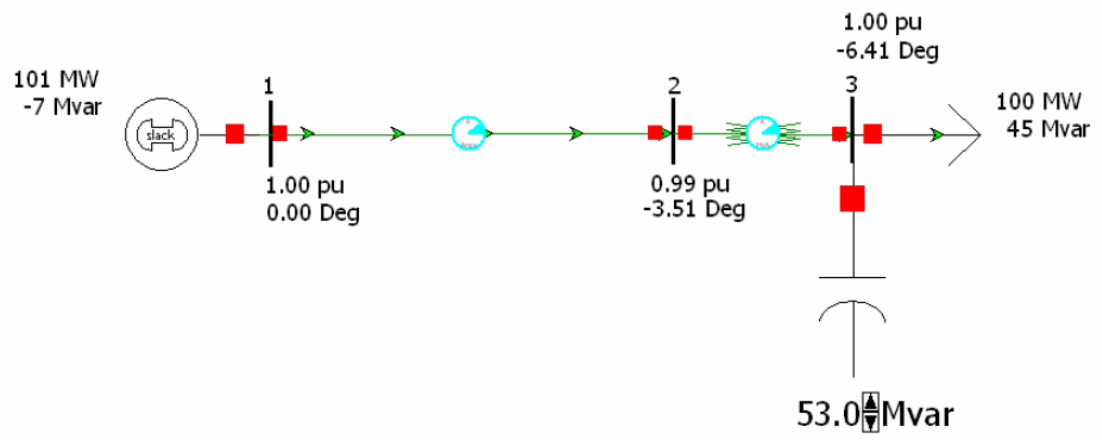
The final single-line diagram should look like the diagram below:



3. RUNNING A CASE

In order to simulate the case that we have designed, we select the **Run Mode** from the toolbar below the menu. Select **Simulation** → **Solve and Animate**.

When you run the simulator you will observe that the bus voltage at bus 3 is less than 1 p.u. You can increase the reactive compensation by clicking on the up button of the MVAr field. You can do this until the voltage at bus 3 reaches 1 p.u. The value of reactive compensation needed is 53 MVAr. The solution should look as shown below:



4. BUILDING A NEW CASE FROM AN EXISTING CASE

Oftentimes is necessary to use a case as a base case and build a number of other cases that address different operating criteria. You have to bear in mind that the simulator case you build is not one file, but two linked files. The file you see is the single-line file, a file with an extension .pwd. The other file is the "case file" with an extension of .pwb. If you copy the .pwb file and rename it, whatever changes you do to the new file will be reflected to the old because they are linked through the same .pwd file. This can cause great misery.

Fortunately, the solution to this problem is rather simple. When you want to build a new case from an existing case, follow the steps below:

i. Open the case you want to duplicate.

ii. Select File → Save Single-line As… and name the new .pwd file accordingly.

iii. Close the open case.

iv. Select File → Open Single-line… and open the newly created .pwd file.

v. Select File → Save Case As… and name the new .pwb file (preferably the same name as the corresponding .pwd file).

vi. Now, if you make any changes in the new file, they shouldn't be reflected in the original file.

REFERENCES

[1] Glover, J. D., Sarma, M. S., and Overbye, T. J., “Power system analysis and design,” Thomson, 4th edition, 2008

[2] “PowerWorld Simulator Help,” Version 12, 2007.

[3] Kyriakides, A., “A guide on PowerWorld Simulator Ver. 12.0,” ECE Depart. University of Cyprus, 2006.