Introduction to PowerWorld
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Commands, buttons, etc appear in **bold** in the text below.
Cautions and special instructions appear in *italics*.

A very good introduction to PowerWorld, complete with small examples, appears on pp. 17-23 of Glover & Sarma 3rd. ed., so we don't need to repeat all these comments here. I will just cover some specific points in its use.

First, please note that PowerWorld will perform both power-flow and short-circuit study. *PowerWorld requires all impedances to be in per-unit on system base.*

Running an existing case

a. Click on the PowerWorld icon to start the program.

b. Click on **File/Open Case** to open an existing case. If you haven't built a case of your own yet, you will only have the sample cases that came on the CD.

Click on the **Run Mode** button near the top of the screen. You can use the **Single Solution** button to run your case and see the results on the screen. Alternatively, you can run an animated simulation using **Simulation/Play** which moves arrows along the system whose size is proportional to line flow.

Try this with **Example 1_1** to see how the program displays the single-line diagram and animates the flow of energy in a small system. How to run this case for power-flow is discussed on p. 18 ff. of the text. Please note the difference between EDIT and RUN modes.

Data entry

If you want to produce a new case, you will need to enter data for the system. In many cases, you can leave the entry blank if it is not applicable to your problem.

a. Click on the Power World icon to start the program if it is not already running.

b. Click on **File/Open Case** to open an existing case (that came with the program or that you built earlier) or go directly to **File/New Case** to build your own (which is what you will need to do in the assignment below).

c. When you have clicked on **File/New Case**, you should see a blank work area and (perhaps) a bar of icons at the bottom of the screen (the bar doesn't always appear). You can use these icons, or commands under the **Insert** pull-down, to add elements successively in order to build your system.

Instead of building a data file, as with many programs, PowerWorld lets you build up the system, piece by piece, by working interactively with the one-line diagram. Therefore, before you start, look at the diagram of the system you want to model and decide how you want to begin entering it on the screen. You don't have to make it look exactly like the prototype, but the connectivity and data should be identical.

You will begin by adding a bus. Use the **Insert/Bus** command in the pull-down menu or the bus icon at the bottom of the screen. Then move the cursor to a point on the screen where you want to begin, and click. A window will appear, asking for information about adding your (first) bus. A default Bus Number will appear, and if it is not be the same as the number on your hard copy, you can change it. Leave the **Area** and **Zone** set to 1 by default.

(Note: It doesn't make any difference which bus you start with. Also, bus numbers need not be sequential or consecutive. You don't need to enter bus names unless you want; they can be spelled-out numbers like One, Two if you wish.)

You can orient the bus horizontally or vertically, using the **Horizontal Bar** or **Vertical Bar** dots. *Be sure to enter the correct nominal bus voltage in kV*. When finished entering information for this bus, click **OK**. You should see your bus on the screen. You can use the mouse (with the left button) to move or resize the bus. (This works with other devices as well.)

Once the bus is on the screen, you can go back to it at any time to change information about it by *right*-clicking on the bus and selecting **Bus Information Dialog.** If you right-click on the bus and select **Add New Fields around Bus,** your can position display "fields" around the bus (to display bus quantities). This can be done now or any time later. *Be sure to display bus voltage and angle at each bus*. If these displays overlap anything on the diagram, you can move them with the mouse (left button). You can also place "fields" at devices such as lines, generators, and loads using the same kind of procedure.

The first bus you add will have at least one or two devices (line, load, generator) attached. *Caution: It's probably best to add an item (e.g., generator) to the bus before going on to the next bus*. Click on the appropriate icon, or use the Insert pull-down, and do this (see below for adding a line or transformer). I found that starting with the first bus and adding successive devices to your network without creating "islands" gives good results.

When adding a generator or load, be sure to click the correct orientation dot, indicating whether the device should appear above, below, or to the left or right of the bus. Once the generator appears on the screen, drag its terminal to the bus.You will need

to enter the P and Q values for a load, and the scheduled real-power output and bus voltage for a generator. When you schedule to voltage (magnitude) to be held constant for a generator, power World knows to hold this value constant for the bus to which the generator is tied.

Very important caution: Be sure to know in advance which bus you want to be the swing (slack) bus for power flow. There is a box to check for this on the Generator dialog panel. Some versions of Power World seem to have a bug that causes problems if you change the swing bus after specifying it. When adding a generator, make sure the box is or is not checked, as appropriate (this is very important to watch, since the box may remain checked for subsequent buses after adding the swing bus). Don't wait to do this later. If you end up with two swing buses in the network, you may have to delete the non-swing bus with everything attached to it and add it and all its incident elements again! I think that the new version corrected this, but don't automatically assume this.

d. The first bus you add will be tied by a line or transformer to another bus. To add that line or transformer, first add its other endpoint bus. Then click on the appropriate icon or Insert command. *Caution: Be sure to use "**Transmission line**" and not "**DC Transmission line**" when adding a line.* Once you have chosen the kind of device to add, click on one of the endpoint buses with the left mouse button. *Release the mouse button* and move to the other endpoint bus. Then click the left mouse button *twice*. This signals that you have bridged the desired pair of buses with a line or transformer, and brings up a dialog box for line/transformer information. Power World allows you to make inflection points (right-angle or non-right-angle turns) in a line on the diagram, by left-clicking each such point. To make your diagram neat, you might want to do this in a few cases. *Caution: It's best to make the transmission lines appear the way you want them the first time, since it may be difficult to change their appearance later*. If you don't like the appearance of a line, delete it at this point and redo it.

Be sure to enter values for line impedance, charging, etc.as needed (you can easily change these values, and other numerical values, any time later). *A compensated or long line may require entering a shunt conductance. To add this, go to the **View/Modify Line Shunts** option on the line/transformer dialog box. Split the total G in half and enter half at each end of the line, as the dialog box allows, unless your compensation is asymmetric, in which case Power World allows different shunt values for the two ends of the pi model.* This allows it to simulate compensated lines nicely.

e. Once you have gotten this far, I suggest that you *save your work*. Use the **Save As...** command under **FILE** the first time. If you are working in the lab, save your work to your floppy disk (and remember take it with you when you finish! Anything stored on the hard drive of a lab computer will probably be erased.) *Caution: It's a good practice to save your work after adding every couple of buses*.

f. Continue to add devices in this manner until your entire system is entered. You may now want to click on lines, transformers, or other devices and check the numerical parameters, add appropriate display fields, etc. *For each line and transformer, you should display the P and Q flow at each end, and for each load and generator, you will want to display the P and Q. Each bus should have per-unit voltage magnitude and angle displayed*. Remember that you make these displays using "fields". Try to move these displays around on the screen to make your one-line diagram neat and easy to read. However, be careful not to confuse the display with a device to which it is not related! Since you have freedom to move the displays around, this can happen easily if you are not very careful. *You can always click on a display field to find out what it relates to.*

You can use the **Format** menus to change fonts, colors, and other display options. The dialog boxes associated with the devices can be used to change how the numerical displays look, such as number of decimal places. *You need to be in the Edit mode to do most of these things. You can select a number items to change at once, by holding down the shift key as you left-click on them.*

I have found the **HELP** file in the program to be fairly explicit and useful.

We have only talked about some of the basic features of PowerWorld here. The program does many more things and allows us much more control over the solution. Don't become too confused by the additional options you see as you are using the program; concentrate on basic power flow and short-circuit operation for now.

Power-Flow Simulation

Now you are ready to do a power-flow simulation (see below for fault simulation). If you saved your file to a diskette and are starting a new session, click **File/Open Case** to select and open your file. Otherwise, if you are just finished editing the case, you need to exit the edit mode. Just click on the **Run Mode** button near the top of the screen. If you have unconnected buses or other "validation problems" in your case, the program will not let you run a simulation at this point.

Assuming the connectivity of the system is complete, you can use the **Single Solution** button to run your case and see the results on the screen. Alternatively, you can run an animated simulation using **Simulation/Play** which moves arrows along the system whose size is proportional to line flow.

Now is a good time to run a power-flow simulation on one of the examples and verify that your answers for bus voltages/angles, and line flows, are close to the expected results. Try both the **Single Solution** and **Simulation/Play** options.

Once you get all the errors out of your final case, you will want to *print* some output as well as other case information. Power World gives you several options to do this.

You can go to **File/ Print Oneline** on the menu bar to print your one-line diagram, with all the information on it that appears on the screen. *(Caution: sometimes the printed diagram may have overlapping text, distorted symbols, etc., but the numerical values should be correct.)*

The **Case Information** tab is particularly useful for obtaining printouts of numerical output. Probably the most useful items under this heading are the **Power Flow List** (which allows you to view and print a complete power-flow output in more or less standard form) and **Buses** (which gives you a table of bus voltage magnitudes and angles). To print any of this, *right*-click the case display that you see and use the print option (see also the section on **Display Options** below). Under **Case Information**, you can also obtain a **Case Summary** which allows you to verify the number of buses, which is the swing bus, total generation and load, etc. The **Bus View** option allows you to examine specific buses.

Fault (Short Circuit) Simulation (not needed in EE431 but included in this instruction set for completeness)

PowerWorld also allows you to do balanced and unbalanced short-circuit study. You will need to do this as part of the assignment below. To understand the procedure and the kind of output available, I suggest that you run the Example 7_5 case stored on the CD and compare with the discussion of the example on pp. 336-340 in the text. Since this is the first short-circuit example in the text using PowerWorld, there is a good discussion at that point in the book on how to use the software for fault study. You should read this discussion and follow the steps. No data entry is required of you to run this or other textbook examples.

*To simulate a short circuit at a bus, while in the **RUN** mode right-click on the desired bus and then left-click on **fault** in the menu box that appears.* You can change the type of fault, etc. from here. Then click the **CALCULATE** button to calculate system voltages and currents during the fault. The output defaults to a table of bus voltages during the fault, but from this screen you can call up different tabs to see fault currents in the lines, fault currents in the generators, etc. as well. From this window, you can also click the appropriate dots in the upper right to set the **One-line display** as desired (often **Normal** is appropriate). Supposedly, any of this tabular data can be copied and then pasted in another file (see section on **Display Options** below).

To enable the simulation to *animate* the fault currents on the single-line diagram, go to **Options/Tools** / **Oneline Display...** / **Animated Flows** / **Fault Visualization** to turn the fault animation option on. For a three-phase fault, you may wish to display only the

phase-a currents. Click on the correct circle. You may then have to go to **Simulation / Play** to start the animation. The Example6_13 file furnished on the CD, which represents a larger (37-bus) system than most in the text, is a good one for viewing the animated short-circuit current flows. You can clearly see the short-circuit currents heading to the faulted bus from all over the network.

Display Options (some of these are discussed elsewhere in this handout)

You can print an entire one-line diagram, showing power-flow output values or fault currents, by going to **File / Print Oneline** .

In general, the **Case Information** tab on the toolbar provides a link to most of the tabular data you might need. Under this tab, for instance, **Case summary** tells you how many buses, generators, transformers, etc. are in the system, while **Power flow list** tells you the line flows.

One way to copy *tabular* data is, of course, to use the left mouse button and block out the data you want co copy, and then use **Ctrl C** and **Ctrl V**. I find that this doesn't always keep the columns straight, though.

PowerWorld provides options for printing or copying from tables. For example, to get a table of bus voltage magnitudes, angles, and loads from a power-flow study, go to **Case Information / Buses**. *Right-click* on the table to **Print** , **Copy all**., or **Copy selection**. Material copied to the clipboard can then be pasted into your report document using **Ctrl V** as discussed earlier. You may want to use the **Print to file** command in some situations to produce a file that can be copied into another document.

In summary, try the basic Windows commands relating to copying, pasting, printing, etc. Also, note that *right*-clicking on an object or table in PowerWorld often brings up an extensive menu of what you can do with that entity.

Please note also that PowerWorld allows you to view and print much more than we have discussed here. For example, you can display the Ybus matrix for your system using **Case Information / Ybus**. This allows you to view the sparsity of Ybus (See G&S p. 298 for an example).Use **Ctrl Pg Down** or **Ctrl Pg Up** to zoom the display. This may not always give a satisfactory-looking display; you might have to play with it a little. You may need to drag the lower right corner to make it larger, or you can use the scroll-bar arrows to zero in on parts of a large Ybus. The Ybus shown on p. 298 looks asymmetric in structure, probably because of the way it is displayed, and that is misleading.

You can display and print many other useful and interesting things, For example, you can display the Jacobian matrix using **Case Information / Other / Power flow Jacobian.**