
LAB2 – ONE-LINE DIAGRAMS

EE461 Power Systems

Colorado State University

Lab 2 – One-Line Diagrams

PURPOSE: The purpose of this lab is to introduce the one-line diagram, also known as the Slider file in PSS/E. This lab will introduce the following aspects:

- Introduction to a one-line diagram
- Explanation of the Slider (*.SLD) file
- Using the Slider file to create a one-line diagram

To properly perform this lab, start PSS/E and open the sample.sav file. Refer to Lab 1 on how to do this.

Introduction to one-line diagrams

A one-line diagram is a simplified graphical representation of a three phase power system, used extensively in power flow studies. In power engineering, one can make the assumption that the three phases of a system are balanced and can therefore be examined as a single phase. The assumption can be made because what happens on one of the three balanced phases, theoretically, will happen to all three phases. This makes the evaluation of the system much less complicated without losing any information. Per unit voltage used extensively in one-line diagrams to further simplify the process.

The main components of a one-line (or single line) diagram are; Buses, Branches, Loads, Machines, 2 Winding Transformers, Switched Shunts, Reactor and Capacitor Banks. An explanation of these components will now be given:

Buses



Buses are represented as a dot, circle or a thick line. The bus name (EAST500) and number (202) are given, as well as the voltage measured on the line (510.5kV and 1.021V in per unit). The final characteristic given is the angle (-26.1 degrees). The voltage is indicated by the color of the bus. In this example, red indicates 500kV.

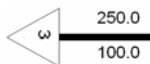
Branches



Branches are represented as a thin line. The real power P, as shown on the branch above, flows from 478MW to -473MW and the reactive power Q, flows from 89.9MVA flow to -229.4MVA. In other words, the power flows from the positive number to the negative number, and the number on top is the real power while the number on the bottom is the reactive power. The voltage is indicated by the color of the branch. In this example, red indicates 500kV.

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Loads



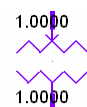
Loads are represented as a triangle with the ID number located inside the triangle. The real power, P_{LOAD} , is denoted by the number on top (250MW), and the reactive power, Q_{LOAD} , is denoted by the number on bottom (100Mvar). The voltage is indicated by the color of the load. In this example, black indicates 230kV.

Machines



Machines are represented as a circle with the ID number located inside the circle. The real power, P_{GEN} , is denoted by the number on top (321.0MW), and the reactive power, Q_{GEN} , is denoted by the number on bottom (142.3RMVAR). The “R” indicates this machine is in voltage regulation mode, and it is controlling a specific bus to a voltage set point which requires it to generate 142.3MVAR. The voltage is indicated by the color of the machine. In this example, red indicates 500kV.

Two Winding Transformers



Two winding transformers are represented as two separate windings with a gap separating them. The arrow pointing in at the connection reflects the primary side of the transformer. In this example, the primary voltage (1.0000 in per unit voltage) is given on the primary side of the transformer and the secondary voltage (1.0000 in per unit voltage), is given on the secondary side of the transformer. The voltage is indicated by the color of the transformer and is dictated by the primary side voltage. In this example, purple indicates 21.6kV.

Switched Shunts



Switched shunts are represented as either a capacitor or an inductor at the end of a line. The “SW” shown on top (or on the left if the shunt is shown vertical) indicates that this unit is a switched shunt compensator. If you see these symbols with a number in place of the “SW”, that particular device is a permanently installed reactor or capacitor bank (see below). The number on bottom (or on the right if the shunt is shown vertical) indicates the initial reactive charge admittance, B_{INIT} (253.8MVAR or -599.6MVAR). The voltage is indicated by the color of the shunt. In this example, red indicates 500kV.

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Reactor Bank



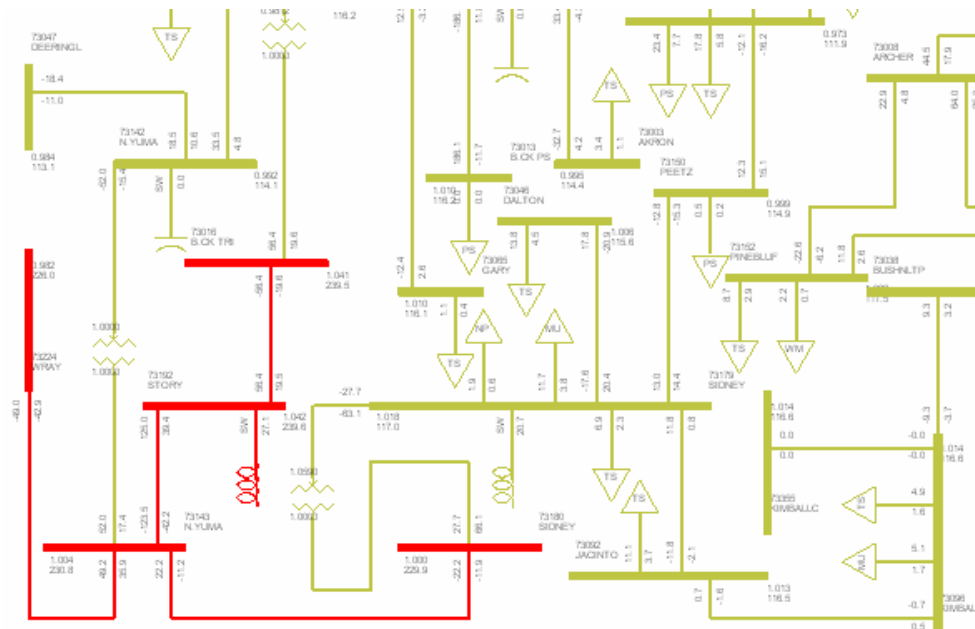
Reactor banks are represented as an inductor at the end of a line. The number on top (or on the left if the reactor is shown vertical) indicates the real charge admittance, G_{SHUNT} , of the line (3.6MW). If you see a “SW” instead of a number, you are looking at a switched shunt compensator (see above). The number on bottom (or on the right if the reactor is shown vertical) indicates the reactive charge admittance, B_{SHUNT} , of the line (490.0MVAR). The voltage is indicated by the color of the reactor. In this example, red indicates 500kV.

Capacitor Bank



Capacitor banks are represented as a capacitor at the end of a line. The number on top (or on the left if the capacitor is shown vertical) indicates the real charge admittance, G_{SHUNT} , of the line (0.0MW). If you see a “SW” instead of a number, you are looking at a switched shunt compensator (see above). The number on bottom (or on the right if the capacitor is shown vertical) indicates the reactive charge admittance, B_{SHUNT} , of the line (-1080.0MVAR). The voltage is indicated by the color of the capacitor.

The Slider File



As described in the previous lab, the Slider (*.SLD) file is a file that contains the one-line diagram. As can be see from the figure above, the one-line diagram can get pretty

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complicated. To simplify matters, all the physical data related to each element shown in the one-line diagram is linked to the data file (*.SAV). This way, a simple thin line represents all of the data located in the branch tab. All of this data is interconnected and linked so as to perform power flow analyses. Once a one-line diagram is created, it can be saved as a Slider (*.SLD) file. The Slider file can be amended and updated as necessary, as long as the amendments and updates correspond with the *.SAV file, since the two files are intertwined.

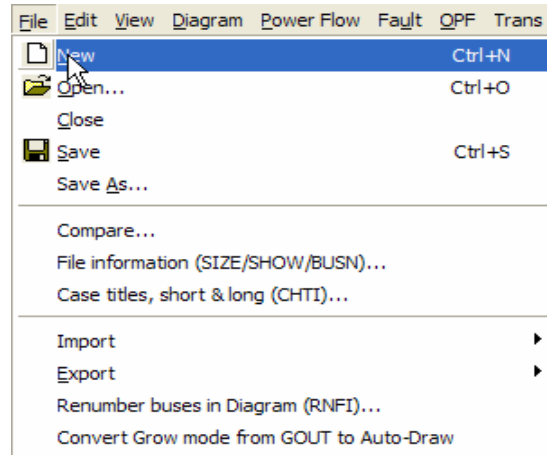
Another advantage of the Slider file is that one can view the power flow and the operating levels of a branch. This allows a Power Engineer to quickly see potential trouble spots in a power system and correct them before problems occur. The process of performing a power flow analysis is the main objective of these labs.

Using the Slider file to create a one-line diagram

As mentioned above, in order to properly perform this lab, PSS/E needs to be running and the data file “sample.sav” opened. Refer back to Lab 1 if problems arise in doing this.

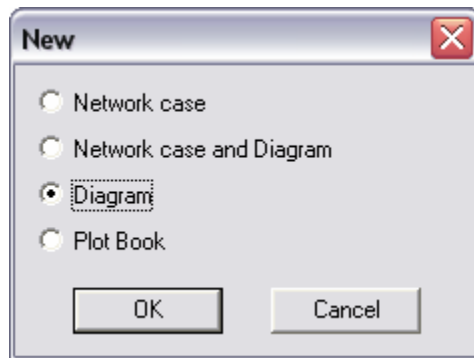
Now go ahead and load a new file and get some buses drawn!
Load new slider (file → new → diagram)

- I. First we need to load a file, and to accomplish this please do the following.
- II. Open PSS/E (it is shown on the previous lab)
- III. Go to file, and click new as shown:



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IV. After clicking new you will see the following:

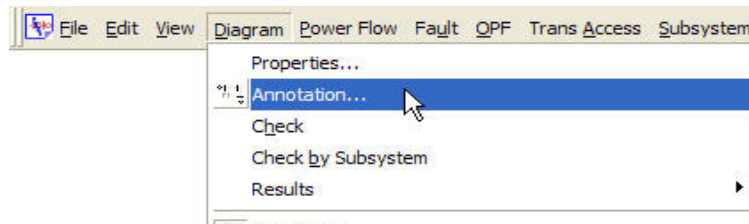


Select Diagram and click OK.

V. A new diagram will be opened. This is where the future drawing will be constructed.



VI. The color code for analyzing the one-line diagram will need to be programmed to distinguish the various voltage ratings for all the different components that the system consists of. This is done by selecting Diagram → Annotation.



This will display the Powerflow Data Annotation window. Select the Diagram Range Checking tab shown below:

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The dialog box is titled "Powerflow Data Annotation" and has two tabs: "Diagram Annotations" and "Diagram Range Checking". The "Diagram Annotations" tab is active. It contains three main sections: "Branch annotation", "Bus annotation", and "Equipment annotation".

- Branch annotation:** Radio buttons for MW/MVAR Flow (selected), MVA Flow, MVA/% Rating, Amps/PU Current, MW/% Rating, Amps/% Rating, and None.
- Bus annotation:** Two sub-sections. "Identification" has checkboxes for Numbers and Names (both checked). "Voltage" has checkboxes for Magnitude (PU) and Magnitude (KV) (both checked), and an unchecked checkbox for Angle (Degrees).
- Equipment annotation:** Radio buttons for MW/MVAR (selected), MVA, and None.

Below these sections is a "Loading basis for % Rating" section with three radio buttons: "Current for transformers and non-transformer branches" (selected), "MVA for transformers and non-transformer branches", and "MVA for transformers, Current for non-transformer branches".

At the bottom is a "Diagram title" text field and "OK" and "Cancel" buttons.

Check the “Use voltage level thresholds”. The voltage level thresholds with their corresponding colors can now be set. Set all values and colors to match the following window.

The dialog box is titled "Powerflow Data Annotation" and has two tabs: "Diagram Annotations" and "Diagram Range Checking". The "Diagram Range Checking" tab is active. It contains several sections for setting thresholds and limits.

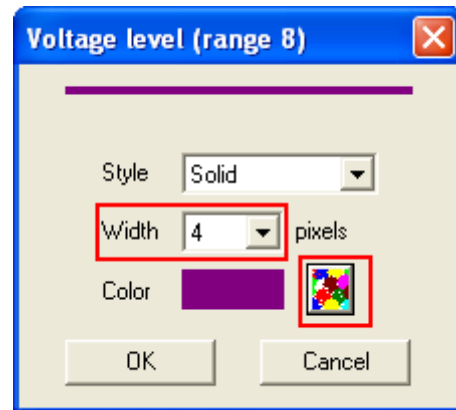
- Use voltage level thresholds:** A checked checkbox. Below it are seven numeric input fields with values: 12.470, 34.500, 69.000, 115.000, 138.000, 230.000, and 345.000. Below these is a horizontal color bar with seven segments of different colors (green, black, blue, green, yellow, orange, red) and a purple segment on the right. A mouse cursor is pointing at the purple segment.
- Use line ratings:** An unchecked checkbox. Below it is a "% Loading" input field with the value 100.0 and a "5%" label. To the right is a "Branch rating set" dropdown menu with "Rate A" selected.
- Use bus voltage limits:** An unchecked checkbox. Below it are two rows of input fields. The first row has "Vmax" with the value 1.050 and "0.01 pu". The second row has "Vmin" with the value 0.950 and "0.01 pu".
- Out-of-service equipment:** A text input field with a dashed line.
- Loading percentages for loading bar charts:** Four numeric input fields with values: 95, 100, 105, and 110.

At the bottom are "OK" and "Cancel" buttons.

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Click the color bar to set the width and color of the voltage level threshold. Click the width drop down outlined in red to select the line pixel width. Click the color box outlined in red to select the color of the line.

Click OK to return to the Power flow Data Annotation window.



(Threshold voltages from left to right: 12.47, 34.5, 69, 115, 138, 230, 345)

(Colors from left to right: dark green, black, blue, bright green, yellow, orange, red, purple)

(Widths from left to right: 1, 1, 1, 2, 2, 3, 3, 4)

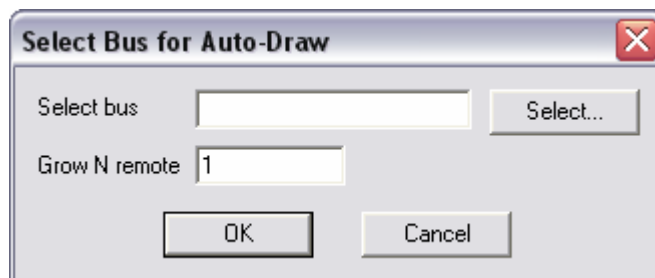
Note: all other values should be default

Click OK to close window and return to blank diagram.

- VII. A bus can be imported from the data (*.sav) file into the diagram. To do this select Auto Draw (located on the tool bar) as shown below:

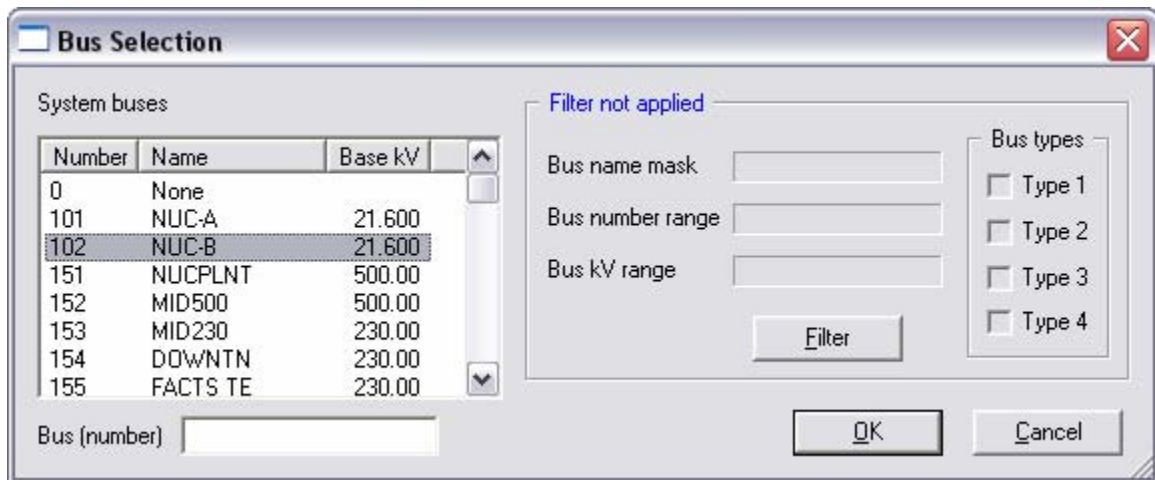
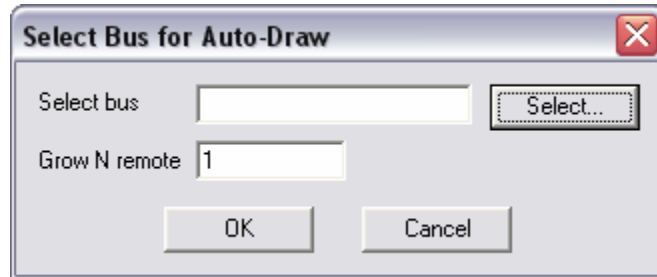


Click an open space in the blank diagram and the following window will be displayed:

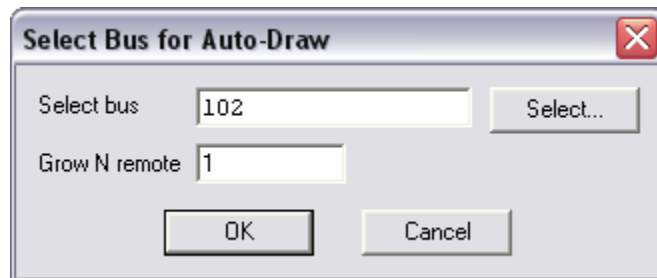


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Next click select in the Select Bus window, or type the desired bus number, which comes from the *.sav file. (In this case, bus number 102 comes from the sample.sav file);



Click OK to return to the select bus window, which will show the bus selected.



Click OK.

Note: As previously mentioned the bus can also be manually typed in to skip the bus selection window.

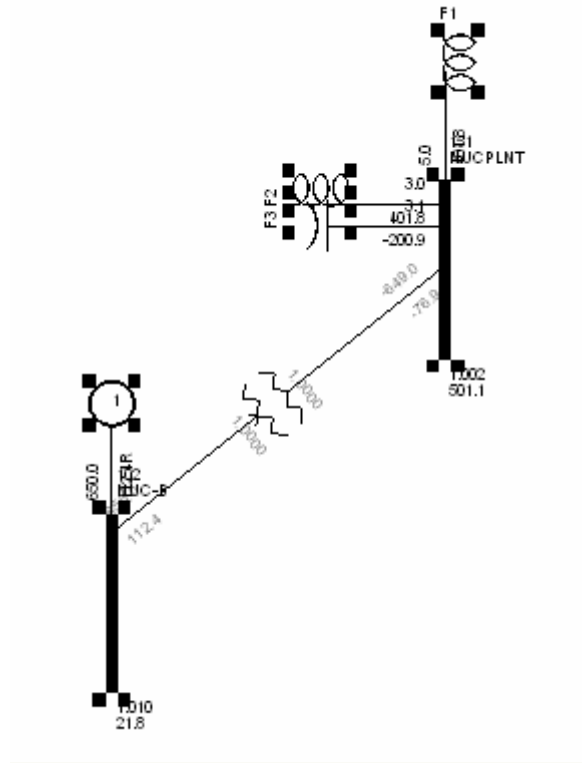
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Note: If a bus number is not in the *.sav data file the following error message will be displayed:



Click OK and enter bus number 102 from the data file.

Bus number 102 and all devices that are directly connected to it will now be displayed as shown below:



Select the pointer from the tool bar to exit out of the auto draw function.

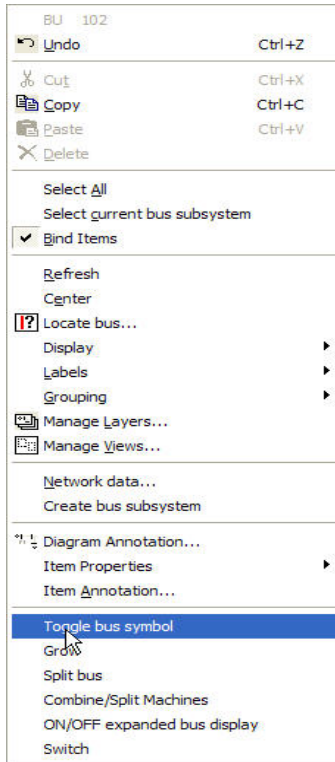


***If needed, the toggle bus symbol feature can be applied to display buses as dots, circles, or lines. This is done by selecting a component by left clicking the component

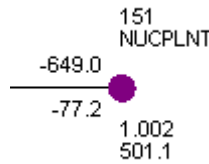
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(the selected component will have a black square on each corner), and then right click the bus symbol and selecting Toggle bus symbol.

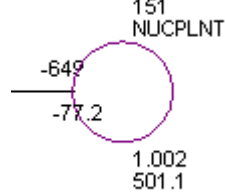
Different bus symbols shown below;



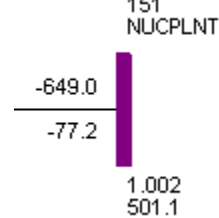
Dot:



Circle:

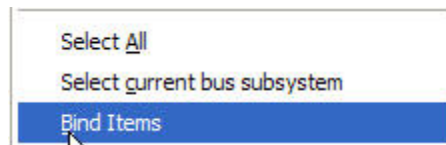


Line:

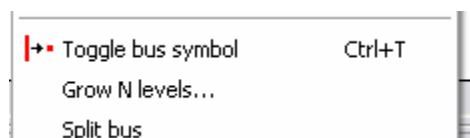


***For all purposes of this lab the line bus symbol will be used.

VIII. **IMPORTANT: The data file (*.sav) and slider (*.sld) diagram are interconnected, therefore deleting a bound item from a diagram removes it from the *.sav data file and will result in analysis corruption. This means that if a change is made to either of the files the other will be affected. To avoid possible corruption of the data file, the “bind items” feature should be turned off. This is done by right clicking a bus and clicking bind items as shown below:

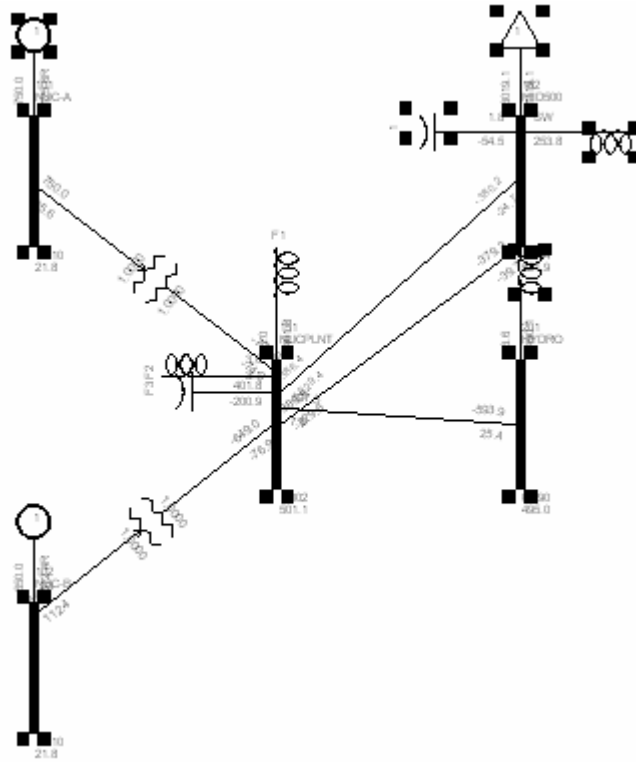


IX. Once the bind items have been unselected, it is safe to grow a small section of the data file into a one-line diagram. This is done by right clicking a bus and selecting Grow N Levels.



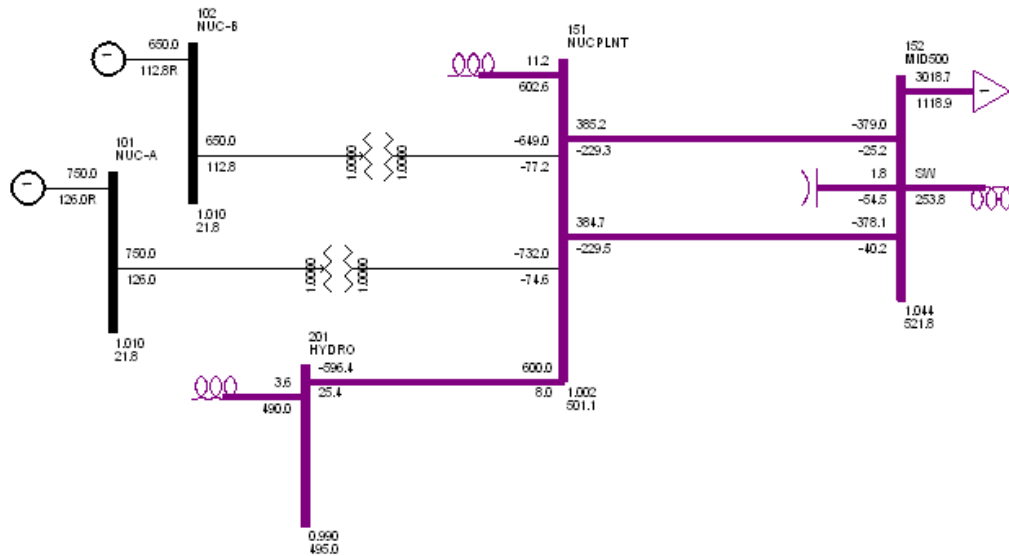
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- X. Try to grow out bus number 151 one level. This will display all the elements connected to bus number 151. The following will be produced:

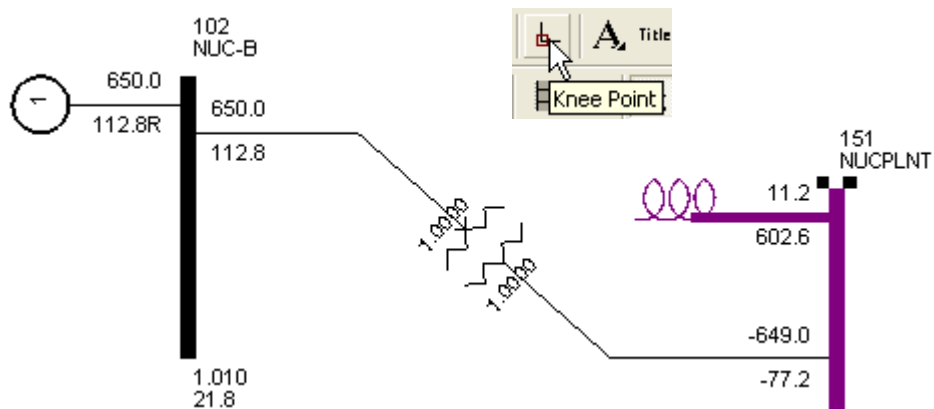


- Notice how PSS/E automatically places the buses and branches in no particular layout. To allow for a legible display, manipulation to the above diagram is required. After growing out a bus, all the elements associated with the grow command will be selected. Click the white space off the drawing to deselect the grown items. Now it is possible to rearrange the drawing by selecting a bus and dragging it to the desired location. **Caution must be exercised so that no buses are moved to a different connecting point in the diagram.**
- XI. Try to rearrange the one-line diagram so that no wires or ratings are overlapping. In other words, make the diagram clean; meaning easy to read and understand. Notice how much clearer the diagram below is.

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***If needed, a knee can be used to bend and manipulate a transmission line. To 'bend' a line, insert a knee point. This is done by selecting Knee Point from the tool bar and then clicking the line where the knee is desired. Multiple knees on a line may be necessary in order to have more control of the design of the layout. Once the knee is placed the line can be bent to any angle by grabbing and dragging the point. An example of a line with two knees in it is shown below:

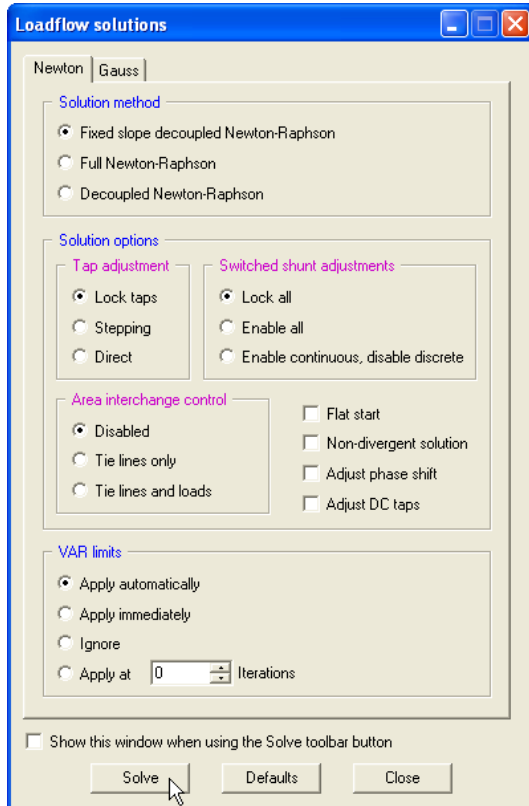


- XII. After a clean layout has been achieved the system is ready to be solved. Solving a system allows PSS/E to make all the necessary calculations used in a power flow analysis. This can be done by clicking the solve icon on the toolbar.



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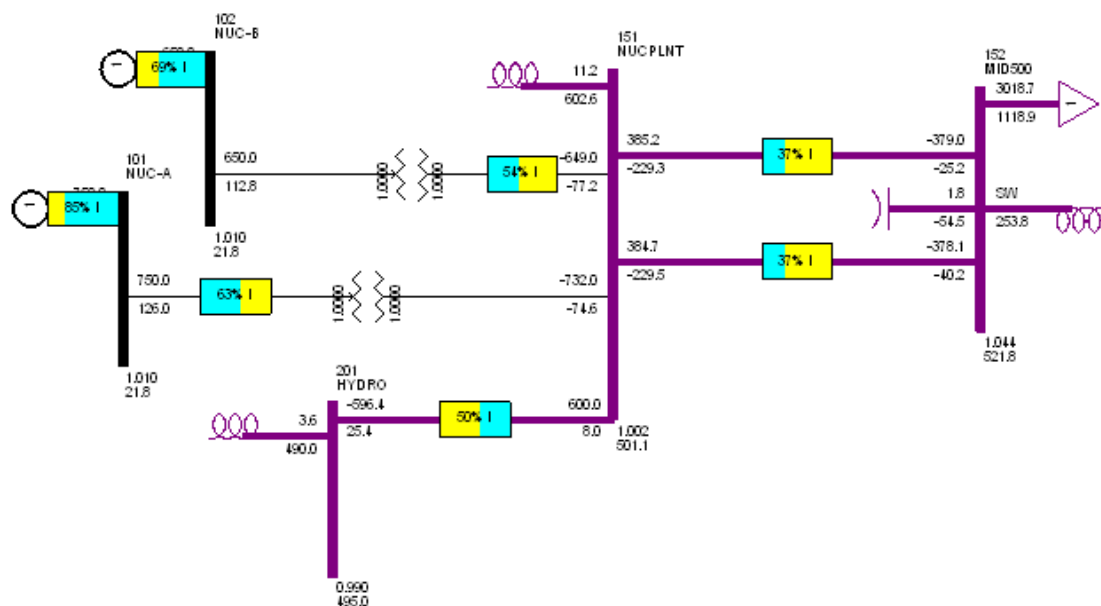
The following window will be displayed:




Configure the Loadflow solutions window to match the one displayed. This could include selecting the “Lock all” radio button under Switched shunt adjustments and uncheck “Adjust DC taps”.

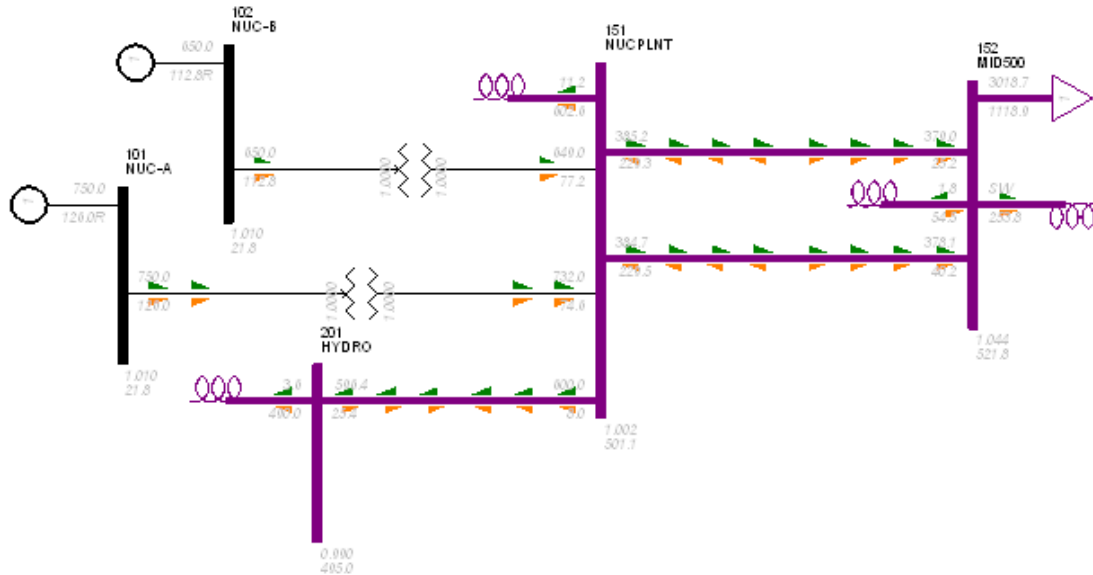
Click solve and PSS/E will solve the system and store the results in the progress window.

XIII. After the system has been solved, the loading percentages can be displayed by clicking the current loadings icon  on the tool bar. The following will be displayed:



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- XIV. Once the system has been solved, the Flow animation can be displayed by clicking the animate flows icon  on the tool bar. The following will be displayed:



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Questions

The “sample.sav” data file must be open to perform this section of the lab.

First, build out a one-line diagram to include the following ten buses (and no others!):

101	NUC-A
102	NUC-B
151	NUCPLANT
152	MID500
153	MID230
201	HYDRO
202	EAST500
3004	WEST
3021	WDUM
3022	EDUM

This is best done by typing “101” into the auto draw function, then right clicking the “151” bus; select grow. From here, right click the “152” bus and select grow. This should prevent you from ending up with extraneous buses. Solve for the system. Display the current loading percentages and the power flow animation.

Print out the one-line diagram and include it in the report.

Save the one-line diagram as “lab2.sld”, this will be needed for future labs.

Using the one-line diagram, and answer the following questions to include in the report. Turn off the loading percentages and the power flow animation for clarity. Make sure that the system has been solved.

- 1) Looking at Bus #152 (MID500), what is the P_{LOAD} and Q_{LOAD} of the load connected to this bus? _____
- 2) Find the two generators in this system. Which buses are they connected to?
What is the P_{GEN} and Q_{GEN} of the two generators?

- 3) How many switched shunts are in this system? _____
How many reactor banks are in this system? _____
How many capacitor banks are in this system? _____
- 4) Looking at Bus #153 (MID230), what is the actual voltage of the bus and what is the per unit voltage? _____