ELEN 460
Computer Laboratory Exercise No: 2
Analysis of Three-Phase Circuits

Objective:

1) Learn the basics of using PowerWorld Simulator to model balanced three-phase systems.
2) Correct the power factor of three-phase load by proper placement of shunt capacitors.

Background

Power World Simulator (PowerWorld) version 20 is a Windows-based, commercial-grade power system analysis and simulation package that accompanies the ECEN 460 book. The purposes of integrating PowerWorld with the text are to provide computer solutions to examples in the text, to extend the examples, to demonstrate topics covered in the text, to provide a software tool for more realistic design projects, and to provide the students with experience using a commercial grade power system analysis package. We will be using it extensively in this class both for lecture and lab. The lab computers have the full commercial version, which solves power systems with up to 100,000 buses. There is a free educational version, which solves power systems with up to 42 buses, that can be downloaded at https://www.powerworld.com/gloveroverbyesarma

This lab introduces PowerWorld, and shows how shunt capacitors can be used for reactive compensation. Power system analysis requires a model of the power system. With PowerWorld, you can either build a new case (model) from scratch or start from an existing case. Most of the time, including here, we'll start from an existing case. In ECEN 460 using PowerWorld we'll be assuming a balanced three-phase, 60 Hz ac system. The model of the system can be shown using a oneline diagram. As the name implies on a oneline the actual three phase conductors are shown using a single line. The initial oneline used here is shown in Figure 1.
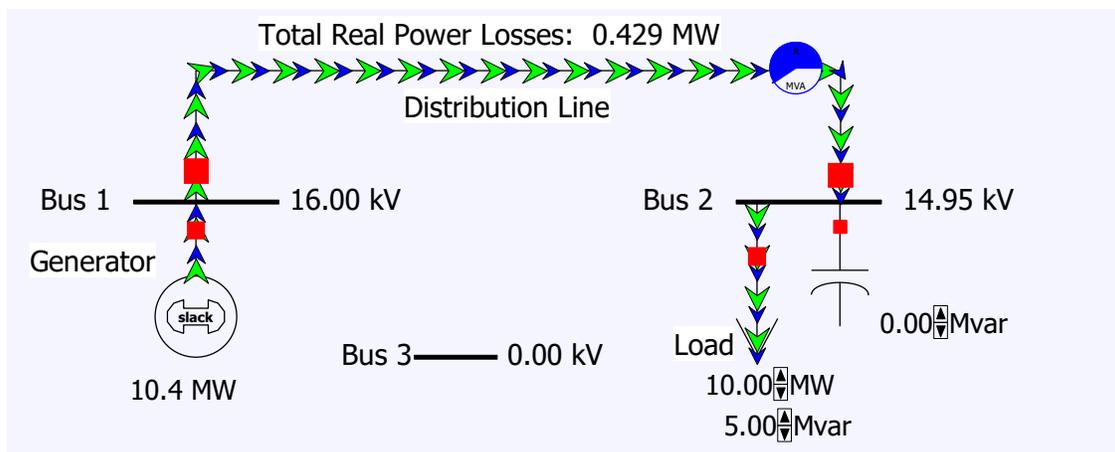
Figure 1: Initial Case Oneline Diagram

In the onelines generators are shown as a circle with a "dog-bone" rotor, large arrows represent loads, and transmission lines are simply drawn as lines. In power system terminology, the nodes at which two or more devices join are called buses. Hence this is a three bus system, though initially Bus 3 is not connected. In PowerWorld thicker lines usually represent buses; the bus voltages are shown in kilovolts (kV) in the fields immediately next to the buses. In addition to voltages, power engineers are also concerned with how power flows through the system (the

solution of the power flow problem will be talked about later in the class and is covered in Chapter 6 of the text). In PowerWorld, power flows can be visualized with arrows superimposed on the generators, loads, and transmission lines. The size and speed of the arrows indicates the direction of flow. Here the green arrows show the flow of real power and the blue arrows the flow of reactive power.

Procedure

1. Start PowerWorld. To open the initial case click **File**, then select **Open Case**. This displays the Open Dialog. Select the Lab2_Start case, and then click **Open**. The display should look similar to Figure 1.

2. PowerWorld has two major modes of operation. The Run Mode is used for running simulations and performing analysis. The Edit Mode is used for modifying existing cases and building new cases. Like many programs, PowerWorld uses a ribbon interface. To change modes, make sure the ribbon is visible, and then click on either the **Edit Mode** or **Run Mode** buttons; both are located in the upper left portion of the display immediately below the PowerWorld icon. For the next steps few steps select the **Run Mode**.

3. One of the unique aspects of PowerWorld is its ability to animate power systems. To start the animation, select the **Tools** tab on the Ribbon and then click on the green and black arrow button above **Solve** (i.e., the "Play" button). The simulation is now running, and the oneline should come to life!

4. Here the amount of nominal reactive power supplied by the capacitor is assumed to be controllable in discrete, 1.0 Mvar increments between 0 and 10 Mvars. Note, the nominal reactive power assumes at rate voltage (here 16.0 kV) while the reactive power shown for the capacitor is the actual reactive power supplied, which varies with the square of the bus voltage. When the simulation is running to change the amount of reactive power click on the up or down arrows next to the capacitor. Record the system losses and the load bus voltage as the reactive power is varied between 0 and 10 Mvars in the 1.0 Mvar increments. What value of nominal capacitance minimizes the losses?

5. In the simulation the assumed real and reactive load can also be varied by clicking on the up or down arrows next to the load fields. Change the load to 12.0 MW and 3.0 Mvar. Then repeat the step 4 analysis.

6. Next, we will add load at bus 3 and then connect it to the other buses by distribution lines. First switch to **Edit Mode**. Load can be inserted graphically by selecting **Network, Load,** and then clicking on bus 3. The Load Options dialog appears, allowing you to set the load parameters. Note that the load was automatically assigned to bus 3. Leave all the fields at their default values, except set the orientation to "Down," and enter 10.0 in the Constant Power column MW Value field. As the name implies, a constant power load treats the load power as being independent of bus voltage; constant power load models are commonly used in power system analysis. By default PowerWorld "anchors" each load symbol to its bus. This is a handy feature when changing a drawing since when you drag the bus the load and all associated fields move as well. Note that two fields showing the load's real (MW) and reactive (Mvar) power were also auto-inserted with the load. You should resize the fields using the **Draw, Format, Font** command.

7. As you make changes to the model be sure to be saving the cases. You can do this by selecting, **File, Save Case As**.

8. Now we need to join the bus 3 load to the rest of the system. We'll do this by adding a line from bus 2 to bus 3. Select **Draw, Network, Transmission Line** and then click on bus 2. This begins the line drawing. During line drawing PowerWorld adds a new line segment for each mouse click. After adding several segments place the cursor on bus 3 and double-click. The Transmission Line/Transformer Options dialog appears allowing you to set the line's parameters. Note that PowerWorld should have automatically set the "from" and "to" bus numbers based upon the starting and ending buses (buses 2 and 3). If these values have not been set automatically then you probably did not click exactly on bus 2 or bus 3; manually enter the values. Next, set the line's Series Resistance (R) field to 0.3, the Series Reactance (X) field to 0.6, and the MVA Limits Limit (A) field to 20 (transformer and transmission line modeling will be covered in future lectures). Select **OK** to close the dialog. Note that PowerWorld also auto-inserted two circuit breakers and a round "pie chart" symbol. The pie charts are used to show the percentage loading of the line. You can change the display size for these objects by right-clicking on them to display their option dialogs.

9. Repeat this process, excepting adding a line between bus 3 and 1 with the same impedance and limit values.

10. Switch back to **Run Mode**, start the simulation, make sure the Bus 2 load is again 10.0 MW and 5.0 Mvar. At the end of this step your oneline should be similar to what is shown in Figure 2.
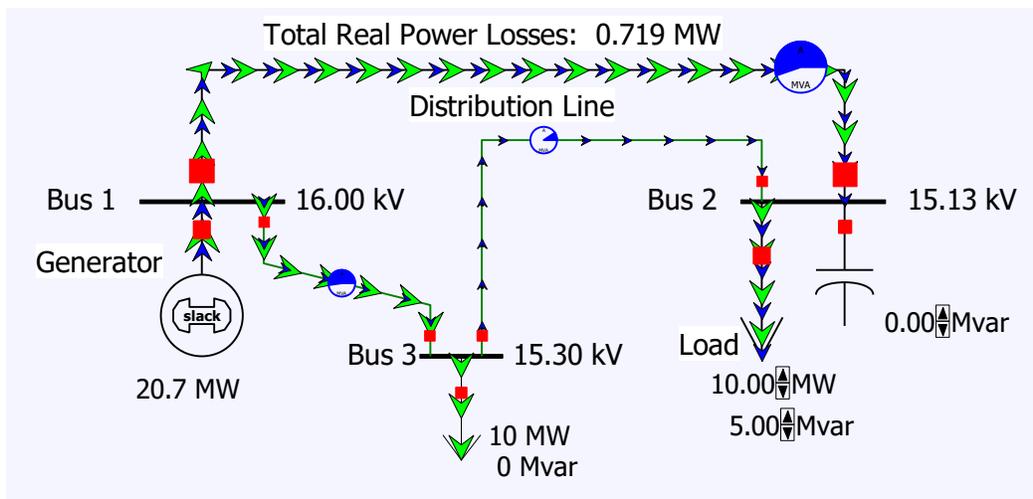
Figure 2: Oneline Diagram After Line Addition

11. Repeat the step 4 analysis.

12. Save an image of your final oneline as a *.jpg file for your report. To save an image, right-click on a black portion of the oneline. This will display a local menu. Select **Export Image to File** and save it in one of your directories.

Report:

Provide a step by step account of the procedure you followed and the results you have obtained. Answer all questions appearing in any of the steps of the procedure. Also include the final image from step 11. As always list all of the references you use in preparing the report. If you use any references, number them and refer to them within your report.