ELEN 460
Computer Laboratory Exercise No: 3
Power System Operations, Maximum Loading

Objective:

To learn the basics of power system operations in the quasi-steady-state (power flow) time frame.

Background

During this lab you'll be learning the basics of operating a small power system in what is known as the quasi-steady-state time frame. That is, how the power system would appear if we neglected all dynamics shorter than say a few seconds, and assuming the system frequency was constant (at 60 Hz). During the experiment you'll be operating two power systems running as a time domain simulation.

Procedure

0. Read through the entire procedure before you start.

1. Start PowerWorld Simulator. Open the Lab3_Bus3 case. This is a three bus, two balancing authority (BA) area case that was demonstrated during lecture. You'll be operating the "Home Area," which consists of buses 2 and 3; the "Other Area" just has bus 1. The case is set to run a four hour time-domain simulation, modeling a load increase between 6am and 10am in the morning. The simulation is set to run at 60 times real-time, meaning the four hour simulation will run in four minutes. The oneline for this system is shown in Figure 1. Note the location of the Start, Pause and Reset buttons in the top menu, and also the simulation time shown on the bottom ribbon.

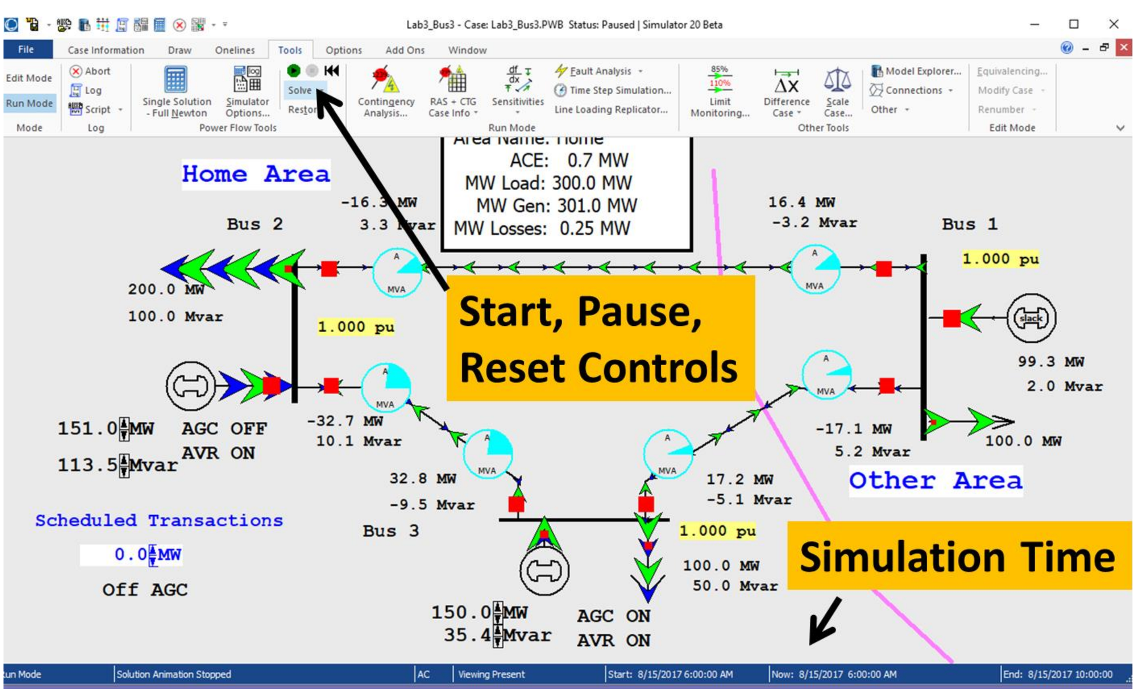

Figure 1: Three Bus, Two Area System

2. Select **Tools, green start arrow** to start the simulation. Notice that the simulation time advances at a rate of 60 times real-time. Observe the simulation with a mind towards answering the questions in the Report Section. When the simulation time gets to about 8am use the red pause button to pause the simulation. Note bus 1 is the slack bus, a concept we'll talk more about in the Chapter 6 material; its purpose here is to insure that for the entire system the total generation is always equal to the total load plus losses.

3. With the simulation paused at about 8am save an image of the oneline. You can do this either by using the Windows Print Screen, or else by right-clicking in a blank area of the oneline to view the local-menu, then selecting **Export Image to File**. You will need to include this image in your report, and also will use it to verify conservation of real and reactive power at all three buses.

4. Again select **Tools, green start arrow** to continue the simulation. Run it until the end (10 am simulation time). Record the simulation time at which any transmission lines reach 100% loading and include these times (if any) in your report.

5. The next step is to consider how changes in the generation and line status affect the system. Reset the simulation by selecting **Tools, reset symbol** (alternatively, you can just reopen the case), and then restart it. Using your engineering judgment play around with the simulation by using the up/down arrows next to the buses 2 and 3 generator MW fields to adjust their generation and by clicking on the red circuit breaker symbols to change their status. Direct your exploration to address the questions that are needed for your report.

6. The next step is to run the system changing the generation in order to keep the area control error (ACE) close to zero. Again reset the simulation. Then, to display the ACE strip chart, right-click on the ACE field in the white box; select **Show Strip Chart**. This shows the Strip Chart Window Options dialog. Select **OK** to use the defaults (if desired you can change the colors to personalize your strip chart). Selecting **OK** will display a strip chart that shows the ACE for the Home Area. Resize and move this window as desired.

7. Start the simulation. Use the up/down arrows next to the buses 2 and 3 generator MW fields to adjust their generation to keep the ACE close to zero. Run the simulation until the end. At the end of the simulation, save an image of your ACE chart. You can do this by right-clicking in an empty portion of the ACE chart, and selecting **Export Image**.

8. As the last step with this case, we'll use automatic generation control (AGC) to automatically control the generation and then will explore the implementation of power transactions. First reset the simulation. Then left-click on the "OFF AGC" field to toggle it to "Part. AGC." This does a participation factor AGC (you'll figure what this is experimentally). Click on the "AGC OFF" (or "AGC ON") fields by each generator to set the field to "AGC ON" to tell the simulation both generators can participate in AGC. Start the simulation. Observe the simulation long enough to address the lab report questions. Pause the simulation once you've gathered sufficient data; feel free to run the simulation multiple times if you need more results to answer the report questions.

9. With the Home Area (and both its generators) on AGC, modify the Scheduled Transactions field to implement power transactions between the Home Area and the Other Area. Play around with the scheduled transactions to address the report questions. Save an image of the oneline showing a non-zero scheduled transaction for your report.

10. Last, in the spirit of friendly competition, we'll consider the 37 bus system (which you'll see again later in the semester) shown in Figure 2. This case is setup so the load, which is originally 1000 MW, continuously increases at a rate of 500 MW per hour of simulation time. This simulation is also set to run at 60 times real-time. So rather quickly the system will reach a point of maximum loadability, which will be indicated by a blackout! The case is also set to show a voltage contour, in which red indicates decreasing voltages. Your goal is to adjust the generation at nine generators (indicated by the magenta background fields) to forestall the inevitable blackout for as long as possible. All generators change at 10 MW per click. Save an image in your report showing that maximum load you achieved at the point of blackout. Feel free to pause the simulation to consider your strategy, and to run the case as many times as time allows (note it may be better just to reload the case after each run rather than trying to reset it). You may wish to run it once initially just to see how it collapses. You may **not** open any loads, but you can open generators and/or transmission lines. We'll see who gets the highest total load! However, only images that have "Total Losses" less than 250 MW will count.

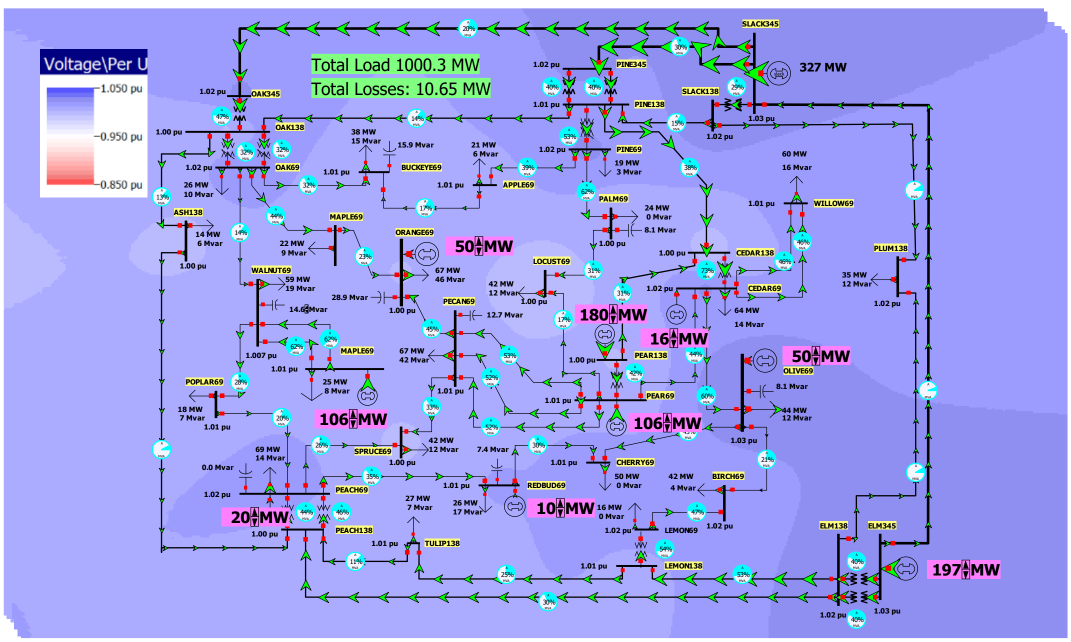

Figure 2: 37 Bus Extreme Loading Scenario Case

Report:

Provide a step by step account of the procedure you followed and the results you have obtained. Answer the following questions in your report.

1. In step 2, comment on what was changing in the simulation and what was not changing. Why?

2. With the image you saved in step 2 when the simulation was paused at 8am, verify the conservation of real and reactive power at all three buses. How does this relate to Kirchhoff's current law? Include this image in your report.

3. In step 4 report the time at which any transmission line reaches 100% loading, and provide an explanation for why. Include the image you saved at the end of the simulation in your report.

4. In your report, address what insights about the system you gained from your step 5 exploration. Example topics you might address include how changes in the generation affect the line flows or how changes in line status affect the system losses.

5. For step 7, turn in a copy of your ACE chart. Why was the ACE changing? Were both generators equally affective in modifying the ACE? Which ones did you use? Why? What would have happened to the ACE if one of the generators had opened?

6. For step 8, how is the ACE now varying? How is AGC adjusting the outputs of the two generators?

7. For step 9, how does a scheduled transaction affect the power flow on the tie lines, and how does it affect the ACE? Include an image showing the system with a scheduled transaction. Do you think there is a limit on the transaction amount? Is it impacted by the system loading?

8. Recognizing that no simulation can exactly duplicate reality, comment on which aspects of this simulation seem most realistic and which seem to be least realistic.

9. For the 37 bus case, what was your maximum load level? Turn in a screenshot of your system at the blackout point. Comment on the strategy you used to maximize you system's loading.