ECEN 460 Lab 10
Transient Stability and Power System Dynamics on Small and Medium Sized Systems

Objective:

Gain experience and insights in the use the transient stability simulation software. In this lab transient stability simulations will be used two small systems and on a 2000 bus systems to determine critical clearing times, to look at the impact of generator losses on system frequency and to consider methods to prevent short-term voltage collapse.

The last part of the lab uses the PowerWorld Dynamics Studio (DS) to do interactive transient stability type power system simulations. The free 42 bus education version of the package is available at https://www.powerworld.com/gloveroverbyesarma.

Background on 37 Bus APL System

As was the case with the previous lab, we'll start working with the 37bus system modeling the fictional Aggieland Power and Light (APL) grid; its oneline is shown in Figure 1.

Figure 1: 37 Bus APL System

Procedure for Running Transient Stability on the APL System

1. Start PowerWorld Simulator. Open the Lab10_AGL_TS case. The system has been setup to run transient stability with several contingencies predefined for the lab. Select **Add Ons, Transient Stability** to display the Transient Stability form. This will be used throughout the lab to do the transient stability simulations. This is shown in Figure 2.
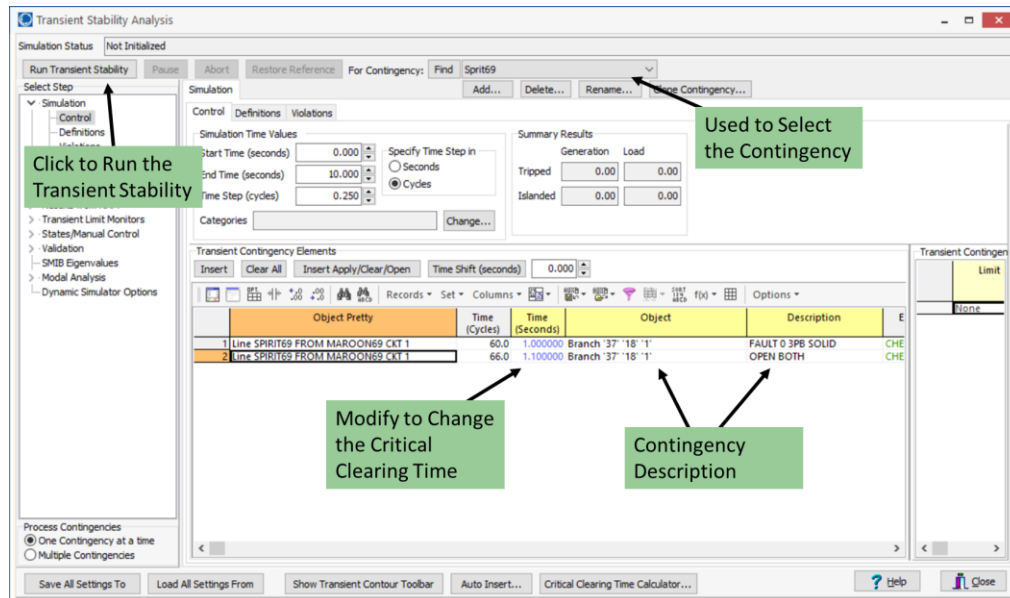

Figure 2: Transient Stability Form

2. For the first transient stability contingency, select the Sprirt69 contingency. This contingency applies a balanced three-phase fault at time equals 1.0 seconds right at the terminal of one of the 69 kV transmission lines going into the Spirit substation. After 0.1 seconds the fault is cleared by opening the transmission line. To do the transient stability run, click on the **Run Transient Stability** button. At the end of the simulation a graph will appear showing the time-varying generator rotor angles. Save a copy of this graph for your report.

3   Iteratively change the time the transmission line is opened to determine the critical clearing time for this fault (to a precision of 0.01 seconds – critical time is defined as the longest time the fault can be applied without one of the generators losing synchronism). The critical clearing time is the time difference between when the fault is applied (i.e., time = 1.0 seconds) and that largest clearing time. Save a copy of the rotor angle graph for the critical clearing time for your report, and record the critical clearing time.

4. Change the output of the Sprit69 generator from 80 to 40 MW, and repeat step 3. In your report comment on why such a change result in a different critical clearing time.

5. Re-open the Lab10_AGL_TS case and the Transient Stability Form. Change the contingency to Kyle138, which simulates a fault on the 138 kV transmission line between the Kyle and WEB substations, which is also cleared by opening the line. Again calculate the critical clearing time for this fault, saving a copy of the graph for your report.

6. Next, change the assumed H value for the Kyle138 generator. There are several ways to do this. One is to right click on the generator on the oneline and select **Generator Information Dialog**. On the **Stability, Machine Models** page change the **H** value from

3.0 to 6.0. Select **OK** to save your change and close the dialog. Again calculate the critical clearing time for the Kyle138 contingency. Did the change in the critical clearing time match your expectations?

Background on the 2000 Bus TSGC System

This is the same Texas Synthetic Grid Company (TSGC) 2000 bus system you used in in previous labs though again the operating conditions are different; its online is shown in Figure 3. In this portion of the lab you'll be considering some of the dynamic aspects of the system.
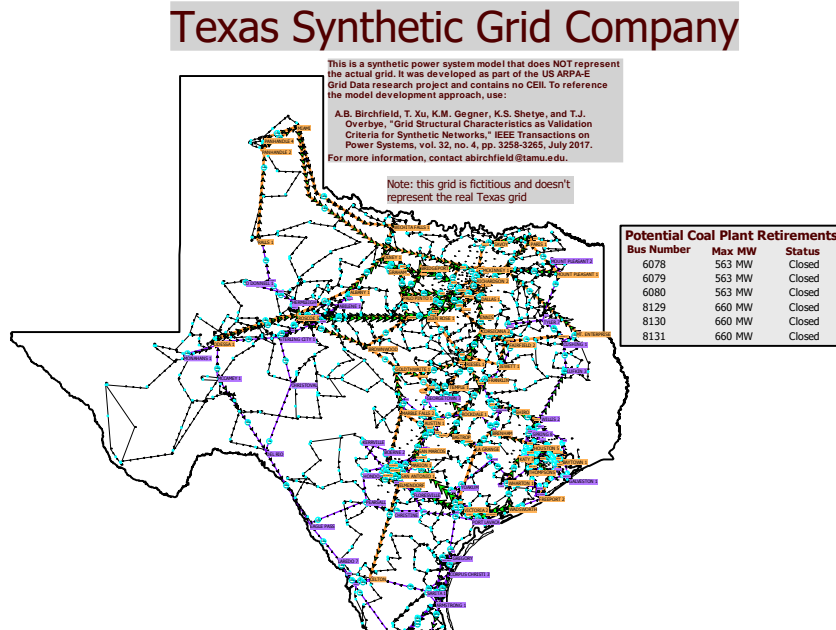
Figure 3: TSGC Lab 10 System

Procedure for TSGC Transient Stability

1. Open up the Lab10_TSGC_GenDrop case, open the Transient Stability Form, and run the "Gen Drop 1350 MW" contingency. This contingency simulates the loss of the largest generator in the system, a 1350 MW nuclear power plant. This contingency does a 20 second simulation (because it is a larger case it does take a little bit of time to run the simulation). During the simulation you'll see a graph showing the time-varying frequency at ten high voltage buses. At the end of the simulation you'll see three additional graphs. One shows the time-varying frequency at all 2000 buses in the system, the second shows the per unit voltage magnitudes at ten high voltage buses, and the last shows the per unit voltage magnitude at all the buses in the system.   Make a note of the lowest bus frequency and the lowest per unit bus voltage magnitude. Save a copy of the graph showing the frequency at all the system buses for inclusion in your report.

2. Next, change the contingency to "Gen Drop 2700 MW Together." This contingency simulates the loss of the two largest generators in the system, consisting of two 1350 MW nuclear power plants located at the same substation. The same four graphs are shown at the end of the simulation. Again note the lowest bus frequency and lowest per unit bus voltage magnitude. Save a copy of the graph showing the frequency at all buses for your report. In your report contrast the two contingencies. Based on these two results, do the responses seem to be proportional to the amount of generation lost?

3.   Next, change the contingency to "Gen Drop 2700 MW Separate."   This contingency also simulates the loss of 2700 MW of generation.   However, now the losses occur in two different locations in the system (the original 1350 MW nuclear power plant from step 1 located on the Texas Gulf Coast and a total of 1350 MW of generation being supplied by several generators at a plant in West Texas).   Again note the lowest bus frequency and lowest per unit bus voltage magnitude, and save a copy of the graph showing the frequency at all buses for your report. In your report contrast the 2700 MW contingencies. Which one seems to be the more severe contingency?

4.   Finally, an issue that is currently confronting the electric power industry is the transient stability impacts due to the retirements of potentially large amounts of coal generation. For example, in the actual ERCOT system more the 4 GW of coal plant retirements have been announced in October 2017.   In this step you will briefly consider the impact of retirements on our lab 10 synthetic grid. Using the table shown on the oneline to the east of Texas, open at least 2000 MW of generator capacity (your choice of which ones to open), and then rerun the "Gen Drop 2700 MW Together" contingency. Again note the lowest bus frequency and lowest per unit bus voltage magnitude, and save a copy of the graph showing the frequency at all buses for your report. In your report contrast the two contingencies. To open a generator from the oneline table you will need to right-click on a field, select **Generator Dialog**, change its **Status** to Open, and click **OK.** Opening generators will change the power flow solution with the change in generation picked up at all the other generators in the system except the ones involved in the transient stability contingencies.

Interactive Simulations Using PowerWorld Dynamics Studio (DS)

In this portion of the lab you'll gain experience on power system dynamics through interactive simulations done using PowerWorld Dynamics Studio (DS).

Procedure for 42 Bus Tornado Case

1.   Start PowerWorld DS, and open the Bus42_Tornado case. This runs a real-time simulation on a 42 bus, 345 and 138 kV case in which a tornado is assumed to move through the center of the system. Starting at ten seconds of simulation time, the tornado rapidly outages three 345 kV lines, and also takes out the supply to a 500 MW wind farm. Your job is to prevent the system from experiencing a blackout by shedding the least amount of load. The oneline for this system is shown in Figure 4. If an initial contour is not shown, right-click on a blank portion of the oneline and select **Contouring**. This displays the Contour Options dialog. Just click **OK** to accept the defaults and display the contur.

2.   Initially just watch the simulation. To do this, select **Simulation Control, Start**. At ten seconds in you'll see a red flash due to the low voltages caused by the first tornado induced transmission line fault. The power system should blackout at a simulation time of about 90 seconds (with the simulation time shown at the top as seen in Figure 4). The simulation models a simple protection system in which overloaded transmission lines are eventually opened using an inverse time relationship (i.e., so more heavily loaded lines trip quicker) and generators can trip because of various other protection systems. The time variation in selected bus voltage magnitudes and frequencies is shown in two strip chart displays as seen in Figure 4.

3.   Now it is your turn. Select **Simulation Control, Reset and Start.** This restarts the simulation. Since the transmission lines are assumed to have tripped and locked out so

they cannot be reclosed (including the wind farm), in this scenario your only control possibilities are to open up loads. You can do this either by left-clicking on the load's red circuit breaker symbol (if necessary zoom and pan as in PowerWorld Simulator) or by right-clicking on the load itself and the selecting **Load Dialog**, which displays the Load Information Dialog with an example shown in Figure 5. Then left-click the **Open Device** button to shed the load. Try to save the system by shedding the minimum amount of load! At any time you can pause the simulation by selecting **Simulation Control, Pause**. Then select **Simulation Control, Continue** to continue.
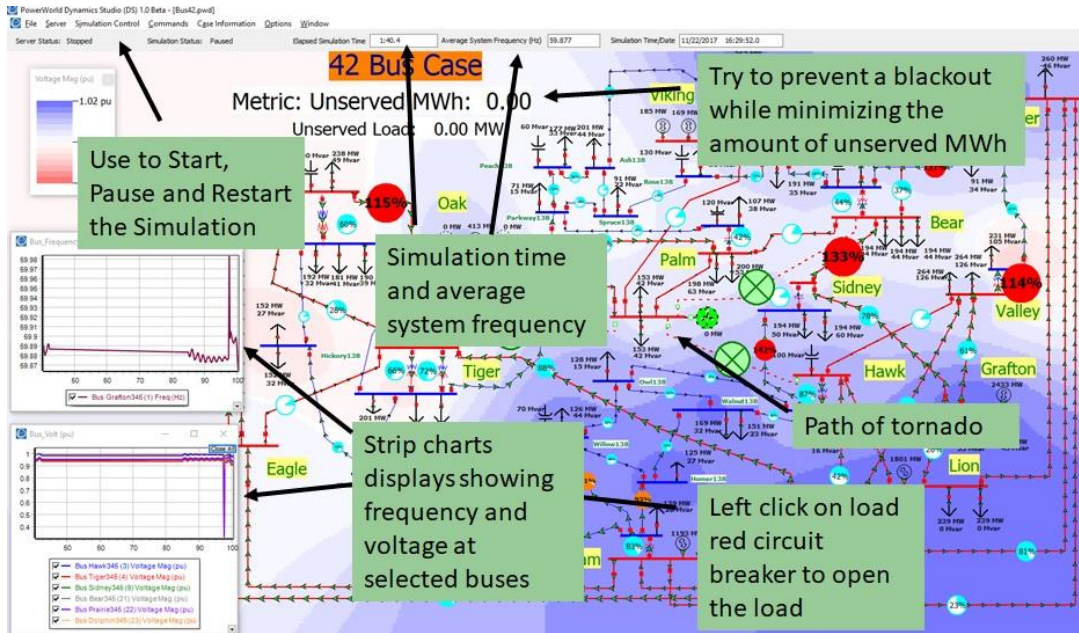

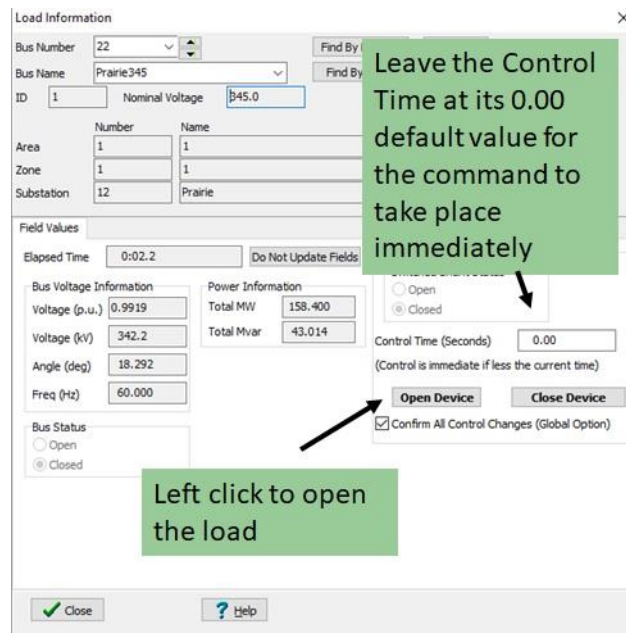Figure 4: 42 Bus Tornado Scenario

Figure 5: DS Load Dialog

4. Iterate through the scenario a number of times trying to develop an optimal strategy. Save a copy of the display at either the end of the simulation or at the time of blackout

with your best strategy for inclusion in your report. Just use the Windows Print Screen function (ALT + Print Screen) to do this. Don't spend too much time on this step, no more than say five iterations. Just do the best you can!

Procedure for 2000 Bus TSGC Tornado Case

1.   Start PowerWorld DS, and open the Lab10_TSGC_DS case. This runs a real-time simulation on a modified version of the 2000 bus TSGC system. The scenario here is again a tornado moving through the system, this time by a 500 kV substation west of Fort Worth, Texas. Starting at ten seconds of simulation time, the tornado rapidly outages three 500 kV lines. Your job is again to prevent the system from experiencing a blackout by either changing generation (which may involve opening the generator) or shedding the least amount of load. The oneline for this system is shown in Figure 6. If an initial contour is not shown, right-click on a blank portion of the oneline and select **Contouring**. This displays the Contour Options dialog; click **OK** to add the contour.
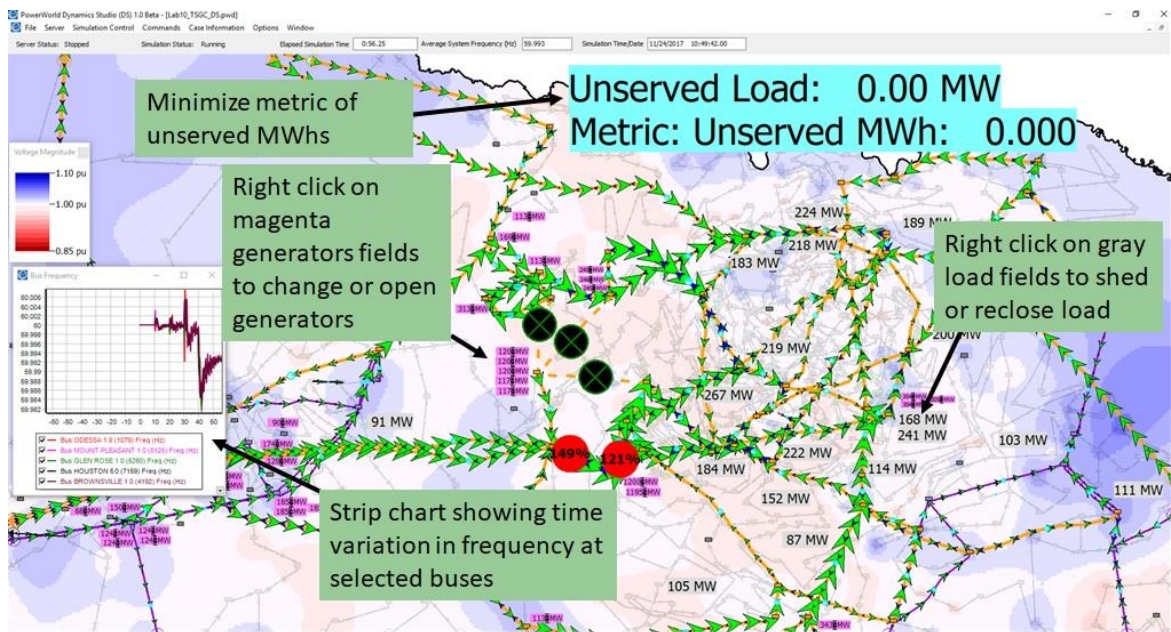

Figure 6: DS TSGC Scenario Oneline

2.   Again initially just watch the simulation selecting **Simulation Control, Start**. The first line will open at ten seconds.   The power system should blackout at a simulation time of about 100 seconds. This simulation also models a simple protection system in which overloaded transmission lines are eventually opened using an inverse time relationship (so more heavily loaded lines trip quicker). The time variation in selected bus frequencies is shown in the strip chart display.

3.   Now try to prevent the blackout for the 200 second duration of the simulation. To restart the simulation select **Simulation Control, Reset and Start.** In this scenario you can either change the outputs of the generators, open the generators, or change the status of the loads. To change the generation, right-click on the magneta generator MW fields shown on the oneline. This displays the Generator Information Dialog with an example shown in Figure 7. To change the MW setpoint for the generator, enter a value into the **Power Setpoint (MW)** field that is in the range between the minimum and maximum MW limits. Then click the **Change Real Power (MW) Setpoint** button. To open the

generator click on the **Open Device** button. Note that once a generator is opened you cannot reclose it for the duration of the simulation.

To shed load right click on the gray load fields shown on the oneline, with each field displaying the amount of load that will be shed. This displays the Load Information dialog. Click the **Open Device** button to shed load. Note, you can also use the **Close Device** button to reclose load that you had previously shed (which will help to minimize the Unserved MWh metric). Try to save the system, with the metric being the total unserved MWh of load.

4. Iterate through the scenario a number of times, trying to develop an optimal strategy. Save a copy of the display at either the end of the simulation or at the time of blackout with your best strategy for inclusion in your report.
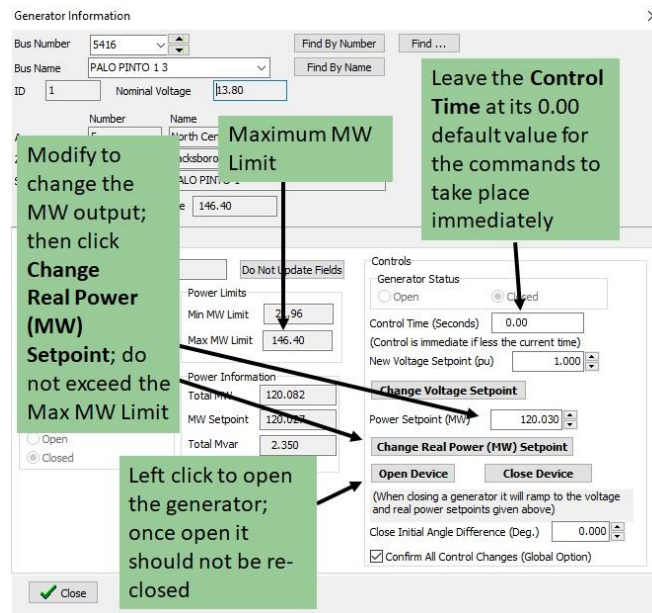

Figure 7: Generator Dialog

Report:

For both the APL and TSGC systems, provide a summary of the procedures you followed and the results you obtained.

For the DS scenarios, describe the strategy you used to solve the scenarios. What additional information would have been helpful to have in developing your optimal strategy?