ECE 421

Final Project

December 2019

Project Rules:

- You may work with up to two other students on this project.
- Please turn in one report per team
- Describe the role each team member played working on the project
- DUE: Thursday December 19 at 11:59pm

Part 1. You are given the 13 bus power system shown below. The transmission system operates at 230 kV.
A. Build a Ybus matrix for this system appropriate for power flow analysis, and write out the power flow equations for BUS 1 in rectangular form.

B. Implement this system in Powerworld. Set BUS 3 as the slack bus. Compare your Ybus from part A with the one from Powerworld.
   • Implement loads as constant PQ loads
   • Enter lines based on impedance and admittance per length and let Powerworld calculate per unit values.
C. Run power flow case with the following set points:
   1. Set each generator to regulate terminal voltage to 1.03 pu
   2. Set the generator power outputs as follows (remember no setpoint for slack bus). Generators named for the bus they are connected to.

\[ P_{\text{gen1}} := 180\text{MW} \quad P_{\text{gen6}} := 40\text{MW} \quad P_{\text{gen10}} := 180\text{MW} \quad P_{\text{gen12}} := 50\text{MW} \]

D. Your system model is correct if you can match these results. Generators and loads are numbered based on the bus they are connected to.

\[ \angle (\text{mag}, \text{ang}) := \text{mag} \cdot \text{cos} (\text{ang} \cdot \text{deg}) + j \cdot \text{mag} \cdot \text{sin} (\text{ang} \cdot \text{deg}) \quad \text{MVAR} := \text{MW} \]

\[ V_{\text{BUS1}} := 1.0300 \angle (-27.63\text{deg}) \quad V_{\text{BUS10}} := 1.0300 \angle (-37.71\text{deg}) \quad Q_{\text{gen10}} := 150.04\text{MVAR} \]

\[ V_{\text{BUS2}} := 1.0114 \angle (-2.59\text{deg}) \quad V_{\text{BUS11}} := 0.9295 \angle (-28.28\text{deg}) \quad Q_{\text{gen12}} := 207.99\text{MVAR} \]

\[ V_{\text{BUS3}} := 1.0300 \angle (-30.00\text{deg}) \quad V_{\text{BUS12}} := 1.0300 \angle (-56.78\text{deg}) \quad P_{\text{gen3}} := 307.12\text{MW} \]

\[ V_{\text{BUS4}} := 1.0094 \angle (-3.39\text{deg}) \quad V_{\text{BUS13}} := 0.8866 \angle (-33.29\text{deg}) \quad P_{\text{loss}} := 12.1\text{MW} \]

\[ V_{\text{BUS5}} := 0.9600 \angle (-13.30\text{deg}) \quad Q_{\text{gen1}} := 46.20\text{MVAR} \quad Q_{\text{loss}} := 153.8\text{MW} \]

\[ V_{\text{BUS6}} := 1.0300 \angle (-38.66\text{deg}) \quad Q_{\text{gen3}} := 115.17\text{MVAR} \]

\[ V_{\text{BUS7}} := 0.8599 \angle (-20.16\text{deg}) \quad Q_{\text{gen6}} := 37.68\text{MVAR} \]

\[ V_{\text{BUS8}} := 0.9344 \angle (-14.44\text{deg}) \quad P_{\text{gen1}} + P_{\text{gen3}} + P_{\text{gen6}} + P_{\text{gen10}} + P_{\text{gen12}} = 757.12\cdot\text{MW} \]

\[ V_{\text{BUS9}} := 0.9612 \angle (-12.92\text{deg}) \quad Q_{\text{gen1}} + Q_{\text{gen3}} + Q_{\text{gen6}} + Q_{\text{gen10}} + Q_{\text{gen12}} = 556.99\cdot\text{MVAR} \]
Analysis of the results of base case power flow results:

- The voltage magnitudes at BUS 7, BUS 8, BUS 11 and BUS 13 are all below 0.95pu
- Generator 6, Generator 10, Generator 12 are all overloaded when add P+jQ
- Transformers between BUS5-BUS6, BUS7-BUS8 and BUS9-BUS10 are at 100% or higher loaded. Two others are close

**Do not go on to part 2 until you complete part 1. If you can't match the results above (to at least 3 decimal places on the voltages), you won't be able to correctly do the rest of the problem!**

- You can turn in part 1 once you have finished it, and then I will send you my solution to work from for the rest of the problem.

Part 2: The system of part 1 clearly has some problems.

A. Consider the following solutions to see if you can alleviate the problems. Propose and test modifications to bring all voltages to within tolerances under the base case conditions, and with the line from BUS9 to BUS11 or the line from BUS5 to BUS11 out of service or the generator at BUS 10 out of service.

Options for correcting the problems (you can do one or more of these). You don't have to try all. Write a summary each case you try. Provide tables with the power flow results with the same information as listed above.

1. Add a second line between BUS 9 and BUS 11
2. Add a second line between BUS 5 and BUS 11
3. Add capacitor bank at BUS 9, include the MVAR rating that was needed
4. Add capacitor bank at BUS 7, include the MVAR rating that was needed
5. Add capacitor bank at BUS 11, include the MVAR rating that was needed
6. Add a capacitor bank at BUS 13, include the MVAR rating that was needed
7. Change the generator voltage or power setpoints (the max voltage set point if 1.05).
8. Adding series compensation or a phase shifting transformer in one or more of the lines
9. Adding another generator at an existing bus (MVA rating up to 100 MVA)
10. Replacement of a transformer with a higher or lower MVA rating.
For any case you test, check for system violations (in Powerworld in Run Mode: Tools: Other Tools-->Limit Monitoring

Look for:

- What is the pu value of the highest bus voltage?
- What is the pu value of the lowest bus voltage?
- What is the smallest nonzero Percent of Limit Used line or transformer?
- What is the largest Percent of Limit Used line or transformer?

B. Have Powerworld perform an N-1 Contingency analysis (in Run Mode: Tools-->Contingency Analysis.)

List any unsolveable Contingencies or cases with extreme low voltages.