ECEN 615 Problem Set #2 Fall 2018

Due 9/27/18

1. Using a programming environment of your choice (such as Matlab, Scilab or Python) write a Newton-Raphson power flow, and use it to solve the five bus system presented in class. You can either hard code the five bus system data in your program, or you can input it from, say, text files. The input is the per unit power for the PQ buses, the voltage setpoints for the generators, and the transmission line and transformer π-model parameters. You need to code PQ, PV and (obviously) a slack bus. However, you do not need to code generatror reactive power limits. Use a flat start initial guess, except set the PV bus voltage to the generator setpoint voltage. Your output should be a list of the bus voltage magnitudes and angles at each iteration. Also calculate the reactive power output for the generators and the real power output for the slack bus generator. Use a 100 MVA per unit base, and use a per unit convergence value of 0.1 MVA. Turn in the output and a complete listing of your program.

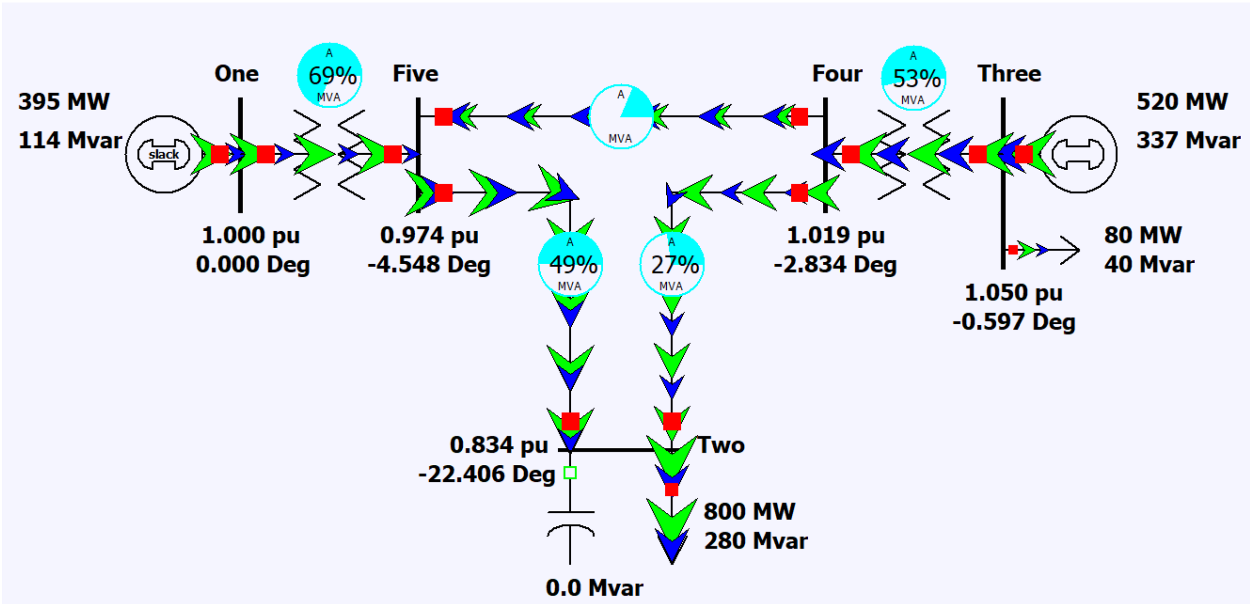
   Solution: Using any of the stated programming software to implement the Newton-Raphson code for solving the power flow, voltage magnitude and angle at all buses are obtained as:

Buses	Voltage Mag.	Voltage Ang.	
	(P.U.)	(Rad.)	(Deg.)
1	1.000	0.000	0.000
2	0.834	-0.391	-22.408
3	1.050	-0.010	-0.600
4	1.019	-0.049	-2.840
5	0.974	-0.079	-4.550

   To compute generator real and reactive powers at buses 1 and 3, plug in the computed states (i.e. voltage magnitudes and angles) and Ybus entries in the power flow equations at the different buses. E.g., at the generator slack bus, G1 (where $P_{D1} = Q_{D1} = 0$),

$$P_{G1} = V_1V_5(G_{15}\cos(\theta_1-\theta_5)+B_{15}\sin(\theta_1-\theta_5))+V_1^2G_{11}+P_{D1}$$
$$Q_{G1} = V_1V_5(G_{15}\sin(\theta_1-\theta_5)-B_{15}\cos(\theta_1-\theta_5))-V_1^2B_{11}+Q_{D1}$$

	Gen. @ slack 1	Gen. @ bus 3
Real Power, P (p.u.)	3.948	5.200
Reactive Power, Q (p.u.)	1.143	3.375

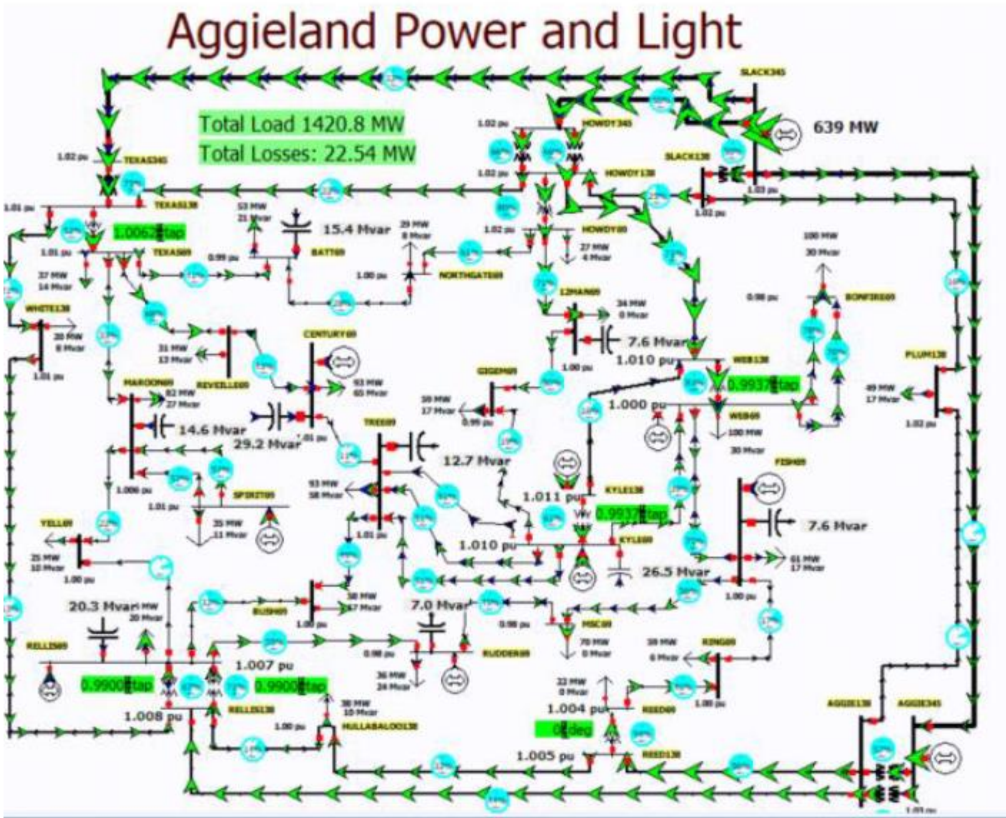


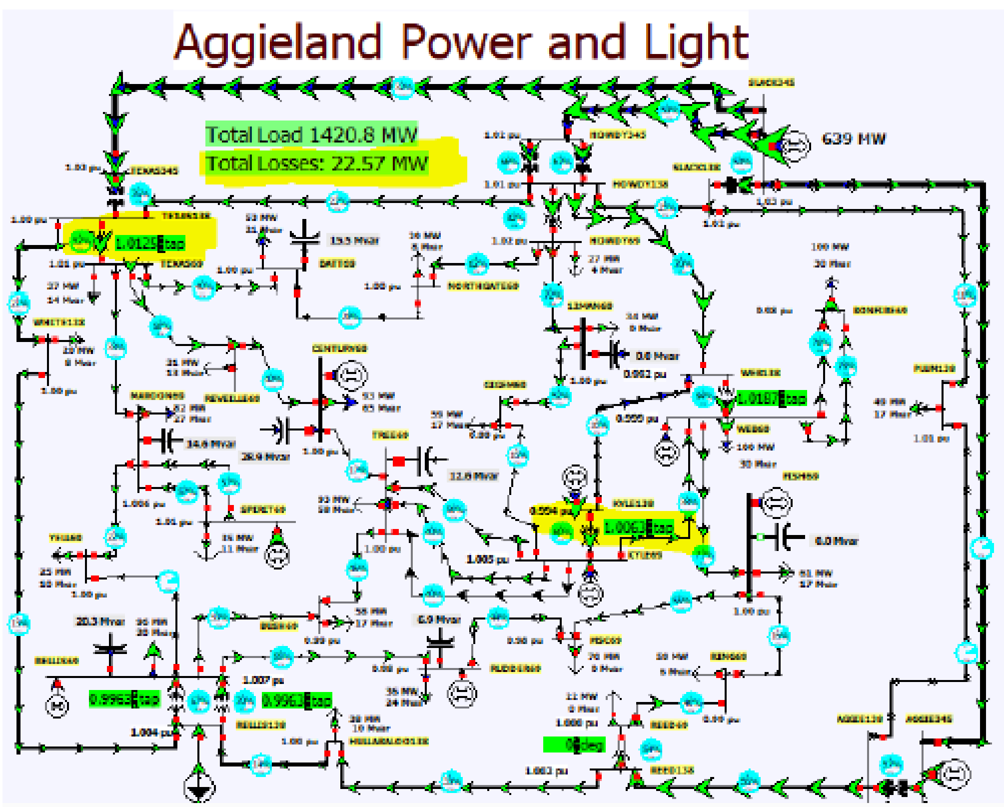
2. In PowerWorld using the case Aggieland37 manually try to minimize the system losses by adjusting 1) the phase shifter at the REED substation, 2) the status of the capacitors, and 3) the LTCs at the TEXAS, WEB, KYLE and RELLIS substations. Turn in your minimum losses and an explanation of the manual procedure that you used to determine the minimum lossesl. Also, explain why you think your solution actually minimizes the losses.

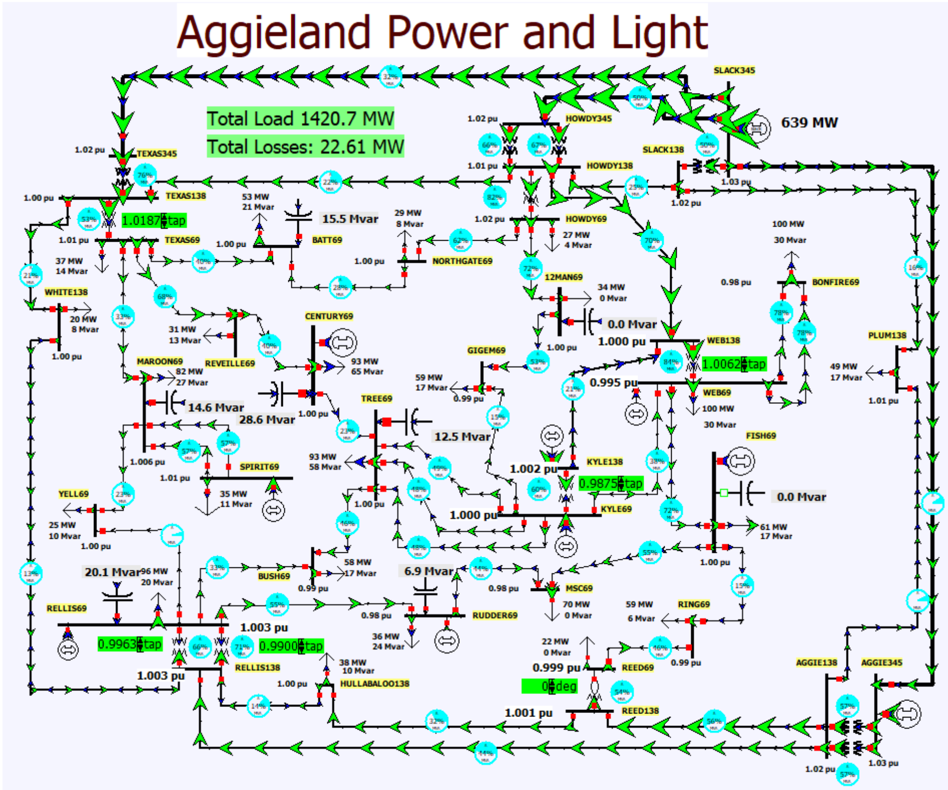
Explanation: Shunt capacitors are local sources of reactive power. By switching them ON, the demand for reactive power sourced from long distances can be reduced, thus decreasing I2R line losses. Further system loss reduction is achieved by adjusting LTC tap settings, which have the effect of controlling line reactive power flow and boosting node voltages. This has an added effect of reducing system losses. While phase-shifting transformers control real power flow, the phase shift setting of 0.0 degrees in the given PowerWorld case appears to be optimal for system loss – a change in either direction of the phase angle increases the total loss.

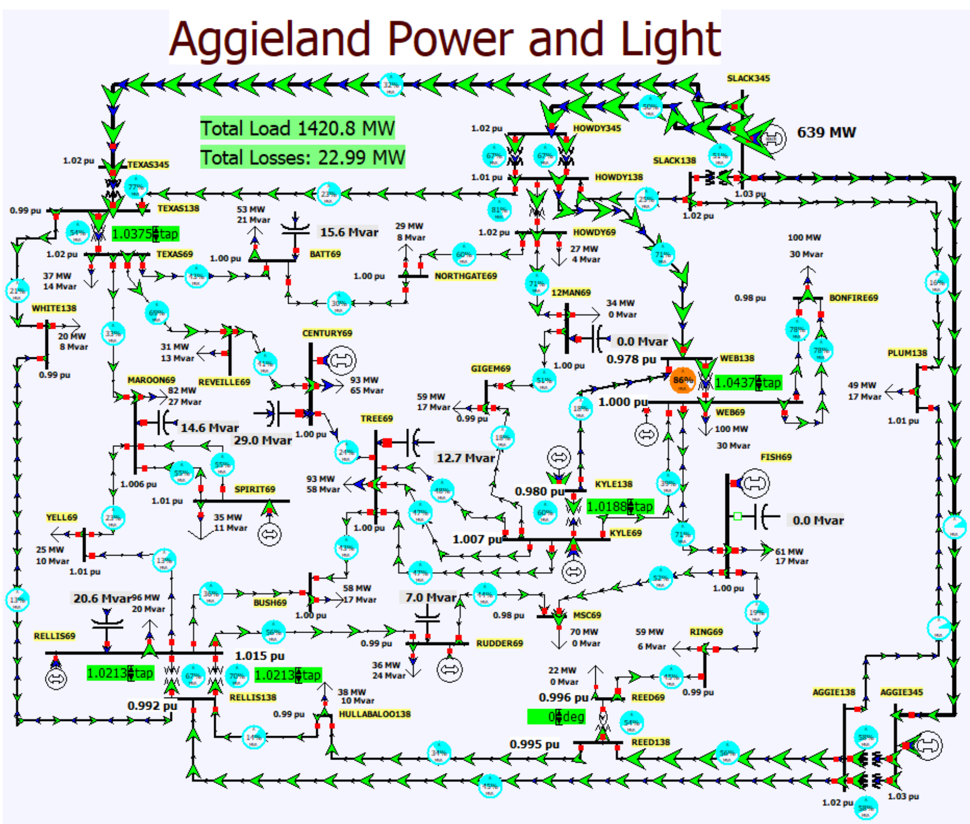
Strategy for loss minimization in the given case: First switch in shunt capacitors to supply local vars. Then, compare different combinations of tap settings of all LTCs in the system. Check for circulating var flows, and adjust LTC taps to reduce them. Arrive at a minimum system loss.

Note: While an outage of some of the lines can reduce system losses, this will often result in fewer loads served, and hence defeating the purpose of a reliable system. Thus, line removal is discouraged.


Aggieland Power and Light
Total Load 1420.8 MW
Total Losses: 22.54 MW
639 MW
15.4 Mvar
7.6 Mvar
14.6 Mvar
29.2 Mvar
12.7 Mvar
7.6 Mvar
26.5 Mvar
20.3 Mvar
7.0 Mvar
1.0062 tap
0.9937 tap
0.9900 tap
1.010 pu
1.000 pu
1.011 pu
1.007 pu
1.008 pu
1.004 pu
1.005 pu
0 deg


Aggieland Power and Light
Total Load 1420.8 MW
Total Losses: 22.57 MW
639 MW
1.0125 tap
1.0187 tap
1.0062 tap
0.9963 tap
1.007 pu
1.004 pu
0 deg


Aggieland Power and Light
Total Load 1420.7 MW
Total Losses: 22.61 MW
639 MW
SLACK345
HOWDY345
TEXAS345
SLACK138
HOWDY138
TEXAS138
HOWDY69
TEXAS69
15.5 Mvar
BATT69
NORTHGATE69
12MAN69
0.0 Mvar
WEB138
1.0062 tap
WEB69
BONFIRE69
PLUM138
WHITE138
MAROON69
REVEILLE69
CENTURY69
14.6 Mvar
28.6 Mvar
TREE69
12.5 Mvar
GIGEM69
KYLE138
0.9875 tap
KYLE69
FISH69
SPIRIT69
YELL69
BUSH69
6.9 Mvar
MSC69
RUDDER69
RING69
20.1 Mvar
RELLIS69
0.9963 tap
0.9900 tap
RELLIS138
HULLABALOO138
REED69
REED138
0 deg
AGGIE138
AGGIE345
1.0187 tap


Aggieland Power and Light
Total Load 1420.8 MW
Total Losses: 22.99 MW
639 MW
SLACK345
HOWDY345
TEXAS345
SLACK138
HOWDY138
TEXAS138
HOWDY69
TEXAS69
1.0375 tap
15.6 Mvar
BATT69
NORTHGATE69
12MAN69
0.0 Mvar
WEB138
1.0437 tap
WEB69
BONFIRE69
PLUM138
WHITE138
MAROON69
REVEILLE69
CENTURY69
14.6 Mvar
29.0 Mvar
TREE69
12.7 Mvar
GIGEM69
KYLE138
1.0188 tap
KYLE69
FISH69
SPIRIT69
YELL69
BUSH69
7.0 Mvar
MSC69
RUDDER69
RING69
20.6 Mvar
RELLIS69
1.0213 tap
1.0213 tap
RELLIS138
HULLABALOO138
REED69
REED138
0 deg
AGGIE138
AGGIE345