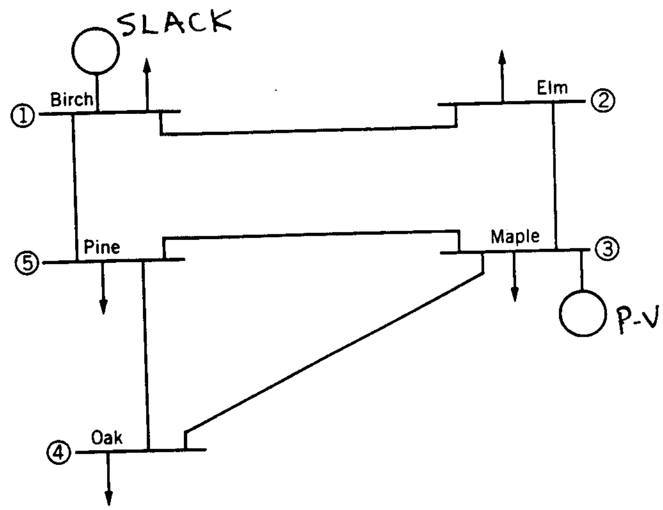
ASPEN (Loadflow) Exercise EE5200

Note: Some delay in getting remote licenses. See e-mail for details on software & submission deadline.

The purpose of this laboratory is to gain insight into the operation of a utility power grid. A simple 5-bus system is to be analyzed using a Newton-Raphson power flow program. Operating problems are to be identified and various means of correcting them shall be explored.

The basic system is given as:

$MVA_{BASE} = 100\,MVA$



Bus	Generation P, MW	Generation Q, Mvar	Load P, MW	Load Q, Mvar	(INITIAL VALUES) V, per unit	Remarks
1	....	....	65	30	$1.04\angle 0^\circ$	Swing bus
2	0	0	115	60	$1.00\angle 0^\circ$	Load bus (inductive)
3	180	....	70	40	$1.02\angle 0^\circ$	Voltage magnitude constant
4	0	0	70	30	$1.00\angle 0^\circ$	Load bus (inductive)
5	0	0	85	40	$1.00\angle 0^\circ$	Load bus (inductive)

Gen Q_{max}/Q_{min}: +1.2/−0.6 p.u.

Line, bus to bus	Length km	Length mi	R Ω	X Ω	R per unit	X per unit	FULL [redacted] - LINE Charging Mvar†
1–2	64.4	40	8	32	0.042	0.168	4.1
1–5	48.3	30	6	24	0.031	0.126	3.1
2–3	48.3	30	6	24	0.031	0.126	3.1
3–4	128.7	80	16	64	0.084	0.336	8.2
3–5	80.5	50	10	40	0.053	0.210	5.1
4–5	96.5	60	12	48	0.063	0.252	6.1

Max Line Flow: 1.0 per unit

† At rated (i.e. 1.0 p.u) voltage.

Background
Ideally, one likes to maintain the bus voltages between 0.95 and 1.0 per unit. Machine power factor should be 0.85 and within Q_{min}/Q_{max} limits. All bus voltage angles should be within 45° of each other. (Theoretically the internal torque angles must be less than 90° apart to maintain stability.) If these criteria are not met, one can adjust generator output or excitation, or adjust transformer tap settings. If the economics are justified, equipment could also be added to the system, such as additional lines, shunt capacitor banks, shunt reactors, synchronous condensors, series condensors, etc. Advanced strategies include the use of static var compensators and other thyristor-based devices.

PART I

1) Your lab instructor will provide you with the input data files for the above data case and explain how to run the power flow program. Obtain the output for this case.
   - Explain why the P & Q flow from Bus 1 to 2 is not equal to that from Bus 2 to 1.
   - What is the efficiency of this system?
   - Identify any directly obvious problems with the operation the this system.
   - Speculate on any contingency problems, i.e. what if one line is lost? What could the consequences be?

2) Find the size of the shunt capacitance (in per unit MVAR) necessary to raise the voltage of Bus 4 up to 0.95 per unit. Save this as a separate data case.
   - Explain how shunt capacitance is added to a bus in this program.
   - Does the program differentiate between the shunt MVAR of the capacitor and that of the line charging susceptance?
   - Is there a way to directly determine the value of this capacitance, if one knows the values of the system impedance matrix? (This would avoid a tedious trial and error approach).

3) Going back to the initial case, add a sixth bus between buses 5 and 4. Connect a tap-changing transformer of X = j0.04 per unit between bus 5 and the new bus. Orient the transformer so the tap changer faces the new bus. Disconnect Line 4-5 and reconnect it between Bus 4 and the new bus.
   - Experiment with tap values between 0.9 and 1.1 with the goal of bringing the Bus 4 voltage up to 0.95 per unit. Find the tap setting required. Save this as a separate case.
   - If the tap were oriented toward Bus 5, what tap setting would be required?
   - Report on the effect that transformer tap position has on the flow of P & Q between Buses 4 & 5.

4) Going back to the original data case, try to solve the voltage problem at Bus 4 by adding additional line(s) between various buses. Use line impedances equal to that of Line 3-4. Save this as a separate data case.
   - State where the line(s) were added to correct the voltage problem.
   - Is this better than capacitors? What is the effect of the new lines vs. the capacitors on system losses and efficiency?

PART II

5) Starting with the system obtained above in part 4, try taking out one line at a time and state any system problems created by the loss of each line. Also recommend fixes for these problems. Discuss these problems in terms of the location of generation, location of load, and line impedances.

6) Starting with the system from part 4, solve the following:
   - Someone wants to add a substation and load. This bus will be tied to Bus 2 and Bus 5. Tie lines will be the same impedance as Line 3-4. How much load at 0.8 PF lag can be added before the system has problems?
   - What is the first operating constraint to be reached? Comment on other possible problems that become more likely as the load increases.

7) Going back to the initial study, assume that the case given is for peak load. Reschedule the plant outputs to maintain voltage if the loads are reduced to 50% at the same power factor. Will shunt reactors or capacitors have to be added to control the voltage?

8) Going back to the initial study, do system losses go up or down as the generator power at Bus 3 is increased 2%? Do system losses go up or down if the voltage at Bus 3 is increased 2%? Explain why these effects are observed.