Homework #1, EE 553, Fall 2012, Dr. McCalley, Due Wednesday August 29

1. Problem 4.1a in the book.
2. Before working this problem, you may review page 102 of your W&W text (note that in class, we use V to denote voltages whereas your W&W text uses E to denote voltages).
   Observe that Jacobian derivative expressions given by equations T7.47 and T7.53 in your notes are almost the same. Also observe that Jacobian derivative equations T7.49 and T7.51 in your notes are almost the same. These two sets of equations are given below.

$$J_{jk}^{P\theta} = \frac{\partial P_j(\underline{x})}{\partial \theta_k} = |V_j||V_k|\left(G_{jk}\sin(\theta_j-\theta_k) - B_{jk}\cos(\theta_j-\theta_k)\right) \qquad \text{(T7.47)}$$

$$J_{jk}^{QV} = \frac{\partial Q_j(\underline{x})}{\partial |V_k|} = |V_j|\left(G_{jk}\sin(\theta_j-\theta_k) - B_{jk}\cos(\theta_j-\theta_k)\right) \qquad \text{(T7.53)}$$

$$J_{jk}^{Q\theta} = \frac{\partial Q_j(\underline{x})}{\partial \theta_k} = -|V_j||V_k|\left(G_{jk}\cos(\theta_j-\theta_k) + B_{jk}\sin(\theta_j-\theta_k)\right) \qquad \text{(T7.49)}$$

$$J_{jk}^{PV} = \frac{\partial P_j(\underline{x})}{\partial |V_k|} = |V_j|\left(G_{jk}\cos(\theta_j-\theta_k) + B_{jk}\sin(\theta_j-\theta_k)\right) \qquad \text{(T7.51)}$$

   a. What is the difference between the right-hand-side expression of T7.47 and that of T7.53? What is the difference between the right-hand-side expression of T7.49 and that of T7.51?
   b. Modify (T7.53) to revise the Jacobian element to $J'^{QV}_{jk} = |V_k|\frac{\partial Q_j(\underline{x})}{\partial |V_k|}$
   c. Modify (T7.51) to revise the Jacobian element to $J'^{PV}_{jk} = -|V_k|\frac{\partial P_j(\underline{x})}{\partial |V_k|}$
   d. Express the relations in (T7.42e) below to account for the two modifications made above. This requires that you express the new Jacobian submatricies $J^{PV,new}$ and $J^{QV,new}$ in terms of its revised elements (from parts (a) and (b) above). It also requires that you modify the elements of the voltage-related part of solution vector $\Delta|\underline{V}|^{new}$.

$$\begin{aligned} \underline{J}^{P\theta}\Delta\underline{\theta} + \underline{J}^{PV,new}\Delta|\underline{V}|^{new} &= -\Delta\underline{P} \\ \underline{J}^{Q\theta}\Delta\underline{\theta} + \underline{J}^{QV,new}\Delta|\underline{V}|^{new} &= -\Delta\underline{Q} \end{aligned} \qquad \text{(T7.42e)}$$

   e. What is the advantage of this new formulation? Hint: Express and compare $J_{jk}^{P\theta}$ to $J_{jk}^{QV,new}$ and express and compare $J_{jk}^{Q\theta}$ to $J_{jk}^{PV,new}$.

3. A transformer with an off-nominal tap ratio *t* connects two buses as shown in Fig. 1. The transformer admittance is *y*. An equivalent representation of the Fig. 1 transformer, used for power flow calculations, is shown in Fig. 2. For each model, give the elements of the admittance matrix $\underline{Y}$, where $\underline{I}=\underline{Y}\underline{V}$, $\underline{I}=[\underline{I}_1\ \ \underline{I}_2]^T$, and $\underline{V}=[\underline{V}_1\ \ \underline{V}_2]^T$. From your results, express the admittances of Fig. 2 in terms of tap *t* and transformer admittance *y*. Doing so will allow us to model the off-nominal turns transformer of Fig. 1 in the standard π-equivalent model of Fig. 2 so that we can represent the tap changer in our power flow algorithm.

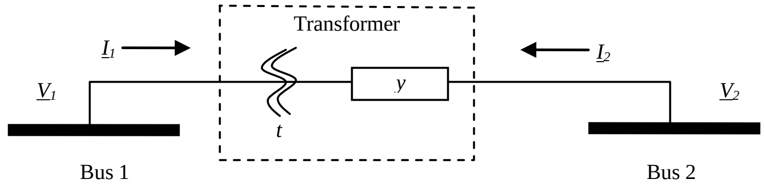

Fig. 1

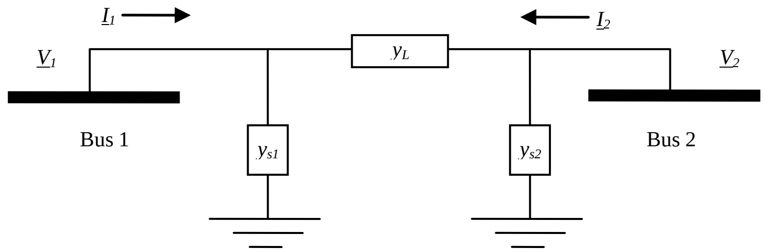

Fig. 2

4. Consider that the transformer of Fig. 1 is a tap-changing-under-load (TCUL) transformer, regulating bus 1, and that buses 1 and 2 are interconnected to a larger system. Bus 2 is a type PQ bus. Which parameters associated with the bus 1 to bus 2 subsystem would be included in the state vector $\Delta\underline{x}$ used to solve the equation $\underline{J}\Delta\underline{x}=-\underline{f}(\underline{x})$ for one iteration of the Newton-Raphson power follow solution? That is, what are the unknowns for this subsystem? Note that the matrices $\underline{J}$ and $\underline{f}(\underline{x})$ are the Jacobian and the mismatch vector, respectively.

5. Consider the two-bus system of Fig. 3, where the tap t is used to regulate the voltage at bus 2 to be equal to 1.0 pu.

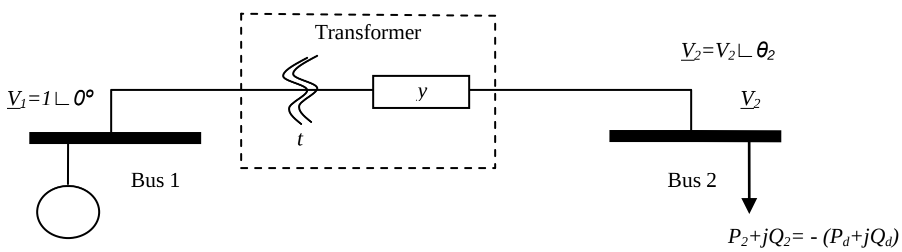

Fig. 3

To solve this system by Newton-Raphson, we need to develop the equation $\underline{J}\Delta\underline{x}=-\underline{f}(\underline{x})$. For this system, specify $\underline{J}$, $\Delta\underline{x}$, and $\underline{f}(\underline{x})$ in terms of the unknowns in the problem and the admittance $y=|y|\angle\gamma$.