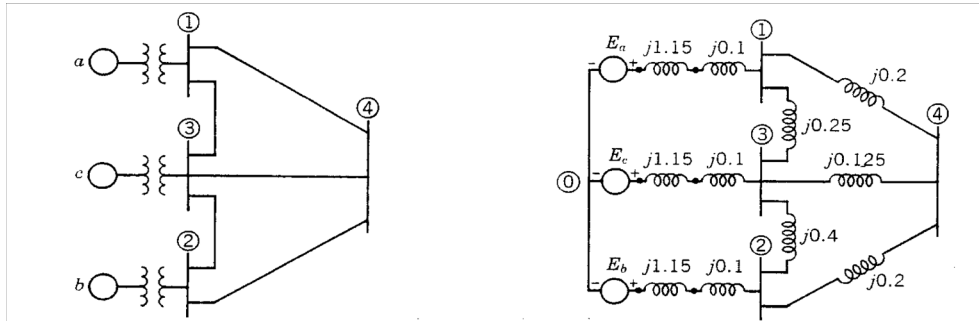


Objectives: Become comfortable with matrix-method approach for solving typical power system problems. Also: Kron reduction, augmenting  $[Y_{BUS}]$ , etc.



- 1) A system one-line and corresponding per unit impedance diagram are given for a 4-bus system. Buses 1, 2, and 3 are supplied by generators thru step-up transformers. Bus 4 is a "load bus" but has no load connected for now.
  - a) Convert the impedance diagram to its corresponding admittance diagram.
  - b) By inspection, build  $[Y_{BUS}]$  for this system and present it in matrix form.
  - c) For  $E_a = 1.5\angle 0^\circ$  pu,  $E_b = 1.5\angle 36.87^\circ$  pu, and  $E_c = 1.5\angle 0^\circ$  pu, present the equations  $[Y][V] = [I]$  in matrix form and solve for  $[V]$ .
  - d) The generator and transformer supplying Bus 3 is disconnected. Make the appropriate modifications to  $[Y_{BUS}]$  and show the result.
  - e) An engineer would like to do a series of calculations involving various operating conditions for the generators at buses 1 and 2 (the generator at bus 3 is still disconnected). Using the node reduction technique discussed in class, eliminate buses 3 and 4 from the system of equations. Present the resulting  $2 \times 2$   $[Y_{BUS}]$ .
  - f) Solve part e) for the voltages at buses 1 and 2. Check that against the solution you get when using the system of equations in part d). Comment on the trade-offs between using the full set of equations vs. the reduced set, in terms of ease of solution, computational efficiency, and system observability.
  - g) From part f) above, calculate the complex power  $S = P + jQ$  flowing into bus 1 and into bus 2. Does total P and Q being generated correspond to what is being consumed by the network?
  
- 2) Revisit the Kron reduction derivation. If we can't assume that the system is bilateral, how does that affect this derivation? i.e. rederive if necessary so that it will also work for a non-bilateral system. Provide details on applying this equation.
  
- 3) Going back to the original system of Problem 1 c),
  - a) Augment the system of equations to include a short circuit between Bus 4 and the reference bus (since this is a L-N per-phase equivalent of a 3-phase system, this is equivalent to a 3-phase fault occurring at Bus 4). Solve the resulting system of 5 equations for the 4 bus voltages and the current flowing through the short circuit from Bus 4 to reference.
  - b) Double check the result of Prob 3 using an alternate method. Hint: One simple way could be to modify  $[Y_{BUS}]$  by adding a near-infinite admittance between Bus 4 and reference and solve for the four bus voltages. Determine the total current in the fault by summing the current contributions from buses 1, 2, and 3, and compare to part a).