Lecture 9

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October 10, 2024

- Modifying an Existing Y_{bus}:
  - Connecting/disconnecting a line from terminals k and m results in addition/subtraction of y from diagonal entries and subtraction/addition from km and mk entries
  - Connecting/disconnecting a line from a single point k results in addition/subtraction of y from the corresponding diagonal entry
- Synchronous Generators
  - A field (excitation) voltage, E_f, is connecting to a reactance jX_s
  - Taking $\hat{V}_t = V_t\angle 0°$, and $\hat{E}_f = \hat{V}_t + jX_s\hat{I}_a$, we may obtain:

$$\hat{E}_f = E_f\angle\delta \quad \text{and } \hat{I}_a = I_a\angle\phi$$

$$S_g = \hat{V}_t \cdot \left(\hat{I}_a\right)^*, \quad \hat{I}_a = \frac{\hat{E}_f - \hat{V}_t}{jX_s}$$

$$S_g = \frac{j}{X_s}\left(V_tE_f\cos(\delta) - jV_tE_f\sin(\delta) - V_t^2\right)$$

  - This gives us:

$$P_g = \frac{V_tE_f}{X_s}\sin(\delta) = V_tI_a\cos(\phi)$$

$$Q_g = \frac{V_tE_f}{X_s}\cos(\delta) - \frac{V_t^2}{X_s}$$

  - We may make some observations:

$$P_g = 0 \to \delta = 0$$

$$Q_g > 0 \to \text{ acts like a capacitor (synchronous condenser)}$$

$$Q_g < 0 \to \text{ acts like a reactor}$$

- Types of Buses:
  - Load/PQ bus
    - Supplies some real and reactive power
  - Generator/PV Bus
    - Supplies some real power and voltage (magnitude), with unknown reactive power
  - Slack/Swing Bus
    - Know the voltage and phase angle, with unknown real and reactive powers
  - Total buses in a system:

$$n = n_{PV} + n_{PQ} + 1$$

$$\left[\underbrace{1}_{\text{slack}}, \underbrace{2, 3, \cdots, (n_{PV}+1)}_{PV \text{ buses}}, \underbrace{(n_{PV}+2), \cdots, n}_{PQ \text{ buses}}\right]$$

  - Thus, we may write:

$$\underbrace{Y_{bus}}_{n\times n}\underbrace{\hat{V}}_{n\times 1} = \underbrace{\hat{I}}_{n\times 1}$$

$$Y_{bus} = G_{bus} + jB_{bus}$$

$$S_k = P_k + jQ_k = \hat{V}_k \hat{I}_k^*$$

$$\hat{I}_k = \sum_{j=1}^{k} Y_{bus}(k,j) \cdot \hat{V}_j$$

  - Finally, we can get:

$$P_k = \sum_{j=1}^{n} V_k V_j \left(G_{kj}\cos(\theta_{kj}) + B_{kj}\sin(\theta_{kj})\right)$$

$$P_k = \sum_{j=1}^{n} V_k V_j \left(G_{kj}\sin(\theta_{kj}) - B_{kj}\cos(\theta_{kj})\right)$$