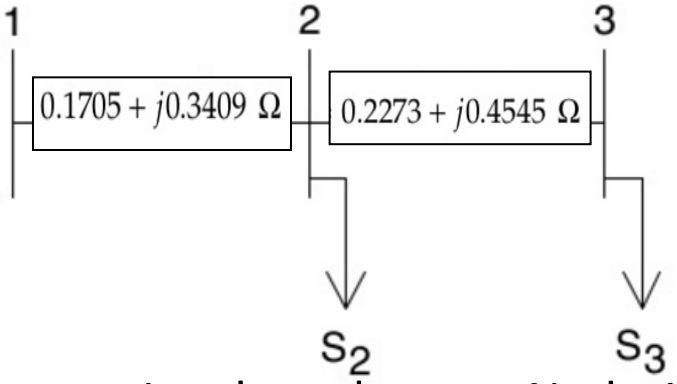
EE 741

Power Flow in Distribution Systems

Power Flow

- Purpose: determine the following:
  - Voltage magnitudes and phase angles at all nodes
  - Current and power flow in each line section
  - Power loss in each line section, and total power loss
  - Total feeder input power (MW, MVAR)
  - Load MW and MVAR based on specified model
- Solution technique
  - Iterative techniques commonly used in transmission network studies (e.g., Newton Raphson, decoupled Newton Raphson, Gauss-Seidel) are not used because of poor convergence characteristics.
  - Instead an iterative technique (i.e., forward/backward substitution) specifically designed for a radial system is used.
  - Refer to Gridlab-D or OpenDSS course slides on power flow module.

Example of forward/backward substitution



- Source voltage at Node 1: 7,200 V

$$S_2 = 1500 + j750$$
$$S_3 = 900 + j500 \quad (\text{kW} + j\text{kvar})$$

- Assume voltage at Node 3 = 7,200 V
- Calculate I_{23}, then voltage at Node 2, then current I_{12}, the voltage at Node 1

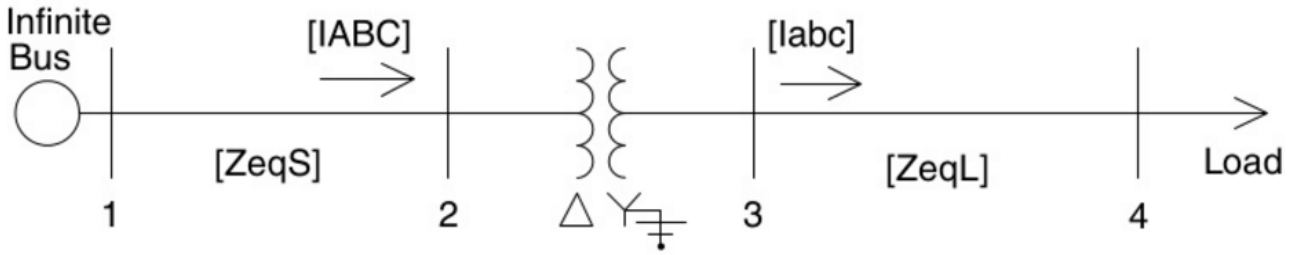
$$V_1 = V_2 + Z_{12} \cdot I_{12} = 7376.2 \angle 0.97 \text{ V} \qquad \text{Error} = \| |V_s| - |V_1| \| = 176.2 \text{ V}$$

- Error greater than tolerance (0.001 p.u. or 7.2 V) – forward substitution:
- Start with voltage at Node 1 = 7,200 V, use line currents calculated previously to compute the voltages at the other nodes

$$V_2 = 7085.4 \angle -0.68 \text{ V} \qquad V_3 = 7026.0 \angle -1.02 \text{ V}$$

- The iteration will be repeated using the new voltage at Node 3 above till, etc. until the error falls below the tolerance.

Example – IEEE 4-Node Feeder

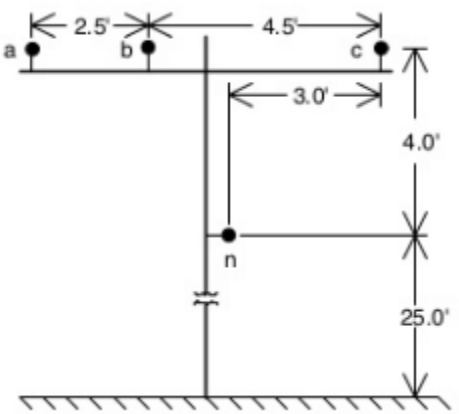


- The infinite bus voltage is balanced 3-phase of 12.47 kV
- Line segment 1-2 is a 3-wire Delta, 2000 ft. long (see pole configuration below). Line segment 3-4 is 2500 ft. long with same pole configuration but is a 4-wire Wye). The lines consist of 336,400 26/7 ACSR phase conductors and the neutral conductor is 4/0 6/1 ACSR (refer to previous examples for cable data).
- The transformer bank is Delta-Wye grounded that consists of 3 single phase transformers.

$$2000\ \text{kVA}, \qquad 12.47 - 2.4\ \text{kV}, \qquad Z = 1.0 + j6.0\%$$

- load data:

$$S_a = 750\ \text{kVA at 0.85 lagging power factor}$$
$$S_b = 1000\ \text{kVA at 0.90 lagging power factor}$$
$$S_c = 1250\ \text{kVA at 0.95 lagging power factor}$$



Example – IEEE 4-Node Feeder

- The iterative process converges after 4 iterations, and the final phase voltages at Node are

$$[V4_{\text{final}}] = \begin{bmatrix} 2278.7 \angle -31.8 \\ 2199.8 \angle -153.5 \\ 2211.2 \angle 83.1 \end{bmatrix} \text{ V}$$

- Assignment # 4. Use OpenDSS to verify the above