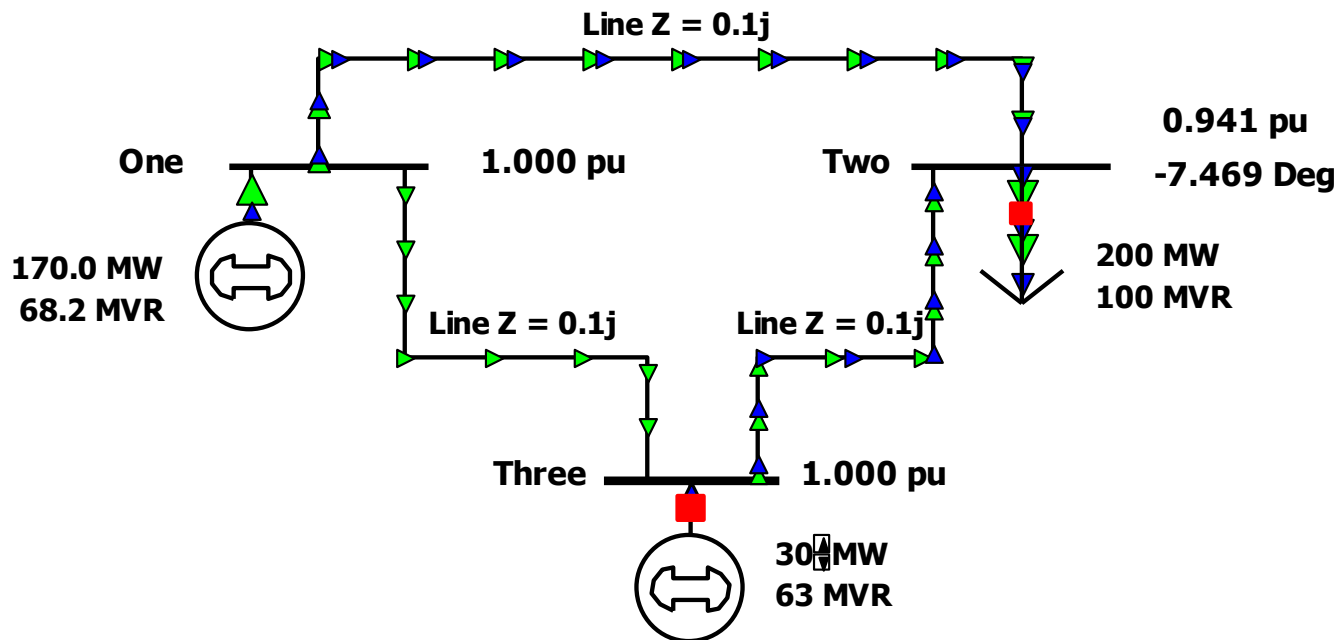# UNIT III

LOAD FLOW ANALYSIS

PV Buses

- Since the voltage magnitude at PV buses is fixed there is no need to explicitly include these voltages in **x** or write the reactive power balance equations
  - the reactive power output of the generator varies to maintain the fixed terminal voltage (within limits)
  - optionally these variations/equations can be included by just writing the explicit voltage constraint for the generator bus
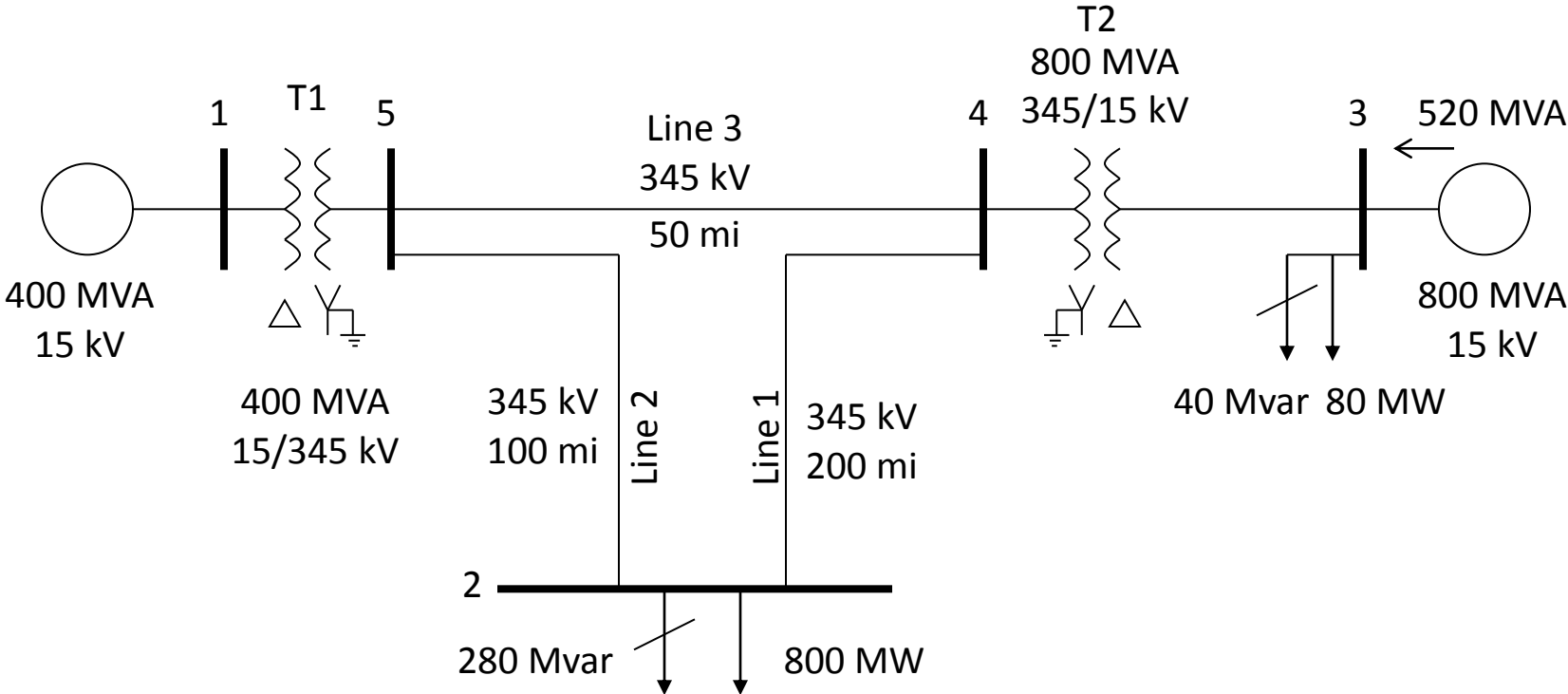
$$|V_i| - V_{i\ setpoint} = 0$$

Three Bus PV Case Example

For this three bus case we have

$$\mathbf{x} = \begin{bmatrix} \theta_2 \\ \theta_3 \\ |V_2| \end{bmatrix} \qquad \mathbf{f}(\mathbf{x}) = \begin{bmatrix} P_2(\mathbf{x}) - P_{G2} + P_{D2} \\ P_3(\mathbf{x}) - P_{G3} + P_{D3} \\ Q_2(\mathbf{x}) + Q_{D2} \end{bmatrix} = 0$$

Line Z = 0.1j

One   1.000 pu   Two   0.941 pu   -7.469 Deg

170.0 MW
68.2 MVR

200 MW
100 MVR

Line Z = 0.1j   Line Z = 0.1j

Three   1.000 pu

30 MW
63 MVR

The N-R Power Flow: 5-bus Example

Single-line diagram

The N-R Power Flow: 5-bus Example

Table 1.
Bus input data

Bus	Type	V per unit	δ degrees	P_G per unit	Q_G per unit	P_L per unit	Q_L per unit	Q_{Gmax} per unit	Q_{Gmin} per unit
1	Swing	1.0	0	—	—	0	0	—	—
2	Load	—	—	0	0	8.0	2.8	—	—
3	Constant voltage	1.05	—	5.2	—	0.8	0.4	4.0	-2.8
4	Load	—	—	0	0	0	0	—	—
5	Load	—	—	0	0	0	0	—	—

Table 2.
Line input data

Bus-to-Bus	R' per unit	X' per unit	G' per unit	B' per unit	Maximum MVA per unit
2-4	0.0090	0.100	0	1.72	12.0
2-5	0.0045	0.050	0	0.88	12.0
4-5	0.00225	0.025	0	0.44	12.0

The N-R Power Flow: 5-bus Example

Table 3. Transformer input data

Bus-to-Bus	R per unit	X per unit	G_c per unit	B_m per unit	Maximum MVA per unit	Maximum TAP Setting per unit
1-5	0.00150	0.02	0	0	6.0	—
3-4	0.00075	0.01	0	0	10.0	—

Table 4. Input data and unknowns

Bus	Input Data	Unknowns
1	$V_1 = 1.0$, $\delta_1 = 0$	P_1, Q_1
2	$P_2 = P_{G2}-P_{L2} = -8$ $Q_2 = Q_{G2}-Q_{L2} = -2.8$	V_2, δ_2
3	$V_3 = 1.05$ $P_3 = P_{G3}-P_{L3} = 4.4$	Q_3, δ_3
4	$P_4 = 0$, $Q_4 = 0$	V_4, δ_4
5	$P_5 = 0$, $Q_5 = 0$	V_5, δ_5

Newton-Raphson Power Flow

- Advantages
  - fast convergence as long as initial guess is close to solution
  - large region of convergence
- Disadvantages
  - each iteration takes much longer than a Gauss-Seidel iteration
  - more complicated to code, particularly when implementing sparse matrix algorithms
- Newton-Raphson algorithm is very common in power flow analysis