Step-by-Step Calculations for Newton-Raphson Load Flow (Iteration 1)

Jacobian Submatrices Calculations

Let us compute the Jacobian submatrices $J_{11}, J_{12}, J_{21}, J_{22}$ for Bus 2 with respect to Bus 1. Assume:

- $V_1 = 1.000$, $V_2 = 1.0116$
- $\theta_1 = 0^\circ = 0$ rad, $\theta_2 = -1.416^\circ = -0.0247\,\text{rad}$
- $G_{21} = -0.0103$, $B_{21} = 0.1930$

1. $J_{11}(2,1) = \frac{\partial P_2}{\partial \theta_1}$

$$\begin{aligned} J_{11}(2,1) &= V_2 V_1 \left(G_{21}\sin(\theta_2 - \theta_1) - B_{21}\cos(\theta_2 - \theta_1)\right) \\ &= 1.0116 \cdot 1.000 \cdot (-0.0103 \cdot \sin(0.0247) - 0.1930 \cdot \cos(0.0247)) \\ &= 1.0116 \cdot (-0.000254 - 0.19295) \\ &= 1.0116 \cdot (-0.1932) = \boxed{-0.1956} \end{aligned}$$

2. $J_{11}(2,2) = \frac{\partial P_2}{\partial \theta_2}$ **(diagonal)**

$$\begin{aligned} J_{11}(2,2) &= -Q_2 - V_2^2 B_{22} \\ &= -0 - (1.0116)^2 \cdot (-1.9303) \\ &= 1.0233 \cdot 1.9303 = \boxed{1.9768} \end{aligned}$$

3. $J_{12}(2,1) = \frac{\partial P_2}{\partial V_1}$

$$\begin{aligned} J_{12}(2,1) &= V_2 \left(G_{21}\cos(\theta_2 - \theta_1) + B_{21}\sin(\theta_2 - \theta_1)\right) \\ &= 1.0116 \cdot (-0.0103 \cdot \cos(0.0247) + 0.1930 \cdot \sin(0.0247)) \\ &= 1.0116 \cdot (-0.01028 + 0.00477) \\ &= 1.0116 \cdot (-0.00551) = \boxed{-0.0056} \end{aligned}$$

4. $J_{21}(2,1) = \frac{\partial Q_2}{\partial \theta_1}$

$$\begin{aligned} J_{21}(2,1) &= V_2 V_1 \left(G_{21}\cos(\theta_2 - \theta_1) + B_{21}\sin(\theta_2 - \theta_1)\right) \\ &= 1.0116 \cdot 1.000 \cdot (-0.01028 + 0.00477) \\ &= 1.0116 \cdot (-0.00551) = \boxed{-0.0056} \end{aligned}$$

5. $J_{22}(2,2) = \frac{\partial Q_2}{\partial V_2}$

$$\begin{aligned} J_{22}(2,2) &= \frac{Q_2}{V_2} - V_2 B_{22} \\ &= 0 - 1.0116 \cdot (-1.9303) = \boxed{1.953} \end{aligned}$$

Bus Voltage Profile (Iteration 1)

Bus	Voltage (p.u.)	Angle (deg)	Bus Type
1	1.0000	0.000	Slack
2	1.0116	-1.416	PQ
3	1.0116	-1.423	PQ
4	1.0116	-1.428	PQ
5	1.0117	-1.508	PQ
6	1.0220	-1.703	PV
7	1.0206	-1.765	PQ
8	1.0190	-1.818	PV
9	1.0157	-2.022	PQ

Table 1: Bus Voltage Profile for First Iteration