9.6 Per-unit and power flow

Name: _____ Class: _____ Date: _____ **Total: 24 marks**

KEY WORDS power flow

Objective

Solve the two-bus power flow by hand: iterate to the receiving voltage, split the drop into its R and X parts, and size the compensation that restores it.

1 Key knowledge and worked examples

■ **The two-bus update**

Sending bus $1.0\angle 0°pu$, line `Z = R + jX`, load `S = P + jQ` at the receiving end. Iterate $V_2 \leftarrow 1.0 - Z \cdot conj(S/V_2)$ until it settles – the hand-scale Gauss–Seidel step.

■ **The voltage-drop approximation**

$\Delta V \approx (P \cdot R + Q \cdot X)/|V|$ – with network X $\gg$ R, the REACTIVE flow through X dominates the drop, which is why shunt compensation is a voltage tool.

■ **Worked example: compensation sweeps the curve**

$Z = 0.02 + j0.10pu$, load 0.8 + j0.4: uncompensated $|V_2| = 0.937$. Adding $Q_c = 0.2$ at the load bus lifts it to 0.959; $Q_c = 0.4$ (full local Q supply) reaches 0.980 – and line loss falls from 0.0182 to 0.0133 pu because the current falls.

2 Practice

2.1 With $Z = 0.02 + j0.10pu$ and load 0.8 + j0.4, compute the approximate drop ΔV and the P · R and Q · X parts separately. [3]

2.2 The converged solution has line current 0.954 pu. Compute the line loss and the sending-end real power. [3]

2.3 For the same system with $Q_c = 0.2$ and $Q_c = 0.4$, compute $|V_2|$ (converged) and the corresponding line losses. [3]

3 Exam-style questions

3.1 A two-bus system: sending bus at 1.0 pu, $Z = 0.05 + j0.15pu$, receiving load 0.5 + j0.25 pu.

Perform the first TWO Gauss–Seidel iterations from a flat start ($V_2 = 1.0$) and give each result in rectangular form. Iterate to convergence and state $|V_2|$ and its angle. Compute the line current, the real line loss and the sending-end real power, and verify the power balance. [8]

3.2 The system of the worked example ($Z = 0.02 + j0.10pu$, load 0.8 + j0.4 pu) suffers a 0.937 pu receiving voltage.

Size the shunt compensation Q_c needed to restore $|V_2|$ to about 0.98, showing the sweep you used. Compute the percentage reduction in line loss at that compensation. Explain, from the drop decomposition, why a Q-based fix works better than a P-based one, and what device supplies Q_c in practice. [7]