Indian Institute of Technology Patna
Department of Electrical Engineering
EE381 - Power Systems
Autumn - 2022
Mid Semester Exam
September 24, 2022

There are 3 questions. They carry equal marks.

$(3 \times 10 = 30)$

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1. A 3-phase transmission line has a span of 250 km long. It supplies a balanced load of 25 MVA at 0.8 lagging power factor. The receiving end load voltage is 132 kV. The line conductors are spaced equilaterally 3 m apart. The conductor resistance is 0.11 Ω/km. Its effective diameter is 1.6 cm. Using the nominal-T model, find the following.

   (a) the sending end line to line voltage and the sending end current

   (b) the voltage regulation at the receiving end

$L = 2\times10^{-7} \ln\left(\frac{GMD}{GMR_L}\right)$ H/m

$GMD = 3m$; $GMR_L = 0.7788 \times \left(\frac{0.016}{2}\right)$ m

$\boxed{L = 1.235 \text{ mH/Km}}$

$\boxed{\bar{I}_s = 85.23 \angle -4.11 \text{ A}}$ 1

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$C = \frac{2\pi\varepsilon_0}{\ln\left(\frac{GMD}{GMR_C}\right)}$

$GMR_C = r$

% Volt regn $= \frac{V_{RNL} - V_{RFL}}{V_{RFL}} \times 100$

$= \frac{\left|\frac{V_S}{A}\right| - V_{RFL}}{V_{RFL}} \times 100$ 2

$\boxed{C = 0.0094 \ \mu F/Km}$

$= \boxed{12.12\ \%}$

$r = 0.11\ \Omega/km$

$Z = (r + jx) \times \text{length} = (27.5 + j97)\ \Omega$

$Y = j\omega C \times \text{length} = j7.38 \times 10^{-4}\ \mho$

Nominal T model

$A = 1 + \frac{ZY}{2} = D$

$B = Z\left(1 + \frac{ZY}{4}\right)$

$C = Y$

$A = 0.964 + j0.012$ 3

$B = 26.5 + j95.4\ \Omega$

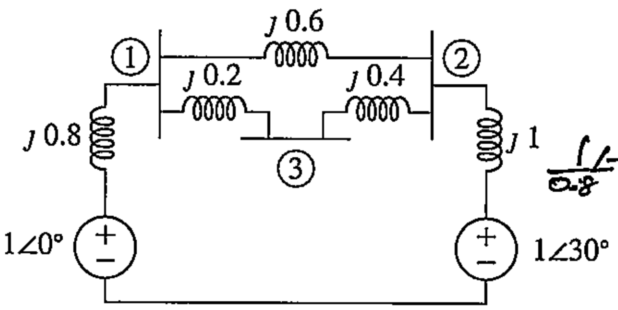
$C = j7.38 \times 10^{-4}\ \mho$

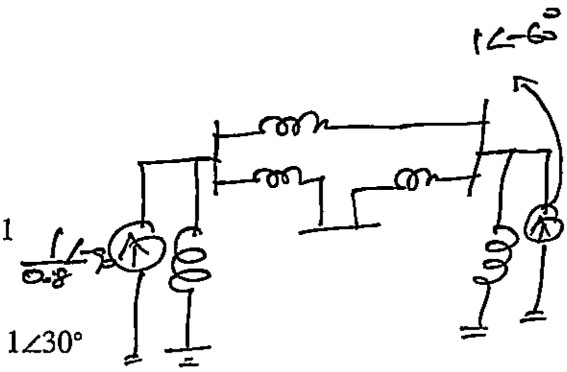
$|I_R| = 109.35$ A

$I_R = 109.35 \angle -36.[illegible]$

$\boxed{\begin{array}{l} V_s = 82.4 \angle 5.14 \text{ KV phase} \\ |V_s| = 142.7 \text{ KV (Line - Line)} \end{array}}$ 1

2. Consider the reactance network shown here.





(a) Find the voltage at node 3.

(b) Find the voltage at node 3 after connecting a capacitor having a reactance of 2.0 per unit connected between node 3 to the reference node.

$$Y_{bus} = \begin{bmatrix} \frac{1}{j0.8}+\frac{1}{j0.2}+\frac{1}{j0.6} & -\frac{1}{j0.6} & -\frac{1}{j0.2} \\ -\frac{1}{j0.6} & \frac{1}{j1}+\frac{1}{j0.4}+\frac{1}{j0.6} & -\frac{1}{j0.4} \\ -\frac{1}{j0.2} & -\frac{1}{j0.4} & \frac{1}{j0.2}+\frac{1}{j0.4} \end{bmatrix}$$

(3)

$$Y_{bus} = \begin{bmatrix} -7.92j & 1.67j & 5j \\ 1.67j & -5.17j & 2.5j \\ 5j & 2.5j & -7.5j \end{bmatrix} \quad I = \begin{bmatrix} 1.25\angle -90^\circ \\ 1\angle -60^\circ \\ 0 \end{bmatrix}$$

$$V = Y_{bus}^{-1} I = \begin{bmatrix} 0.95 + j0.19 \\ 0.93 + j0.26 \\ 0.94 + j0.21 \end{bmatrix}$$ (2)

a)
$$\boxed{\begin{aligned} V_3 &= 0.94 + j0.21 \\ V_3 &= 0.967\angle 12.61^\circ \end{aligned}}$$

if $X_c = -j2$ is added between (3) and ref;

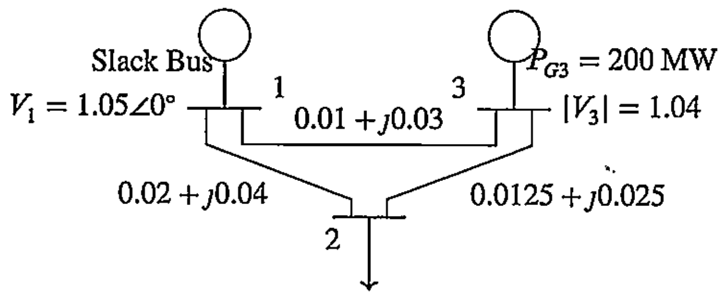
$$Y_{bus}^{mod} = \begin{bmatrix} -7.92j & 1.67j & 5j \\ 1.67j & -5.17j & j2.5 \\ 5j & j2.5 & -7j \end{bmatrix}$$

Y_{33} alone gets changed. (3)

$$V = \begin{bmatrix} 1.25 + j0.26 \\ 1.21 + j0.33 \\ 1.33 + j0.30 \end{bmatrix}$$

$$\boxed{V_3 = 1.36\angle 12.81^\circ}$$ (2)

3. The figure below shows the single line diagram of a simple three bus power system with generators at buses 1 and 3. The line reactances are in p.u on a 100 MVA base.



If after several iterations the bus voltages converge to

$$V_2 = 0.97\angle -2.7^\circ$$
$$V_3 = 1.04\angle -0.5^\circ$$

find the following.

(a) Total real and reactive power losses

(b) P_{G1}, Q_{G1} and Q_{G3}.

$$I_{13} = (V_1 - V_3)\, y_{13} = 0.3727 - j0.2104 = 0.4280\angle -29.45^\circ$$

$$I_{12} = 1.7246 - j\,1.1646 = 2.0810\angle -34.0302^\circ$$

$$I_{32} = 2.3084 - j\,1.6873 = 2.86\angle -36.16^\circ$$

$$S_{13} = V_1 I_{13}^*$$

$$\boxed{S_{13} = 0.3913 + j0.2210}$$

$$S_{31} = V_3 I_{31}^* = V_3 (-I_{13}^*)$$

$$\boxed{S_{31} = -0.3895 - j0.2155}$$

Losses in line 1-3

$$S_{13} + S_{31} = \boxed{0.0018 + j0.0055}$$

$$S_{12} = V_1 I_{12}^*$$

$$\boxed{S_{12} = 1.8109 + j\,1.223}$$

$$S_{21} = V_2 I_{21}^* = V_2 (-I_{12})^*$$

$$\boxed{S_{21} = -1.7243 - j1.05}$$

losses in line 1-2

$$S_{12} + S_{21} = \boxed{0.0866 + j0.1732}$$

$$S_{32} = V_3 I_{32}^*$$

$$\boxed{S_{32} = 2.4159 + j\,1.7338}$$

$$S_{23} = V_2 I_{23}^* = V_2 (-I_{32})^*$$

$$\boxed{S_{23} = -2.3137 - j\,1.5294}$$

losses in line 32

$$\boxed{S_{32} + S_{23} = 0.1022 + j0.2044}$$

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Total losses

$P_L =$ sum of P_L in all the lines

$Q_L =$ sum of Q_L for all the lines

$$\boxed{P_L = 0.1906 \text{ pu} \quad Q_L = 0.3831 \text{ p.u}}$$

$$\boxed{P_L = 19.06 \text{ MW} \quad Q_L = 38.31 \text{ MVAr}}$$

$$P_{G1} = P_1 = \text{Real}\{V_1 \, I_1^*\}$$

$$= \text{Real}\{V_1 \, (I_{13} + I_{12})^*\}$$

$$\boxed{P_{G1} = 2.\cancel{4}9 \text{ p.u}}$$

$$\boxed{Q_{G1} = 1.44 \text{ p.u}}$$

3

$$Q_{G3} = Q_3 = \text{Imag}\{V_3 \, I_3^*\}$$

$$= \text{Imag}\{V_3 \, (I_{32} + I_{31})^*\}$$

$$= \text{Imag}\{V_3 \, (I_{32} - I_{13})^*\}$$

$$\boxed{Q_{G3} \approx 1.5 \text{ p.u}}$$

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