Indian Institute of Technology Patna
Department of Electrical Engineering
EE381 - Power Systems
Autumn - 2022
Quiz - I – Solution.
September 16, 2022

There are 5 problems. They carry equal marks.

$(5 \times 2 = 10)$

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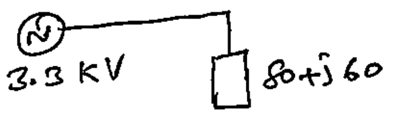
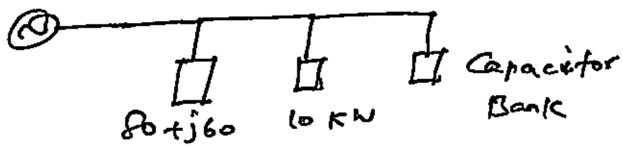
1. A three phase cable is supplying 80 kW and 60 kVAr to an inductive load. It is intended to supply an additional resistive load of 10 kW through the same cable without increasing the heat dissipation in the cable, by providing a three-phase bank of capacitors connected in delta across the load. Given the line voltage is 3.3 kV, 50 Hz, determine the capacitance per phase of the bank, expressed in micro-farads.



KVA = 100



To have the same heat dissipation the KVA (current) supplied by the source must be the same

To have the same KVA (overall)

$Q_{new} = \sqrt{100^2 - 90^2}$ $(\sqrt{S^2 - P^2})$

$Q_{new} = 43.59$ KVAr

$\therefore Q_c = 60 - 43.59 = \boxed{16.41 \text{ KVAr}}$

1

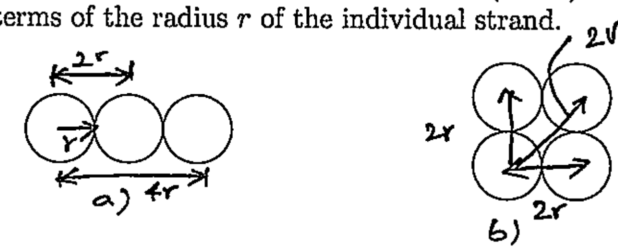
$\frac{Q_c}{3} = \frac{(3300)^2}{X_c} = (3300)^2 \times \omega C$

$C = \frac{16.41 \times 10^3}{3 \times (3300)^2 \times 2\times\pi\times 50}$

$\boxed{C = 1.6\ \mu F}$

1

2. Determine the geometric mean radius (GMR) of the following configurations in terms of the radius r of the individual strand.



a)

$GMR = \sqrt[9]{0.7788 \times r \times 2r \times 4r \times 0.7788 \times r \times 2r \times 2r \times 0.7788 \times r \times 2r \times 4r}$

$= (0.7788)^{1/3} \times (256)^{1/9} \times r$

$\boxed{GMR_{\text{for } L} = 1.703\, r}$

1

$\boxed{GMR_{\text{for } C} = 1.852\, r}$

b)

$GMR = \sqrt[16]{(0.7788 \times r \times 2r \times 2r \times 2\sqrt{2}r)^4}$

$= (0.7788)^{1/4} \times 1.834 \times r$

$\boxed{GMR_{\text{for } L} = 1.723\, r}$

1 $\boxed{GMR_{\text{for } C} = 1.834\, r}$

3. A 3-phase, 50 Hz transmission line is 200 km long. The voltage at the sending end is 220 kV. The parameters of the line are $r = 0.1250\ \Omega/\text{km}$, $x = 0.5\ \Omega/\text{km}$ and $y = 3.3\ \mu\mho/\text{km}$. Find the sending end current and the receiving end voltage when there is no load on the line.

$V_S = A V_R$ (if $I_R = 0$)

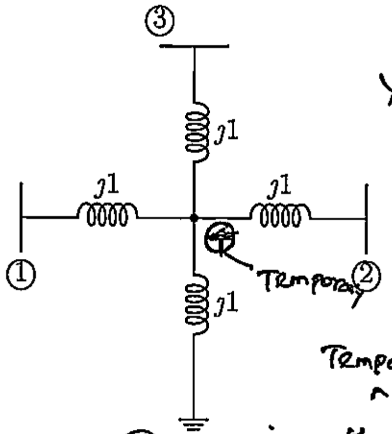
$I_S = C V_R$

$$\boxed{\begin{aligned} |V_r| &= 227.5\ \text{kV} \\ |I_s| &= 82.5\ \text{A} \end{aligned}} \quad 1$$

$$A = 1 + \frac{ZY}{2} = 1 + \frac{(0.1250 + j0.5) \times 200 \times 3.3 \times 10^{-6} \times 200}{2} = 0.9670 + j0.0083 \quad 1$$

$$C = Y\left(1 + \frac{ZY}{4}\right) = -2.72 \times 10^{-6} + j6.5 \times 10^{-4}$$

4. Form the Y_{bus} matrix of the network shown below. All the reactances are in per unit. (Hint : Treat the junction point as a node and eliminate it later.)



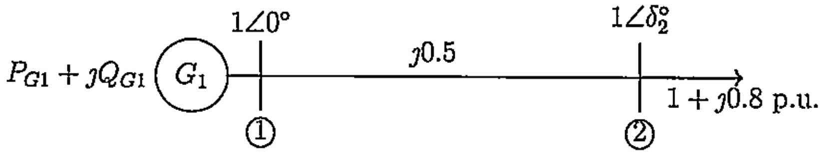
$$Y = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ T \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & T \end{array} \\ \begin{bmatrix} -j & 0 & 0 & j \\ 0 & -j & 0 & j \\ 0 & 0 & -j & j \\ j & j & j & -4j \end{bmatrix} \end{array} \quad 1$$

T Temporary node

By eliminating the node T using the node elimination (Kron reduction),

$$Y_{bus} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{c} \begin{array}{ccc} 1 & 2 & 3 \end{array} \\ \begin{bmatrix} -\frac{3}{4}j & \frac{j}{4} & \frac{j}{4} \\ \frac{j}{4} & -\frac{3}{4}j & \frac{j}{4} \\ \frac{j}{4} & \frac{j}{4} & -\frac{3}{4}j \end{bmatrix} \end{array} \quad 1$$

5. Find P_{G1} and Q_{G1}



Since it is a lossless system,

$\boxed{P_{G1} = 1}$ 1

$Q_{G1} = Q_1$

To find Q_1, we need δ_2.

$$P_1 = \frac{V_1 V_2 \sin(\delta_1 - \delta_2)}{X}$$

$$1 = \frac{1 \times 1}{0.5} \sin(0 - \delta_2)$$

$$\boxed{\delta_2 = -30^\circ}$$

2

$$Q_1 = \frac{V_1^2}{X} - \frac{V_1 V_2 \cos\delta_2}{X} = 0.268\ \text{p.u}$$

$$\boxed{Q_{G1} = 0.268} \quad 1$$