Indian Institute of Technology Patna
Department of Electrical Engineering
EE3101-Power Systems-I
End Semester Exam

Time: 3 Hours | Autumn 2026 | Max Marks: 50

All questions are compulsory

1. An industry has an average electrical load of 600 kW at a p.f. of 0.6 lagging. A synchronous motor with an efficiency of 90% is used to raise the combined p.f. to 0.9 lagging and at the same time supply a mechanical load of 100 kW. Calculate
   (a) the kVA of the synchronous motor (5)
   (b) the synchronous motor operating power factor. (5)

$P_{industry} = 600$ KW PF = 0.6 lag

$Q_{industry} = 800$ KVAr

Syn. Motor:

To get 0.9 pf lagging,

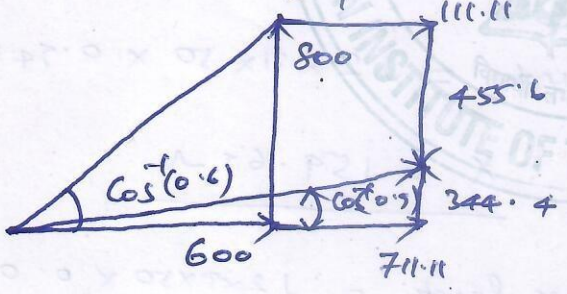
o/p $P_{mech} = 100$ KW

$Q_{combined} = 344.4$ KVAr

i/p $P_{elec} = \frac{100}{0.9} = 111.11$ KW

$\therefore Q_{Motor} = -455.6$ KVAr

(-ve sign indicates that the motor is supplying Q)



a) KVA of the motor

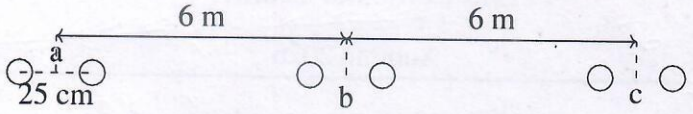
$= \sqrt{(111.11)^2 + (455.6)^2}$

$= 468.94$ KVA

b) PF of the motor $= \tan^{-1}\left(\frac{Q}{P}\right)$

$= 0.237$ leading (Q_{Motor} = -ve)

2. Consider the following single circuit, two-bundle and 200 km long line. The diameter of each conductor is 5 cm. ($\epsilon_0 = 8.854 \times 10^{-12} F/m$) Determine



(a) the total series reactance in Ω. **(5)**

(b) the total shunt admittance in ℧ **(5)**

$GMD = \sqrt[3]{6 \times 6 \times 12} = 7.56\ m$

$GMR_L = \sqrt[2]{r \times d} = 0.07\ m$

$GMR_C = \sqrt[2]{r \times d} = 0.08\ m$

$L = 2 \times 10^{-7} \ln\left(\frac{GMD}{GMR_L}\right) = 0.94\ mH/km$

$C = \frac{2\pi \epsilon_0}{\ln\left(\frac{GMD}{GMR_L}\right)} = 0.012\ \mu F/km$

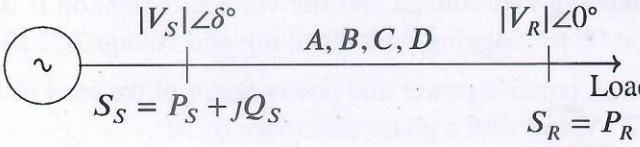
$X = jx \times \text{length} = j 2 \times \pi \times 50 \times 0.94 \times 10^{-3} \times 200$

$X = j59.69\ \Omega$

$Y = j\omega C \times \text{length} = j 2 \times \pi \times 50 \times 0.012 \times 10^{-6} \times 200$

$Y = j766.55\ \mu\mho$

3. For a two bus system shown below, derive expressions for real power at receiving end and sending end in terms of A, B, C, D parameters. Also show that the sending end and receiving end real power are equal for a loss less system having a short transmission line. Let A, B, C and D be $|A|\angle\alpha$, $|B|\angle\beta$, $|C|\angle\gamma$ and $|A|\angle\alpha$, respectively. **(10)**



$V_S = AV_R + BI_R$ —①

$I_S = CV_R + DI_R$ —②

① ⇒ $I_R = \dfrac{V_S - AV_R}{B}$

② ⇒ $I_S = CV_R + D\left(\dfrac{V_S - AV_R}{B}\right)$

$I_S = \dfrac{V_S D}{B} - \dfrac{V_R}{B}$

$S_S = V_S I_S^*$

$S_S = \dfrac{V_S^2 A}{B}\angle B-\alpha - \dfrac{V_S V_R}{B}\angle\delta+\beta$

$P_S = \dfrac{V_S^2 A}{B}\cos(\beta-\alpha) - \dfrac{V_S V_R}{B}\cos(\delta+\beta)$

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$S_R = V_R I_R^*$

$S_R = \dfrac{V_S V_R}{B}\angle\beta-\delta - \dfrac{V_R^2 A}{B}\angle\beta-\alpha$

$P_R = \dfrac{V_S V_R}{B}\cos(\beta-\delta) - \dfrac{V_R^2 A}{B}\cos(\beta-\alpha)$

For short line,

$A = 1\angle 0° = D$

$B = X\angle 90°$

$C = 0$

Hence

$P_S = \dfrac{V_S V_R}{X}\sin\delta$

$P_R = \dfrac{V_S V_R}{X}\sin\delta$

4. A transmission line has the following parameters :

$$A = D = 1\angle 5°; B = 88\angle 75°$$

(a) Determine the sending-end voltage and the voltage regulation if the line supplies a load of 40 MW at 08 p.f. lagging with receiving-end voltage 132 kV. **(5)**

(b) Find the real power, reactive power and power factor of the load if the voltages at the two ends are 132 kV and with a phase difference of 30°. **(5)**

a) $I_R = \frac{40 \times 10^3}{\sqrt{3} \times 132 \times 0.8} = 218.7$ A

$V_{R(phase)} = 76.21$ KV

$\bar{I}_R = 218.7 \angle -36.87°$ A

$\bar{V}_S = V_R \times A + B \times I_R = 92.92\angle 11.5°$ KV (phase)

$= 92.06 + j\,18.52$ KV (phase)

$V_{S\,L-L} \simeq 161$ KV

$\%\ \text{reg} = \frac{\frac{V_S}{A} - V_R}{V_R} \times 100$

$= 21.93\ \%$

b)

$|\bar{V}_S| = |V_R| = 132$ KV (Line - Line)

$= 76.21$ KV (phase)

$\bar{V}_S \angle \delta = 76.21 \angle 30°$

$\bar{V}_R \angle 0° = 76.21 \angle 0°$

$\bar{I}_R = \frac{V_S - AV_R}{B} = 374.88 \angle 32.5°$ A

$= 316.17 + j\,201.42$ A

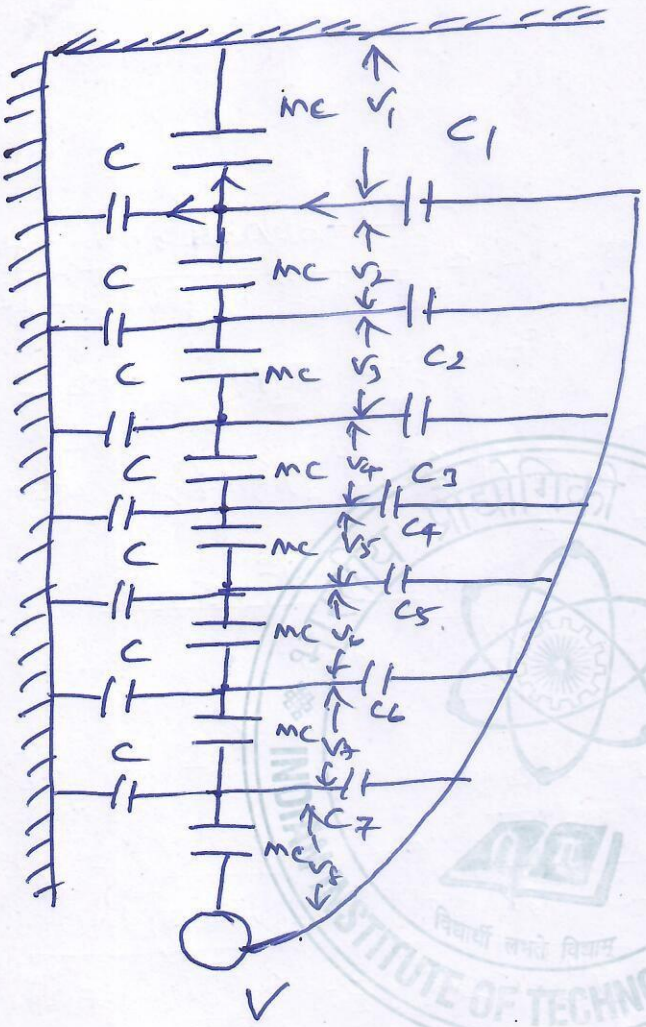
$S_{R(phase)} = V_R I_R^* = 24.1 - j\,15.35$ MVA

$P_{R\,3\phi} = 72.3$ MW

$Q_{R\,3\phi} = -46$ MVAr

$P_f = \cos(32.5) = 0.8434$ (leading)

5. A string of eight suspension insulators is to be fitted with a grading ring. If the pin to earth capacitances are all equal to C, find the values of line to pin capacitances that would give a uniform voltage distribution over the string. **(10)**



To get the equal voltage distribution,

$$\boxed{I_{\text{Line to pin capacitance}} = I_{\text{Pin to earth capacitance}}}$$

Since the voltage distribution is equal,

$$V_1 = V_2 = V_3 = V_4 = V_5 = V_6 = V_7 = V_8 = \frac{V}{8}$$

$$\frac{V}{8} j\omega C = (V - V/8)\, j\omega C_1$$

$$\boxed{C_1 = \frac{C}{7}}$$

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$$C_2 = 2/6\, C = \frac{C}{3}$$

$$C_3 = \frac{3}{5} C$$

$$C_4 = C$$

$$C_5 = \frac{5}{3} C$$

$$C_6 = 3C$$

$$C_7 = 7C$$