

Q1

a) i) The line voltages V_{BC} and V_{CA}

$$\text{Given } V_{AB} = 200 \angle 0^\circ$$

$$\begin{aligned} V_{BC} &= V_{AB} \angle -120^\circ \\ &= 200 \angle -120^\circ \text{ V} \end{aligned}$$

$$\begin{aligned} V_{CA} &= V_{AB} \angle +120^\circ \\ &= 200 \angle 120^\circ \text{ V} \end{aligned}$$

ii) The phase voltages V_{AN} , V_{BN} , V_{CN}

$$V_{AN} = \frac{V_{AB}}{\sqrt{3} \angle 30^\circ} = \frac{200 \angle 0^\circ}{\sqrt{3} \angle 30^\circ} = 115.47 \angle -30^\circ \text{ V}$$

$$\begin{aligned} V_{BN} &= V_{AN} \angle -120^\circ \\ &= 115.47 \angle -150^\circ \text{ V} \end{aligned}$$

$$\begin{aligned} V_{CN} &= V_{AN} \angle +120^\circ \\ &= 115.47 \angle 90^\circ \text{ V} \end{aligned}$$

iii) The phase currents I_{an} , I_{bn} , I_{cn}

$$\begin{aligned} I_{an} &= \frac{V_{an}}{Z_y} & I_{bn} &= I_{an} \angle -120^\circ & I_{cn} &= I_{an} \angle +120^\circ \\ &= 115.47 \angle -30^\circ \end{aligned}$$

iv) The line currents I_a , I_b , I_c

$$\begin{aligned} I_a &= I_{an} \\ &= \end{aligned}$$

$$\begin{aligned} I_b &= I_{bn} \\ &= \end{aligned}$$

$$\begin{aligned} I_c &= I_{cn} \\ &= \end{aligned}$$

Q1

PG 2/8

b

i) The phase voltages V_{an}, V_{bn}, V_{cn}

$$V_{an} = 120 \angle 20^\circ \text{ V} \quad V_{bn} = V_{an} \angle -120^\circ = 120 \angle -100^\circ \text{ V} \quad V_{cn} = V_{an} \angle +120^\circ = 120 \angle 140^\circ \text{ V}$$

ii) The line voltages V_{ab}, V_{bc}, V_{ca}

$$V_{AB} = \sqrt{3} V_{an} \angle 30^\circ = \sqrt{3} \times 120 \angle 50^\circ = 207.85 \angle 50^\circ \text{ V} \quad V_{BC} = \sqrt{3} V_{an} \angle -120^\circ = 207.85 \angle -70^\circ \text{ V} \quad V_{CA} = V_{AB} \angle +120^\circ = 207.85 \angle 170^\circ \text{ V}$$

iii) The Phase currents I_{AB}, I_{BC}, I_{CA}

$$Z_{\Delta} = 12 j 8 \Omega$$

$$P_{OL} = 14.42 \angle 33.69^\circ$$

$$I_{AB} = \frac{V_{AB}}{Z_{\Delta}} = \frac{207.85 \angle 50^\circ}{14.42 \angle 33.69^\circ}$$

$$I_{BC} = \frac{V_{BC}}{Z_{\Delta}} = \frac{207.85 \angle -70^\circ}{14.42 \angle 33.69^\circ}$$

$$I_{CA} = \frac{V_{CA}}{Z_{\Delta}} = \frac{207.85 \angle 170^\circ}{14.42 \angle 33.69^\circ}$$

$$= 14.41 \angle 16.31^\circ \text{ A}$$

$$= 14.41 \angle -153.69^\circ \text{ A}$$

$$= 14.41 \angle 86.31^\circ \text{ A}$$

iv) The line currents I_a, I_b, I_c

$$I_a = \sqrt{3} I_{AB} \angle -30^\circ = \sqrt{3} 14.41 \angle 16.31 - 30^\circ = 24.96 \angle -13.69^\circ \text{ A}$$

$$I_b = I_a \angle -120^\circ = 24.96 \angle -133.69^\circ \text{ A}$$

$$I_c = I_a \angle +120^\circ = 24.96 \angle 106.31^\circ \text{ A}$$

Q2

a

i) The apparent, real, reactive power by the line

$$V_{line} = (6 + j3)I = (6.71 \angle 26.57^\circ)(7.59 \angle -34.7^\circ) \\ = 50.93 \angle -8.13^\circ \text{ V}$$

apparent power S

$$S = V \times I \Rightarrow S = (50.93 \angle -8.13^\circ)(7.59 \angle -34.7^\circ) \\ = 386.56 \angle -42.83^\circ \text{ VA}$$

$$\text{Re}(386.56 \angle -42.83^\circ) = 283.49 - j262.79$$

$$\text{Real Power } P = 283.49 \text{ W} \quad \text{Reactive power} = +262.79 \text{ VAR} \\ \text{leading}$$

ii) The apparent, real, reactive power absorbed by the load

$$V_L = (20 + j15)I = (25 \angle 36.87^\circ)(7.59 \angle -34.7^\circ) \\ = 189.75 \angle 2.17^\circ \text{ V}$$

apparent power S

$$S = V \times I \Rightarrow S = (189.75 \angle 2.17^\circ)(7.59 \angle -34.7^\circ) \\ = 1440.20 \angle -32.53^\circ \text{ VA}$$

$$\text{Re}(1440.20 \angle -32.53^\circ) = 1214.25 - j774.45$$

$$\text{Real power } P = 1214.25 \text{ W} \quad \text{Reactive power } Q = 774.45 \text{ VAR} \\ \text{leading}$$

Q2

a

i) The apparent, real and reactive Power absorbed by the source

$$\begin{aligned} Z &= (6 + j3) + (20 + j15) \\ &= 26 + j18 \\ &= 31.62 \angle 34.70^\circ \Omega \end{aligned}$$

$$\begin{aligned} I &= \frac{V_s}{Z} = \frac{240 \angle 0}{31.62 \angle 34.70} \\ &= 7.59 \angle -34.7^\circ \text{ A} \end{aligned}$$

Apparent power (S)

$$\begin{aligned} S &= V \times I \Rightarrow S = 240 \angle 0 \times 7.59 \angle -34.7^\circ \\ &= 1821.60 \angle -34.7^\circ \text{ VA} \end{aligned}$$

~~Real power (P)~~

$$\text{Rec}(1821.6, -34.7)$$

~~Reactive power (Q)~~

$$\Rightarrow X = 1497.62 \quad Y = j1037.00$$

$$\text{Real power (P)} = 1497.62 \text{ W}$$

$$\text{Reactive power (Q)} = 1037.00 \text{ VAR lagging}$$

x

Q2

a

iv) The total apparent power and the power factor.

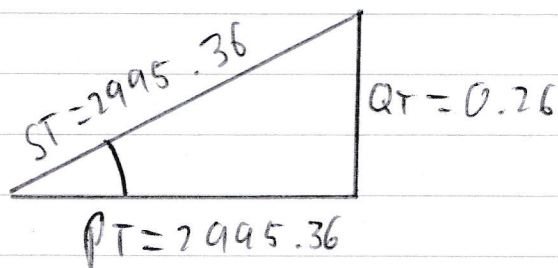
$$P_T = 1497.62 + 283.49 + 1214.25 \\ = 2995.36 \text{ W}$$

$$Q_T = 1037 - 262.29 - 774.45 \\ = 0.26 \text{ VAR}$$

Apparent power total

$$S_T = P_T + jQ_T \\ = 2995.36 + j0.26 \leftarrow \text{Rec} \\ \angle 4.97^\circ \leftarrow$$

$$S_T = 2995.36 \text{ VAR}$$



$$\cos \theta = \frac{A}{H} = \frac{S_T}{P_T}$$

$$\theta = \cos^{-1} \left(\frac{S_T}{P_T} \right)$$

$$\theta = \cos^{-1} \left(\frac{2995.36}{2995.36} \right) \\ = 0^\circ$$

$$PF = 1$$

Q2

b i)

$$\frac{R}{L} = \frac{P}{A} = \frac{2.95 \times 10^{-8}}{\pi \times 0.03^2} = 1.04 \times 10^{-5} \Omega/\text{m}$$

$$R = 1.04 \times 10^{-5} \times 1000$$

$$= 0.01 \Omega/\text{km}$$

ii) The total series impedance of this line

$$\begin{aligned} Z &= R \times L \\ &= 0.01 \times 60 \\ &= 0.6 \Omega \end{aligned}$$

$$\begin{aligned} Z_{eq} &= R + jX_L \\ &= 0.01 + j + 2\pi \times 50 \times 1.4 \times 10^{-3} \\ &= 0.01 + j0.44 \Omega/\text{km} \end{aligned}$$

$$\begin{aligned} Z_{eq} &= (R + jX_L) \times 60 \\ &= (0.01 + j0.44) \times 60 \\ &= 0.6 + j26.4 \Omega/\text{km} \end{aligned}$$

iii) The total shunt reactance

$$X_C = \frac{1}{j\omega C} = \frac{1}{j2\pi \times 50 \times 8.4 \times 10^{-9}}$$

$$= -j378.94 \times 10^3 \Omega/\text{m}$$

$$X_C = X_C/\text{km} = \frac{-j378.94 \times 10^3}{60}$$

$$= -j6315.6 \text{ k}\Omega$$

Q 3

- i) Determine the active and reactive components of the motor current I_m

Real power P

$$P = V \times I \cos \theta$$

$$= 500 \times 28.5 \times 0.75$$

$$= 10687.5 \text{ W}$$

Reactive power Q

$$= V \times I \sin \theta$$

$$\theta = \cos^{-1}(0.75)$$

$$= 41.41^\circ$$

$$= 500 \times 28.5 \sin(41.41)$$

$$= 9425.56 \text{ VAR}$$

- ii) calc supply current I when PF = 0.95

$$\cos \theta_1 = 0.75$$

$$\theta_1 = 41.41^\circ$$

$$\cos \theta_2 = 0.95$$

$$\theta_2 = 18.19^\circ$$

$$S = \frac{P_1}{\cos \theta_1}$$

$$= \frac{10687.5}{0.75}$$

$$= 14250 \text{ VAR}$$

$$Q_1 = S \sin \theta_1$$

$$= 9425.56 \text{ VAR}$$

$$S = \frac{10687.5}{0.95}$$

$$= 11250 \text{ VAR}$$

$$Q_2 = 11250 \sin(18.19)$$

$$= 3511.90 \text{ VAR}$$





Q 3

PG 8/8

(iii) Calc capacitance required in parallel with motor to improve P F to 0.95 lagging

$$\begin{aligned} Q_c &= Q_1 - Q_2 \\ &= 9425.56 - 3511.90 \\ &= \cancel{5443} 5913.66 \text{ VAR} \end{aligned}$$

$$\begin{aligned} X_c &= \frac{V^2}{Q_c} \\ &= \frac{500^2}{5913.66} \\ &= 42.28 \end{aligned}$$

$$X_c = \frac{1}{2\pi f C}$$

$$C = \frac{1}{2\pi f X_c}$$

$$C = 6.27 \times 10^{-5} \text{ F}$$