Q1

(a)

$$A = 1 + \frac{ZY}{2} = 1 + \frac{(13.36 + j95.07)(j15.8 \times 10^{-4})}{2}$$ (4)

$$= 0.925 \angle 0.654^\circ$$

$$B = Z = 13.36 + j95.07$$ (1)

$$C = Y\left(1 + \frac{ZY}{4}\right) = (j15.8 \times 10^{-4})\left[1 + \frac{(13.36 + j95.07)(j15.8 \times 10^{-4})}{4}\right]$$

$$= 1.52 \times 10^{-3} \angle 90.3^\circ$$ (6)

$$D = A = 0.925 \angle 0.654^\circ$$ (1)

(b)

$$P = 3 V_{ph} I_{ph} \cos\theta$$ (1)

$$|I_R| = \frac{P}{3 V_R \cos\theta} = \frac{20 \times 10^6}{3\left(\frac{275 \times 10^3}{\sqrt{3}}\right)(0.86)} = 48.82$$

$$\angle I_R = \cos^{-1} 0.86 = -30.68^\circ$$ (1)

$$\therefore I_R = 48.82 \angle -30.68^\circ$$

(1)

$$V_S = AV_R + BI_R = (0.925 \angle 0.654)\left(\frac{275k}{\sqrt{3}}\right) + (13.36 + j95.07)\, 48.82 \angle -30.62$$

$$= 149\,878 \angle 2.04^\circ$$ (1)

$$I_S = CV_R + DI_R$$

(1)

$$I_S = (1.52 \times 10^{-3} \angle 90.3^\circ)\left(\frac{275 \times 10^3}{\sqrt{3}}\right) + (0.925 \angle 0.654^\circ)\, 48.82 \angle -30.68$$

$$= 222 \angle 30.19^\circ$$ (1)

(1)

$$P_s = 3 V_R I_R \cos\theta_{V-I}$$

$$= 3\left(\frac{275 \times 10^3}{\sqrt{3}}\right)(48.82 \angle -30.68) \cos(0 - (-30.68^\circ))$$ (1)

$$= 20.48 \text{ MW}$$

$$Q_s = 3 V_R I_R \sin(\theta_V - \theta_I)$$ (1)

$$= -97.72 \text{ MVar}$$ (1)

Q2

Load 1 : 50 MW (0.85 p.f lagging)

(a)

$$P = S\cos\theta$$

$$S = \frac{P}{\cos\theta} = \frac{50\times10^6}{0.85}$$ (1)

$$Q = S\sin\theta = \frac{50\times10^6}{0.85}\sin(\cos^{-1}0.85)$$

$$= 31\ \text{MVar}$$ (1)

Load 2 :

$$S = 100\angle 75$$

$$= 25.88 + j96.6$$

$$\therefore P = 25.88\ \text{MW}, \quad Q = 96.6\ \text{MVar}$$ (1)

Load 3 : $Q = 100$ MVar.

$$P_{load}^{total} = 50 + 25.88 = 75.88\ \text{MVar}$$ (1)

(1)

using $$P_R = \frac{3|V_R||V_S|}{|B|}\cos(\beta-\delta) - \frac{3|V_R|^2|A|}{|B|}\cos(\beta-\alpha)$$

$$75.88\times10^6 = \frac{(275\times10^3)^2}{132}\cos(72.9-\delta) - \frac{(275\times10^3)^2 0.945}{132}\cos(72.9-1.7)$$ (1)

$$0.437 = \cos(72.9-\delta)$$

$$64.1^\circ = 72.9^\circ - \delta$$

$$\delta = 8.8^\circ$$ (1)

(1)

using $$Q_R = \frac{3|V_R||V_S|}{|B|}\sin(\beta-\delta) - \frac{3|V_R|^2|A|}{|B|}\sin(\beta-\alpha)$$

$$= \frac{(275\times10^3)^2}{132}\sin(72.9-8.8^\circ) - \frac{(275\times10^3)^2}{132}0.945\sin(72.9-1.7)$$ (1)

$$= 515\,371\,644.2 - 512\,521\,826$$ (1)

$$= 2.85\ \text{MVar}$$

compensation type : capacitor bank. (1)

(1)

Rating : 31 MVar + 96.6 MVar + 100 MVar − 2.85 MVar

= 224.8 MVar. (1)

Q2

(b) the voltage at receiving end will increase since the compensation is higher than the required.

$$Q_{net} \neq 0$$

$$Q_c > Q_R + Q_1 + Q_2 + Q_3$$

(Q3)

$L = 800$ ft.

$w = 5100$ lb/mi

$d_1 = 140 - 85 = 55$

$d_2 = 100 - 85 = 15$

$$w_i = 1.25 t_i (d_c + t_i) \quad (1)$$
$$= 1.25(0.3)(1.1 + 0.3)$$
$$= 0.525 \text{ lb/ft} \quad (1)$$

$$w_T = \frac{5100}{5280} + 0.525 = 1.4909 \text{ lb/ft} \quad (1)$$

$$P = \frac{d_c + 2t_i}{12} \cdot P \quad (1) = \frac{1.1 + 2(0.3)}{12} \cdot 9 = 1.275 \text{ lb/ft} \quad (1)$$

$$w_{eff} = \sqrt{w_T^2 + P^2} = \sqrt{1.4909^2 + 1.275^2}$$
$$= 1.9617 \text{ lb/ft} \quad (1)$$

$$d_1 = \frac{w x_1^2}{2T} \qquad d_2 = \frac{w x_2^2}{2T}$$

$$\frac{T}{w} = \frac{x_1^2}{2d_1} \; -(1) \qquad \frac{T}{w} = \frac{x_2^2}{2d_2} \; -(2)$$

$$(1) = (2): \quad \frac{x_1^2}{2d_1} = \frac{x_2^2}{2d_2} \quad (1)$$

$$x_1^2 = \frac{d_1}{d_2} x_2^2$$
$$= \frac{55}{15} x_2^2$$
$$x_1^2 = 3.67 x_2^2 \quad (1)$$
$$x_1 = \sqrt{3.67}\, x_2 = 1.91 x_2 \; -(3)$$

$$x_1 + x_2 = 800 \; -(4)$$

$$(3) \rightarrow (4): \quad 1.91 x_2 + x_2 = 800 \quad (1)$$
$$x_2 = \frac{800}{2.91} = 274 \text{ ft.}$$

$$\therefore \; T = \frac{x_2^2}{2d_2} w_{eff} = \frac{(274)^2 (1.9617)}{2(15)} = 4909 \text{ lb} \quad (1)$$