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POWER SYSTEMS-1

ELECTRICAL ENGINEERING

Date of Test : 27/10/2026

ANSWER KEY ➤

1. (b)	7. (d)	13. (d)	19. (b)	25. (b)
2. (c)	8. (b)	14. (d)	20. (b)	26. (d)
3. (a)	9. (d)	15. (a)	21. (b)	27. (a)
4. (d)	10. (b)	16. (c)	22. (d)	28. (a)
5. (b)	11. (c)	17. (c)	23. (a)	29. (a)
6. (a)	12. (c)	18. (c)	24. (a)	30. (a)

DETAILED EXPLANATIONS

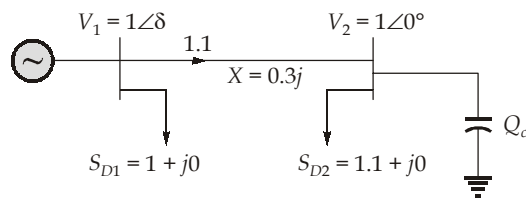
1. (b)

We know that, $X_L = \frac{B}{1-A} = \frac{36.54}{1-0.99} = 3654 \Omega$

$$L = \frac{X_L}{2\pi f} = \frac{3654}{2 \times \pi \times 50}$$

$$\Rightarrow L = 11.63 \text{ H}$$

2. (c)



$$P = \frac{V_1 V_2 \sin \delta}{X}$$

$$\Rightarrow 1.1 = \frac{\sin \delta}{0.3} \Rightarrow \delta = 19.268^\circ$$

$$Q_C = \frac{V_1 V_2}{X} (\cos \delta - 1)$$

$$= \frac{1 \times 1}{0.3} (\cos 19.268^\circ - 1)$$

$$Q_C = -0.186 \text{ or } 0.186 \text{ leading}$$

3. (a)

Load, $P_1 = 300 \text{ kW}$, motor load = 100 kW

P.f. of load, $\cos \phi_1 = 0.6$ lagging

P.f. of load, $\cos \phi_2 = 0.8$ lagging

Combined load $P = P_1 + P_2 = 300 + 100 = 400 \text{ kW}$

Loading kVAR taken by the motor

$$= P_1 \tan \phi_1 - P \tan \phi_2$$

$$= 300 \tan(\cos^{-1} 0.6) - 400 \tan(\cos^{-1} 0.8)$$

$$= 400 - 300 = 100 \text{ kVAR}$$

$$\text{Rating of the motor} = \sqrt{(100)^2 + (100)^2} = 141.42 \text{ kVA}$$

$$\text{P.f. of motor, } \cos \phi_m = \frac{100}{141.42} = 0.707 \text{ leading}$$

4. (d)

$$\text{Plant load factor, } P_f = \frac{P_{\text{avg}}}{P_{\text{max}}}$$

$$0.8 = \frac{P_{\text{avg}}}{100}$$

$$P_{avg} = 80 \text{ MW}$$

$$\text{Hence plant capacity factor} = \frac{P_{avg}}{P_c} = \frac{80}{300} = 0.267$$

5. (b)

$$V_{ph} = \frac{110}{\sqrt{3}} \text{ kV}$$

$$f = 50 \text{ Hz}$$

$$C_{ph} = 125 \text{ nF/km}$$

$$\tan \delta = 2 \times 10^{-4}$$

$$\text{Hence dielectric power loss, } P_L = V_{ph}^2 \omega C_{ph} (\tan \delta) \text{ w/km/ph}$$

$$= \left(\frac{110}{\sqrt{3}} \right)^2 \times 10^6 \times 2\pi \times 50 \times 125 \times 10^{-9} \times 2 \times 10^{-4}$$

$$= 31.678 \text{ W/km/ph}$$

6. (a)

$$\text{No. of insulator disc} = \frac{\frac{440 \times 10^3}{\sqrt{3}}}{11 \times 10^3}$$

$$= 23.094 \approx 24$$

7. (d)

$$R = \frac{1}{2} \sqrt{\frac{L}{C}} = \frac{1}{2} \sqrt{\frac{8}{0.02 \times 10^{-6}}}$$

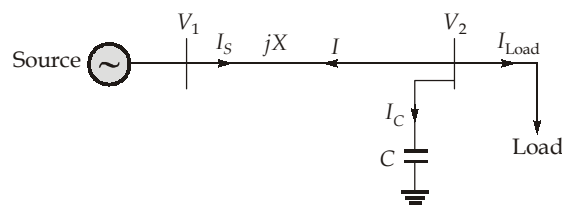
$$= \frac{1}{2} \sqrt{400 \times 10^6} = 10 \text{ k}\Omega$$

8. (b)

The voltage transmitted into the overhead line is

$$V'' = \frac{2VZ_L}{Z_L + Z_C} = \frac{2 \times 8 \times 450}{450 + 50} = 14.4 \text{ kV}$$

9. (d)



$$\text{Current supplied by source, } I_s = -I$$

$$\Rightarrow I_s = 0.78 \angle (180^\circ - 165^\circ) \text{ pu}$$

$$\Rightarrow I_s = 0.78 \angle 15^\circ \text{ pu}$$

By KCL at node 2, $I_{\text{Load}} = -I - I_c = I_s - I_c$

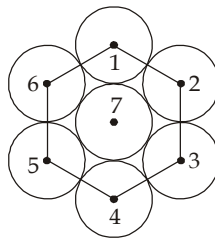
$$I_{\text{Load}} = 0.78 \angle 15^\circ - \frac{1}{-1.25j}$$

$$\Rightarrow I_{\text{Load}} = 0.962 \angle -38.445^\circ$$

Power factor of load, $\cos \phi_L = \cos(38.445^\circ)$

$$\cos \phi_L = 0.783 \text{ (lag)}$$

10. (b)



$$D_{S1} = D_{S2} = D_{S3} = D_{S4} = D_{S5} = D_{S6}$$

$$D_{S1} = \sqrt[7]{D_{11}D_{12}D_{13}D_{14}D_{15}D_{16}D_{17}}$$

$$D_{S1} = \sqrt[7]{(0.7788r)(2r)^3(2\sqrt{3}r)^2 4r}$$

$$D_{S1} = 2.2578r$$

$$D_{S7} = \sqrt[7]{(0.7788r)(2r)^6}$$

$$D_{S7} = 1.7479r$$

So,

$$\text{GMR} = \sqrt[7]{(2.2578r)^6 (1.7479r)}$$

$$\text{GMR} = 2.1767r \quad \text{where } r = \frac{\text{diameter}}{2}$$

$$\text{GMR} = 1.0884 \text{ mm}$$

11. (c)

$$\text{The turns ratio of CT} = \frac{200}{1}$$

Pickup current setting of over current relay = 50%

The operating current of the relay = $1 \times 0.5 = 0.5 \text{ A}$

Hence the secondary terminal voltage of CT

$$= \frac{4}{0.5} = 8 \text{ V}$$

12. (c)

$$P_R = \frac{V_S V_R}{Z} \cos(\theta - \delta) - \frac{V^2}{Z} \cos \theta$$

For maximum power transfer,

$$\theta = \delta$$

and also it is given that, $V_R = V_S = V$

$$P_{R \max} = \frac{V^2}{Z} - \frac{V^2}{Z} \cos \theta$$

$$Z = \sqrt{R^2 + X^2}$$

$$\cos \theta = \frac{R}{Z}$$

$$P_{R \max} = \frac{V^2}{\sqrt{R^2 + X^2}} - \frac{V^2 R}{(R^2 + X^2)}$$

$$Z = R + jX$$

So, keeping $\frac{dP_{R \max}}{dX} = 0$

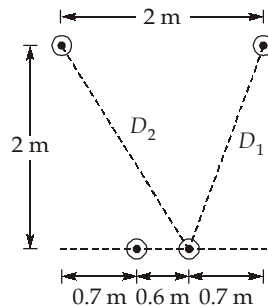
We get,

$$X = \sqrt{3}R$$

$$X = \sqrt{3} \times \sqrt{3}$$

$$X = 3 \Omega$$

13. (d)



Mutual Inductance,

$$M = 2 \times 10^{-7} \ln \left(\frac{D_2}{D_1} \right) \text{ H/m}$$

$$\Rightarrow D_2 = \sqrt{1.3^2 + 2^2} \text{ m}$$

$$D_2 = 2.3854 \text{ m}$$

$$\Rightarrow D_1 = \sqrt{0.7^2 + 2^2} \text{ m}$$

$$D_1 = 2.119 \text{ m}$$

So, $M = 4 \times 10^{-7} \ln \left(\frac{2.3854}{2.119} \right) \times 10^3 \text{ H/km}$

$$M = 0.474 \times 10^{-4} \text{ H/km}$$

Voltage induced, $V = j\omega MI$

$$|V| = 2\pi \times 50 \times 0.474 \times 10^{-4} \times 120$$

$$|V| = 1.787 \text{ V}$$

14. (d)

For unity power factor load,

$$Q_R = 0$$

$$V_S = V_R = 132 \text{ kV}$$

$$Q_R = 0$$

$$0 = \frac{|V_S||V_R|}{B} \sin(\beta - \delta) - \frac{|A||V_R|^2}{|B|} \sin(\beta - \alpha)$$

$$0 = \frac{(132)^2}{110} \sin(75 - \delta) - \frac{0.98 \times 132^2}{110} \sin(75 - 3) \text{ MVAR}$$

$$0 = \sin(75 - \delta) - 0.98 \sin 72^\circ$$

$$\sin(75 - \delta) = 0.98 \sin 72^\circ$$

$$\delta = 6.25^\circ$$

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

$$= \frac{132^2}{110} \cos(75 - 6.25) - \frac{0.98 \times 132^2}{110} \cos(75 - 3) \text{ MW}$$

$$= 57.41 - 47.97 \text{ MW} = 9.44 \text{ MW}$$

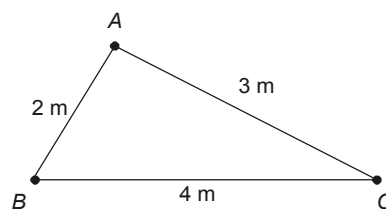
15. (a)

$$L = 0.4 l n \left(\frac{2 \times 100}{0.7788 \times 1} \right) \text{ mH/km} = 2.22 \text{ mH/km}$$

$$X_L = 2\pi \times 50 \times 10 \times 2.22 \times 10^{-3}$$

$$= 6.97 \Omega$$

16. (c)



$$r = \frac{2}{2} = 1 \text{ cm}$$

$$D_m = \sqrt[3]{D_{AB} \times D_{BC} \times D_{CA}} = \sqrt[3]{2 \times 3 \times 4} = 2.884 \text{ m}$$

$$D_s = \text{GMR} = 0.7788 r = 0.7788 \text{ cm}$$

$$\text{Inductance/phase/meter} = 2 \times 10^{-7} \ln \left(\frac{D_m}{D_s} \right) = 2 \times 10^{-7} \ln \left(\frac{D_m}{D_s} \right)$$

$$= 2 \times 10^{-7} \ln \left(\frac{288.4}{0.7788} \right) = 1.18 \mu\text{H/m}$$

17. (c)

$$\text{New surge impedance, } Z_{s1} = Z_s \sqrt{\left(\frac{1 - K_{se}}{1 - K_{sh}} \right)} = 400 \sqrt{\left(\frac{1 - 0.3}{1 - 0.2} \right)}$$

$$Z_{s1} = 374.165 \, \Omega$$

New surge impedance loading

$$= \frac{V^2}{Z_{s1}} = \frac{(400)^2}{374.165} = 427.61 \text{ MW}$$

18. (c)

Transmission line parameters,

$$V_s = AV_r + BI_r \quad \dots(i)$$

There is no load current but current flowing through the shunt inductor is I_L .

Now equation (i) becomes,

$$V_s = AV_r + BI_L$$

Dividing the above equation with I_L on both sides.

$$\frac{V_s}{I_L} = A \frac{V_r}{I_L} + B \frac{I_L}{I_L}$$

Since,

$$V_s = V_r$$

$$X_L = AX_L + B$$

$$X_L(1 - A) = B$$

$$X_L = \frac{B}{1 - A} = \frac{160}{1 - 0.95} = 3200 \, \Omega$$

19. (b)

Let base impedance = Z_B

$$X_{(\Omega)} = 0.025 Z_B$$

$$Y_{(S)} = \frac{1.4}{Z_B}$$

Assuming inductance of line, L H/km and capacitance as C F/km.

$$X = \omega L$$

$$Y = \omega C$$

$$L = \frac{X}{\omega l} = \frac{0.025 Z_B}{\omega l}; \quad C = \frac{Y}{\omega l} = \frac{1.4}{\omega l Z_B}$$

Velocity of propagation is,

$$v = \frac{1}{\sqrt{LC}}$$

$$3 \times 10^5 = \frac{1}{\sqrt{\frac{0.025 Z_B}{\omega l} \times \frac{1.4}{\omega l Z_B}}}$$

$$\text{Length of the line, } l = \frac{\sqrt{0.025 \times 1.4 \times 3 \times 10^5}}{2\pi \times 50} = 178.65 \text{ km}$$

20. (b)

Given,

$$IC_1 = 1.0 P_1 + 85 \text{ Rs/MWhr}$$

$$IC_2 = 1.2 P_2 + 72 \text{ Rs/MWhr}$$

$$\begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} = \begin{bmatrix} 0.012 & -0.001 \\ -0.001 & 0.04 \end{bmatrix}$$

Total transmission loss,

$$P_L = B_{11}P_1^2 + 2B_{12}P_1P_2 + B_{22}P_2^2$$

$$\frac{\partial P_L}{\partial P_1} = 2B_{11}P_1 + 2B_{12}P_2 = 0.024P_1 - 0.002P_2$$

$$\frac{\partial P_L}{\partial P_2} = 2B_{12}P_1 + 2B_{22}P_2 = -0.002P_1 + 0.08P_2$$

The penalty factor for the plant-1

$$L_1 = \frac{1}{1 - \frac{\partial P_L}{\partial P_1}} = \frac{1}{1 - (0.024P_1 - 0.002P_2)}$$

The penalty factor for the plant-2

$$L_2 = \frac{1}{1 - \frac{\partial P_L}{\partial P_2}} = \frac{1}{1 - (-0.002P_1 + 0.08P_2)}$$

We know,

$$IC_1L_1 = IC_2L_2 = \lambda$$

$$\frac{P_1 + 85}{1 - 0.024P_1 + 0.002P_2} = \frac{1.2P_2 + 72}{1 + 0.002P_1 - 0.08P_2} = 150$$

Using above relation,

$$\begin{aligned} 4.6P_1 - 0.3P_2 &= 65 \\ -0.3P_1 + 13.2P_2 &= 78 \\ P_1 &= 14.537 \text{ MW} \\ P_2 &= 6.239 \text{ MW} \end{aligned}$$

21. (b)

Given,

Real power $(P) = 10 \text{ MW}$

Reactive power $(Q) = 3 \text{ MVar}$

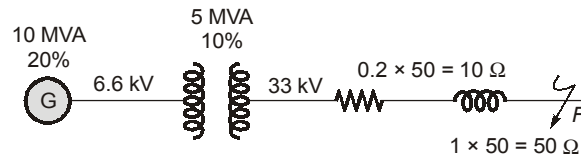
$\therefore$ MVA rating of alternator $= \sqrt{P^2 + Q^2} = \sqrt{100 + 9} = 10.44 \text{ MVA}$

$$Z_s = 5 \angle 90^\circ \Omega$$

Now,

$$\text{Line current } (I_L) = \frac{\text{Load power in MVA}}{\sqrt{3} \times V_L} \approx \frac{10.44 \times 10^6}{\sqrt{3} \times 11 \times 10^3} = 547.96 \text{ A}$$

22. (d)



The above figure shows the single line diagram of the network.

Let 10 MVA ($= 10^4$ KVA) be the base MVA.

% reactance of the alternator on base MVA is

$$\% X_A = \frac{10}{10} \times 20 = 20\%$$

% reactance of the transformer on base MVA is

$$\% X_T = \frac{10}{5} \times 10 = 20\%$$

% reactance of the transmission line is

$$\% X_L = \frac{(KVA) \times \text{reactance in } \Omega}{10 (KV)^2} = \frac{10^4 \times 50}{10(33)^2} = 45.9\%$$

% resistance of the transmission line is

$$\% R_L = \frac{(KVA) \times \text{resistance in } \Omega}{10 (KV)^2} = \frac{10^4 \times 10}{10 \times (33)^2}$$

$$\% R_L = 9.18\%$$

When the symmetrical fault occurs at point F on the transmission line (50 km away), then total % reactance upto the point of fault F .

$$= \% X_A + \% X_T + \% X_L = 20\% + 20\% + 45.9\% = 85.9\%$$

$$\% \text{ resistance} = 9.18\%$$

$\therefore$ % impedance from generator neutral upto fault point F

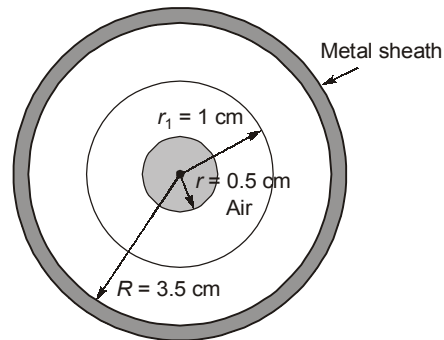
$$= \sqrt{(9.18)^2 + (85.9)^2} = 86.4\%$$

$$\text{Short circuit MVA} = 10 \times \frac{100}{86.4} = 11.57 \text{ MVA}$$

$\therefore$ Short circuit current fed to the fault by the alternator is

$$I_{SC} = \frac{11.57 \times 10^6}{\sqrt{3} \times 6.6 \times 1000} = 1012 \text{ A}$$

23. (a)



Let q be the charge per unit length of the conductor

$$g_{1 \max} = \frac{q}{2\pi \epsilon_0 r} \quad \dots(i)$$

and
$$g_{2 \max} = \frac{q}{2\pi \epsilon_0 \epsilon_r r_1} \quad \dots(ii)$$

From equation (i) and (ii), we get

$$r g_{1 \max} = g_{2 \max} \epsilon_r r_1$$

$$g_{2 \max} = \frac{r g_{1 \max}}{\epsilon_r r_1} = \frac{0.5 \times 34}{5 \times 1} = 3.4 \text{ kV/cm}$$

$$V = r g_{1 \max} \ln \frac{r_1}{r} + r_1 g_{2 \max} \ln \frac{R}{r_1}$$

$$= \left(0.5 \times 34 \times \ln \frac{1}{0.5} + 1 \times 3.4 \times \ln \frac{3.5}{1} \right)$$

$$11.7835 + 4.2593 = 16.0428 \text{ kV peak}$$

$$V_{\text{rms}} = \frac{16.0428}{\sqrt{2}} = 11.34 \text{ kV(rms)}$$

24. (a)

Given,

$$P_L = 2000 \text{ W}$$

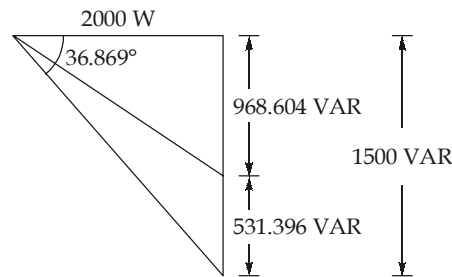
$$S_L = \frac{2000}{0.8} = 2500 \text{ VA}$$

$$Q_{L1} = \sqrt{S_L^2 - P_L^2} = \sqrt{(2500)^2 - (2000)^2} = 1500 \text{ VAR}$$

$$\phi_1 = \cos^{-1}(0.80) = 36.869^\circ$$

$$\phi_2 = \cos^{-1}(0.90) = 25.841^\circ$$

$$Q_{L2} = P_L \tan \phi_2 = 2000 \tan 25.841^\circ = 968.604 \text{ VAR}$$



reactive power supplied by the capacitor,

$$Q_C = 1500 - 968.604 \\ = 531.396 \text{ VAR}$$

We know,

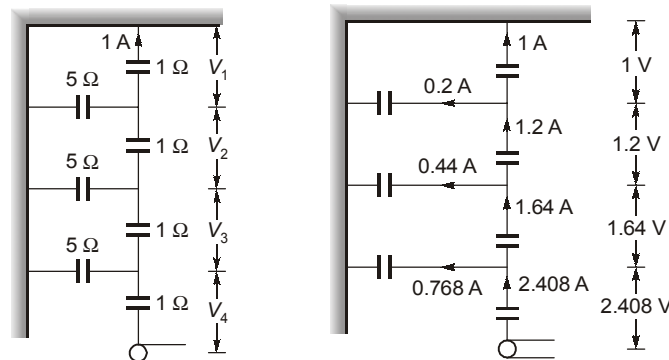
$$Q_C = \frac{V^2}{\left(\frac{1}{\omega C}\right)} = V^2 \omega C$$

$$\therefore C = \frac{Q_C}{V^2 \omega} = \frac{531.396}{(230)^2 \times 2 \times \pi \times 50} = 31.975 \mu\text{F} \approx 31.98 \mu\text{F}$$

25. (b)

The ratio of self capacitance (c) to pin-earth capacitance (c_1) is $\frac{c}{c_1} = 5$. Suppose $X_c = 1 \Omega$, then

$X_{c1} = 5 \Omega$. Suppose the voltage V across the string is such that current in the top insulator is 1 A as shown below then the potential across various insulators will be as shown below,



The voltage obtained across the string is

$$V = 1 + 1.2 + 1.64 + 2.408 \\ V = 6.248 \text{ V}$$

$$\therefore \text{String efficiency} = \frac{6.248}{4 \times 2.408} \times 100$$

$$\eta = 64.86\%$$

26. (d)

We know, natural frequency of oscillation,

$$f_n = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$$

$$X_L = 2\pi f L$$

$$8 = 2\pi \times 50 \times L$$

$$\Rightarrow L = \frac{8}{2\pi \times 50} = 0.02546 \text{ H}$$

$$\therefore f_n = \frac{1}{2\pi} \sqrt{\frac{1}{0.02546 \times 0.025 \times 10^{-6}}}$$

$$f_n = 6.31 \text{ kHz}$$

Required damped frequency of oscillation

$$= \frac{f_n}{4} = 1.577 \text{ kHz}$$

Also frequency of damped oscillation,

$$f = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{1}{4C^2R^2}}$$

$$1577 = \frac{1}{2\pi} \sqrt{\frac{1}{0.02546 \times 0.025 \times 10^{-6}} - \frac{1}{4 \times (0.025 \times 10^{-6})^2 \cdot R^2}}$$

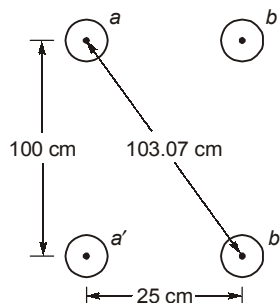
$$98180021.61 = 1571091909 - \frac{4 \times 10^{14}}{R^2}$$

$$\frac{4 \times 10^{14}}{R^2} = 1472911887$$

$$R^2 = 2.7157 \times 10^5$$

$$R = 521.124 \Omega$$

27. (a)



$$\text{GMR of conductor} = 0.7788 \times r$$

$$= 0.7788 \times 0.5 = 0.3894 \text{ cm}$$

Self GMD of aa' combination is,

$$D_s = \sqrt[4]{D_{aa} \cdot D_{aa'} \cdot D_{a'a'} \cdot D_{a'a}}$$

$$= \sqrt[4]{(0.3894)^2 \cdot (100)^2} = 6.2402 \text{ cm}$$

Mutual GMD between a and b ,

$$= D_m = \sqrt[4]{D_{ab} \cdot D_{ab'} \cdot D_{a'b} \cdot D_{a'b'}}$$

$$= \sqrt[4]{(25)^2 \times (103.07)^2} = 50.76 \text{ cm}$$

Inductance per conductor per meter,

$$= 2 \times 10^{-7} \log_e \left(\frac{D_m}{D_s} \right)$$

$$= 2 \times 10^{-7} \log_e \left(\frac{50.76}{6.2402} \right) = 0.42 \times 10^{-6} \text{ H}$$

$$\therefore \text{loop inductance per km of the line}$$

$$= 2 \times 0.42 \times 10^{-6} \times 1000 = 0.84 \text{ mH}$$

28. (a)

Let the operating voltage and power factor in both the systems be V volts and $\cos \phi$ respectively. If I_1 is single phase current, I_2 is the three phase current and R is the resistance of each conductor, then

Single phase system:

$$P_1 = VI_1 \cos \phi \text{ Watts}$$

$$\text{Losses} = 2I_1^2 R \text{ Watts}$$

$$\text{Percentage line losses} = \frac{W_1}{P_1} \times 100 = \frac{2I_1^2 R}{VI_1 \cos \phi} \times 100$$

3- ϕ system:

$$P_2 = \sqrt{3}VI_2 \cos \phi$$

$$\text{Line losses} = 3I_2^2 R$$

$$\text{Percentage line losses} = \frac{3I_2^2 R}{\sqrt{3}VI_2 \cos \phi} \times 100$$

For the same percentage line losses in both the cases, we have

$$\frac{2I_1^2 R}{VI_1 \cos \phi} \times 100 = \frac{3I_2^2 R}{\sqrt{3}VI_2 \cos \phi} \times 100$$

$$2I_1 = \sqrt{3}I_2$$

$$I_2 = \frac{2}{\sqrt{3}}I_1$$

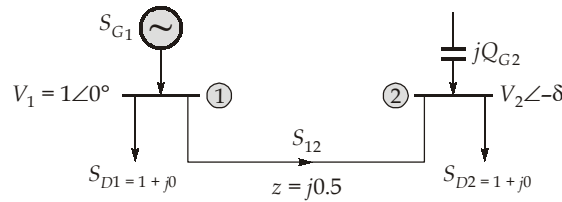
$\therefore$ Power transmitted in 3- ϕ system,

$$P_2 = \sqrt{3}V \times \frac{2}{\sqrt{3}}I_1 \cos \phi = 2VI_1 \cos \phi = 2P_1$$

$$\therefore \text{Percentage of additional load} = \frac{P_2 - P_1}{P_1} \times 100$$

$$= \frac{P_1}{P_1} \times 100 = 100\%$$

29. (a)



$$P_S = \frac{V_1 V_2}{X_L} \sin \delta$$

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

$$\delta = -30^\circ$$

$$Q_R = \frac{V_S V_R}{X_L} \cos \delta - \frac{V_R^2}{X_L}$$

$$= -0.268 \text{ pu}$$

$$Q_C = Q_{G2} = -Q_R = -(-0.268)$$

$$= 0.268 \text{ pu}$$

30. (a)

The initial symmetrical rms current is the current to subtransient state where the reactance is 10% or 0.1 p.u.

$$\text{Initial symmetrical rms current} = \frac{\text{Rated kVA}}{(\text{p.u. } X_d'') \times \sqrt{3} \times \text{Rated voltage in kV}}$$

$$= \frac{8000}{0.1 \times \sqrt{3} \times 13.8} = 3346.95 \text{ A}$$

$$= 3.346 \text{ kA}$$

Current to be interrupted by the breaker,

$$= 1.1 \times \text{symmetrical breaking current} \quad (\because \text{the breaker is 5-cycle one})$$

$$= 1.1 \times 3.346 \text{ kA} = 3.681 \text{ kA}$$

