CLASS TEST

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POWER SYSTMS-1

ELECTRICAL ENGINEERING

Date of Test : 22/08/2022

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. (c)
4. (d)	10. (b)	16. (c)	22. (d)	28. (a)
5. (b)	11. (c)	17. (b)	23. (c)	29. (b)
6. (a)	12. (c)	18. (d)	24. (a)	30. (a)

DETAILED EXPLANATIONS

1. **(b)**

We know that,
$$X_L = \frac{B}{1-A} = \frac{36.54}{1-0.99} = 3654\ \Omega$$
$$L = \frac{X_L}{2\pi f} = \frac{3654}{2\times\pi\times 50}$$
$$\Rightarrow \quad L = 11.63\text{ H}$$

2. **(c)**

At SIL, the VARs consumed by series inductance of line are equal to the VARs generated by shunt capacitance of line so no VARs is required by transmission line. Hence at all the points on the line there is in phase voltage and current, i.e. upf, i.e. flat voltage.

3. **(a)**

Load, P_1 = 300 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 $P = P_1 + P_2 = 300 + 100 = 400$ kW

Loading kVAR taken by the motor

$$= P_1\tan\phi_1 - P\tan\phi_2$$
$$= 300\tan(\cos^{-1}0.6) - 400\tan(\cos^{-1}0.8)$$
$$= 400 - 300 = 100\text{ kVAR}$$

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

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

4. **(d)**

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

$$0.8 = \frac{P_{avg}}{100}$$
$$P_{avg} = 80\text{ MW}$$

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

5. **(b)**

$$V_{ph} = \frac{110}{\sqrt{3}}\text{kV}$$
$$f = 50\text{ Hz}$$
$$C_{Ph} = 125\text{ nF/km}$$
$$\tan\delta = 2\times10^{-4}$$

Hence dielectric power loss, $P_L = V_{ph}^2 \omega c_{ph} (\tan\delta)$ 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)

$$\text{GMR} = \sqrt[4]{0.7788 \times r \times 2r \times 2r \times 2\sqrt{2}r} = 1.723\, r$$

10. (b)

- SF_6 is non-inflammable and chemically stable. Its products of decomposition are not explosive there is no danger of fire or explosion.
- The operation of SF_6, CB is noiseless as there is no exhaust to atmosphere as in case of air blast CB.

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 × 0.5 = 0.5 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, $V_R = V_S = V$

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

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

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

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

$$Z = R + jX$$

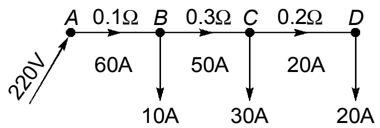
So, keeping $\frac{dP_{R\max}}{dX} = 0$

We get, $X = \sqrt{3}R$

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

$$X = 3\ \Omega$$

13. (d)



Voltage node D = 220 – [(0.1 × 60) + (0.3 × 50) + (0.2 × 20)]
= 195 V

14. (d)

For unity power factor load, $Q_R = 0$

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

$$Q_R = 0$$

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

$$0 = \frac{(132)^2}{110}\sin(75-\delta) - \frac{0.98\times132^2}{110}\sin(75-3)\text{ MVAR}$$

$$0 = \sin(75-\delta) - 0.98\sin72°$$

$$\sin(75-\delta) = 0.98\sin72°$$

$$\delta = 6.25°$$

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

$$= \frac{132^2}{110}\cos(75-6.25) - \frac{0.98\times132^2}{110}\cos(75-3)\text{MW}$$

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

15. (a)

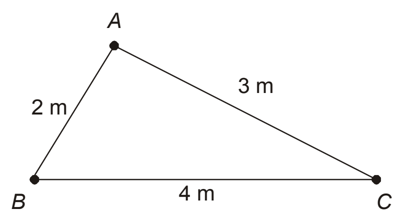
$$L = 0.4 \ln\left(\frac{2\times100}{0.7788\times1}\right) \text{mH/km}$$

$$= 2.22 \text{ mH/km}$$

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

$$= 6.97\ \Omega$$

16. (c)



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

$$D_m = \sqrt[3]{D_{AB}\times D_{BC}\times D_{CA}} = \sqrt[3]{2\times3\times4} = 2.884 \text{ m}$$

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

$$\text{Inductance/phase/meter} = 2\times10^{-7} \ln\left(\frac{D_m}{D_s}\right) = 2\times10^{-7} \ln\left(\frac{D_m}{D_s}\right)$$

$$= 2\times10^{-7} \ln\left(\frac{288.4}{0.7788}\right) = 1.18\ \mu\text{H/m}$$

17. (b)

Penalty factor,

$$L_1 = \frac{1}{1-\left(\frac{dP_{Loss}}{dP_1}\right)} = \frac{1}{1-\frac{2}{10}} = \frac{10}{8}$$

and cost of received power

$$= L_1\frac{dF_1}{dP_1} = (0.1\times10+3)\times\frac{10}{8} = \text{Rs } 5/\text{MWhr}$$

18. (d)

From the given voltages,

$$I_a = \frac{V_{an}}{R} = \frac{10\angle 0°}{R}$$

$$I_b = \frac{V_{bn}}{jX_L} = \frac{10\angle -120°}{j1} = 10\angle 150° \text{ A}$$

$$I_c = \frac{V_{cn}}{-jX_C} = \frac{10\angle 120°}{-j1} = 10\angle -150° \text{A}$$

Given,

$$I_n = 0 = I_a + I_b + I_c$$

$$= \frac{10\angle 0°}{R} + 10\angle 150° + 10\angle -150° = 0$$

$$R = 0.577 \simeq 0.58\ \Omega$$

19. (b)

$$\text{Let base impedance} = Z_B$$

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

$$Y_{(℧)} = \frac{1.4}{Z_B}$$

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

$$X = \omega l L$$

$$Y = \omega l C$$

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

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 penality 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 penality 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,

$$4.6P_1 - 0.3P_2 = 65$$
$$-0.3P_1 + 13.2\,P_2 = 78$$
$$P_1 = 14.537 \text{ MW}$$
$$P_2 = 6.239 \text{ MW}$$

21. (b)

Given,

Real power $(P) = 10$ MW

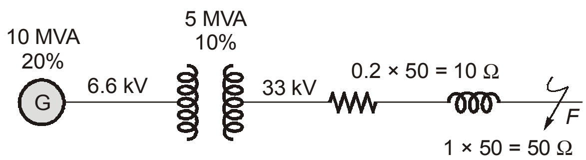
Reactive power $(Q) = 3$ MVAr

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

$$Z_s = 5\angle 90°\ \Omega$$

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

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

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

∴ % impedance from generator neutral upto fault point F

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

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

∴ 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. (c)

Since there is no load at bus 1, evidently the transmission loss does not directly depend on P_{G_2}.
Thus B_{12}, and B_{22} both are zero.
Further a power of 100 MW flows from bus 1 to bus 2 and causes a loss of 10 KW. So

$$P_L = B_{11} P_{G_1}^{\ 2}$$

$$10\times 10^3 = B_{11}\,(100\times 10^6)^2$$

$$B_{11} = 1\times 10^{-6}\ \text{MW}^{-1}$$

$$P_L = 1\times 10^{-6} P_{G_1}^{\ 2} \text{ and } \frac{\partial P_L}{\partial P_{G2}} = 0$$

Penality factor for plant 1,

$$L_1 = \frac{1}{1-\dfrac{\partial P_L}{\partial P_{G_1}}} = \frac{1}{1-2\times 10^{-6} P_{G_1}}$$

Penality factor for plant 2,

$$L_2 = \frac{1}{1-0} = 1$$

The generation at plant 1 is required to be determined for λ = Rs 25/MWh

$$\frac{dF_1}{dP_{G1}}.L_1 = \frac{dF_2}{dP_{G2}}.L_2 = \lambda$$

$$\frac{0.02\,P_{G1}+16}{1-2\times10^{-6}P_{G1}} = 25$$

$$P_{G1} = 448.9 \text{ MW}$$

24. (a)

Given,

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

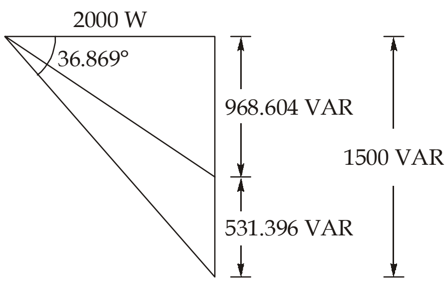
$$S_L = \frac{2000}{0.8} = 2500 \text{ VA}$$

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

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

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

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



reactive power supplied by the capacitor,

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

We know,

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

$$\therefore \quad C = \frac{Q_C}{V^2\omega} = \frac{531.396}{(230)^2\times2\times\pi\times50} = 31.975\ \mu\text{F} \approx 31.98\ \mu\text{F}$$

25. (b)

Let V_P as reference phasor,

$$V_P = 220\angle0° \text{ V}$$

Current in section PQ, $I_1 = 20\angle0°$ A

Voltage at load point Q,

$$V_Q = V_P + I_1Z_2$$
$$= 220\angle0° + 20\angle0°\,(j1)$$
$$= 220.907\angle5.20° \text{ V}$$

Phase angle between V_Q and V_P,

$$\theta_1 = 5.20°$$

Phase angle between load armature I_2 and V_Q

$$\phi = \cos^{-1}(0.6) = -53.13°$$

Phase angle between load current I_2 and voltage at point P (V_p)

$$\phi = -53.13° + 5.2° = -47.93°$$

So, load current at point Q, I_2

$$I_2 = 12\angle -47.93° \text{ A}$$

$$I_S = I_1 + I_2 = 20 + 12\angle -47.93°$$

$$= 29.42\angle -17.62° \text{ A}$$

$$V_S = V_Q + Z_1 I_S$$

$$= 220.907\angle 5.2° + (j1)(29.42\angle -17.62°)$$

$$= 233.90\angle 11.86° \text{ V}$$

Source power factor,

$$\cos\phi_s = \cos(11.86° - (-17.62°)) = 0.870 \text{ lagging}$$

26. (d)

We know, natural frequency of oscillation,

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

$$X_L = 2\pi f L$$

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

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

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

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

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. (c)

Primary earth-fault current at which the relay operates,

$$= \frac{100 \times 10^6}{\sqrt{3} \times 11 \times 10^3} \times \frac{15}{100} = 787.29 \text{ A}$$

The percentage of winding which remains unprotected is

$$P = 100 - 80 = 20\%$$

$$\text{The fault current} = \frac{20}{100} \times \frac{11 \times 10^3}{\sqrt{3} R_n}$$

Where R_n is the resistance in the neutral to ground connection

$$\frac{20}{100} \times \frac{11 \times 10^3}{\sqrt{3} R_n} = 787.29$$

$$\therefore \quad R_n = \frac{20 \times 11 \times 10^3}{100 \times \sqrt{3} \times 787.29} = 1.61 \text{ ohms}$$

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. (b)

Since active power demand at bus-2 is 1 p.u. only S_{G1} can supply real power to the load at bus-2. So this real power should flow in the transmission line from bus-1 to bus-2 complex power flowing from bus-1 to bus-2, S_{12}

$$S_{12} = V_1 I_{12}^*$$

V_1 = voltage at bus-1

I_{12} = current through transmission line from bus-1 to bus-2

$$S_{12} = V_1 I_{12}^*$$

$$= 1\angle 0^\circ \left[\frac{1\angle 0^\circ - 1\angle -\delta}{j0.5}\right]^* = 2[1\angle -90^\circ - 1\angle(-\delta - 90^\circ)]^*$$

$$S_{12} = 2[1\angle 90^\circ - 1\angle 90^\circ + \delta]$$

$$S_{12} = 2\angle 90^\circ - 2\angle 90^\circ + \delta$$

The real power flow from bus-1 to bus-2 is,

$$P_{12} = 2\cos 90^\circ - 2\cos(90^\circ + \delta)$$

Given that, $P_{12} = 1$ [Real power flow from bus-1 to bus-2 to supply S_{D2}]

Therefore, $1 = -2\cos(90^\circ + \delta)$

$$1 = 2\sin\delta$$

$\therefore$ $\delta = 30^\circ$

$\therefore$ Voltage at bus-2, $V_2 = 1\angle -30^\circ$ V

Complex power flow from bus-2 to bus-1,

$$S_{21} = V_2 I_{21}^*$$

I_{21} = Current flowing through transmission line from bus-2 to bus-1

$$S_{21} = 1\angle -30^\circ \left[\frac{1\angle -30^\circ - 1\angle 0^\circ}{j0.5}\right]^* = 2\angle -30^\circ\ [1\angle -120^\circ - 1\angle -90]^*$$

$$= 2\angle -30^\circ\ [1\angle 120^\circ - 1\angle 90^\circ]$$

$$S_{21} = 2\angle 90^\circ - 2\angle 60^\circ$$

The reactive power supplied by capacitor,

$$Q_{G2} = 2[\sin 90^\circ] - 2\sin 60^\circ = 2 - \sqrt{3} = 0.268 \text{ p.u.}$$

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 × symmetrical breaking current ($\because$ the breaker is 5-cycle one)

= 1.1 × 3.346 kA = 3.681 kA

■■■■