CLASS TEST

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Power System-1

ELECTRICAL ENGINEERING

Date of Test : 14/10/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. **(a)**

Solar cell maximum power,

$$P_{max} = V_{max} \times I_{max}$$
$$= -6 \times 10^{-3} \times 0.14$$
$$= 0.84 \text{ mW}$$
$$P_{input} = \text{Intensity} \times \text{Area}$$
$$= 100 \times 5 \times 10^{-4} \text{ W}$$

Cell efficiency, $$\eta = \frac{0.84\times10^{-3}}{100\times5\times10^{-4}} = 0.0168 \text{ or } 1.68\%$$

2. **(c)**

The self GMD of the seven strand conductor is the 49th root of 49 distances,

$$D_s = ((r')^7 (D_{12}^2 D_{26}^2 D_{14}^2 D_{17})^6 (2r)^6)^{1/49}$$

$$D_s = ((0.7788r)^7 (D_{12}^2 D_{26}^2 D_{14} D_{17})^6 (2r)^5)^{1/49}$$

$$D_{12} = 2r,\ D_{26} = 2\sqrt{3}\,r,\ D_{14} = 4r,\ D_{17} = 2r$$

$$D_s = ((0.7788r)^7 (2^2r^2 \times 3 \times 2^2r^2 \times 2^2 \times r \times 2r \times 2r)^6)^{1/49}$$

$$D_s = \frac{2r(3\times0.7788)^{1/7}}{6^{1/49}}$$

$$= 2.1767 \times 2 = 0.435 \approx 0.44 \text{ cm}$$

3. **(d)**

For given system:

Total reactive power at,

G_1 = Reactive power demand at Bus 1 + Reactive power being transferred to Bus 2

Reactive power demand at bus = 10 pu

Reactive power transferred to bus 2,

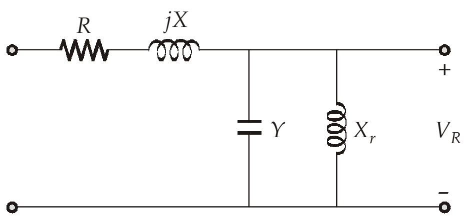
$$Q_s = \frac{|V_s|}{X}(|V_s| - |V_R|\cos\delta)$$

$$Q_s = \frac{1}{0.04}(1 - 1\times\cos 20°) = 1.508 \text{ pu}$$

∴ Total reactive power at G_1 Q_{G1} = 1.508 + 10 = 11.508 pu

4. **(d)**

Given transmission line model can be drawn,



Equivalent T-matrix will be

$$\begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} = \begin{bmatrix} 1+YZ & Z \\ Y & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ 1/jX_r & 1 \end{bmatrix}$$

For no ferranti effect,

$$V_s = V_R \rightarrow A_1 = 1$$

$$1+YZ+\frac{Z}{jX_r} = 1$$

Simplifying, $$YZ = j\frac{Z}{X_r}$$

or $$|X_r| = \frac{Z}{YZ} = \frac{1}{Y} = \frac{1}{4\times 10^{-4}} = 2500\ \Omega$$

5. **(b)**

$$\text{Plug setting} = \frac{\text{Primary fault current of C.T.}}{\text{CT ratio} \times \text{relay current setting}}$$

$$1 = \frac{I_f}{\frac{500}{1}\times 0.3}$$

$$I_f = 0.3 \times 500 = 150 \text{ A}$$

$$\text{Fault current, } I_f = 3\, I_{a0}$$

$$I_{a0} = \frac{I_f}{3} = \frac{150}{3} = 50 \text{ A}$$

6. **(a)**

$$C_{an} = \frac{2\pi\varepsilon_0}{\ln\left(\frac{GMD}{r}\right)} \text{F/m}$$

$$\text{GMD} = (3 \times 4 \times 5)^{1/3} = 3.914 \text{ m}$$

$$C_{an} = \frac{2\pi\times 8.854}{\ln\left(\frac{3.914}{2\times 10^{-2}}\right)}\times 10^{-12}\,\text{F/m}$$

$$C_{an} = 10.54 \text{ pF/m}$$

7. **(c)**

Transmission line parameters,

$$V_s = A\, V_r + B\, I_r \quad \text{...(i)}$$

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

Now equation (i) becomes,

$$V_s = A\, V_r + B\, I_L$$

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, $$V_S = V_R$$

$$X_L = A\,X_L + B$$
$$X_L\,(1 - A) = B$$
$$X_L = \frac{B}{1-A} = \frac{160}{1-0.9} = 1600\ \Omega$$

8. **(c)**

P_{max} is more if 'X' of line is low,

$$P_{max} = \frac{V_1 V_2}{X}$$

∴ L is low ($X = 2\pi f L$)

$$L = 2\times 10^{-7}\ln\left(\frac{GMD}{GMR}\right)$$

To get more P_{max}, GMD should be low and GMR should be high.

9. **(b)**

$$V = i\sqrt{\frac{L}{C}} = 20\sqrt{\frac{2}{8\times 10^{-6}}} = \frac{20}{2\times 10^{-3}} = 10\text{ kV}$$

10. **(c)**

Maximum dielectric stress = g_{max}

$$g_{max} = \frac{V}{r\ln\left(\frac{R}{r}\right)}$$

Minimum dielectric stress = g_{min}

$$g_{min} = \frac{V}{R\ln\left(\frac{R}{r}\right)}$$

∴ the ratio of maximum to minimum dielectric stress

$$= \frac{g_{max}}{g_{min}}$$

(or) $$\frac{g_{max}}{g_{min}} = \frac{\dfrac{V}{r\ln\left(\frac{R}{r}\right)}}{\dfrac{V}{R\ln\left(\frac{R}{r}\right)}} = \frac{R}{r} = \frac{D}{d}$$

11. **(d)**

$$\text{GMD} = (20 \times 20 \times 40)^{1/3} = 25.2\text{ feet}$$
$$\text{GMR} = (0.7788 \times 0.5 \times 8)^{1/2} = 1.765\text{ inch}$$
$$= \frac{1.765}{12}\text{ feet} = 0.147\text{ feet}$$

$$\text{Inductance, } L = 0.2 \ln \frac{\text{GMD}}{\text{GMR}} \text{ mH/km}$$

$$= 0.2 \ln \frac{25.2}{0.147} = 1.028 \text{ mH/km}$$

12. (a)

$$\text{Input to motor} = \frac{\text{Motor output}}{\eta} = \frac{80\,\text{kW}}{0.95} = 84.21 \text{ kW}$$

Initial power factor, $\cos \phi_1 = 0.75$ (lagging)

Power factor after improvement,

$$\cos \phi_2 = 0.95 \text{ (lagging)}$$

KVAR rating of capacitor bank $= P(\tan \phi_1 - \tan \phi_2)$

$$= 84.21 [\tan(\cos^{-1} (0.75)) - \tan(\cos^{-1} (0.95))]$$

$$= 46.58 \text{ kVAR}$$

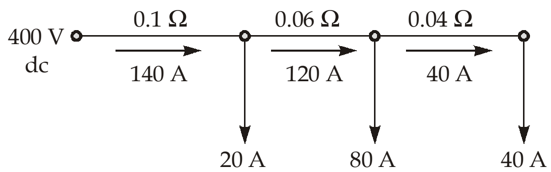
13. (b)

$$\text{GMR} = \left[\left((0.7788 \times 2) \times 50 \times 50 \times 50\sqrt{2}\right)^4\right]^{1/16}$$

$$= 22.9 \text{ cm}$$

14. (b)

For given dc system, SLD can redrawn,



$$V_{min} = V_{dc} - I_1R_1 - I_2R_2 - I_3R_3$$

$$= 400 - (140 \times 0.1) - (120 \times 0.06) - (0.04 \times 40)$$

$$= 400 - 14 - 7.2 - 1.6 = 377.2 \text{ V}$$

15. (c)

Given, $|V_S| = |V_R| = 220$ kV

$$\alpha = 5°,$$

$$\beta = 75°$$

Since the power is received at unity power factor,

$$Q_R = 0$$

$$0 = \frac{220 \times 220}{200} \sin(75° - \delta) - \frac{0.85}{200} \times (220)^2 \sin(75° - 5°)$$

$$= 242 \sin(75° - \delta) - 193.29$$

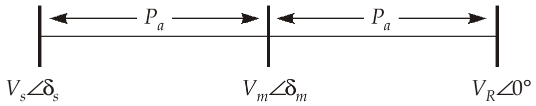
$$193.29 = 242 \sin (75° - \delta)$$

$$75° - \delta = 53°$$

Power angle, $\delta = 22$

16. (c)

Considering the midpoint location with compensator,



The reactance of line upto midpoint is $X/2$,

$$P_e = \frac{V_s V_m}{X/2}\sin(\delta_s - \delta_m) = \frac{V_m V_R}{X/2}\sin(\delta_m - 0)$$

or

$$\delta_s - \delta_m = \delta_m \text{ or } \delta_m = \frac{\delta_s}{2} = \frac{30°}{2} = 15°$$

$$P_e = \frac{V_s V_m}{X/2}\sin(\delta_s - \delta_m)$$

$$= \frac{1\times 0.90}{0.4/2}\sin 15° = 1.16 \text{ pu}$$

17. (d)

$$V_S = 120 \text{ kV}, \qquad V_r = 110 \text{ kV},$$

$$A = 0.96$$

$$\alpha = 1°, \qquad \beta = 80°$$

Maximum power transmitted is given by

$$P_{max} = \frac{V_s \cdot V_r}{B} - \frac{AV_r^2}{B}\cos(\beta - \alpha)$$

$$= \frac{110\times 120}{100} - \frac{0.96\times 110^2}{100}\cos(80° - 1°)$$

$$P_{max} = 109.83 \text{ MW}$$

18. (a)

Core radius, $\quad r_1 = \frac{1.5}{2} = 0.75 \text{ cm}$

Sheath radius, $\quad r_2 = \frac{5}{2} = 2.5 \text{ cm}$

$$\ln\left(\frac{r_2}{r_1}\right) = \log_e^{2.5/0.75} = 1.2$$

$$\rho = \frac{R_{INS}\times 2\pi l}{\ln\left(\frac{r_2}{r_1}\right)} = \frac{1820\times 10^6\times 2\pi\times 3500}{1.2} = 33.35\times 10^{12}\ \Omega\text{-m}$$

19. (c)

Capacitance between any two core,

$$C_2 = 3.7\ \mu F$$

Capacitance of each core to neutral,

$$C_N = 2C_2 = 2\times 3.7 = 7.4\ \mu F$$

$$I_C = 2\pi f\, V_P\, C_N$$

$$= 2\pi\times 50\times\frac{11000}{\sqrt{3}}\times 7.4\times 10^{-6} = 14.76 \text{ A}$$

20. (b)

Insulation resistance, $R = \frac{\rho}{2\pi l}\ln\left(\frac{R}{r}\right)\Omega$

$$\frac{R_2}{R_1} = \frac{l_1}{l_2}$$

$$R_2 = 1\,\text{M}\Omega\left(\frac{100}{10}\right) = 10\ \text{M}\Omega$$

21. (c)

Power transfer capacity $\propto V^2$

$$\frac{P_1}{P_2} = \frac{V_1^2}{V_2^2}$$

$$P_2 = P_1\frac{V_2^2}{V_1^2} = P\left(\frac{100}{400}\right)^2 = \frac{P}{16}$$

22. (b)

Primary line current $= I_{LP} = \frac{10\times10^6}{\sqrt{3}\times132\times10^3} = 43.74$ A

CT connected to primary of transformer is delta connected.

So, the current in the secondary of the CT is $\frac{5}{\sqrt{3}}$A

$\therefore$ The CT ratio of primary of the transformer is, 43.74/(5/1.732)

The secondary line current of the transformer is,

$$I_{LS} = \frac{10\times10^6}{\sqrt{3}\times66\times10^3} = 87.47\ \text{A}$$

$\therefore$ The CT ratio on the secondary is, $\frac{87.47}{5}$.

23. (a)

In π model, the shunt admittance at each end of the line is $\frac{Y}{2}$

$$\frac{Y}{2} = j\omega\frac{C}{2} = j(2\pi\times50)\times\frac{0.03}{\pi}\times\frac{1}{2}\times10^{-6}\times100$$

$$= 150\times10^{-6}\angle90°\ \mho$$

24. (d)

Zero regulation of a transmission line occurs at a leading power factor,

when $\phi = \tan^{-1}\left(\frac{X}{R}\right)$

Given, $X = R$

$\phi = 45°$

Hence $\cos\phi = 0.707$ leading.

25. (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 $\dfrac{dP_{R\max}}{dX} = 0$

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

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

$$X = 3\ \Omega$$

26. (b)

The relay current setting = 25%

∴ The relay operates at a current of

= 0.25 × 5 = 1.25 A

The VA burden on the relay is,

$$VA = 5$$

$$5 = V \times 1.25$$

∴ $V = 4$ V.

27. (b)

$$\text{String efficiency} = \frac{\text{Voltage across the string}}{n \times \text{Voltage across the lower most unit}}$$

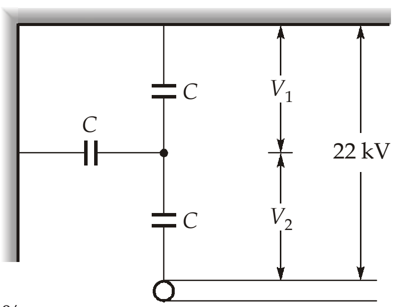
$$\eta = \frac{V_1 + V_2}{n \times V_2} \times 100$$

$$V_2 = V_1 + KV_1$$

$$V_2 = 2\,V_1$$

$$\eta = \frac{V_1 + 2V_1}{2 \times 2V_1} \times 100$$

$$= \frac{3V_1}{4V_1} \times 100 = 0.75 \times 100 = 75\%$$



28. (a)

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum demand}}$$

$$\text{Plant capacity factor} = \frac{\text{Average load}}{\text{Plant capacity}}$$

$$\frac{\text{Load factor}}{\text{Plant capacity factor}} = \frac{0.6}{0.5} = \frac{\text{Plant capacity}}{\text{Maximum demand}}$$

$$\text{Plant capacity} = \frac{0.6}{0.5} \times 30 = 36 \text{ MW}$$

$$\text{Reserve capacity} = \text{Plant capacity} - \text{Maximum demand}$$

$$= 36 - 30 = 6 \text{ MW}$$

29. (a)

The secondary current, $I_S = \frac{I_P}{n}$

Where, $n = \frac{500}{5}$

$$I_S = 7500 \times \frac{5}{500} = 75 \text{ A}$$

$$\text{Relay current setting} = 125\% \text{ of } 5\text{A} = 1.25 \times 5 = 6.25 \text{ A}$$

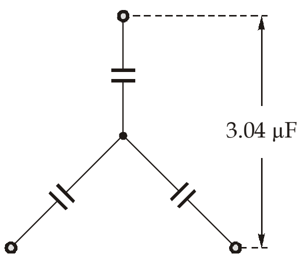
$$\text{Plug setting multiplier (PSM)} = \frac{75}{6.25} = 12$$

Using data in characterstic table is

Operating time corresponding to PSM = 12 is 2.8 sec (at TMS = 1)

Operating time of relay = 2.8 sec × 0.4 = 1.12 sec.

30. (a)



Since the capacitance measured is 3.04 μF between the conductors, the capacitance per phase will be

$$2 \times 3.04 = 6.08 \text{ μF}$$

$$\text{3-phase kVAR required} = V^2\omega C$$

$$= 20^2 \times 314 \times 6.08 \times 10^{-3}$$

$$= 763.6 \text{ kVAR}$$

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