CLASS TEST

S.No.: 01SK_ABCDEFG_13102024

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Power System-1

ELECTRICAL ENGINEERING

Date of Test : 13/10/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)

$$(RRRV)_{\max} = \frac{V_m}{\sqrt{LC}} \qquad (X_L = 2\pi f L)$$

$$L = \frac{10}{2\times\pi\times 50} = 0.0318$$

$$(RRRV)_{\max} = \left(\frac{400}{\sqrt{3}}\times\sqrt{2}\right)\times\frac{1}{\sqrt{0.0318\times 0.040\times 10^{-6}}}$$

$$(RRRV)_{\max} = 9.16 \text{ kV}/\mu\text{s}$$

2. (d)

$$C_{AB} = \left(\frac{\pi\in_0\in_r}{\ln\left(\dfrac{d}{r\sqrt{1+\dfrac{d^2}{4h^2}}}\right)}\right) = \frac{\pi\times 8.854\times 10^{-12}}{\ln\left(\dfrac{2}{0.5\times 10^{-2}\sqrt{1+\dfrac{2^2}{4\times 10^2}}}\right)} = 4.646 \text{ nF/km}$$

3. (b)

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

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

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

4. (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.

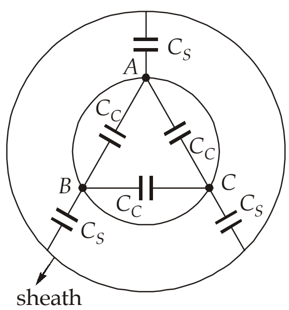
5. (b)

$$(\text{SIL})_N = (\text{SIL})_{\text{old}}\times\sqrt{1+K_1} = (\text{SIL})_{\text{old}}\times\sqrt{1+0.3}$$

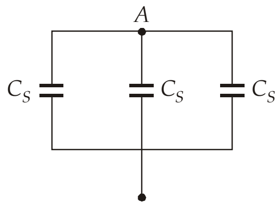
$$\%\text{ change} = \frac{\sqrt{1.3}-1}{1}\times 100 = 14.02\%$$

6. (c)

When all conductors are shorted,



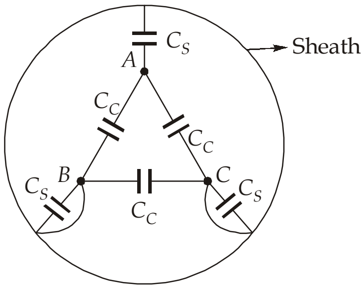
Capacitance between shorted conductors and sheath is $3C_s$.



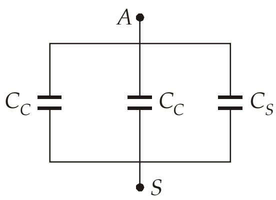
$\therefore \quad 3C_s = 0.8\ \mu F$

$$C_s = \frac{0.8\mu F}{3} = 0.2667\ \mu F$$

When two conductors shorted with sheath



$\therefore$



$$C_{AS} = 2C_C + C_S$$

$\therefore$ Capacitance between two conductors shorted with sheath and the third conductor is $2C_C + C_S$.

$$\therefore \quad 2\,C_C + C_S = 0.4$$
$$2C_C + 0.2667 = 0.4$$
$$2C_C = 0.1333$$
$$C_C = 0.0666\ \mu F$$

7. **(a)**

Voltage across the circuit breaker contacts after the interruption of 10 A current

$$V = i\sqrt{\frac{L}{C}} = 10\sqrt{\frac{5}{0.01\times10^{-6}}}$$
$$= 10\sqrt{5}\times10^{4}$$
$$= 100\sqrt{5}\ \text{kV}$$

8. **(c)**

Reactive power of capacitor $Q_C \propto V^2\omega$

$$Q_C \propto V^2 f$$

$$\therefore \text{Reactive power supplied} = \left(\frac{1.1\times33}{33}\right)^2\times\left(\frac{0.85\times f}{f}\right)\times100$$
$$= 102.85\ \text{MVAR}$$

9. (b)

Given,

$$V_s = 120 \text{ kV},$$
$$V_r = 110 \text{ kV}$$
$$A = 0.96$$
$$\alpha = 10°,$$
$$B = 100$$
$$\beta = 80°$$

Maximum power transmitted is given by,

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

$$= \frac{110 \times 120}{100} - \frac{0.96 \times (110)^2}{100}\cos(80° - 10°)$$

$$P_{\max} = 92.27 \text{ MW}$$

10. (b)

Capacitance per meter length,

$$C_N = \frac{2\pi\varepsilon_0}{\ln\frac{D}{r}} \text{F/m} = \frac{2\pi \times 8.854 \times 10^{-12}}{\ln\left(\frac{2}{3 \times 10^{-3}}\right)} = 8.555 \times 10^{-12} \text{F/m}$$

$$C_N = 8.555 \times 10^{-3}\ \mu\text{F/km}$$

$$C_N \text{ of 50 km line} = 0.4277\ \mu\text{F}$$

$$\text{Charging current} = \frac{V}{X_C} = V\omega C = 220 \times 10^3 \times 2\pi \times 50 \times 0.4277 \times 10^{-6}$$

$$I = 29.56 \text{ A}$$

11. (c)

$$|V_S| = |V_R| = 1 \text{ p.u.}$$

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

$$\tan\theta = \frac{X}{R} = \sqrt{3}$$

$$\theta = 60°$$

$$Z = \frac{R}{\cos\theta} = \frac{R}{\cos 60} = 2R$$

$$P_{\text{delivered}} = \frac{V_S V_R}{Z}\cos(\delta - \theta) - \frac{V_R^2}{Z}\cos\theta$$

$$= \frac{1}{2R}\cos(\delta - 60°) - \frac{1}{2R}\cos 60°$$

$$P_{\text{delivered}} = \frac{1}{2R}\left[\cos(\delta - 60°) - \frac{1}{2}\right]$$

$$= \frac{1}{2R}[\cos(\delta - 60°) - 0.5]$$

12. (a)

$$C_n = 12\ \mu\text{F}$$

$$C_n = \frac{12\mu\text{F}}{400\text{km}} = 0.03\ \mu\text{F/km}$$

$$C_n = \frac{2\pi \in}{\ln\frac{D}{r}} = \frac{55.631\times 10^{-12}}{\ln\frac{D}{r}}\text{F/m} = \frac{55.631\times 10^{-3}}{\ln\frac{D}{r}}\mu\text{F/km}$$

$$\Rightarrow \quad \frac{55.631\times 10^{-3}}{\ln\frac{D}{r}} = 0.03$$

$$\ln\frac{D}{r} = 1.854$$

$$\frac{D}{r} = 6.3877$$

$$r = \frac{1}{6.3877} = 15.65\text{ cm}$$

Now,Inductance per phase= $0.2\ln\frac{D}{r'}\text{mH/km}$

$$= 0.2\ln\frac{100}{0.7787\times 15.65} = 0.42\text{ mH/km}$$

13. (a)

Load, $P = 1000$ kW

Phase angle of load, $\phi_1 = \cos^{-1}(0.707) = 45°$

Improved phase angle of load,

$$\phi_2 = \cos^{-1}(0.95) = 18.19°$$

Required rating of p.f. improvement equipment

$$= P(\tan\phi_1 - \tan\phi_2)$$

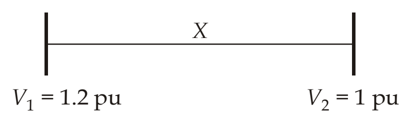
$$= 1000(\tan 45° - \tan 18.19°)$$

$$= 1000(1 - 0.328) = 671.32\text{ kVAR}$$

$$\therefore \quad \text{kVA rating} = \frac{671.32}{\sin(84.26°)} = 674.7\text{ kVA}$$

14. (d)

Given system can be drawn as,



As real power flow is zero, load angle is, $\delta = 0$.

Let, Bus 1 voltage = 1.2 pu = V_1

Bus 2 voltage = 1 pu = V_2

$$Q_{12} = \frac{V_1^2}{X} - \frac{V_1V_2}{X}\cos\delta$$

$$= \frac{(1.2)^2}{X} - \frac{(1.2)\times(1)}{X}\cos 0°$$

$$= \frac{1.44}{X} - \frac{1.2}{X} = \frac{0.24}{X}$$

When reactive power requirement is increased by 20%.

$$Q'_{12} = 1.2\, Q_{12} \text{ and Bus 2 voltage remains unchanged}$$

Using reactive power relation again,

$$1.2\, Q_{12} = \frac{V_1'^2}{X} - \frac{V_1'^1 \times (1)}{X} = 1.2 \times \frac{0.21}{X}$$

Resolving,

$$V_1'^2 - V_1' - 0.288 = 0$$

So, $V_1' = 1.23, \quad -0.233$

Ignoring second value as it is impractical.

$\therefore \quad V_1' = 1.23$ pu

15. (b)

For maximum power transfer putting $\delta = \beta$ in below equation,

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

$$P_{R\max} = \frac{|V_s||V_R|}{|B|} - \frac{|A||V_R^2|}{|B|}\cos(\beta-\alpha) \quad \text{...(1)}$$

Given, $P_{R\max} = 100$ MW, $V_R = 110$ kV

Solving for sending end voltage $|V_s|$ using equation (1),

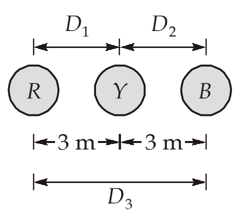
$$100 = \frac{|V_s|\times 110}{98} - \frac{0.98\times 110^2}{98}\cos(78° - 3°)$$

$$100 = \frac{V_s \times 110}{98} - 121\cos 75°$$

$$100 = \frac{V_s\times 110}{98} - 31.317$$

$$V_s = \frac{131.317\times 98}{110} = 116.991 \text{ kV}$$

16. (b)



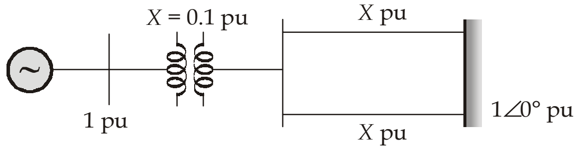
$$\text{Inductance, } L = \frac{\mu_0}{2\pi}\ln\left(\frac{d}{r'}\right) = \frac{\mu_0}{2\pi}\ln\left(\frac{(D_1D_2D_3)^{1/3}}{r'}\right)$$

$$= 2\times10^{-7}\ln\left(\frac{(3\times3\times6)^{\frac{1}{3}}}{0.7788\times\frac{10^{-2}}{2}}\right)$$

$$L = 1.375 \text{ mH/km/phase}$$

17. (a)

Given system can be represented assuming transmission line reactance X pu.



Initially when both line are working.

Steady state stability power limit,

$$P_{1\text{-max}} = \frac{E_f V_t}{X_{\text{total}}} = \frac{1\times1}{0.1+(X||X)} = \frac{1}{0.1+\frac{X}{2}} = 5.25$$

or,
$$\frac{X}{2} = 0.190 - 0.10$$

$$X = 0.180 \text{ pu}$$

Now, when one line is tripped steady state power limit,

$$P_{2\text{-max}} = \frac{1\times1}{0.1+X} = \frac{1\times1}{0.1+0.18} = \frac{1}{0.28} = 3.57 \text{ pu}$$

18. (b)

$$\text{Capacitance of the cable, } C = \frac{2\pi\in_r\in_0}{\ln\left(\frac{R}{r}\right)}\text{F/m} = \frac{2\pi\times4\times8.854\times10^{-12}}{\ln\left(\frac{1.6}{0.4}\right)} = 0.16\ \mu\text{F/km}$$

Power factor on open circuit,

$$\cos\phi = 0.08$$

$$\phi = \cos^{-1}(0.08) = 85.41°$$

$\therefore$ Dielectric loss anlge, $\delta = 90° - 85.41° = 4.59°$

$\therefore$ Dielectric loss $= \omega CV^2 \tan\delta$

$$= 2\pi \times 50 \times 0.16 \times 10^{-6} \times (11\times10^3)^2 \times \tan 4.59° = 488.28 \text{ W}$$

19. (c)

Primary earth-fault current at which the relay operates,

$$= \frac{100\times10^6}{\sqrt{3}\times11\times10^3}\times\frac{15}{100} = 787.29 \text{ A}$$

The percentage of winding which remains unprotected is

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

$$\text{The fault current} = \frac{20}{100}\times\frac{11\times10^3}{\sqrt{3}R_n}$$

Where R_n is the resistance in the neutral to ground connection

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

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

20. (c)

Since the generators are in parallel, they will operate at the same frequency at steady load. Let load on generator G_1 is P_{G1} , and load on generator G_2 is P_{G2}.

If Δf is the change in frequency,

then, $$\frac{\Delta f}{P_{G1}} = \frac{0.04 \times 50}{200} \quad \text{...(i)}$$

$$\frac{\Delta f}{600 - P_{G1}} = \frac{0.05 \times 50}{400} \quad \text{...(ii)}$$

From equation (i),

$$\frac{\Delta f}{P_{G1}} = 0.01$$

$$\Delta f = 0.01 \times P_{G1} \quad \text{...(iii)}$$

From second equation, $$\Delta f = \frac{1}{160}(600 - P_{G1}) \quad \text{...(iv)}$$

From equation (iii) and (iv), we get

$$\frac{P_{G1}}{100} = \frac{600 - P_{G1}}{160}$$

$$16\, P_{G1} = 6000 - 10\, P_{G1}$$

$$26\, P_{G1} = 6000$$

$$P_{G1} = 230.76 \text{ MW}$$

$$\therefore \quad P_{G2} = 600 - 230.76 = 369.23 \text{ MW}$$

21. (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

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

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

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

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

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

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

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

22. (c)

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

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

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

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

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

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

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

23. (b)

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.

$$X = \omega lL$$

$$Y = \omega lC$$

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

Velocity of propagation is,

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

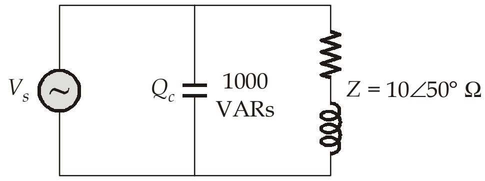
$$3\times 10^5 = \frac{1}{\sqrt{\frac{0.025Z_B}{\omega l}\times\frac{1.4}{\omega lZ_B}}}$$

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

24. (a)

$$\text{Load current, } I = \frac{V_s}{Z} = \frac{220\angle 0°}{10\angle 50°}$$

$$I = 22\angle -50° \text{ A}$$



Real power supplied by source is,

$$P_s = |V||I|\cos\phi$$

$$= 220 \times 22 \times \cos(50°) = 3111 \text{ W}$$

25. (a)

At no load, $V_S = A\, V_R$

$$V_{R\,(\text{NL})} = \frac{V_S}{A} = \frac{240}{0.91} = 263.73 \text{ kV}$$

The percentage voltage regulation is,

$$\%VR = \frac{V_{R(NL)} - V_{R(FL)}}{V_{R(FL)}} \times 100$$

$$= \frac{263.73 - 220}{220} \times 100 = 19.87\%$$

26. (c)

For cable, insulation resistance and length relationship is:

$$R \propto \frac{1}{l}$$

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

$$\Rightarrow \quad R_2 = \frac{25 \times 100}{180}$$

$$R_2 = 13.89 \text{ M}\Omega$$

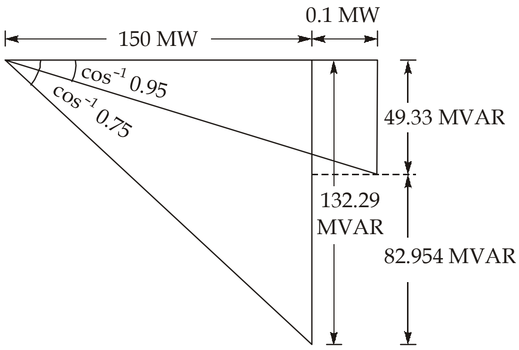
27. (a)

Self GMD for 4 bundled conductors

$$D_S = \left(r' \times s \times s \times \sqrt{2}s\right)^{1/4}$$

$$= \left(0.7788 \times 0.5 \times 10^{-2} \times 1 \times 1 \times \sqrt{2}\right)^{1/4} = 0.272 \text{ m}$$

28. (d)



Without Synchronous motor:

$$Q_1 = S_1 \sin \phi_1$$

$$= \frac{150}{0.75}\sin(\cos^{-1} 0.75)$$

$$Q_1 = 132.29 \text{ MVAR}$$

With Synchronous motor:

$$Q_2 = S_2 \sin \phi_2$$

$$= \frac{150+0.1}{0.95}\sin(\cos^{-1} 0.95)$$

$$Q_2 = 49.33 \text{ MVAR}$$

$$\text{VAR supplied by motor} = 82.954 \text{ MVAR}$$

29. (b)

Mutual GMD between bundles of phases c and a is given by,

$$D_{ca} = \sqrt[4]{D_{ac} \cdot D_{ac'} \cdot D_{a'c} \cdot D_{a'c'}}$$

$$= \sqrt[4]{2d \cdot (2d+s) \cdot (2d-s) \cdot 2d}$$

$$= \sqrt[4]{14 \times 14 \times 14.4 \times 13.6}$$

$$= 13.99 \approx 14 \text{ m}$$

30. (a)

Capacitance between any two cores of cable is

$$= 0.3 \times 10^{-6} \text{ F/km}$$

$$C = \frac{1}{2}C_N = 0.3 \times 10^{-6} \text{F/km}$$

$$C_N = 0.6 \times 10^{-6} \text{ F/m}$$

$$\text{Capacitance per phase, } C_N = 0.6 \times 10^{-6} \times 10 = 6 \text{ μF}$$

$$\text{KVA taken by cable} = 3\, V_{ph}\, I_{ph}$$

$$= 3\, V_{ph}\, I_{ph}\, \omega C$$

$$= 3V_{ph}^2 2\pi f C$$

$$= 3 \times \left(\frac{10000}{\sqrt{3}}\right)^2 \times 2\pi \times 50 \times 6 \times 10^{-6}$$

$$= 188.49 \text{ kVA}$$

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