CLASS TEST

S.No. : 01 SKEE_ABCD_180923

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POWER SYSTMS-1

ELECTRICAL ENGINEERING

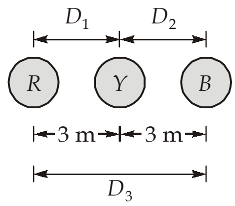
Date of Test : 18/09/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (a)



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

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

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

2. (b)

For cable, insulation resistance and length relationship is:

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

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

$$\Rightarrow \quad R_2 = \frac{25\times100}{180}$$

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

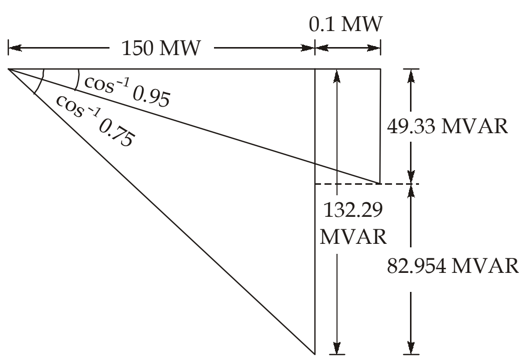
3. (b)

Self GMD for 4 bundled conductors

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

$$= \left(0.7788\times0.5\times10^{-2}\times1\times1\times\sqrt{2}\right)^{1/4} = 0.272 \text{ m}$$

4. (c)



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:

$$Q_2 = S_2 \sin\phi_2$$
$$= \frac{150+0.1}{0.95}\sin(\cos^{-1}0.95)$$
$$Q_2 = 49.33 \text{ MVAR}$$

VAR supplied by motor = 82.954 MVAR

5. (c)

$$\text{GMD} = (20 \times 20 \times 40)^{1/3} = 25.2 \text{ feet}$$
$$\text{GMR} = (0.7788 \times 0.5 \times 8)^{1/2} = 1.765 \text{ inch}$$
$$= \frac{1.765}{12} \text{ feet} = 0.147 \text{ feet}$$
$$\text{Inductance, } L = 0.2\ln\frac{\text{GMD}}{\text{GMR}} \text{ mH/km}$$
$$= 0.2 \ln\frac{25.2}{0.147} = 1.028 \text{ mH/km}$$

6. (b)

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

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

$$= 84.21\,[\tan(\cos^{-1}(0.75)) - \tan(\cos^{-1}(0.95))]$$
$$= 46.58 \text{ kVAR}$$

7. (d)

$$\text{GMR} = \left[\left((0.7788\times 2)\times 50\times 50\times 50\sqrt{2}\right)^4\right]^{1/16}$$
$$= 22.9 \text{ cm}$$

8. (a)

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

$$\alpha = 5°,$$
$$\beta = 75°$$

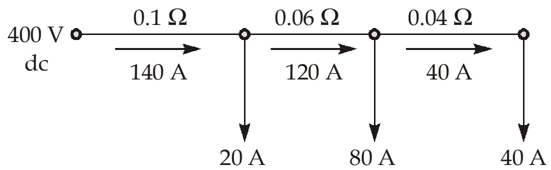
Since the power is received at unity power factor,

$$Q_R = 0$$
$$0 = \frac{220\times 220}{200}\sin(75° - \delta) - \frac{0.85}{200}\times(220)^2\sin(75° - 5°)$$
$$= 242\sin(75° - \delta) - 193.29$$

$$193.29 = 242 \sin (75° - \delta)$$
$$75° - \delta = 53°$$
$$\text{Power angle, } \delta = 22$$

9. (c)

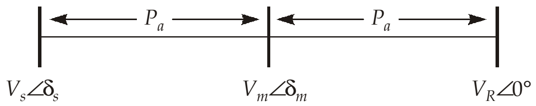
For given dc system, SLD can redrawn,



$$V_{min} = V_{dc} - I_1R_1 - I_2R_2 - I_3R_3$$
$$= 400 - (140 \times 0.1) - (120 \times 0.06) - (0.04 \times 40)$$
$$= 400 - 14 - 7.2 - 1.6 = 377.2 \text{ V}$$

10. (d)

Considering the midpoint location with compensator,



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

$$P_e = \frac{V_sV_m}{X/2}\sin(\delta_s - \delta_m) = \frac{V_mV_R}{X/2}\sin(\delta_m - 0)$$

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

$$P_e = \frac{V_sV_m}{X/2}\sin(\delta_s - \delta_m)$$
$$= \frac{1\times 0.90}{0.4/2}\sin 15° = 1.16 \text{ pu}$$

11. (b)

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, $$I_n = 0 = I_a + I_b + I_c$$
$$= \frac{10\angle 0°}{R} + 10\angle 150° + 10\angle -150° = 0$$
$$R = 0.577 \ \Omega$$

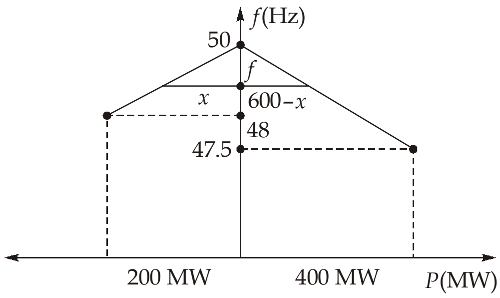
12. (b)

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

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

$$= \sqrt[4]{2d \cdot (2d+s) \cdot (2d-s) \cdot 2d}$$
$$= \sqrt[4]{14 \times 14 \times 14.4 \times 13.6}$$
$$= 13.99 \approx 14 \text{ m}$$

13. (b)



$$\frac{50-f}{x} = \frac{50-48}{200}$$
$$0.01\,x + f = 50 \quad \text{...(i)}$$

and
$$\frac{50-f}{600-x} = \frac{50-47.5}{400}$$
$$50 - f = 3.75 - 6.25 \times 10^{-3}\,x$$
$$6.25 \times 10^{-3}\,x - f = -46.25 \quad \text{...(ii)}$$
$$x = 230.77 \text{ MW}$$

From equation (i),
$$(0.01 \times 230.77) + f = 50$$
$$f = 47.69 \text{ Hz}$$

14. (a)

Capacitance between any two cores of cable is
$$= 0.3 \times 10^{-6} \text{ F/km}$$
$$C = \frac{1}{2}C_N = 0.3 \times 10^{-6}\,\text{F/km}$$
$$C_N = 0.6 \times 10^{-6} \text{ F/m}$$
Capacitance per phase, $C_N = 0.6 \times 10^{-6} \times 10 = 6\ \mu\text{F}$

KVA taken by cable $= 3\,V_{ph}\,I_{ph}$
$$= 3\,V_{ph}\,I_{ph}\,\omega C$$
$$= 3V_{ph}^2 2\pi f C$$
$$= 3 \times \left(\frac{10000}{\sqrt{3}}\right)^2 \times 2\pi \times 50 \times 6 \times 10^{-6}$$
$$= 188.49 \text{ kVA}$$

15. (d)

In order to circulating currents in the relay are in the phase opposition. The CTs on the star connected low voltage side of the transformer should be connected in delta and CTs on the delta connected HV side of the transformer should be connected in star.

Let the currents on the primary and secondary sides of the transformers be I_{L1} and I_{L2} respectively.

Then, $\sqrt{3} \times 400 \times I_{L1} = \sqrt{3} \times 11000 \times I_{L2}$

$$I_{L2} = \frac{4}{110} I_{L1}$$

For, $I_{L1} = 1000$

$$I_{L2} = \frac{4}{110} \times 1000 = \frac{400}{11} \text{ Amp}$$

Since the CTs on the low side are connected in delta, the current through the secondary of the CT is 5 A (in phase) and the current through the pilot wire will be $5\sqrt{3}$ A.

Hence, the CT ratio on HV side $= \dfrac{400}{11\left(5\sqrt{3}\right)} = 4.2$

16. (d)

Number of units, $n = 3$

Ratio of shunt capacitance to mutual capacitance,

$$K = \frac{0.15C}{C} = 0.15$$

Voltage across bottom most unit,

V_3 = safe working voltage of the unit = 20 kV

So voltage across top most unit,

$$V_1 = \frac{V_3}{1+3K+K^2} = \frac{20}{1+3(0.15)+(0.15)^2} = \frac{20}{1.4725}$$

$$V_1 = 13.58 \text{ kV}$$

Voltage across middle unit, $V_2 = V_1(1 + K)$

$= (13.58 \text{ kV})\ (1 + 0.15)$

$= 15.617$ kV

Maximum safe working voltage of the string,

$$V = V_1 + V_2 + V_3$$

$= 13.58 + 15.617 + 20$

$$V = 49.197 \text{ kV}$$

$$\text{String efficiency} = \frac{V}{nV_n} \times 100 = \frac{49.197}{3 \times 20} \times 100 = 81.995 \approx 82\%$$

17. (b)

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

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

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

$= 3.346$ kA

Current to be interrupted by the breaker,

$$= 1.1 \times \text{symmetrical breaking current}$$

($\because$ the breaker is 5-cycle one)

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

18. (d)

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

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

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

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

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

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

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

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

Therefore, $1 = -2\cos(90° + \delta)$

$$1 = 2\sin\delta$$

$\therefore$ $\delta = 30°$

$\therefore$ Voltage at bus-2, $V_2 = 1\angle -30°$ 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

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

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

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

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

The reactive power supplied by capacitor,

$$Q_{G2} = 2[\sin 90°] - 2\sin 60°$$

$$= 2 - \sqrt{3} = 0.268 \text{ p.u.}$$

19. (d)

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

20. (d)

$V_S = 120$ kV, $V_r = 110$ kV,

$A = 0.96$

$$\alpha = 1°, \qquad \beta = 80°$$

Maximum power transmitted is given by

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

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

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

21. (b)

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

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

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

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

22. (c)

Capacitance between any two core,

$$C_2 = 3.7\ \mu\text{F}$$

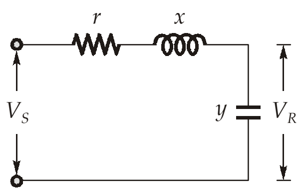
Capacitance of each core to neutral,

$$C_N = 2C_2 = 2 \times 3.7 = 7.4\ \mu\text{F}$$

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

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

23. (c)



Let length of line be l km,

$$|V_S| = |A||V_R| \qquad \text{When } I_R = 0 \text{ at no load.}$$

$$|A| = \frac{220}{235} = 0.936$$

For receiving end condenser

$$|A| = |1 + YZ|$$

$$Y = j2.8 \times 10^{-6}\, l$$

$$Z = j0.4l$$

$$|A| = |1 + YZ|$$

$$YZ = j0.4l \times j2.8 \times 10^{-6}\, l$$
$$YZ = -1.12 \times 10^{-6}\, l^2$$
$$|A| = |1 + YZ| = |1 - 1.12 \times 10^{-6} l^2|$$
$$0.936 = 1 - 1.12 \times 10^{-6}\, l^2$$
$$l^2 = \frac{1 - 0.936}{1.12 \times 10^{-6}} = \frac{400000}{7}$$
$$l = 239.04 \text{ km}$$

24. (b)

$$I_f = 4000 \text{ A}$$
$$\text{CT ratio} = 400 : 5$$

Relay current, $I_R = \frac{I_f}{CT \text{ ratio}} = \frac{4000}{400/5} = 50 \text{ A}$

Pickup value of relay = Current setting × rated secondary current of CT
= 1.60 × 5 = 8 A

Plug setting of multiplier of the relay,

$$\text{PSM} = \frac{I_R}{\text{pick up value of relay}} = \frac{50}{8} = 6.25$$

Time corresponding to the PSM of 6.25 is 3 sec

So actual operating time = 3 × TMS
= 3 × 0.5 = 1.5 sec

25. (b)

The minimum current which will operate the relay during fault conditions,
= Relay pickup current × CT ratio

$$= 1.5 \times \frac{250}{5} = 75 \text{ A}$$

Let the earthing resistance required to protect the 80% of the winding,

x = 100 – 80 i.e. 20%

The emf induced in 20% of winding,

$$= \frac{11000}{\sqrt{3}} \times 0.2 = 1270.17 \text{ V}$$

Earth fault current in unprotected winding

$$= \frac{1270.17}{R}$$

$$\therefore \quad \frac{1270.17}{R} = 75$$
$$R = 16.93\ \Omega$$

26. (c)

$$|V_S| = |V_R| = 1 \text{ p.u.}$$
$$X = \sqrt{3}R$$
$$\tan\theta = \frac{X}{R} = \sqrt{3}$$

$$\theta = 60°$$

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

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

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

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

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

27. (d)

$$V_{\text{ph (peak)}} = \frac{33000}{\sqrt{3}} \times \sqrt{2} = 26944 \text{ V}$$

Inner diameter of sheath, D = d + 2 × radial thickness of insulation

= 2.5 + 2 × 0.6 = 3.7 cm

$$g_{\max} = \frac{2V}{d\ln\left(\frac{D}{d}\right)} = \frac{2 \times 26944}{0.025\ln\frac{0.037}{0.025}} = 5.5 \times 10^6 \text{ V/m (peak)}$$

28. (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 $= 0.2\ln\frac{D}{r'}\text{mH/km}$

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

29. (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

$$= P(\tan\phi_1 - \tan\phi_2)$$
$$= 1000(\tan 45° - \tan 18.19°)$$
$$= 1000(1 - 0.328) = 671.32 \text{ kVAR}$$

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

30. (a)

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

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

The percentage voltage regulation is,

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

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

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