CLASS TEST

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POWER SYSTEM-2

ELECTRICAL ENGINEERING

Date of Test : 23/09/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (a)

$$P_{in} = 100 \text{ kW}$$
$$P_{loss} = 20 \text{ kW} = 2I^2R$$
$$R = \frac{P_{loss}}{2I^2}$$
$$P_{load} = V_{load}\, I \cos \phi$$
$$I = \frac{P_{load}}{V_{load}\cos\phi} = \frac{100\times10^3}{5\times10^3\times0.8} = 25 \text{ A}$$
$$R = \frac{20\times10^3}{2\times25^2} = 16\ \Omega$$

2. (a)

3-phase fault on the transmission line is most severe.

3. (b)

- Shunt inductors are installed locally at load centers to regulate the voltage during light load.
- Series capacitors are installed to increase the steady state stability limit by decreasing the series reactance.

4. (a)

$$V = i\sqrt{\frac{L}{C}} = 5\times\sqrt{\frac{1}{1\times10^{-6}}} = 5\times10^3 \text{ V} = 5 \text{ kV}$$

5. (c)

Monopolar has one conductor and a ground return bipolar has two conductor. Homopolar link has two conductor and a ground return.

6. (b)

$$\omega_0 = \sqrt{\frac{1}{LC}-\frac{1}{4C^2R^2}}$$
$$= \sqrt{\frac{10^{12}}{0.025\times4}-\frac{1}{4\times(0.025)^2\times10^{-12}\times(100)^2}}$$
$$= \sqrt{10^{13}-\frac{1}{500^2\times10^{-18}}} = 3.15 \text{ Mrad/sec}$$

7. (c)

For a 3-ϕ fault positive sequence current is equal to fault current,

$$I_f = \frac{1}{0.08} = 12.5 \text{ p.u.}$$
$$I_f \text{ (in amp)} = \frac{12.5\times10000}{11\times\sqrt{3}} = 6.56 \text{ kA}$$

8. (c)

$$P_{out} = \frac{EV}{Z}\cos(\theta_s - \delta) - \frac{V^2}{Z}\cos\theta_s$$

P_{out} is maximum when, $\delta = \theta_s$

$$P_{max} = \frac{EV}{Z}\cos 0° - \frac{V^2}{Z}\cos\theta_s$$

$$= \frac{EV}{|Z|} - \frac{V^2}{|Z|}\cos\theta_s$$

$$= \frac{50\times 50}{5} - \frac{50\times 50}{5}\cos(36.86°)$$

$$= \frac{50\times 50}{5}(1-0.8) = \frac{2500}{5}\times 0.2 = 100 \text{ MW}$$

9. (d)

10. (b)

Dead short circuit fault = 3-ϕ fault (LLLG fault)

$$I_{f\,\text{LLLG}} = \frac{E_a}{X_1} = \frac{1}{0.15} = \frac{100}{15} = \frac{20}{3}\text{ p.u.}$$

For SLG fault,
$$I_a = \frac{1}{X_1 + X_2 + X_0} = \frac{1}{0.15+0.15+0.05} = \frac{100}{35} = \frac{20}{7}$$

$$I_{f\,\text{SLG}} = 3I_{a0} = \frac{60}{7}\text{ p.u.}$$

$$\frac{I_{f\,\text{LLLG}}}{I_{f\,\text{SLG}}} = \frac{20\times 7}{3\times 60} = \frac{7}{9}$$

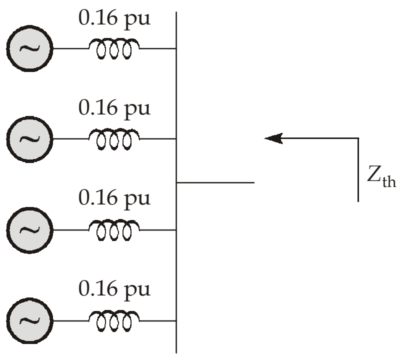
11. (a)

$$Y_{bus} = \begin{bmatrix} \frac{1}{j0.2}+\frac{1}{j1.0}+\frac{1}{j0.8} & \frac{-1}{j0.2} \\ \frac{-1}{j0.2} & \frac{1}{j0.2}+\frac{1}{j1.0}+\frac{1}{j0.8} \end{bmatrix} = \begin{bmatrix} -j7.25 & +j5 \\ +j5 & -j7.25 \end{bmatrix}$$

$$[Z_{bus}] = \begin{bmatrix} j0.263 & j0.18 \\ j0.18 & j0.263 \end{bmatrix} = [Y_{bus}]^{-1}$$

12. (c)

For given power system four alternators are connected in parallel,



Thevenin's impedance, $Z_{th} = \dfrac{0.16}{4} = 0.04$ pu

Also, fault current in pu, $I_f = \dfrac{1}{Z_{th}} = \dfrac{1}{0.04} = 25$ pu

per unit short-circuit of system,

$MVA_{sc} = 25$ pu

∴ short-circuit MVA, $MVA_{sc} = 25 \times \text{base MVA} = 25 \times 5 = 125$ MVA

13. (d)

During fault, the current value increases the voltage drops, power factor decreases reactive power drawn increases generally due to reactance of line.

∴ fault current is high having 90° lagging nature in a transmission line for phasor diagram.

The phasor of $\vec{I}_2$ is having largest magnitude and lags voltage V_1 by almost 90°.

So quantities $\vec{V}_1$ and $\vec{I}_2$ resembles faulty condition.

∴ location B is most feasible fault position according to phasor diagram.

14. (b)

We know for transposed transmission line,

$X_2 = X_s - X_m = X_1$

$X_0 = X_s + 2X_m$

Given, $X_s = 0.8\ \Omega/\text{km}$ and $X_m = 0.2\ \Omega/\text{km}$

where, X_1 = +ve sequence reactance

X_2 = –ve sequence reactance

X_0 = zero sequence reactance

∴ Negative sequence reactance,

$X_2 = 0.8 - 0.2 = 0.6\ \Omega/\text{km}$

Zero sequence reactance,

$X_0 = 0.8 + 2(0.2) = 1.2\ \Omega/\text{km}$

15. (a)

We know for coherently swinging generators,

$G_{eq} \cdot H_{eq} = G_1H_1 + G_2H_2$

$= 300 \times 1.8 + 450 \times 1$

Also given, G_{eq} = common MVA = 200 MVA

∴ $H_{eq} = \dfrac{300 \times 1.8 + 450 \times 1}{200} = 4.95$ pu

16. (b)

The short-circuit current, I_{sc} = 6 pu

$$I_{sc} = \frac{100}{\%X}\times I = 6I$$

or $$\%X = \frac{100}{6} = \frac{50}{3} = 16.67\%$$

% internal reactance = 5%

∴ Required extra reactance = (16.67 – 5)% = 11.67%

Also, $$\%X = 100\times x \text{ pu} = 100\times\frac{I_x}{V}$$

$$\Rightarrow \quad x = \frac{\%x}{100}\times\frac{V}{I}$$

∴ The reactance per phase, $$x = \frac{11.67}{100\times I}\times\frac{(10\times10^3)}{\sqrt{3}}$$

where I, full load current

$$\therefore \quad I = I_L = \frac{VA}{\sqrt{3}V_L} = \frac{20\times10^6}{\sqrt{3}\times10\times10^3} = 1154.7\text{ A}$$

Using above value, $$x = \frac{11.67\times10^4}{\sqrt{3}\times100\times1154.7} = 0.584\ \Omega$$

17. (b)

Given, balanced system bus phase sequence RYB,

$$\vec{I}_R = I_R\angle 0° = 10\text{ A}$$

$$\vec{I}_Y = I_R\angle 240° = a^2\,10$$

$$\vec{I}_B = I_R\angle 120° = a\,10$$

$$\begin{bmatrix} I_{R0} \\ I_{R1} \\ I_{R2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} 10 \\ a^2\,10 \\ a10 \end{bmatrix}$$

$$\therefore \quad I_{R1} = \frac{1}{3}(10 + a^3\,10 + a^3 10) = \frac{30}{3} = 10\text{ A}$$

After fuses were blown,

$$I'_{R0} = I'_{R1} = I'_{R2} = \frac{10}{3}\text{ A}$$

As, I_R = 10 A and $I_Y = I_B = 0$

$$\therefore \quad \text{Ratio} = \frac{I_{R1}}{I'_{R1}} = \frac{10}{10/3} = 3$$

18. (c)

We know, $$\delta = \delta_0 + \frac{P_a}{M}\frac{t^2}{2} \quad \text{...(1)}$$

Also, 5 cycles of 50 Hz frequency

= 20 ms × 5 = 100 msec = 0.1 sec

$$M = \frac{GH}{180f} = \frac{840}{180 \times 50} \text{ (MJ sec/elec. degree)} \qquad \text{...(data in electrical degree)}$$

According power,

$$P_a = P_M - P_E$$

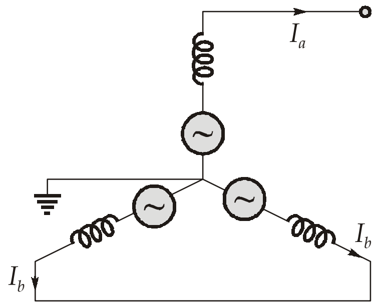
Using equation (1) as load in removed,

$$P_a = P_M$$

$$\delta = 10° + \frac{50 \times 180 \times 50 \times (0.1)^2}{2 \times 840} = 12.679° \text{ electrical degree}$$

19. (b)

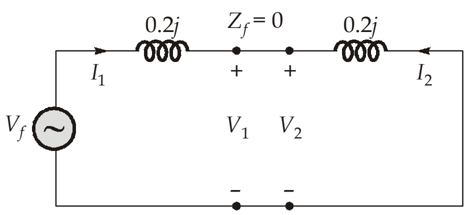
Line-to line fault occurs on b and c phases of generator,



$$I_f = I_b = -I_c$$

and $I_a = 0$

The sequence network for line to line fault is



$$I_1 = \frac{V_f}{z_1 + z_2}$$

$\Rightarrow$ $$I_f = I_b = (\alpha^2 - \alpha)I_1 = -j\sqrt{3}I_1 = \frac{-j\sqrt{3}V_f}{z_1 + z_2}$$

and $$I_{f\text{ p.u.}} = \frac{-j\sqrt{3} \times 1}{j0.2 + j0.2}$$

$$\left|I_{f\text{ p.u.}}\right| = \frac{\sqrt{3}}{0.4} = 4.33 \text{ p.u.}$$

$$\text{Base current} = \frac{25 \times 10^3}{\sqrt{3} \times 11} = 1312.16 \text{ A}$$

$$\text{Fault current, } I_f = 4.33 \times 1312.16 = 5.68\text{kA}$$

20. (b)

For the fully transposed transmission line,

Positive sequence impedance $Z_1 = Z_s - Z_m$

Negative sequence impedance $Z_2 = Z_s - Z_m$

Zero sequence impedance, $Z_s = Z_s + 2Z_m + 3Z_n$

Where, Z_s = Self impedance/ph

Z_m = Mutual impedance/ph

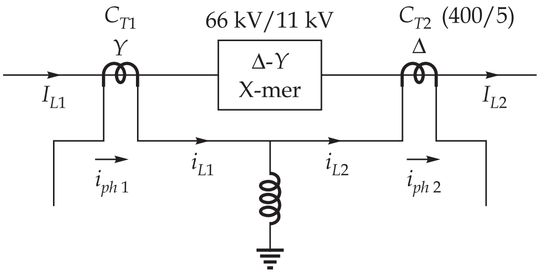
If the system voltages are unbalanced, we have a neutral current, I_n flowing through the neutral (ground) having impedance Z_n.

From above equations, we can say

1. Positive and negative sequence impedance are equal.
2. Zero sequence impedance is much larger than the positive or negative sequence impedance.

∴ Statement (I) is true and statement (II) is false.

22. (a)



Assume, $I_{L2} = 400$ A, $i_{ph\,2} = 5$ A

Then, $i_{L2} = \sqrt{3} i_{ph2} = 5\sqrt{3}$ A

So, $i_{L1} = 5\sqrt{3}$ A, $i_{ph} = 5\sqrt{3}$ A

Now, $V_{L1} I_{L1} = V_{L2} I_{L2}$

$$I_{L1} = \frac{11 \times 400}{66} = \frac{400}{6}$$

$$CT_1 \text{ ratio} = \frac{I_{L1}}{i_{ph1}} = \frac{400/6}{5\sqrt{3}} = 7.7:1$$

23. (c)

$$I_{F(3\text{-}\phi)} = \frac{E_a}{X_1} = 2 \text{ kA}$$

$$I_{F(L\text{ - }L)} = \frac{\sqrt{3}E_a}{X_1 + X_2} = 2 \text{ kA}$$

$$I_{F(1\text{ - }\phi)} = \frac{3E_a}{X_1 + X_2 + X_0} = 2 \text{ kA}$$

$$\frac{E_a}{X_1} = \frac{\sqrt{3}E_a}{X_1 + X_2}$$

$$X_1 + X_2 = \sqrt{3}X_1$$

$$X_2 = 0.732\ X_1$$

Again,
$$\frac{E_a}{X_1} = \frac{3E_a}{X_1 + X_2 + X_0}$$

$$X_1 + X_2 + X_0 = 3X_1$$
$$X_2 + X_0 = 2X_1$$
$$X_0 = 1.268\ X_1$$
$$X_0 = \sqrt{3}X_2$$

24. (c)

Formation of Z_{bus} when connected from bus-0 to bus-1,

$$Z_{bus} = [j0.2]$$

Z_{bus} when connected from bus-1 and bus-2 is

$$Z_{bus} = \begin{bmatrix} j0.2 & j0.2 \\ j0.2 & j0.5 \end{bmatrix}$$

Z_{bus} when connected from bus-2 and bus-0

$$= \begin{bmatrix} j0.2 & j0.2 \\ j0.2 & j0.5 \end{bmatrix} - \frac{1}{j0.5 + j0.5}\begin{bmatrix} j0.2 \\ j0.5 \end{bmatrix}\begin{bmatrix} j0.2 & j0.5 \end{bmatrix}$$

$$Z_{bus} = \begin{bmatrix} j0.2 & j0.2 \\ j0.2 & j0.5 \end{bmatrix} - \begin{bmatrix} j0.04 & j0.1 \\ j0.1 & j0.25 \end{bmatrix}$$

$$Z_{bus} = \begin{bmatrix} j0.16 & j0.1 \\ j0.1 & j0.25 \end{bmatrix}$$

$$I_{fault} = \frac{V}{Z_{22}} = \frac{1}{j0.25} = 4 \text{ p.u.}$$

25. (a)

$$E = 1.5 \text{ p.u.}$$
$$V = 1 \text{ p.u.}$$
$$X = j0.3 + j0.2 = j0.5 \text{ p.u.}$$
$$\sin\delta_0 = 0.6$$

$\Rightarrow$
$$\cos\delta_0 = 0.8$$

$$M = \frac{2H}{\omega_s} = \frac{2\times 30}{2\times\pi\times 50} = \frac{0.6}{\pi} \text{ MJ-s/radian}$$

$$\frac{\partial P_e}{\partial\delta} = \frac{EV}{X}\cos\delta_0 = \frac{1.5\times 1}{0.5}\times 0.8 = 2.4 \text{ p.u.}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{M}\frac{\partial P_e}{\partial\delta}}$$

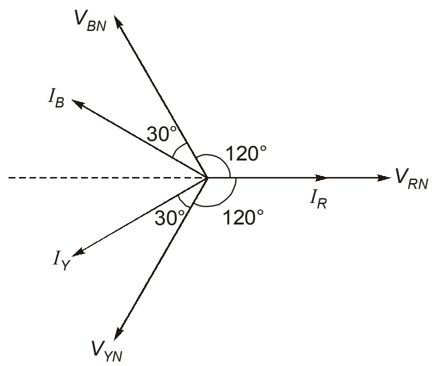
$$f_s = \frac{1}{2\pi}\sqrt{\frac{\pi}{0.6}\times 2.4} = \frac{1}{2\pi}\sqrt{4\pi}$$

$$= \frac{2\sqrt{\pi}}{2\pi} = \frac{1}{\sqrt{\pi}} = 0.5641 \text{ Hz}$$

26. (a)

Reactance relay is unaffected by fault resistance, quadrilateral relay is least effected. Mho relay is less affected than impedance relay because admittance calculated is inversely proportional to arc resistance.

27. (a)



$$I_R = \frac{20000}{230} = 86.95 \text{ A}$$

$$\vec{I}_R = 86.95\angle 0° \text{ A}$$

$$I_Y = \frac{28.75\times 10^3}{230} = 125 \text{ A}$$

$$\vec{I}_Y = 125\angle{-150°} \text{ A}$$

$$\vec{I}_B = 125\angle{+150°} \text{ A}$$

$$\vec{I}_N = \vec{I}_R + \vec{I}_Y + \vec{I}_B = (86.95\angle 0°) + (125(\angle{-150°}) + (125\angle 150°)$$

$$\vec{I}_N = 129.55\angle 180° \text{ A}$$

Magnitude of neutral current,

$$\left|\vec{I}_N\right| = 129.55 \text{ A}$$

28. (c)

$$Y_{11} = y_{12} + y_{13} = -j\,10 \text{ p.u.} \quad \text{...(i)}$$

$$Y_{22} = y_{12} + y_{23} = -j\,13 \text{ p.u.} \quad \text{...(ii)}$$

$$Y_{33} = y_{23} + y_{13} = -j\,8 \text{ p.u.} \quad \text{...(iii)}$$

By subtracting equation (ii) from (i), we get

$$y_{13} - y_{23} = j3 \quad \text{...(iv)}$$

By subtracting (iii) from (iv), we get

$$y_{23} = -j\,5.5 \text{ p.u.}$$

$$Z_{23} = \frac{1}{-j5.5} = j0.18 \text{ p.u.}$$

29. (d)

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

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

$$\frac{\text{Annual load factor}}{\text{Plant capacity factor}} = \frac{0.50}{0.40} = \frac{\text{Plant capacity}}{\text{Maximum demand}}$$

$$\text{Plant capacity} = \frac{0.50}{0.40}\times 15 = 18.75 \text{ MW}$$

Reserve capacity of the plant is

= Plant capacity – Maximum demand

= 18.75 – 15.00

= 3.75 MW

30. **(a)**

$$\text{Base MVA} = 75 \text{ MVA}$$

and Base kV = 69 kV on high voltage = 13.8 kV on low voltage

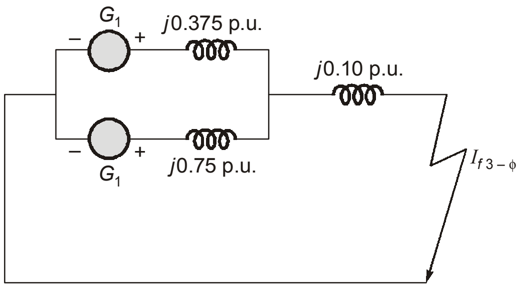
Subtransient reactance of generator 1,

$$X''_{d1} = 0.25 \times \frac{75}{50} = 0.375 \text{ p.u.}$$

Substransient reactance of generator 2,

$$X''_{d2} = 0.25 \times \frac{75}{25} = 0.75 \text{ p.u.}$$

Reactance Diagram:



Substransient fault current,

$$I''_f = \frac{(66/69)}{j0.10 + \left(\frac{j0.375 \times j0.75}{j0.375 + j0.75}\right)}$$

$$I''_f = -j\,2.733 \text{ p.u.}$$

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