CLASS TEST

S.No.: 01SK_ABCDEFG_24062024

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Power system-2

ELECTRICAL ENGINEERING

Date of Test : 24/06/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (a)

Fault current at bus 3 is,

$$I_{f3} = \frac{V_3(0)}{Z_{33} + Z_f} = \frac{1}{j0.2780 + j0.15}$$

$$I_{f3} = -j\,2.336 \text{ p.u.}$$

$$|I_{f3}| = 2.336 \text{ p.u.}$$

2. (b)

When arc resistance is comparable to the impedance of line, then we always prefer the reactance relay to the short transmission line against the ground fault so that the resistance won't impact the relay.

3. (a)

$$P_{iK} = \frac{V_i V_K}{X}\sin\delta \qquad \text{for lossless line}$$

P flows from higher voltage angle to lower voltage angle

$$Q_{iK} = \frac{V_i^2}{X} - \frac{V_i V_K}{X}\cos\delta$$

$\Rightarrow$ Q flows from higher voltage magnitude to lower voltage magnitude.

4. (b)

$$P_g = \frac{E_g E_m}{X_{dg} + X_T + X_{dm}}\sin(\delta_g - \delta_m)$$

$$0.5 = \frac{2 \times 1.3}{1.1 + 1.2 + 0.5}\sin(\delta_g - \delta_m)$$

$$(\delta_g - \delta_m) = \sin^{-1}\left(\frac{1.4}{2.6}\right) = 32.57°$$

5. (c)

We know, $$Z_{pu} = \frac{Z_{act}}{Z_{base}}$$

also, $$Z_{base} = \frac{kV_{base}^2}{MVA_{base}}$$

$\therefore$ $$Z_{pu} = Z_{act} \times \frac{MVA_{base}}{kV_{base}^2} = x \qquad \text{...(1)}$$

After capacity is tripled and voltage is halved,

$$Z'_{pu} = (Z_{act}) \times \frac{3\,MVA_{base}}{\left(\frac{kV_{base}}{2}\right)^2} = Z_{act} \times \frac{12\,MVA_{base}}{kV_{base}^2} \qquad \text{...(2)}$$

Dividing equation (1) and (2),

$$\frac{x}{Z'_{pu}} = \frac{1}{12} \quad \text{or} \quad Z'_{pu} = 12x$$

6. (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

$$\therefore \quad H_{eq} = \frac{300 \times 1.8 + 450 \times 1}{200} = 4.95 \text{ pu}$$

7. (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.

$\therefore$ Statement (I) is true and statement (II) is false.

8. (a)

Penalty factor for bus-1 = 1.5

Penalty factor for bus-2 = 1

For optimum cost of power generation

$$\frac{dC_1}{dP_1} L_1 = \frac{dC_2}{dP_2} L_2$$

$$300 \times 1.5 = \frac{dC_2}{dP_2}$$

$$\frac{dC_2}{dP_2} = 450 \text{ Rs/MWhr}$$

9. (a)

Total Kinetic energy of the two machines,

$$= G_1H_1 + G_2H_2$$
$$= 400 \times 4 + 1600 \times 2$$
$$= 4800 \text{ MJ}$$

The equivalent H on the base of 200 MVA,

$$= \frac{4800 \text{ MJ}}{200 \text{ MVA}} = 24 \text{ MJ/MVA}$$

10. (c)

$$\text{Minimum number of equations} = 2n - m - 2$$
$$= 2(112) - 20 - 2$$
$$= 202$$

11. (b)

Kinetic energy $\propto$ frequency^2

$$W \propto f^2$$

$$\frac{W_1}{W_2} = \frac{f_1^2}{f_2^2}$$

$$f_2 = f_1\sqrt{\frac{W_2}{W_1}} = 50 \times \sqrt{\frac{500-(0.5\times 50)}{500}} \quad [\because W = GH = 100 \times 5 \text{ MJ}]$$

$$= 48.734 \text{ Hz}$$

Percentage deviation in frequency,

$$= \frac{50-48.734}{50}\times 100 = 2.532\%$$

Thus we can say that I_1 and I_3 currents are going into bus thus they are PQ bus and I_2 is going away from bus

$\therefore$ Bus-2 is generator bus (PV bus).

12. (d)

Zero sequence current in R line is

$$\vec{I}_{R_0} = \frac{1}{3}\times \text{Current in neutral wire}$$

$$= \frac{1}{3}\times 300\angle 300° = 100\angle 300° \text{ A}$$

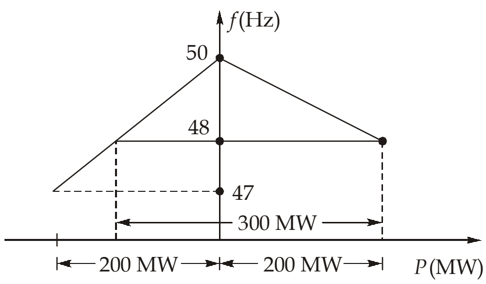
$$\text{Current in } Y\text{-line} = \vec{I}_Y = \vec{I}_{R_0} + a^2\vec{I}_{R_1} + a\vec{I}_{R_2}$$

$$= (100\angle 300°) + (1\angle 120°)^2\,(200\angle 0°) + (1\angle 120°)\,(100\angle 60°)$$

$$= (100\angle 300°) + (200\angle -120°) + (100\angle 180°)$$

$$\vec{I}_Y = (300\angle -120°) \text{ A}$$

13. (c)



New frequency of operation of 200 MW alternator,

$$f_1 = 50 - \frac{2}{200}P_1$$

and, $$f_2 = 50 - \frac{3}{200}P_2$$

Total load, $$P_1 + P_2 = 300 \text{ MW} \quad \text{...(i)}$$

Units operated in parallel so,

$$f_1 = f_2 = f$$

$$50 - \frac{2}{200}P_1 = 50 - \frac{3}{200}P_2$$

$$2P_1 - 3P_2 = 0 \quad \text{...(ii)}$$

From equations (i) and (ii), we get

$$P_1 = 180 \text{ MW}$$

$$P_2 = 120 \text{ MW}$$

Machine (1) which has better speed regulation will be loaded first to its full load rating, so it will operate on maximum load of 200 MW.

$$2P_1 - 3P_2 = 0 \quad \text{...(iii)}$$

$$2 \times 200 - 3P_2 = 0$$

$$P_2 = \frac{400}{3} = 133.33 \text{ MW}$$

Total power delivered by two machine without overloading

$\therefore$ $$P_1 + P_2 = 200 + 133.33 = 333.33 \text{ MW}$$

14. (a)

Let, $$\text{Base MVA} = 20 \text{ MVA}$$

$$\text{Base KV} = 12 \text{ kV}$$

Per unit impedance of generator G_1 on 20 MVA base,

$$X'_{G1} = X_{G1} \times \frac{(\text{MVA})_{\text{new}}}{(\text{MVA})_{\text{old}}} = 0.30 \times \frac{20}{15} = 0.40 \text{ p.u.}$$

Per unit fault current at point F

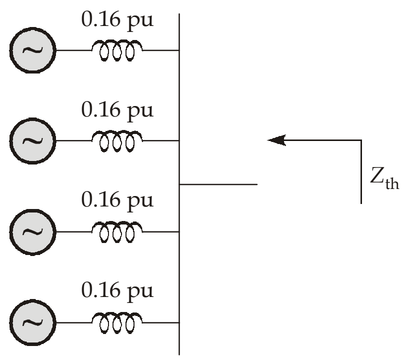
$$I_f = I_{fG1} + I_{fG2}$$

$$= \frac{1}{0.4} + \frac{1}{0.5} = 4.50 \text{ p.u.}$$

$$I_{f\,(\text{actual})} = 4.5 \times \frac{20000}{12\sqrt{3}} = 4330 \text{ A}$$

15. (c)

For given power system four alternators are connected in parallel,



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

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

per unit short-circuit of system,

$$MVA_{sc} = 25 \text{ pu}$$

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

$$= 25 \times 5 = 125 \text{ MVA}$$

16. (d)

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

$\therefore$ 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.

$\therefore$ location B is most feasible fault position according to phasor diagram.

17. (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

$\therefore$ Negative sequence reactance,

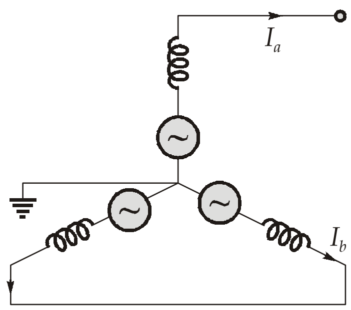
$$X_2 = 0.8 - 0.2 = 0.6\ \Omega/\text{km}$$

Zero sequence reactance,

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

18. (b)

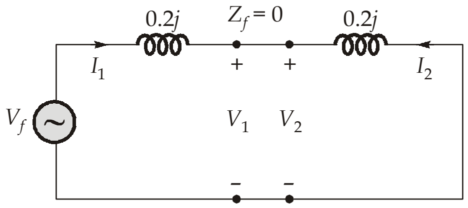
Line-to line fault occurs on b and c phases of generator,



$$I_f = I_b = -I_c$$

and $I_a = 0$

The sequence network for line to line fault is



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

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

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

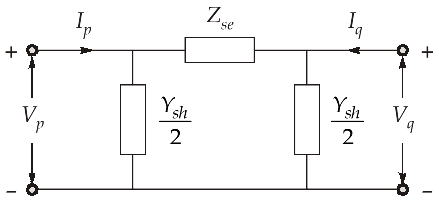
$$\left|I_{f\,\text{p.u.}}\right| = \frac{\sqrt{3}}{0.4} = 4.33 \text{ p.u.}$$

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

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

19. (b)

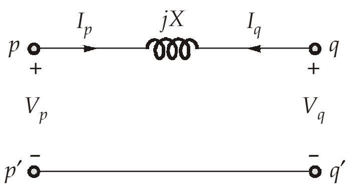
Y-bus matrix for the π equivalent circuit.



$$Y_{\text{bus}} = \begin{bmatrix} \frac{1}{Z_{se}} + \frac{Y_{\text{sh}}}{2} & -\frac{1}{Z_{se}} \\ -\frac{1}{Z_{se}} & \frac{1}{Z_{se}} + \frac{Y_{\text{sh}}}{2} \end{bmatrix}$$

Here, $Z_{\text{se}} = jX;\ Y_{\text{sh}} = 0$

The above circuit diagram becomes,



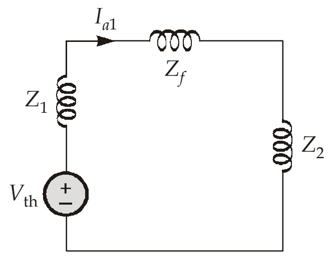
$$\therefore \qquad Y_{\text{bus}} = \begin{bmatrix} \frac{1}{jX} & \frac{-1}{jX} \\ \frac{-1}{jX} & \frac{1}{jX} \end{bmatrix}$$

20. (c)

For given system, fault impedance Z_f is given.

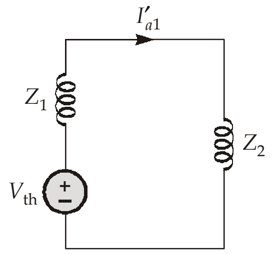
∴ L-L fault current will flow through Z_f.

∴ Including Z_f in our impedance we can draw,



Fault current, $$I_{f1} = \sqrt{3}I_{a1} = \sqrt{3}\cdot\frac{V_{th}}{Z_1+Z_2+Z_f}$$

Also, zero sequence impedance diagram,



Also we know, fault current,

$$I_f = \sqrt{3}I'_{a1} = \sqrt{3}\cdot\frac{V_{th}}{Z_1+Z_2}$$

Also given, $I_{f1} = 0.2I_f$

Substituting value, we get

$$\frac{\sqrt{3}\,V_{th}}{Z_1+Z_2+Z_f} = 0.2\cdot\frac{\sqrt{3}\,V_{th}}{Z_1+Z_2}$$

$$Z_1 + Z_2 = 0.2(Z_1 + Z_2 + Z_f)$$

$$\frac{0.8(Z_1+Z_2)}{0.2} = Z_f$$

$$Z_f = \frac{0.8(0.4+0.3)}{0.2} = 4(0.4 + 0.3) = 2.8 \text{ pu}$$

21. (c)

For 3-ϕ transmission line we can use relation,

$$X_1 = X_s - X_m \quad ...(1)$$
$$X_0 = X_s + 2X_m \quad ...(2)$$

Also given, $X_0 = 32\ \Omega$ and $X_1 = 16\ \Omega$

∴ Solving (1) and (2) simultaneously,

$$X_s - X_m = 16$$
$$X_s + 2X_m = 32$$
$$(-) \quad (-) \quad (-)$$
$$-3X_m = -16$$
$$X_m = \frac{16}{3} \simeq 5.33\ \Omega$$

22. (d)

Positive sequence reactance

$$X_1 = X_d = 0.1 \text{ p.u.}$$

Negative sequence reactance

$$X_2 = \frac{X_d + X_q}{2} = \frac{0.1 + 0.05}{2} = \frac{0.15}{2} = 0.075 \text{ p.u.}$$

23. (c)

Stored Kinetic energy in rotor (K.E.)

$$= \frac{1}{2} J \omega_{sm}^2$$

$$\text{K.E.} = \frac{1}{2} \times 10000 \times \left(\frac{4\pi f}{P}\right)^2 = \frac{1}{2} \times 10000 \times 4\pi^2 \times (50)^2 = 493.48 \text{ MJ}$$

As we know, $$H = \frac{K.E.}{\text{MVA}} = \frac{493.48 \times 0.9}{90} = 4.93 \text{ MJ/MVA}$$

24. (c)

$$\text{CT ratio} = 1 : K$$

$$I_{\text{sec}} \text{ (CT)} = K \cdot \left(\frac{x \cdot V_{\text{ph}}}{R_n}\right) \qquad [\because x = \text{unprotected region of winding}]$$

If I_{sec} (CT) $\geq I_{\text{pick-up (relay)}}$ then relay will operate

$$\frac{5}{1000} \times x \times \frac{11000}{\sqrt{3} \times 5} = 0.75$$

$$x = 0.1180 \text{ or } 11.80\%$$

Percentage protected region $= 100 - x\% = (100 - 11.80)\%$

$= 88.20\%$

25. (a)

$$E_g' = V_t + jI_L X_d'$$

$$E_g' = (1 + j0) + j(0.8 - j0.6) \times 0.35$$

$$= 1 + 0.21 + j0.28$$

$$= 1.2419\angle 13.029$$

26. (c)

As we know, $$(I_{ci})(L_i) = \lambda$$

$$L_i = \text{Penalty factor of } i^{\text{th}} \text{ unit}$$

$$= \frac{1}{1 - \frac{\partial P_L}{\partial P_i}} = \frac{1}{1 - 0.1} = \frac{1}{0.9} = \frac{10}{9}$$

So, $$[1.8 + 0.04P_i] \times \frac{10}{9} = 34$$

Output of generator is, $$Pi = \frac{\frac{9 \times 34}{10} - 1.8}{0.04} = 720 \text{ MW}$$

27. (b)

$$V_{R1} = 2 \text{ kV}$$

$$V_{RY} = V_R - V_Y$$
$$= (V_{R0} + V_{R1} + V_{R2}) - (V_{R0} + K^2V_{R1} + KV_{R2}) \qquad \text{(Where } K = 1\angle 120°\text{)}$$
$$= 2V_{R1} - (-V_{R1})$$
$$= 3V_{R1}$$
$$= 3 \times 2 \text{ kV} = 6 \text{ kV}$$

28. (b)

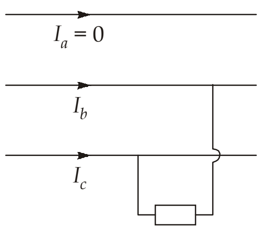
Row	Sum of elements	Impedance
1.	$-j40 + j10 + j50 = j20$	$\frac{1}{j20} = -j0.05$ ∴ Capacitance
2.	$-j30 - j20 + j10 = j20$	$\frac{1}{j20} = -j0.05$ ∴ Capacitance
3.	$j10 + j10 - j30 = -j10$	$\frac{1}{-j10} = j0.1$ ∴ Inductance

∴ There are 2 shunt capacitances and 1 shunt inductance are in a system.

29. (d)

$$I_{a0} = \frac{1}{3}(I_a + I_b + I_c) = \frac{1}{3}I_n$$
$$I_n = 3I_{a0} = 3(0) = 0 \text{ A}$$

30. (c)



Now, $I_a = 0$

$$I_b = \frac{100 \times 10^3}{3.3 \times 10^3} = 30.3 \text{ A}$$
$$I_c = -I_b = -30.3 \text{ A}$$
$$\therefore \quad |I_b| = |I_c| = 30.3 \text{ A}$$
$$I_b + I_c = 0 \text{ A}$$

Zero sequence component,

$$I_{a0} = \frac{1}{3}(I_a + I_b + I_c)$$
$$= \frac{1}{3}(0 + I_b - I_b) = 0 \text{ A}$$

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