CLASS TEST

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POWER SYSTMS-2

ELECTRICAL ENGINEERING

Date of Test : 07/08/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)

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

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

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

After capacity is tripled and voltage is halved,

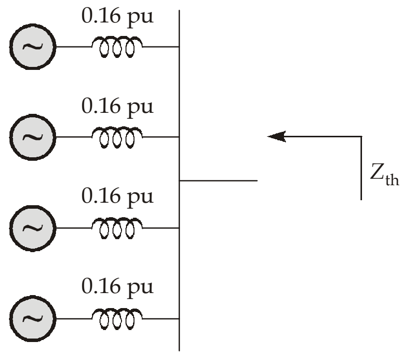
$$Z'_{pu} = (Z_{act}) \times \frac{3\,MVA_{base}}{\left(\frac{kV_{base}}{2}\right)^2} = Z_{act} \times \frac{12\,MVA_{base}}{kV_{base}^2} \quad \text{...(2)}$$

Dividing equation (1) and (2),

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

2. (c)

For given power system four alternators are connected in parallel,



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

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

per unit short-circuit of system,

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

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

3. (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.

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

4. (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,

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

5. (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

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

6. (b)

Kinetic energy ∝ 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

∴ Bus-2 is generator bus (PV bus).

7. (b)

This method is not directly applicable to multi-machine system.

8. (a)

Fault current at bus 3 is,

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

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

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

9. **(d)**

Zero sequence current in R line is

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

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

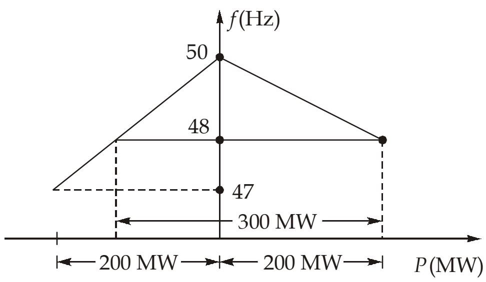
Current in Y-line $= \vec{I}_Y = \vec{I}_{R_0} + a^2\vec{I}_{R_1} + a\vec{I}_{R_2}$

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

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

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

10. **(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, $P_1 + P_2 = 300$ MW ...(i)

Units operated in parallel so,

$$f_1 = f_2 = f$$

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

$2P_1 - 3P_2 = 0$ ...(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.

$2P_1 - 3P_2 = 0$ ...(iii)

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

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

Total power delivered by two machine without overloading

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

11. (d)

We know,

$$Z_{pu} = Z_{act} \times \frac{\text{MVA}_{base}}{\text{kV}^2_{base}}$$

For generators G_1 and G_2, base voltage remains same but MVA doubled to 40 MVA and Z_{pu} = 0.05 pu.

$$\therefore \quad Z_{pu\ new} = Z_{pu\ old} \times \frac{\text{MVA}_{new}}{\text{MVA}_{old}} \times \left(\frac{\text{kV}_{old}}{\text{kV}_{new}}\right)^2$$

$$= 0.05 \times \frac{40}{20}(1)^2 = 0.10 \text{ or } 10\%$$

For transformers base voltage is same and per unit value is given as 10% or 0.10 pu.

$$\therefore \quad X_{pu\ base} = 0.10 \text{ pu} \times \frac{40}{18} = 0.22 \text{ pu}$$

For transmission line, hv side voltage will be base value,

$$Z_{pu} = Z_{act} \times \frac{\text{MVA}_{base}}{(\text{kV}_{base})^2} = 90 \times \frac{40}{(100)^2} = 0.36 \text{ pu}$$

12. (b)

Given, balanced system bus phase sequence RYB,

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

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

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

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

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

After fuses were blown,

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

As, $\quad I_R = 10 \text{ A}$ and $I_Y = I_B = 0$

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

13. (c)

We know,

$$\delta = \delta_0 + \frac{P_a}{M}\frac{t^2}{2} \qquad \text{...(1)}$$

Also, 5 cycles of 50 Hz frequency

$$= 20 \text{ ms} \times 5 = 100 \text{ msec} = 0.1 \text{ sec}$$

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

According power,

$$P_a = P_M - P_E$$

Using equation (1) as load in removed,

$$P_a = P_M$$

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

14. (b)

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

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

or

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

$$\% \text{ internal reactance} = 5\%$$

$\therefore$ Required extra reactance = (16.67 – 5)% = 11.67%

Also,

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

$\Rightarrow$

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

$\therefore$ The reactance per phase,

$$x = \frac{11.67}{100 \times I} \times \frac{(10 \times 10^3)}{\sqrt{3}}$$

where I, full load current

$\therefore$

$$I = I_L = \frac{VA}{\sqrt{3} V_L} = \frac{20 \times 10^6}{\sqrt{3} \times 10 \times 10^3} = 1154.7 \text{ A}$$

Using above value,

$$x = \frac{11.67 \times 10^4}{\sqrt{3} \times 100 \times 1154.7} = 0.584\ \Omega$$

15. (d)

Voltage drop in each phase of generator is

$$\begin{bmatrix} \Delta V_a \\ \Delta V_b \\ \Delta V_c \end{bmatrix} = \begin{bmatrix} j2 & j1 & j1 \\ j1 & j2 & j1 \\ j1 & j1 & j2 \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

or we can write in sequence components,

$$\begin{bmatrix} \Delta V_{a0} \\ \Delta V_{b0} \\ \Delta V_{c0} \end{bmatrix} = \begin{bmatrix} X_0 & 0 & 0 \\ 0 & X_1 & 0 \\ 0 & 0 & X_2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}$$

$$X_0 = X_s + 2X_m = j2 + 2(j1) = j4 \text{ p.u.}$$

$$X_1 = X_s - X_m = j2 - j1 = j1 \text{ p.u.}$$

$$X_2 = X_s - X_m = j2 - j1 = j1 \text{ p.u.}$$

$$I_f = I_a = \frac{3E_a}{X_1 + X_2 + X_0} = \frac{3 \times 1}{j(4+1+1)} = -j0.5 \text{ p.u.}$$

$$\begin{bmatrix} \Delta V_a \\ \Delta V_b \\ \Delta V_c \end{bmatrix} = \begin{bmatrix} j2 & j1 & j1 \\ j1 & j2 & j1 \\ j1 & j1 & j2 \end{bmatrix} \begin{bmatrix} -j0.5 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 0.5 \\ 0.5 \end{bmatrix}$$

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \begin{bmatrix} E_{an} \\ E_{bn} \\ E_{cn} \end{bmatrix} - \begin{bmatrix} \Delta V_a \\ \Delta V_b \\ \Delta V_c \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} 1 \\ 0.5 \\ 0.5 \end{bmatrix} = \begin{bmatrix} 0 \\ 0.5 \\ 0.5 \end{bmatrix}$$

16. (a)

From coordination equation,

$$\frac{dF_n}{dP_{Gn}} \cdot \frac{1}{1 - \frac{\partial P_L}{\partial P_{Gn}}} = \lambda$$

Given, $P_L = 0.5P_{G1}^2$

So, $$\frac{dF_1}{dP_{G1}} \cdot \frac{1}{1 - P_{G1}} = \frac{dF_2}{dP_{G2}} \cdot \frac{1}{1-0}$$

$\Rightarrow$ $$10000 \times \frac{1}{1 - P_{G1}} = 12500$$

$$P_{G1} = \frac{1}{5} \text{p.u.}$$

as the base value of 100 MVA

$$P_{G1} = \frac{1}{5} \times 100 = 20 \text{ MVA}$$

$$P_L = 0.5P_{G1}^2 = 0.5 \times \left(\frac{1}{5}\right)^2 = 0.02 \text{ p.u.}$$

$$= 0.02 \times 100 = 2 \text{ MVA}$$

$$P_D = P_{G1} + P_{G2} - P_L$$

$$40 = 20 + P_{G2} - 2$$

$\Rightarrow$ $$P_{G2} = 22 \text{ MVA}$$

17. (a)

Given, $P_e = 50$ MW

K.E. = 800 MJ

$f = 50$ Hz;

$\delta_0 = 10°$

$$\text{Time for 8 cycles} = \frac{8}{50} = 0.16 \text{ sec}$$

Time for 4 cycles = 0.08 sec

$P_a = 50$ MW

$$M = \frac{K.E.}{180 f} = \frac{GH}{180 \times f}$$

$$M = \frac{800}{180 \times 50} = 0.088$$

We know that, $M\frac{d^2\delta}{dt^2} = P_a$

$$\frac{d^2\delta}{dt^2} = \frac{P_a}{M}$$

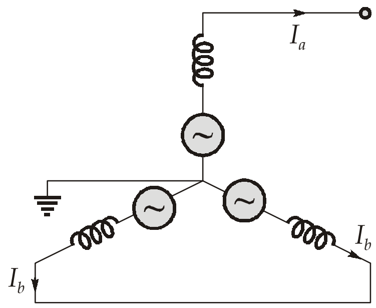
Integrating twice we have,

$$\delta = \frac{P_a}{M}\left[\frac{t^2}{2}\right] + \delta_0 = \frac{50}{0.088}\left[\frac{0.08^2}{2}\right] + 10°$$

New value of power angle = 1.81° + 10° = 11.81°

18. (b)

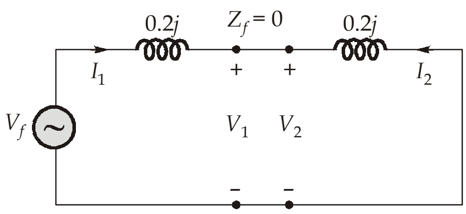
Line-to line fault occurs on b and c phases of generator,



$$I_f = I_b = -I_c$$

and $I_a = 0$

The sequence network for line to line fault is



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

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

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

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

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

Fault current, I_f = 4.33 × 1312.16 = 5.68kA

19. (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.

20. (a)

Total Kinetic energy of the two machines,

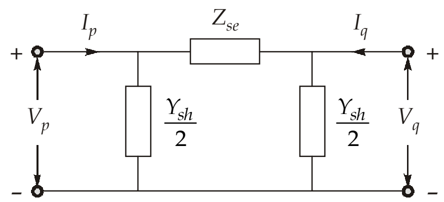
$$= G_1H_1 + G_2H_2$$
$$= 400 \times 4 + 1600 \times 2$$
$$= 4800 \text{ MJ}$$

The equivalent H on the base of 200 MVA,

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

21. (b)

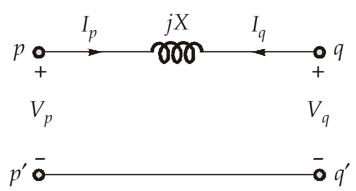
Y-bus matrix for the π equivalent circuit.



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

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

The above circuit diagram becomes,



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

22. (c)

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

23. (b)

Let the base kVA be 500 kVA and base voltage be 2.5 kV,

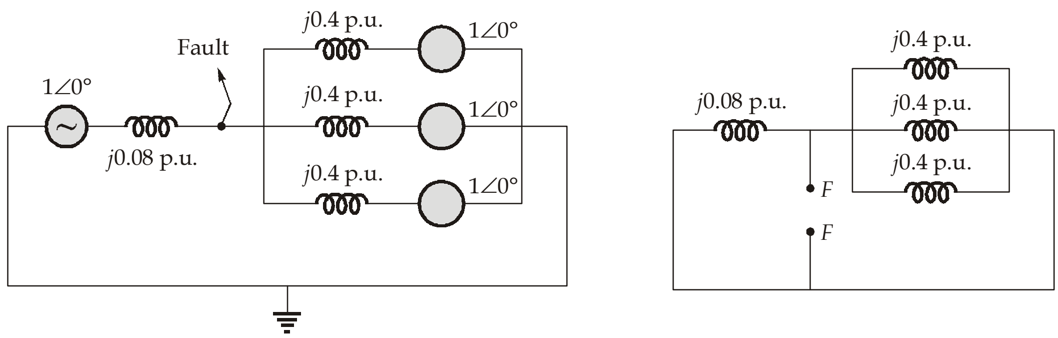
Per unit transient reactance of generator,

$$X_g' = \frac{j8}{100} = j0.08 \text{ p.u.}$$

Per unit subtransient reactance of each motor,

$$X_m'' = j0.2 \times \frac{500}{250} = j0.4 \text{ p.u.}$$

Per unit reactance diagram is shown below,



Thevenin reactance when viewed from fault terminals,

$$X_{th} = \frac{\frac{j0.4}{3} \times j0.08}{\frac{j0.4}{3} + j0.08} = j0.05 \text{ p.u.}$$

At fault location V_{th} = rated voltage,

$$\text{Fault current at } F, I_f = \frac{1}{j0.05} = -j20 \text{ p.u.}$$

The generator contribution is,

$$I_g = -j20 \times \frac{j\frac{0.4}{3}}{j\frac{0.4}{3} + j0.08}$$

$$I_g = -j12.5 \text{ p.u.}$$

Contribution of motors,

$$3I_m = I_f - I_g = -j20 - (-j12.5)$$
$$3I_m = -j7.5$$
$$I_m = -j2.5 \text{ p.u.}$$

24. (c)

Only Y_{22}, Y_{24}, Y_{42}, Y_{44} will change because transmission line is connected between 2nd and 4th buses.

$$Y_{22} = -j60 + \frac{1}{Z_{se}} + \frac{Y_{sh}}{2}$$

$$= -j60 + \frac{1}{j0.1} + j20 = -j60 - j10 + j20 = -j50$$

$$Y_{24} = Y_{42} = 0 - \frac{Y_{sh}}{2} = -j20$$

$$Y_{44} = -j25 + \frac{1}{Z_{se}} + \frac{Y_{sh}}{2} = -j25 + \frac{1}{j0.1} + j20 = -j25 - j10 + j20$$

$$Y_{44} = -j15$$

25. (c)

Reactive power supplied by capacitor to bus-1,

$$Q_{21} = \frac{|V_2|^2}{X} - \frac{|V_2||V_1|}{X}\cos\delta$$

Given that, $Q_{21} = 0$

$$\frac{|V_2|^2}{X} = \frac{|V_2||V_1|}{X}\cos\delta$$

$$|V_2| = |V_1|\cos\delta$$

Given that, $|V_1| = 1$ p.u.

$$|V_2| = \cos\delta \quad \text{...(i)}$$

Since load demand at bus 2 is 1 p.u. (real power). This real power can be supplied by generator S_{G1} only. So this power should flow through transmission line from bus 1 to bus 2

$\therefore$ $P_{12} = 1$ p.u.

$\therefore$ real power flow from bus 1 to bus 2,

$$P_{12} = \frac{|V_1||V_2|}{X}\sin\delta$$

$$1 = \frac{1\cdot\cos\delta}{0.5}\cdot\sin\delta$$

$$0.5 = \frac{\sin 2\delta}{2}$$

$$\sin 2\delta = 1$$

$$2\delta = 90°$$

$$\delta = 45°$$

$\therefore$ from equation (i),

$$|V_2| = \cos\delta = \cos 45° = \frac{1}{\sqrt{2}}$$

Voltage at bus-2, $V_2 = \frac{1}{\sqrt{2}}\angle -45°$

26. (b)

Given, before fault,

$$0.6\,P_{m1} = P_{m1}\sin\delta_0$$

$\therefore$ $\delta_0 = 36.86°$ (or) 0.643 radian

During fault,

$$P_{m2} = 0.25\,P_{m1} \text{ as } X_2 = 4X_1$$

After fualt,

$$P_{m3} = 0.75\ P_{m1} \text{ (given)}$$

$$\therefore \quad \delta_{max} = 180 - \sin^{-1}\left(\frac{0.6P_{m1}}{0.75P_{m1}}\right)$$

$$= 126.86° \text{ (or) } 2.214 \text{ radian}$$

Since,

$$\cos\delta_{cr} = \frac{P_s(\delta_{max} - \delta_0) + P_{m3}\cos\delta_m - P_{m2}\cos\delta_0}{P_{m3} - P_{m2}}$$

$$\cos\delta_{cr} = \frac{0.6P_{m1}[2.214 - 0.643] + 0.75P_{m1}\cos(126.86) - 0.25P_{m1}\cos(36.86)}{0.75P_{m1} - 0.25P_{m1}}$$

$$= \frac{0.6(2.214 - 0.643) + 0.75\cos(126.86) - 0.25\cos(36.86)}{0.75 - 0.25}$$

$$\cos\delta_{cr} = 0.585$$

$$\delta_{cr} = 54.2°$$

27. (b)

$$\text{The reactance in p.u.} = Z_{\text{p.u.}} = Z_{\Omega} \times \frac{\text{MVA}_{(b)}}{(\text{kV})_b^2}$$

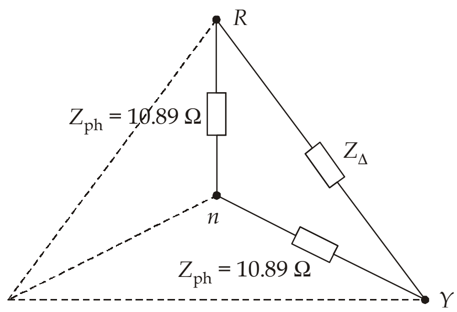
$$Z_{\Omega} = Z_{\text{p.u.}} \times \frac{(kV_b)^2}{(\text{MVA})_b}$$

$$= 0.10 \times \frac{(33)^2}{10} = 10.89\ \Omega$$

$$\text{So reactance per phase} = Z_{ph} = 10.89\ \Omega$$

$$Z_{\Delta} = 3 \times Z_{ph} = 3 \times 10.89$$

$$Z_{\Delta} = 32.67\ \Omega$$



28. (b)

$$S_{D2} = (0.8 + j0) \text{ p.u.}$$

This 0.8 p.u. active power is supplied by the generator G_1

$$\therefore \quad 0.8 = \frac{1 \times 1}{0.5}\sin\delta$$

$$\delta = \sin^{-1}\left(\frac{0.8}{2}\right) = 23.58°$$

$$Q_R = \frac{|V_1| \times |V_2|}{X}\cos\delta - \frac{|V_1|^2}{X}$$

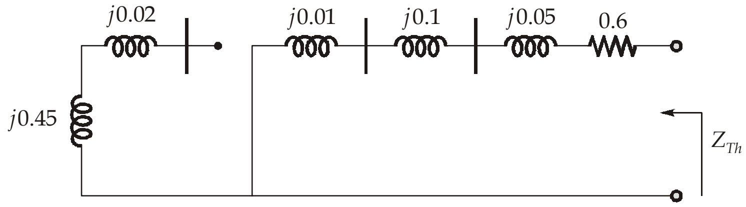
$$= \frac{1}{0.5}\cos(23.58°) - \frac{1}{0.5}$$

$$Q_R = -0.167 \text{ p.u.}$$

The VAR rating of the capacitor = 0.167 p.u.

29. (b)

The zero sequence impedance network from point *P* and ground



The Thevenin's equivalent zero sequence impedance

$$Z_{Th} = (0.6 + j\,0.16) \text{ p.u.}$$

30. (b)

3-ϕ fault current:

Let system is under no load condition before fault,

$$\therefore \quad E = 1\angle 0° \text{ p.u.}$$

$$\text{3-}\phi \text{ fault current, } I_f = \frac{E}{X_1}$$

$$\Rightarrow \quad X_1 = \frac{1}{-j5} = j0.2 \text{ p.u.}$$

Line-line fault current:

$$I_f = \frac{\sqrt{3}E}{X_1 + X_2}$$

$$\Rightarrow \quad X_1 + X_2 = \frac{\sqrt{3}}{-j2.5}$$

$$\Rightarrow \quad j\,0.2 + X_2 = j\,0.69 \text{ p.u.}$$

$$\Rightarrow \quad X_2 = j\,0.49 \text{ p.u.}$$

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