CLASS TEST

S.No. : 01 SK_ABCD_250422

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POWER SYSTMS-2

ELECTRICAL ENGINEERING

Date of Test : 25/04/2022

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (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:

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

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

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

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

2. (c)

For a solid LG fault,

Fault current is: $(I_F)_{LG} = \dfrac{3E}{(2X_1 + X_0 + 3X_n)}$ (Here, $X_1 \approx X_2$ for synchronous generator)

Similarly, for a solid 3-ϕ fault

$$(I_F)_{3\text{-}\phi} = \frac{E}{X_1}$$

For LG fault current to be less than 3-ϕ fault current,

$$\frac{3E}{2X_1 + X_0 + 3X_n} < \frac{E}{X_1}$$

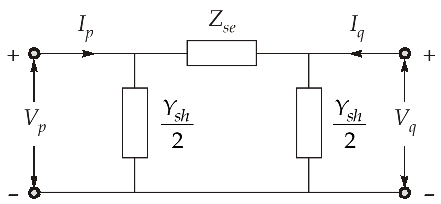
or, $$2X_1 + X_0 + 3X_n > 3X_1$$

or, $$X_n > \frac{1}{3}(X_1 - X_0)$$

Hence, option (c) is correct.

3. (b)

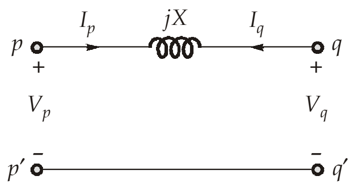
Y-bus matrix for the π equivalent circuit.



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

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

The above circuit diagram becomes,



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

4. (c)

In LLG fault,

$$I_{positive} + I_{negative} + I_{zero} = 0$$

Here, $j1.653 - j\,0.5 - j1.153 = 0$

Hence fault is double line to ground fault.

5. (b)

Synchronizing power coefficient $= P_{max} \cos \delta_0 = \frac{dP_e}{d\delta}$

Here, $P_{max} = 2,$

$\delta = 30°$

$\therefore$ $S_p = 2 \cos 30°$

$$= 2 \times \frac{\sqrt{3}}{2} = \sqrt{3}$$

6. (c)

SLG fault current $I_f = \frac{3E}{X_1 + X_2 + X_0 + 3X_n} = 1$

or, $3X_n = 3 - (0.75)$

or, $X_n = 0.75$ pu

7. (c)

$$P_{m_0} = P_m \sin \delta_0$$

$\therefore$ $\delta_0 = \sin^{-1}\left(\frac{1}{2}\right) = 30$ degree or, 0.5235 rad

Critical clearing angle

or, $\delta_{cr} = \cos^{-1}[(\pi - 2\delta_0) \sin \delta_0 - \cos \delta_0]$

or, $\delta_{cr} = \cos^{-1}[(\pi - 2(0.5235)) \sin(30°) - \cos(30°)]$

$$\delta_{cr} = 79.55°$$

8. (c)

$$Y_{11} = y_{11} + y_{12} + y_{13} = -j\,2.86$$
$$Y_{22} = y_{12} + y_{22} + y_{23} = -j\,6$$
$$Y_{33} = y_{13} + y_{23} + y_{33} = -j\,8.86$$
$$Y_{12} = Y_{21} = -y_{12} = 0$$
$$Y_{13} = Y_{31} = -y_{13} = j\,2.86$$
$$Y_{23} = Y_{32} = -y_{23} = j\,2$$

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)

Minimum number of equations $= 2n - m - 2$

$$= 2(112) - 20 - 2 = 202$$

11. (b)

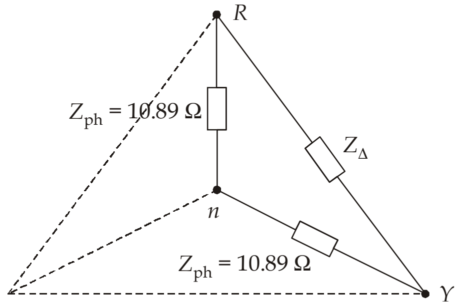
The reactance in p.u. $= Z_{\text{p.u.}} = Z_\Omega \times \dfrac{\text{MVA}_{(b)}}{(\text{kV})_b^2}$

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

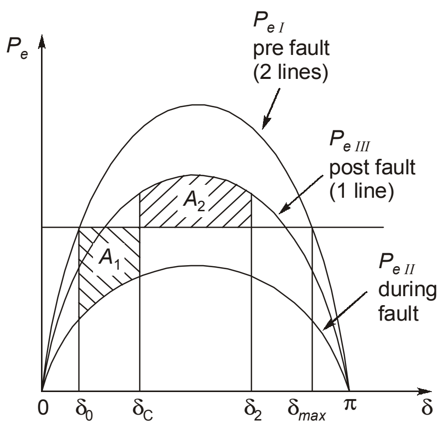
$$= 0.10 \times \frac{(33)^2}{10} = 10.89\ \Omega$$

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

$$Z_\Delta = 3 \times Z_{\text{ph}} = 3 \times 10.89$$
$$Z_\Delta = 32.67\ \Omega$$



12. (b)



$$P_{\text{max I}} = 2.0 \text{ pu,}$$

$$P_{\text{max II}} = 0.5 \text{ pu},$$

and,

$$P_{\text{max III}} = 1.5 \text{ pu}$$

Initial loading $P_m = 1.0$ pu

$$\delta_0 = \sin^{-1}\left(\frac{P_m}{P_{\text{max I}}}\right) = \sin^{-1}\frac{1}{2} = 0.523 \text{ rad}$$

$$\delta_{max} = \pi - \sin^{-1}\left(\frac{P_{max}}{P_{\text{max III}}}\right) = \pi - \sin^{-1}\left(\frac{1}{1.5}\right) = 2.41 \text{ rad}$$

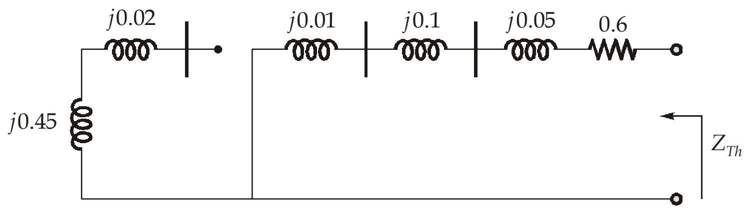
$$\cos\delta_{cr} = \frac{P_m(\delta_{max} - \delta_0) - P_{\text{max II}}\cos\delta_0 + P_{\text{max III}}\cos\delta_{max}}{P_{\text{max III}} - P_{\text{max II}}}$$

$$\cos\delta_{cr} = \frac{1.0(2.41 - 0.523) - 0.5\cos 0.523 + 1.5\cos 2.41}{1.5 - 0.5}$$

$$\delta_{cr} = 70.3°$$

13. (b)

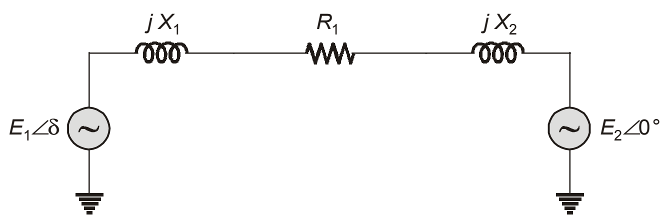
The zero sequence impedance network from point *P* and ground



The Thevenin's equivalent zero sequence impedance

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

14. (a)



$$P_2 = E_2 I_2^*$$

$$P_2 = E_2\left(\frac{E_1\angle\delta - E_2\angle 0°}{R_1 + j(X_1 + X_2)}\right)^*$$

Let $R_1 + j(X_1 + X_2) = Z$

$$|Z|\angle\beta$$

$$P_2 = E_2\left[\frac{E_1\angle\delta - E_2}{|Z|\angle\beta}\right]^*$$

$$P_2 = E_2\left[\frac{E_1}{|Z|}\angle(\beta - \delta) - \frac{E_2}{|Z|}\angle\beta\right]$$

$$P_2 = \frac{E_2E_1}{|Z|}\cos(\beta-\delta) - \frac{E_2}{|Z|}\cos\beta$$

to obtain the maximum value of P_2, differentiate it with respect to δ and equate it to zero.

$$\left(\frac{dP_2}{d\delta}\right) = 0$$

$$\frac{E_2E_1}{|Z|}\sin(\beta-\delta) = 0$$

$$\sin(\beta-\delta) = 0$$

$$\beta = \delta$$

i.e. $\delta < 90°$

similarly $$P_1 = E_1 I_1^* = E_1\left(\frac{E_1\angle\delta - E_2}{|Z|\beta}\right)^*$$

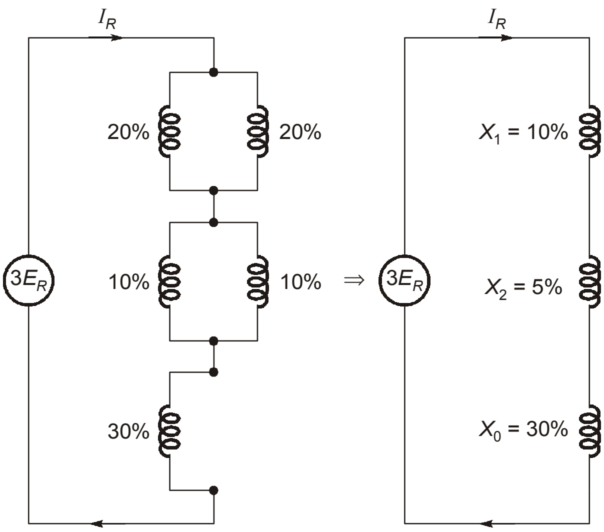
∴ Both $P_{1\,max}$ and $P_{2\,max}$ occur at $\delta < 90°$.

15. (a)

The earth fault is assumed to occur on the red phase. Taking red phase as the reference, its phase e.m.f.

$$E_R = \frac{11\times1000}{\sqrt{3}} = 6351 \text{ V}$$

For line to ground fault the equivalent circuit will be



The percentage reactances can be converted into ohmic values as under :

$$\%\ X = \frac{Z\,(MVA_b)}{(KV)^2}\times100$$

$$Z = \frac{\%X\times(KV)^2}{(MVA_b)\times100}$$

$$X_1 = \frac{10\times(11)^2}{20\times100} = 0.605\ \Omega$$

$$X_2 = \frac{5\times 11^2}{20\times 100} = 0.3025\ \Omega$$

$$X_0 = \frac{30\times 11^2}{20\times 100} = 1.815\ \Omega$$

Fault current

$$\vec{I_R} = \frac{3\vec{E_R}}{X_1+X_2+X_0} = \frac{3\times 6351}{j0.605+j0.3025+j1.815}$$

$$\vec{I_R} = -j\,6998\ \text{A}$$

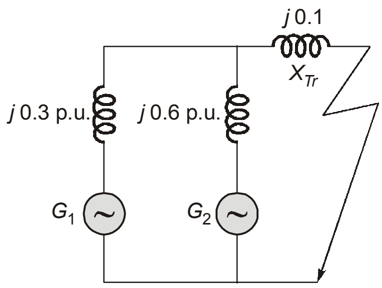
$$|I_R| = 6998\ \text{A}$$

16. (d)

Let us choose a base of 15 MVA, 11 kV on LV side of transformer.

We know that:

$$Z_{(\text{pu})\text{new}} = Z_{p(\text{old})}\times\frac{(MVA)_{b,\text{new}}}{(MVA)_{b,\text{old}}}\times\frac{(kV)^2{}_{b,\text{old}}}{(kV)^2{}_{b,\text{new}}}$$



∴

$$X_{g_1} = 0.2\times\frac{15}{10} = 0.3\ \text{p.u.}$$

$$X_{g_2} = 0.2\times\frac{15}{5} = 0.6\ \text{p.u.}$$

$$X_{\text{Tr}} = 0.1\ \text{p.u.}$$

∴

$$I_F'' = \frac{E_g}{Z_1} = \frac{1.0}{(j0.3\ \|\ j0.6)+j0.1}$$

$$= -j\,3.333\ \text{p.u.}$$

Thus, I_{G1}'' = Substransient current of generator-1 = $-j$ 3.333 pu

17. (a)

$$|I''| = \frac{E}{|X_d''|} = \frac{1}{0.22} = 4.54\ \text{p.u.}$$

$$I_{\text{base}} = \frac{\text{MVA}_b}{\sqrt{3}(\text{kV}_b)} = \frac{100\times 10^6}{\sqrt{3}\times 11\times 10^3} = 5248.6\ \text{A} = 5.248\ \text{kA}$$

The magnitude of initial symmetrical rms current

$$= 4.54 \times 5.248 = 23.82\ \text{kA}$$

18. (d)

Since the new branch is connected between bus-2 and reference bus, therefore

$$Z_{\text{bus, new}} = Z_{\text{bus,old}} - \frac{1}{(Z_{kk}+Z_s)}\left[2^{\text{nd}}\ \text{column}\right][2^{\text{nd}}\ \text{row}]$$

or,

$$Z_{22,\ \text{new}} = Z_{22,\text{old}} - \frac{1}{(Z_{22}+Z_s)}(Z_{22})(Z_{22})$$

$$= 0.34 - \frac{1(0.34)(0.34)}{(0.34+0.1)}$$

$$= 0.0772\ \text{pu}$$

Also, $$Z_{23,\text{ new}} = Z_{23,\text{old}} - \frac{1}{(Z_{22}+Z_s)}(Z_{22})(Z_{23})$$

$$= 0.25 - \frac{1}{(0.34+0.1)}(0.34)(0.25)$$

$$= 0.0568 \text{ pu}$$

19. (a)

For three phase fault,

$$I_{f(3\text{-}\phi)} = \frac{E}{X_1}$$

$$\Rightarrow \quad 2000 = \frac{\frac{11000}{\sqrt{3}}}{X_1}$$

$$X_1 = \frac{11000}{\sqrt{3}\times 2000} = 3.175\Omega$$

For a line to line fault

$$I_{f(L\text{-}L)} = \frac{\sqrt{3}E}{X_1+X_2}$$

$$\Rightarrow \quad 2600 = \frac{\sqrt{3}\times\left(\frac{11000}{\sqrt{3}}\right)}{X_1+X_2}$$

$$X_1 + X_2 = 4.231\ \Omega$$

$$X_2 = 4.231 - 3.175 = 1.056\ \Omega$$

For SLG fault

$$I_{f(L\text{-}G)} = \frac{3E}{X_1+X_2+X_0}$$

$$\Rightarrow \quad 4200 = \frac{3\times\frac{11000}{\sqrt{3}}}{X_0+X_1+X_2}$$

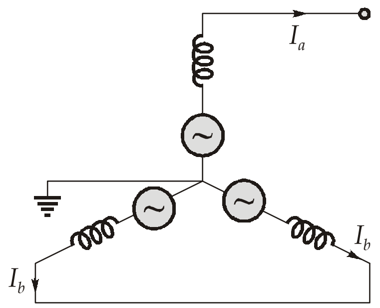
$$X_0 + X_1 + X_2 = 4.536\ \Omega$$

$$X_0 + 4.231 = 4.536$$

$$X_0 = 4.536 - 4.231 = 0.305\ \Omega$$

20. (b)

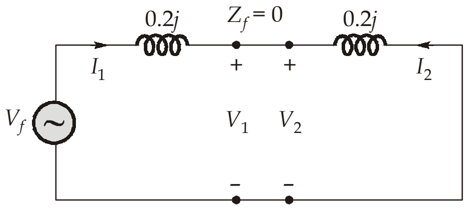
Line-to line fault occurs on *b* and *c* phases of generator,



$$I_f = I_b = -I_c$$

and $$I_a = 0$$

The sequence network for line to line fault is



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

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

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

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

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

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

21. (b)

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

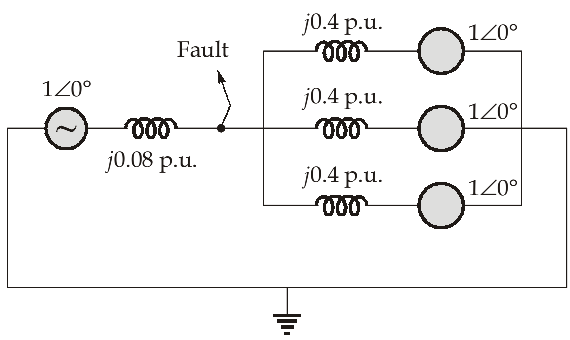
Per unit transient reactance of generator,

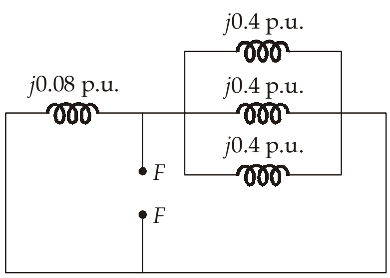
$$X_g' = \frac{j8}{100} = j0.08 \text{ p.u.}$$

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,

$$3I_m = I_f - I_g = -j20 - (-j12.5)$$

$$3I_m = -j7.5$$

$$I_m = -j2.5 \text{ p.u.}$$

22. (c)

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

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

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

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

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

$$Y_{44} = -j15$$

23. (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.

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

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

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

$\therefore$ 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, $\quad V_2 = \dfrac{1}{\sqrt{2}}\angle -45°$

24. (d)

$$\text{Inertia constant, } H = 4 \text{ MW-sec/MVA}$$

$$= 4 \text{ MJ/MVA}$$

$$\text{No load voltage, } V_1 = 1.2 \text{ p.u.}$$

$$\text{Infinite bus voltage, } V_2 = 1 \text{ p.u.}$$

$$\text{Total reactance, } X = X_G + X_L = 0.25 + 0.15$$

$$X = 0.4 \text{ p.u.}$$

$$\text{Angular momentum, } M = \frac{GH}{\pi f} = \frac{1\times 4}{\pi\times 50} = 0.0254 \text{ p.u.}$$

For 80% loading, $\quad \sin\delta_0 = \dfrac{80}{100} = 0.8$

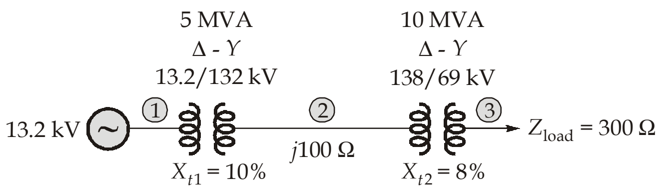
$$\cos\delta_0 = \sqrt{1-\sin^2\delta_0} = \sqrt{1-0.8^2} = 0.6$$

$$\therefore \quad \frac{\partial P_e}{\partial\delta} = \frac{V_1V_2}{X}\cos\delta_0 = \frac{1.2\times 1}{0.4}\times 0.6 = 1.8$$

$$f_n = \sqrt{\frac{\left.\frac{\partial Pe}{\partial\delta}\right|_{\delta_0}}{M}} = \sqrt{\frac{1.8}{0.0254}} = 8.41 \text{ rad/sec}$$

$$= 1.34 \text{ Hz}$$

25. (a)



Let, $S_{base} = 10$ MVA

$V_{base} = 13.8$ kV

Base impedance at section-3,

$$Z_{3\ base} = \frac{(69\times10^3)^2}{10\times10^6} = 476.1\,\Omega$$

$$Z_{load} = \frac{300}{476.1} = 0.63 \text{ p.u.}$$

Base impedance at section-2,

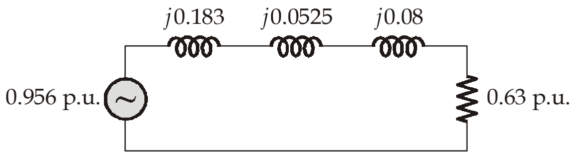
$$Z_{2\ base} = \frac{(138\times10^3)^2}{10\times10^6} = 1904.4\ \Omega$$

$$Z_{line} = \frac{j100}{1904.4} = j0.0525 \text{ p.u.}$$

$$X_{t1\ (new)} = 0.1\times\left(\frac{132}{138}\right)^2\times\frac{10}{5} = 0.183 \text{ p.u.}$$

$$X_{t2} = 0.08 \text{ p.u.}$$

$$E_s = \frac{13.2}{13.8} = 0.956 \text{ p.u.}$$



$$V_L = 0.956\times\frac{0.63}{j(0.183+0.0525+0.08)+0.63}$$

$$V_{L\ (p.u.)} = 0.956\times\frac{0.63}{\sqrt{(0.3155)^2+(0.63)^2}} = 0.854$$

Voltage at load $= V_{L\ (p.u.)} \times V_{L\ (base)}$

$= 0.854 \times 69$ kV

$= 58.926$ kV

26. (b)

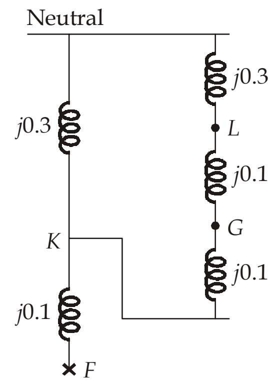
Let base MVA = 10 MVA

Per unit reactance of each generator is 0.3 p.u.

Per unit reactance of each reactor is 0.1 p.u.

Per unit reactance of each transformer on the base MVA

$$= \frac{5}{100}\times\frac{10}{5} = 0.1 \text{ p.u.}$$



Total per unit impedance from generator neutral upto fault point F

$$= 0.1 + [(0.3) \,||\, (0.5)]$$

$$= 0.1 + \frac{(0.3)(0.5)}{(0.3)+(0.5)} = 0.2875 \text{ p.u.}$$

$$\text{Short circuit MVA} = \frac{\text{Base MVA}}{\text{Per unit fault reactance}} = \frac{10}{0.2785} = 34.78 \text{ MVA}$$

27. (c)

The rating of the machine, G = 100 MVA

Inertia constant, H = 5 kW-s/kVA

= 5 KJ/KVA = 5 MJ/MVA

Kinetic energy stored in the rotating parts of generator and turbine at synchronous speed (f = 50 Hz)

= HG = 5 × 100 = 500 MJ

Excess power input to the generator shaft before the steam valve begins to close,

= 100 – 60 = 40 MW

Excess energy transferred to rotating parts in 0.5 sec

= 40 × 0.5 = 20 MJ

Since, Kinetic energy, $K.E. \propto (\text{speed})^2 \propto f^2$

So, frequency at the end of 0.5 sec

$$f_2 = f_1\sqrt{\frac{\text{Total energy stored in 0.5 sec}}{\text{Energy stored at synchronous speed}}}$$

$$f_2 = 50\sqrt{\frac{500+20}{500}} = 50 \times 1.02 \approx 51 \text{ Hz}$$

$$\text{Change in frequency} = f_2 - f_1$$

$$= 51 - 50 \approx 1 \text{ Hz}$$

28. (c)

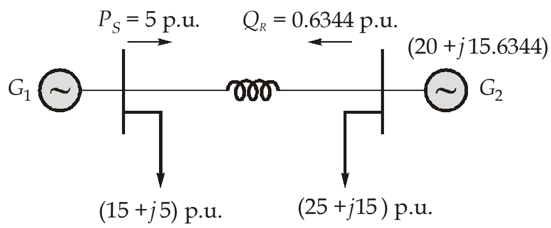
By equalizing the station,

$$P_{G_1} = P_{G_2} = 20 \text{ p.u.}$$

Now,

$$5 = \frac{|E||V|}{|X|}\sin\delta = \frac{1\times 1}{0.05}\sin\delta$$

$$\delta = 14.47°$$



$$Q_R = \frac{|V_1||V_2|}{X}\cos\delta - \frac{|V_1|^2}{X} = -0.6344 \text{ p.u.}$$

$$\text{Total load on station 2} = (25 + j15) + (-5 + j0.6344)$$
$$= (20 + j15.6344)$$

$$\text{Power factor of station 2} = \cos\left(\tan^{-1}\left(\frac{15.6344}{20}\right)\right)$$
$$= 0.78 \text{ lagging}$$

29. (a)

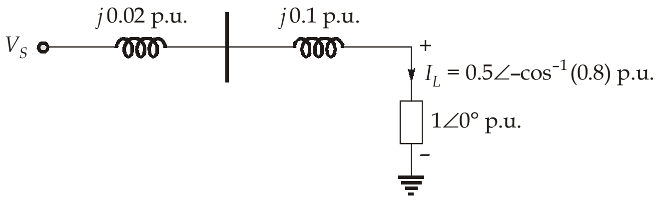
$$\text{Base MVA} = 2 \text{ MVA}$$

The p.u. reactance of 2 MVA transformer is $j0.1$ p.u.

The p.u. reactance of 10 MVA transformer,

$$X_{\text{p.u. (new)}} = X_{\text{p.u.(old)}} \times \frac{2}{10}$$
$$= 0.1 \times \frac{2}{10} = 0.02 \text{ p.u.}$$

The load current is 0.5 p.u. for 2 MVA base



KVL in the loop:

$$V_S = I_L Z + V\angle 0°$$
$$= [(0.5\angle -36.87°)(j0.12)] + (1\angle 0°)$$
$$= 1.037\angle 2.65° \text{ p.u.}$$
$$V_S = 1.037 \times 33 = 34.22 \text{ kV}$$

30. (b)

Sum of the line currents in a Δ is always zero

$$I_a + I_b + I_c = 0$$
$$I_b = -I_a$$
$$I_{a1} = \frac{1}{3}\left[I_a + \alpha I_b + \alpha^2 I_c\right] = \frac{1}{3}[I_a - \alpha I_a]$$
$$= \frac{I_a(1 - 1\angle 120°)}{3} = \frac{(10\angle 0°)(1 - 1\angle 120°)}{3}$$
$$I_{a1} = 5.77\angle -30° \text{ A}$$

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