CLASS TEST

S.No.: 2DLSK_JKLMNOPQ_151125

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POWER SYSTEM-2

ELECTRICAL ENGINEERING

Date of Test : 15/11/2025

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (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,

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

2. (c)

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

3. (a)

$$\text{Line to line fault current, } |I_f| = \frac{\sqrt{3} \cdot E_a}{X_1 + X_2}$$

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

$$2 = \frac{\sqrt{3}}{X_1 + X_2}$$

$$X_1 + X_2 = \frac{\sqrt{3}}{2} \text{ p.u.}$$

$$\text{Line to ground fault current} = \frac{3 \cdot E_a}{X_1 + X_2 + X_0}$$

$$3 = \frac{3}{X_1 + X_2 + X_0}$$

$$\therefore \quad X_1 + X_2 + X_0 = 1$$

$$X_0 = 1 - (X_1 + X_2)$$

$$X_0 = 1 - \frac{\sqrt{3}}{2}$$

Zero sequence reactance, $X_0 = 0.134$ p.u.

4. (b)

Equivalent impedance of transmission line,

$$Z_{eq} = 0.1\angle 85° - j0.05$$
$$Z_{eq} = 0.05\angle 80°$$

Complex power flow through transmission line,

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

$$S_{12} = 1\angle\delta \left[\frac{1\angle\delta - 1\angle 0°}{0.05\angle 80°}\right]^*$$

$$= 20\angle\delta[1\angle(80° - \delta) - 1\angle 80°]$$

$$S_{12} = 20\angle 80° - 20\angle(80° + \delta)$$

Real power flow through transmission line,

$$P_{12} = 20\cos 80° - 20\cos(80° + \delta)$$

$$1 = 20\cos 80° - 20\cos(80° + \delta)$$

$$\delta = \cos^{-1}\left[\frac{20\cos 80° - 1}{20}\right] - 80°$$

$$\delta = 2.9°$$

5. **(c)**

The rating of the machine, $G = 100$ MVA

Inertia constant, $H = 10$ MJ/MVA

Accelerating power, $P_a = 90\text{ MW} - 60\text{ MW} = 30\text{ MW}$

Angular momentum, $M = \frac{GH}{180f} = \frac{100 \times 10}{180 \times 50} = \frac{1}{9}$ MJ-s/electrical degree

Acceleration, $\alpha = \frac{P_a}{M} = \frac{30}{1/9} = 270$ elec. degree/s^2

6. **(d)**

Size of Jacobian matrix $[J] = (2n - m - 2) \times (2n - m - 2)$

where, n = total number of buses = 200

m = (reactive power support buses) + (generator buses – one slack bus)

$\therefore$ $m = 40 + (30 - 1) = 69$

$\therefore$ $[J] = (2 \times 200 - 69 - 2) \times (2 \times 200 - 69 - 2)$

$= (329 \times 329)$

7. **(d)**

Total number of elements in the matrix

$= 50 \times 50 = 2500$

Total number of non-zero entries

$= 2500 - (2500 \times 80\%) = 500$

Out of 500 non-zero elements, 50 are diagonal elements and 450 are non-diagonal elements.

1 transmission line consists of 2 off diagonal element ($y_{ik} = y_{ki}$).

$\therefore$ No. of transmission lines $= \frac{450}{2} = 225$

8. **(d)**

$y_{10} = Y_{11} - y_{12} - y_{13} - y_{14} = -0.5$ ($\therefore$ Shunt element is present)

$y_{20} = Y_{22} - y_{12} - y_{23} - y_{24} = -0.5$ ($\therefore$ Shunt element is present)

$y_{30} = Y_{33} - y_{13} - y_{23} - y_{43} = -2$ ($\therefore$ Shunt element is present)

$y_{40} = Y_{44} - y_{14} - y_{24} - y_{34} = 0$

$\therefore$ Only bus 4 is not having shunt element.

9. (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.

10. (b)

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

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

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

11. (a)

Given,

$$P_e = 50 \text{ MW}$$
$$\text{K.E.} = 800 \text{ MJ}$$
$$f = 50 \text{ Hz;}$$
$$\delta_0 = 10°$$

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

$$\text{Time for 4 cycles} = 0.08 \text{ sec}$$

$$P_a = 50 \text{ MW}$$

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

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

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 $= 1.81° + 10° = 11.81°$

12. (d)

Inertia constant, $H = 4$ MW-sec/MVA

$= 4$ MJ/MVA

No load voltage, $V_1 = 1.2$ p.u.

Infinite bus voltage, $V_2 = 1$ p.u.

Total reactance, $X = X_G + X_L$

$$= 0.25 + 0.15$$
$$= 0.4 \text{ p.u.}$$

Angular momentum, $M = \dfrac{GH}{\pi f} = \dfrac{1 \times 4}{\pi \times 50} = 0.0254$

For 80% loading,

$$\sin \delta_0 = \frac{80}{100} = 0.8$$

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

$$\frac{dP_c}{d\delta} = \frac{V_1 V_2}{X} \cos \delta_0 = \frac{1.2 \times 1}{0.4} \times 0.6 = 1.8$$

$$f_n = \sqrt{\frac{\left.\frac{dP_e}{d\delta}\right|_{\delta_0}}{M}} = \sqrt{\frac{1.8}{0.0254}} = 8.41 \text{ rad/sec} = 1.34 \text{ Hz}$$

13. (b)

Sum of the line currents in a Δ is always zero

$$I_a + I_b + I_c = 0$$
$$I_b = -I_a$$

$$I_{a1} = \frac{1}{3}\left[I_a + \alpha I_b + \alpha^2 I_c\right] = \frac{1}{3}[I_a - \alpha I_a]$$

$$= \frac{I_a(1 - 1\angle 120°)}{3} = \frac{(10\angle 0°)(1 - 1\angle 120°)}{3}$$

$$I_{a1} = 5.77\angle -30° \text{ A}$$

14. (b)

Full load current of each alternator,

$$= \frac{20 \times 10^6}{\sqrt{3} \times 11 \times 10^3} = 1.05 \text{ kA}$$

Since the two identical alternators are operating in parallel

$$Z_1 = \frac{j0.18}{2} = j0.09 \text{ p.u.}$$

$$Z_2 = \frac{j0.15}{2} = j0.075 \text{ p.u.}$$

$$Z_0 = j0.10 + 3R_n$$

$$= j0.1 + 3 \times \frac{2 \times 20}{11^2} = j0.1 + 0.992$$

For an L-G fault,

fault current, $I_f = 3I_{a1} = \dfrac{3E_a}{Z_1 + Z_2 + Z_0} = \dfrac{3}{j0.09 + j0.075 + j0.1 + 0.992}$

$$= 2.92\angle -14.96° \text{ p.u.}$$

fault current, $I_f = 2.92 \times 1.05 = 3.066$ kA

Voltage drop across grounding resistor

$$= 3.066 \times 2 = 6.132 \text{ kV}$$

15. (b)

Voltage magnitude at bus-2,

$$V_2 = 1 - \frac{Z_{12}}{Z_{11}} = 1 - Z_{12}\, I_{f1} \qquad \left(\because I_{f1} = \frac{1}{Z_{11}}\right)$$

$$0.9 = 1 - Z_{12} \times 12.5$$

$$Z_{12} = \frac{0.1}{12.5} = 0.008 \text{ p.u.}$$

and voltage magnitude at bus-1,

$$V_1 = 1 - \frac{Z_{12}}{Z_{22}} = 1 - Z_{12} \cdot I_{f2}$$

$$= 1 - 0.008 \times 10$$

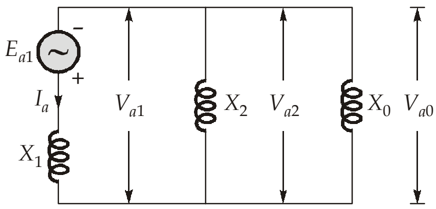
$$= 1 - 0.08$$

$$V_1 = 0.92 \text{ p.u.}$$

16. (d)

Given, $X_1 = j0.2$ p.u, $X_2 = j0.12$ p.u.

$X_0 = j0.05$ p.u. , $X_n = X_f = 0$



In the above diagram,

$$V_{a1} = V_{a2} = V_{a0}$$

$$V_{a1} = E_{a1} - I_a X_1$$

$$I_{a1} = \frac{E_a}{X_1 + (X_2 \,\|\, X_0)} = \frac{1}{0.2 + (0.12 \,\|\, 0.05)} = 4.25 \text{ p.u.}$$

$$V_{a1} = 1 - 4.25 \times 0.2 = 0.15 \text{ p.u.}$$

As we know, healthy phase is 'a',

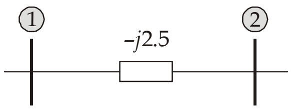
So $V_a = V_{a0} + V_{a1} + V_{a2}$

$$= 3\, V_{a1} = 0.45 \text{ p.u.}$$

Actual voltage of healthy phase,

$$V_{a(\text{actual})} = 0.45 \times \frac{6.6}{\sqrt{3}} = 1.71 \text{ kV}$$

17. (b)



$$\Rightarrow \qquad [Y_{bus}] = \begin{bmatrix} -j2.5 & j2.5 & 0 \\ j2.5 & -j2.5 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$[Y_{bus}]_{mod} = [Y_{bus}]_{old} - [Y'_{bus}]$$

$$= \begin{bmatrix} -j10 & j5 & j5 \\ j5 & -j10 & j5 \\ j5 & j5 & -j10 \end{bmatrix} - \begin{bmatrix} -j2.5 & j2.5 & 0 \\ j2.5 & -j2.5 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$[Y_{bus}]_{mod} = \begin{bmatrix} -j7.5 & j2.5 & j5.0 \\ j2.5 & -j7.5 & j5.0 \\ j5.0 & j5 & -j10 \end{bmatrix}$$

18. (b)

$$P_e = P_{max} \sin \delta$$

When $P_e = 0.6 \times P_{max}$;

$$\delta = \delta_0$$

$$\delta_0 = \sin^{-1}[0.6] = 36.86°$$

$$M = \frac{H}{\pi f} = \frac{4}{\pi \times 60} = \frac{1}{15\pi} \text{ sec}^2/\text{rad}$$

$$\text{Frequency of oscillation} = \sqrt{\frac{\left(\frac{\partial P_e}{\partial \delta}\right)_{\delta_0}}{M}} = \sqrt{\frac{\left(\frac{1.1 \times 1}{1.35} \cos 36.87°\right)}{\frac{1}{15\pi}}} = 5.54 \text{ rad/sec}$$

$$f_n = \frac{5.54}{2\pi} = 0.882 \text{ Hz}$$

19. (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.

20. (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.

21. **(b)**

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

Here, $P_{max} = 2,$
$\delta = 30°$

$\therefore$ $S_p = 2 \cos 30°$

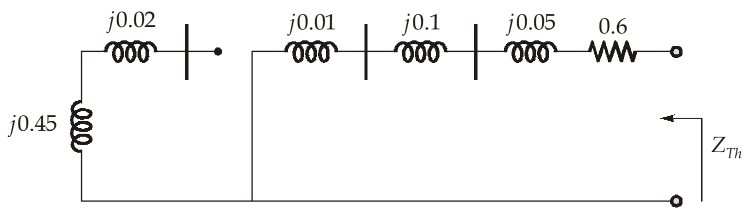
$$= 2 \times \frac{\sqrt{3}}{2} = \sqrt{3}$$

22. **(c)**

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

23. **(b)**

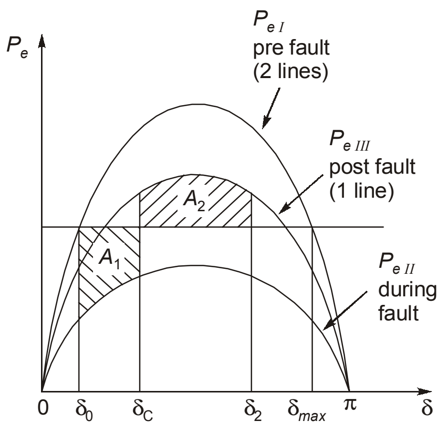
The zero sequence impedance network from point P and ground



The Thevenin's equivalent zero sequence impedance

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

24. **(b)**



$P_{max\ I} = 2.0$ pu,
$P_{max\ II} = 0.5$ pu,

and,

$P_{max\ III} = 1.5$ pu

Initial loading $P_m = 1.0$ pu

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

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

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

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

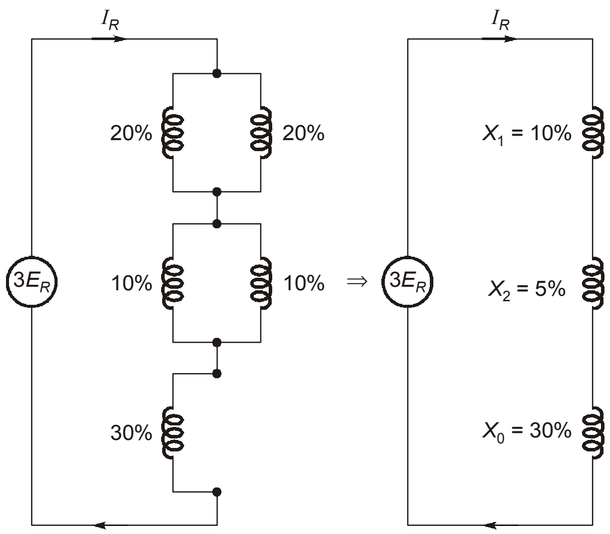
$$\delta_{cr} = 70.3°$$

25. (a)

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

$$E_R = \frac{11 \times 1000}{\sqrt{3}} = 6351 \text{ V}$$

For line to ground fault the equivalent circuit will be



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

$$\% X = \frac{Z(MVA_b)}{(KV)^2} \times 100$$

$$Z = \frac{\% X \times (KV)^2}{(MVA_b) \times 100}$$

$$X_1 = \frac{10 \times (11)^2}{20 \times 100} = 0.605\ \Omega$$

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

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

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

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

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

26. (b)

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

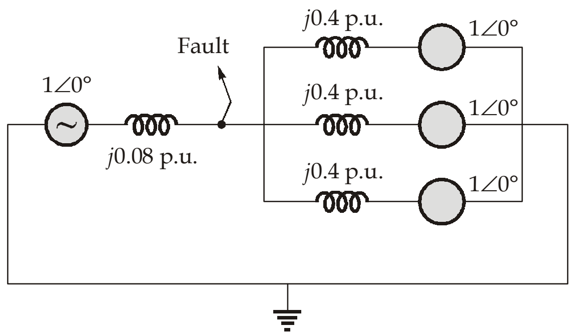
Per unit transient reactance of generator,

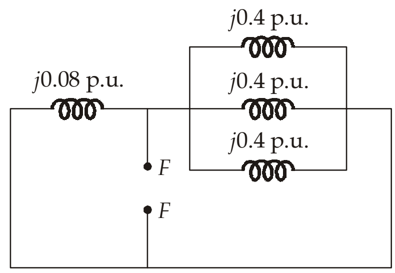
$$X_g' = \frac{j8}{100} = j0.08\text{ p.u.}$$

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,

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

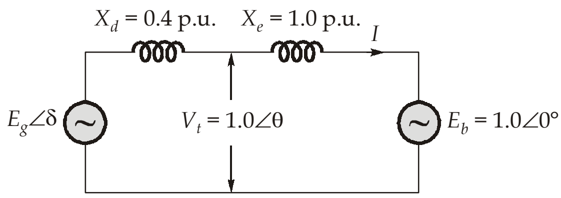
$$I_g = -j12.5\text{ p.u.}$$

Contribution of motors,

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

$$3I_m = -j7.5$$
$$I_m = -j2.5 \text{ p.u.}$$

27. (b)



$$I = \frac{\vec{V}_t - \vec{E}_b}{jX_e} = \frac{1\angle\theta - 1\angle 0}{j1}$$

Also,
$$E_g = V_t + jX_d I$$
$$= 1\angle\theta + j0.4\left[\frac{1\angle\theta - 1\angle 0}{j1}\right]$$
$$= 1\angle\theta + 0.4\angle\theta - 0.4$$
$$= 1.4\angle\theta - 0.4$$
$$E_g = (1.4 \cos\theta - 0.4) + j1.4 \sin\theta$$

Under steady state stability, angle of E_g is 90°, which means the real part of E_g is zero

Therefore, $1.4 \cos\theta - 0.4 = 0$

$$\theta = \cos^{-1}\left(\frac{0.4}{1.4}\right) = 73.40°$$

Also
$$E_g = j1.4 \sin\theta$$
$$= 1.4 \sin(73.40)\angle 90°$$
$$|E_g| = 1.34$$

Maximum steady state power $= \dfrac{E_g \cdot E_b}{X} = \dfrac{1.34 \times 1.0}{1 + 0.4} = 0.9583$ p.u.

28. (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,
$$|V_1| = 1 \text{ p.u.}$$
$$|V_2| = \cos\delta \qquad \text{...(i)}$$

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

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

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

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

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

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

$$\sin 2\delta = 1$$

$$2\delta = 90°$$

$$\delta = 45°$$

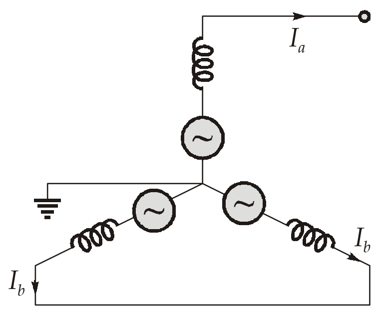
∴ from equation (i),

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

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

29. (b)

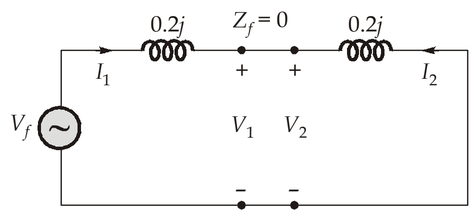
Line-to line fault occurs on b and c phases of generator,



$$I_f = I_b = -I_c$$

and $$I_a = 0$$

The sequence network for line to line fault is



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

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

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

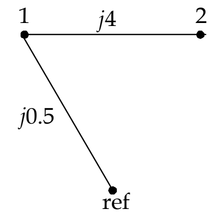
$$\left|I_{f\,\text{p.u.}}\right| = \frac{\sqrt{3}}{0.4} = 4.33 \text{ p.u.}$$

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

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

30. **(d)**

Existing system and bus matrix is



$$Z_{\text{Bus}} = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 \end{bmatrix}$$

Modifying line with reactance $j2$ is equivalent to adding a line in parallel with impedance $j4$. Thus it is type-4 modification.

$$[Z_{\text{new}}] = [Z_{old}] - \frac{1}{Z_{11} + Z_{22} - 2Z_{12} + Z_s}\begin{bmatrix} \text{subtract} \\ 2^{\text{nd}}\text{ column} \\ \text{from first column} \end{bmatrix}[\text{Transpose}]$$

$$[Z_{\text{Bus}}]_{\text{new}} = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 \end{bmatrix} - \frac{1}{j0.5 + j4.5 - 2(j0.5) + j4}\begin{bmatrix} j0 \\ -j4 \end{bmatrix}\begin{bmatrix} j0 & -j4 \end{bmatrix}$$

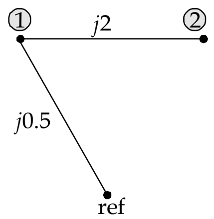
$$= \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 \end{bmatrix} - \frac{1}{j8}\begin{bmatrix} 0 & 0 \\ 0 & -16 \end{bmatrix}$$

$$= \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 \end{bmatrix} - \begin{bmatrix} 0 & 0 \\ 0 & -\dfrac{16}{j8} \end{bmatrix}$$

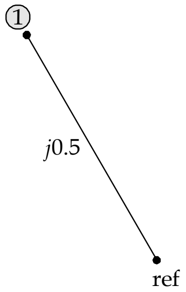
$$= \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j4.5 - \dfrac{j16}{8} \end{bmatrix} = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j2.5 \end{bmatrix}$$

Alternative :

New system will

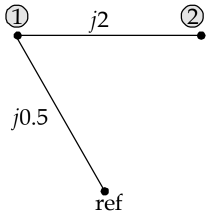


First branch :



$$Z = [\ j0.5]$$

Type – 2 modification



$$Z = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j0.5 + j2 \end{bmatrix} = \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j2.5 \end{bmatrix}$$

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