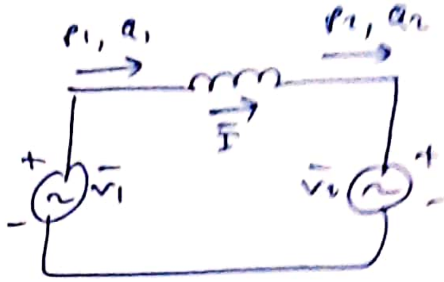
Q-I

(a)



$\bar{V}_1 = V_1 \angle \delta_1$

$\bar{V}_2 = V_2 \angle \delta_2$

$$\bar{I} = \frac{\bar{V}_1 - \bar{V}_2}{jX}$$

$\rightarrow$ $P_1 + jQ_1 = \bar{V}_1 \bar{I}^*$

$$= V_1 \angle \delta_1 \left[\frac{V_1 \angle -\delta_1 - V_2 \angle -\delta_2}{X \angle -90^\circ} \right]$$

$$\therefore P_1 = \frac{V_1 V_2}{X} \sin(\delta_1 - \delta_2)$$

$$Q_1 = \frac{V_1^2}{X} - \frac{V_1 V_2}{X} \cos(\delta_1 - \delta_2)$$

$\rightarrow$ $P_2 + jQ_2 = \bar{V}_2 \bar{I}^*$

$$= V_2 \angle \delta_2 \left[\frac{V_1 \angle -\delta_1 - V_2 \angle -\delta_2}{X \angle -90^\circ} \right]$$

$$\therefore P_2 = \frac{V_1 V_2}{X} \sin(\delta_1 - \delta_2)$$

$$Q_2 = \frac{V_1 V_2}{X} \cos(\delta_2 - \delta_1) - \frac{V_2^2}{X}$$

(b) If $\delta_1 > \delta_2 \Rightarrow P_1 > 0$ & $P_2 > 0$

$\therefore$ Active power flow from source 1 to source 2.

(c) $$P_{max} = \frac{V_1 V_2}{X} = \frac{400 \times 400}{50} = 3200 \text{ MW}$$

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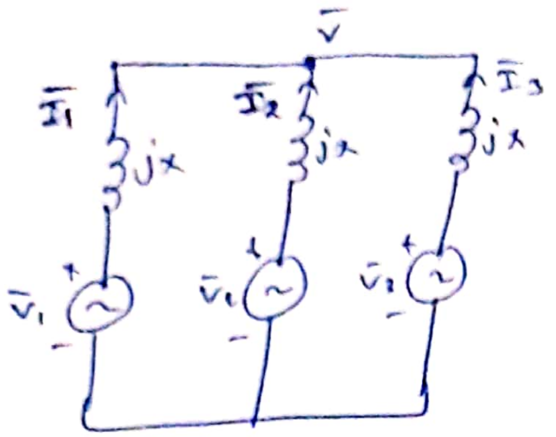
(d)



→ KVL eq^{n}s

$$\bar{V}_1 - jx\bar{I}_1 + jx\bar{I}_2 - \bar{V}_2 = 0$$

$$\bar{V}_2 - jx\,\bar{I}_2 + jx\bar{I}_3 - \bar{V}_3 = 0$$

→ KCL eq^n

$$\bar{I}_1 + \bar{I}_2 + \bar{I}_3 = 0$$

$$\therefore \quad \bar{V} = \frac{\bar{V}_1 + \bar{V}_2 + \bar{V}_3}{3} = 234.18\angle -3.2227^\circ$$

$\therefore$ $P_1 > 0$, $P_2 > 0$ & $P_3 < 0$

(e) To reduce the capacitor voltage real power should flow from AC side of inverter to ~~source~~ grid. So, first we have to make δ positive until capacitor voltage reduce to its desire value and then we have to make $\delta = 0$ to stop further reduction of capacitor voltage.

→ Ans → (B) Make δ positive and return to its original value.

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Q-2

Under steady state condiⁿ ($s \to 0$)

$$\frac{1+sT_1}{1+sT_2} \to 1$$

$$\frac{1}{1+sT_p} \to 1$$

$$K\frac{sT}{1+sT} \to 0$$

$$K_p + \frac{K_i}{s} \to \infty$$

→ ∴ $A_1 = 0$ & $A_5 = 0$

Also, $A_2 = A_3 = A_4$

→ Now, $A_1 = -A_5 - A_4 + J_{ref}$

∴ $A_4 = J_{ref} = 1$

∴ $A_2 = A_3 = 1$

Q-3

→ Initial output $y(t=0) = 0$, when $u(t)$ become 1, input to the limiter is 10 and it will clip the limiter output to 2. So, initially output $y(t)$ will rise slowly (with $\tau = 10$ s) until it ~~be~~ reaches the value of 0.8. When $y(t) = 0.8$, input to limiter is 2, and after that $y(t)$ very quickly reaches to its steady-state value of $\frac{50}{51}$ (with $\tau = 0.2$ s)

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→ when $x(t)$ again become zero, input to limiter is less than (-2), and it will clip the output of the limiter by (-2). And $y(t)$ starts ~~to~~ reducing (with $\tau = 10\ s$). Once input to limiter become greater than (-2), $y(t)$ very quickly reduces to zero (with $\tau = 0.2\ s$)

⇒ Option (A), wrong – $y(t)$ increase very quickly (with $\tau = 0.2\ s$)

Option (B), Correct option

Option (C), wrong – Incorrect steady-state value.

Option (D), wrong – no delay is applicable

Option (E), wrong – no delay is applicable output should change immediately after change in $x(t)$.

Option (F), wrong – Incorrect steady-state value.

Q-4

(a)

KVL $eq^n s$

$$\bar{V}_{an} - j\,\bar{I}_a(X_L - X_C) + j\,\bar{I}_b(X_L - X_C) - \bar{V}_{bn} = 0$$

$$\bar{V}_{bn} - j\,\bar{I}_b(X_L - X_C) + j\,\bar{I}_c(X_L - X_C) - \bar{V}_{cn} = 0$$

KCL eq^n

$$\bar{I}_a + \bar{I}_b + \bar{I}_c = 0 \quad \left(\because \text{ under balanced condi}^n \ \bar{I}_G = 0\right)$$

$\therefore \quad \bar{V}_{nG} = -\left(\frac{\bar{V}_{an} + \bar{V}_{bn} + \bar{V}_{cn}}{3}\right)$

$\therefore \quad \boxed{\bar{V}_{nG} = 0 \text{ V}}$ (as source is balanced)

(b) When line-to-ground fault happens on phase 'a', potential diffⁿ betⁿ point 'a' and 'G' is approx. zero. (because $\omega L << \frac{1}{\omega C}$)

$\therefore \quad \bar{V}_{aG} \approx 0$

→ Now,

$\bar{V}_{an} - \bar{V}_{aG} + \bar{V}_{bG} - \bar{V}_{bn} = 0$

$\therefore \quad \bar{V}_{bG} \approx \bar{V}_{bn} - \bar{V}_{an}$

$= \sqrt{3} \times 250 \angle -150^\circ \text{ V}$

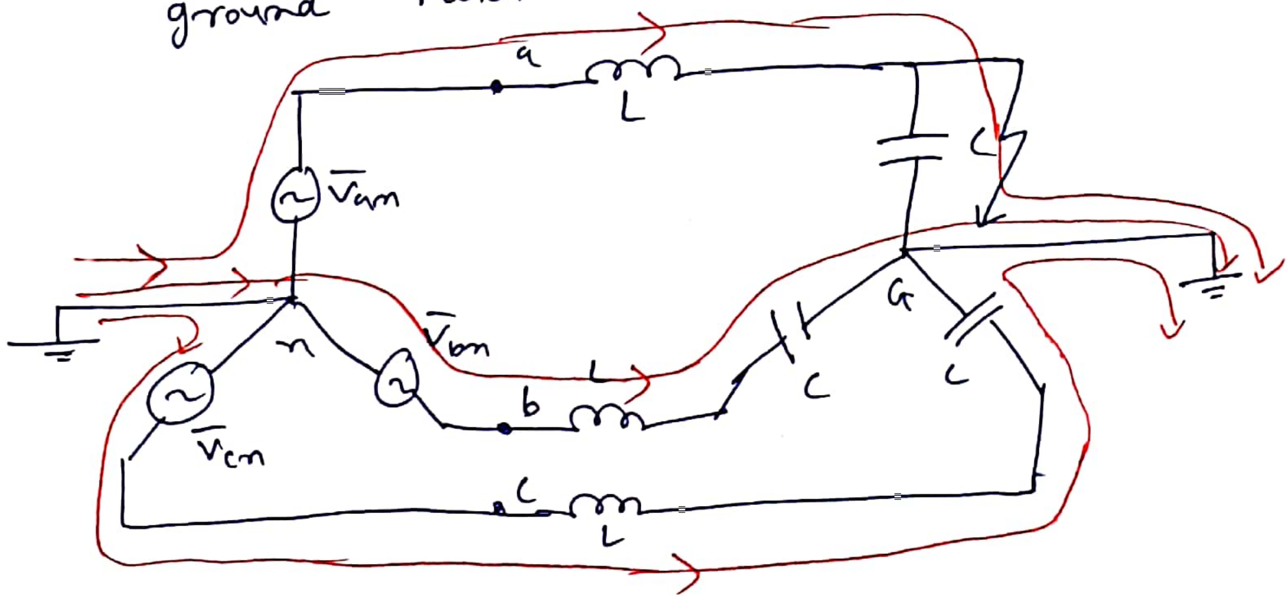
→ $\bar{V}_{an} - \bar{V}_{aG} + \bar{V}_{cG} - \bar{V}_{cn} = 0$

$\therefore \quad \bar{V}_{cG} \approx \bar{V}_{cn} - \bar{V}_{an}$

$= \sqrt{3} \times 250 \angle 150^\circ \text{ V}$

→ $I_G = 0$, because no closed path is available.

(c) When neutral is also grounded and ground resistance is neglected.



$\rightarrow \quad \bar{V}_{an} - j\omega L \bar{I}_a = 0$

$$\therefore \bar{I}_a = \frac{\bar{V}_{an}}{j\omega L} = \frac{250}{2\times\pi\times 50\times 30\times 10^{-6} \angle 90^\circ}$$

$$\bar{I}_a = 26.525 \angle -90^\circ \text{ kA}$$

$$\& \ \bar{V}_{aG} = \bar{V}_{an} = 250\angle 0^\circ \text{ V}$$

$\rightarrow \quad \bar{V}_{bn} - j\left(\omega L - \frac{1}{\omega C}\right)\bar{I}_b = 0$

$$\therefore \bar{I}_b = \frac{\bar{V}_{bn}}{j\left(\omega L - \frac{1}{\omega C}\right)}$$

$$= 4.998 \angle -210^\circ \ \mu A$$

$$\& \ \bar{V}_{bG} = \bar{V}_{bn} = 250\angle -120^\circ \text{ V}$$

$\rightarrow \quad \bar{V}_{cn} - j\left(\omega L - \frac{1}{\omega C}\right)\bar{I}_c = 0$

$$\therefore \bar{I}_c = \frac{\bar{V}_{cn}}{j\left(\omega L - \frac{1}{\omega C}\right)}$$

$$= 4.998 \angle 30^\circ \ \mu A$$

$$\& \ \bar{V}_{cG} = \bar{V}_{cn} = 250\angle 120^\circ \text{ V}$$

$\rightarrow \quad \bar{I}_G = \bar{I}_a + \bar{I}_b + \bar{I}_c$

$$= 26.525 \angle -90^\circ \text{ kA}$$

Q-5

In all the three cases, because of the balanced load, the stator current and stator flux is balanced.

→ Balanced stator flux produce stator field rotating at synchronous speed. Also rotor field is rotating at synchronous speed.

→ So, Net electro-magnetic torque is constant in all the cases. (in steady state).

⇒ Case-(1)

Because of no resistance is present in this load. Active power of the load is zero. And so, torque is zero (constant).

⇒ Case-(2), (3)

→ In both cases because of resistance, it will absorb active power. (Passive load and generator convention of torque)

→ So, net electro-magnetic torque is constant positive value

Q-7

Following informations can be extracted from the observations.

→ (i) Thevenin impedance have inductive nature.

(ii), (iii) } Thevenin impedance is non-zero (non-ideal)

(iv) Efd ∝ field voltage (under open ckt)

(v) Thevenin impedance does not have resistance.

⇒ From the above information option (A) is correct. All other options does not have inductive thevenin impedance.

Q-8

(a), (b)

→ Under-steady state condi^n $(s \to 0)$

$\therefore \frac{1}{Js} \to \infty \Rightarrow$ Net torque $= 0 = \frac{P_m - P_e}{\omega}$

$\therefore \boxed{P_m = P_e = 60}$ MW

→ Also, $\frac{100}{1+0.5s} \to 100$

$\therefore$ Normalised gate position $= \frac{60}{100} = 0.6$

→ Governor output $= 0.6 - 0.8 = -0.2$

$\therefore$ Governor input $= \frac{-0.2}{0.25} = -0.8$

→ $\omega_{ref} - \omega = -0.8$

$\therefore \omega = \omega_{ref} + 0.8$

$= 314.96$ rad

$\therefore \boxed{\omega = 50.127 \text{ Hz}}$

(c) Under steady state condi^n $(s \to 0)$

$\therefore \frac{1}{Js} \to \infty$ & $\frac{100}{1+0.5s} \to 100$

$\therefore \boxed{P_e = P_m = 60}$ MW

& Governor output $= -0.2$

→ But Governor $= \left(\cancel{25}\ 0.25 + \frac{0.5}{s}\right) \to \infty$

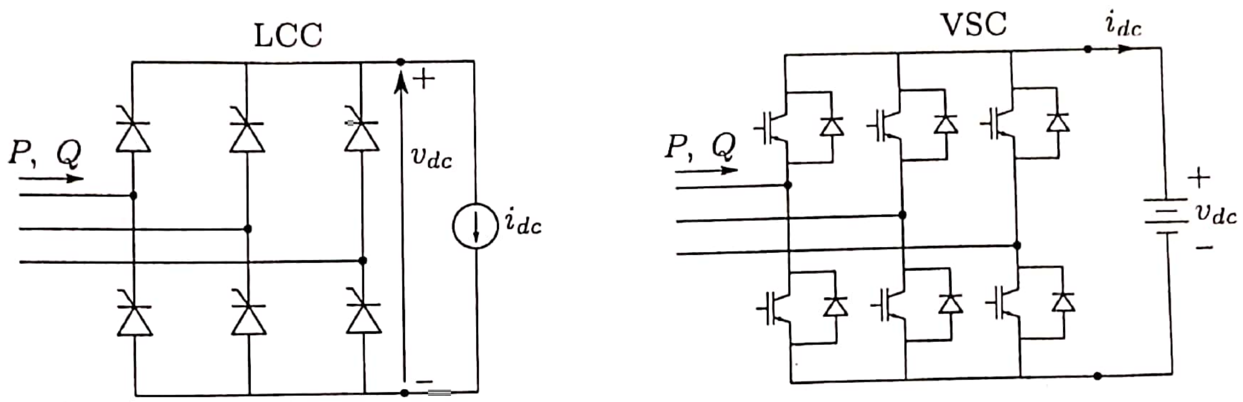
$\therefore$ Governor input $= 0$

$\therefore \omega_{ref} - \omega = 0$

$\therefore \omega = \omega_{ref} = 314.16$ rad

$\therefore \boxed{\omega = 50 \text{ Hz}}$

6. Consider an LCC and a VSC based device with the directions of v_{dc}, i_{dc}, P and Q for each of them are as shown in the figure below.



For each of the following statements, choose the correct option (for both LCC and VSC).

7 marks

Sl. No.	Statement	LCC	VSC
(i)	Instantaneous i_{dc} can be both positive and negative	~~True~~/False	True/~~False~~
(ii)	Average i_{dc} can be both positive and negative	~~True~~/False	True/~~False~~
(iii)	Instantaneous v_{dc} can be both positive and negative	True/~~False~~	~~True~~/False
(iv)	Average v_{dc} can be both positive and negative	True/~~False~~	~~True~~/False
(v)	Active power (P) can be both positive and negative	True/~~False~~	True/~~False~~
(vi)	Reactive power (Q) can be both positive and negative	~~True~~/False	True/~~False~~
(vii)	Can feed a purely passive load on the AC side	~~True~~/False	True/~~False~~