CLASS TEST

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Electrical Machines

(Synchronous Machine)

ELECTRICAL ENGINEERING

Date of Test : 05/08/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)

Frequency, $f = \dfrac{PN}{120} = \dfrac{4 \times 1500}{120} = 50$ Hz

Total number of stator conductor = Number of slots × conductor per slot

$= 80 \times 6 = 480$

Stator conductor per phase, $Z_p = \dfrac{480}{3} = 160$

Winding factor, $k_w = 0.98$

Generated voltage per phase, $E_p = 2.22 \times k_w \times f \times \phi \times Z_p$

$= 2.22 \times 0.98 \times 50 \times 0.04 \times 160$

$= 696.19$ V

Generated line voltage, $E_L = \sqrt{3}E_p = 1205.83$ V

2. (a)

Given,

Synchronous impedance, $X_S = 0.8 + j5.6 = 5.656\angle 81.86°\ \Omega$

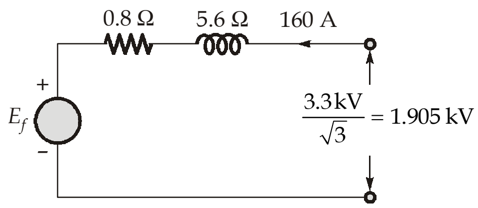
Per phase voltage, $V_p = \dfrac{\text{Rated line voltage}}{\sqrt{3}} = \dfrac{3.3\text{ kV}}{\sqrt{3}} = 1.905$ kV

$\vec{E}_{f\,\text{phase}} = 1.905 - 5.656\angle 81.86° \times 0.16\angle -36.9°$

$= 1.905 - 0.90496\angle 44.96°$

$= 1.417\angle -26.82°$ kV or 2.454 kV (line)

We can draw per phase diagram,



Mechanical power developed,

$P_{\text{mech (dev)}} = 3E_f I_P \cos(\phi + \delta)$

$= 3 \times 1.417 \times 160 \cos(-36.9° + 26.82°)$

$= 669.66$ kW

Shaft power output $= 669.66 - 30 = 639.66$ kW

Power input $= \sqrt{3} \times 3.3 \times 160 \times 0.8 = 731.5$ kW

$\eta = \dfrac{\text{Shaft power output}}{\text{Total input}} = \dfrac{639.66}{731.5} \times 100 = 87.44\%$

Alternate Solution :

Power input $= \sqrt{3} \times 3.3 \times 160 \times 0.8$

$= 731618.26 = 731.618$ kW

Copper loss $= 3I^2R = 3 \times (160)^2 \times R$

$= 61.44$ kW

$$\text{Power output} = 640.178 \text{ kW}$$

$$\eta = \frac{640.178}{731.618} \times 100 = 87.44\%$$

3. (c)

We know, terminal voltage, $V_t = 1$ p.u.

$$I_a = 1 \text{ p.u. } 0.8 \text{ p.f. lagging}$$

$$\phi = \cos^{-1} 0.8 = 36.86°$$

Also, $X_d = 0.8$ p.u.

$$X_q = 0.6 \text{ p.u.}$$

$$\tan\psi = \frac{V_t \sin\phi + I_a X_q}{V_t \cos\phi + I_a X_a} = \frac{1 \times 0.6 + 0.6 \times 1}{1 \times 0.8 + 0} = 1.5$$

$$\psi = \tan^{-1}(1.5) = 56.309°$$

$$\text{Power angle, } \delta_1 = \psi - \phi = 56.309° - 36.86°$$

$$= 19.449°$$

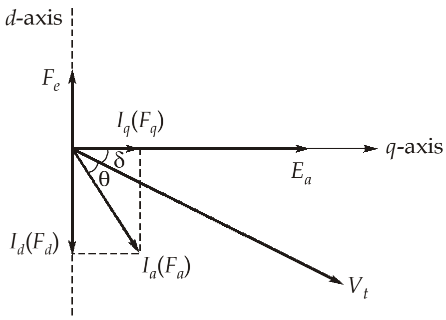
$$E_f = V_t \cos\delta + I_d X_d + I_a r_a = V_t \cos\delta + (I_a \sin\psi) X_d$$

$$= 1 \times \cos 19.449 + (1 \times \sin 56.309) \times 0.8$$

$$= 0.9429 + 0.66563$$

$$= 1.60853 \text{ p.u.}$$

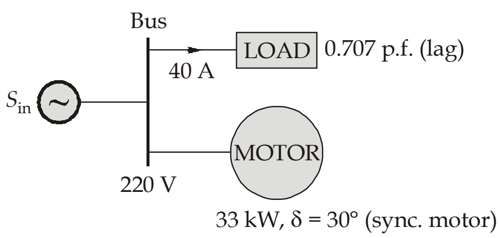
4. (c)



Thus by phasor we can conclude that

- F_e leads F_a by angle $(90 + \theta + \delta)$
- F_q leads F_a by angle $(\delta + \theta)$
- F_d lags F_a by angle $(90 - (\delta + \theta))$
- F_e leads V_t by angle $(90 + \delta)$.

5. (d)



$$\vec{S}_{\text{Load}} = \sqrt{3} \times 220 \times 40 \times \angle\cos^{-1}(0.707)$$

$$= 15.242\angle 45° \text{ kVA}$$

$$= (10.78 + j10.78)\text{kVA}$$

$$\vec{S}_{motor} = P_{motor} + jQ_{motor}$$

$$P_{motor} = 33 \text{ kW}$$

Using $$P_{motor} = \frac{E_f \times 220}{1.27}\sin 30° = 33 \times 10^3$$

$$E_f = (\sqrt{3} \times 220) = 381 \text{ V (L-L)}$$

$$Q_{motor} = \frac{220}{1.27}(-381\cos 30° + 220) = -19.047 \text{ kVAR (leading)}$$

$$\vec{S}_{motor} = (33 - j19.047) \text{ kVA}$$

$$\vec{S}_{in} = \vec{S}_{motor} + \vec{S}_{Load}$$

$$= (33 + 10.48) + j(10.78 - 19.047)$$

$$= 43.78 - j8.267$$

$$= 45.55\angle -10.70° \text{ kVA}$$

Power factor $= \cos(-10.70) = 0.9826$ leading

6. (b)

At maximum power conditions,

$$\delta = \theta_s$$

$$\delta = \cos^{-1}\left[\frac{0.4}{8}\right] = \cos^{-1}[0.05] = 87.134°$$

$$E_f\angle\delta = V_t\angle 0 + I_a Z_s$$

$$E_f \text{ (per phase)} = \frac{12000}{\sqrt{3}} = 6928.20 \text{ V}$$

$$V_t \text{ (per phase)} = \frac{11000}{\sqrt{3}} = 6350.852 \text{ V}$$

$$E_f \cos\delta + j E_f \sin\delta = V_t + I_a\angle -\phi \cdot Z_s\angle\theta_s$$

$$= V_t + I_a Z_s \angle\theta_s - \phi$$

$$E_f \cos\delta + j E_f \sin\delta = V_t + I_a Z_s \cos(\theta_s - \phi) + jI_a Z_s \sin(\theta_s - \phi)$$

Comparing real and imaginary part,

$$E_f \cos\delta = V_t + I_a Z_s \cos(\theta_s - \phi)$$

$$E_f \sin\delta = I_a Z_s \sin(\theta_s - \phi)$$

$$6928.20 \times \cos 87.134 = 6350.85 + 8I_a \cos(\theta_s - \phi)$$

$$346.411 = 6350.85 + 8I_a \cos(\theta_s - \phi)$$

$$8 I_a \cos(\theta_s - \phi) = -6004.438$$

$$I_a \cos(\theta_s - \phi) = -750.554 \quad \text{...(i)}$$

Also $$8 I_a \sin(\theta_s - \phi) = 6928.20 \times \sin 87.134$$

$$8 I_a \sin(\theta_s - \phi) = 6919.534$$

$$I_a \sin(\theta_s - \phi) = 864.941 \quad \text{...(ii)}$$

By squaring and adding equation (i) and (ii),

$$I_a = 1145.187 \text{ A}$$

Using equation (i),

$$I_a \cos(\theta_s - \phi) = -750.554$$

$$\cos(\theta_s - \phi) = -0.65539$$

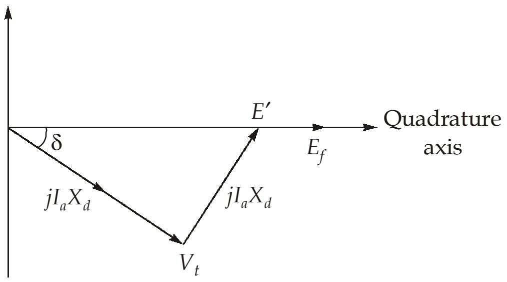
$$\theta_s - \phi = 130.949$$

$$87.134 - \phi = 130.949$$
$$\phi = -43.815°$$
$$\cos\phi = 0.7215$$

7. (b)

Power angle is the angle between E_f and V_t

As E' and E_f are in phase, angle between E' and V_t is also equal to power angle, δ



$$I_a = 1\angle 0° \text{ p.u.}$$

Quadrature axis function, $X_q = 1.2$ p.u.

$$E' = V_t + jI_aX_q = 1 + j1 \times 1.2 = 1.562\angle 50.19° \text{ A}$$
$$\delta = 50.194°$$

8. (b)

Emf equation synchronous motor is given as

$$\vec{E} = \vec{V}_t - \vec{I}_a\vec{Z}_s$$

Given that, $\vec{V}_t = 1\angle 0°$ p.u., $\vec{I}_a = 1\angle 90°$ p.u., $\vec{Z}_s = 0.5\angle 90°$ p.u.

$$\vec{E} = 1\angle 0° - (1\angle 90°) \times (0.5\angle 90°)$$
$$= 1 - 0.5\angle 180°$$
$$\vec{E} = 1 + 0.5\angle 0° = 1.5 \text{ p.u.}$$

9. (c)

Given that, $V_t = 1.0$ pu, $I_a = 1.0$ pu, 0.8 pf lagging

$$\phi = \cos^{-1} 0.8 = 36.9°$$
$$x_d = 0.8 \text{ pu}, x_q = 0.5 \text{ pu}$$

$$\tan\psi = \frac{V_t \sin\phi + I_a x_q}{V_t \cos\phi + I_a r_a} = \frac{1 \times 0.6 + 1 \times 0.5}{1 \times 0.8 + 0} = \frac{11}{8}$$

$$\psi = \tan^{-1}\left(\frac{11}{8}\right) = 53.97° \simeq 54°$$

Power angle, $\delta = \psi - \phi = 54° - 36.9° = 17.1°$

10. (b)

As we know, $I_{sc} \propto \dfrac{E_f}{X_s} \propto \dfrac{I_f \times f}{f}$ $(\because I_{sc} \propto I_f)$

$$I_{sc2} = I_{sc1} \times \frac{I_{f2}}{I_{f1}} = 20 \times \frac{1.5}{1} = 30 \text{ A}$$

11. (a)

Since winding is double layer,

So, No. of coils = No. of slots

No. of coils = 36

Since each coil is passes 8 turns,

So total number of turns = 36 × 8 = 288 turns

$$\text{Turns per phase} = \frac{\text{Total no. of turns}}{\text{No. of phases}} = \frac{288}{2} = 144 \text{ Turns/phase}$$

$$m = \frac{\text{Slot}}{\text{Pole} \times \text{Phase}} = \frac{36}{6 \times 2} = 3$$

$$\beta = \frac{180° \times \text{Poles}}{\text{Slots}} = \frac{180° \times 6}{36} = 30°$$

Distribution factor,
$$K_d = \frac{\sin\left(\frac{m\beta}{2}\right)}{m\sin\left(\frac{\beta}{2}\right)} = \frac{\sin(45°)}{3\sin(15°)} = 0.91$$

$$\text{Emf per phase} = 4.44\phi_m f N_{ph} K_d = 4.44 \times 0.015 \times 50 \times 144 \times 0.91$$

= 436.36 volts/phase

$$E_{L(\text{rms})} = \sqrt{2}E_{\text{ph(rms)}} = \sqrt{2} \times 436.36 = 617.11 \text{ volts}$$

12. (b)

$$\vec{I}_a = 1\angle 36.86 \text{ p.u.}$$

$$\vec{V}_t = 1 \text{ p.u.}$$

$$\vec{Z}_s = j0.6 \text{ p.u.}$$

$$\vec{E}_f = \vec{V}_t - \vec{I}_a\vec{Z}_s = 1\angle 0 - 0.6\angle 126.86°$$

$$= 1.44\angle -19.44° \text{ p.u.}$$

∵ $E_f = 1.44$ p.u.,

$\delta = -19.44°$

As we know,

Ful-load torque = (Maximum torque) · sin δ

$$\frac{\text{Maximum torque}}{\text{Full load torque}} = \frac{1}{\sin\delta} = \frac{1}{\sin 19.44} = 3.00$$

Hint: The ratio of two torque of a single machine can't be negative, don't put δ to –δ.

13. (b)

$$375 = \frac{120\,xf}{16} \Rightarrow f = 50 \text{ Hz}$$

$$\text{Slots per pole} = \frac{144}{16} = 9$$

Slots per pole per phase,
$$m = \frac{144}{16 \times 3} = 3$$

$$\beta = \frac{180°}{\text{slots per pole}} = 20°$$

$$k_d = \frac{\sin\frac{m\beta}{2}}{m\sin\frac{\beta}{2}} \Rightarrow k_d = \frac{0.5}{3\times0.174} = 0.96$$

Z = number of conductors in series per phase = $\frac{144\times10}{3} = 480$

$$E_{\text{line}} = \sqrt{3}\times4.44\, f\, N_{ph}\phi_m k_d$$

$$= \sqrt{3}\times4.44\times0.96\times0.03\times\frac{480}{2}\times50$$

$$= 2657.76 \text{ V}$$

14. (b)

$$P_{sy} = \frac{EV}{X_s}\cos\delta$$

where P_{sy} = symmetrical power coefficient

$$P_{sy} \;\alpha\; \text{stability} \;\alpha\; \text{excitation}$$

At 'Q' the excitation is more than at 'P'.

So it is more stable at Q.

15. (a)

$$Z_{s(\text{adjusted})} = \left.\frac{V_{\text{rated}}/\sqrt{3}}{I_{\text{sc}}}\right|_{\text{At } I_f \text{ corresponding to } V_{\text{oc}} = V_{\text{rated}}}$$

Rated armature current,

$$\sqrt{3}V_{\text{rated}}\, I_{a(\text{rated})} = 10 \text{ MVA}$$

$$I_{a(\text{rated})} = \frac{10\times10^3}{\sqrt{3}\times13.8} = 418.4 \text{ A}$$

$$I_{f(\text{rated})} = 842 \text{ A}$$

$$I_{\text{sc}} = \frac{418.4}{226}\times842 = 1558.8 \text{ A}$$

$$Z_{s(\text{adjusted})} = \frac{13.8\times10^3/\sqrt{3}}{1558.8} = 5.11\ \Omega$$

$$X_{s(\text{adjusted})} = \sqrt{Z^2_{s(\text{adjusted})} - R_a^2}$$

$$= \sqrt{5.11^2 - 0.75^2} = 5.054\ \Omega$$

$$X_{s(\text{pu})} = 5.054\times\frac{10}{(13.8)^2} = 0.2654$$

16. (a)

$$Z_a = (0.5 + j2)\ \Omega$$
$$= 2.06\angle 75.96^\circ\ \Omega;\ V_t = 415\text{ V},\ E_f = 500\text{ V}$$

$$\text{Maximum developed power} = \frac{E_f V_t}{Z_s} - \frac{E_f^2}{Z_s^2} \times R_a$$

$$P_{\text{dev}} = \frac{500 \times 415}{2.06} - \left(\frac{500}{2.06}\right)^2 \times 0.5$$
$$= 71.272\text{ kW}$$

This is per phase power.

$\therefore$ Shaft power output $= [3 \times 71.272 - 1]$ kW
$= 212.81$ kW

17. (b)

$$\text{Power (P)} = \frac{VE_f}{X_s}\sin\delta$$

$$0.75 = \frac{1 \times 1.25}{0.7}\sin\delta$$
$$\delta = 24.83^\circ$$

Current is given by,

$$\vec{I} = \frac{\vec{E}_f - \vec{V}}{jX} = \frac{1.25\angle 24.83^\circ - 1\angle 0^\circ}{j0.7}$$
$$I = 0.77\angle -14.36^\circ$$
$$\text{Phase angle, } \phi = 14.36^\circ$$
$$\text{Power factor} = \cos\phi = 0.9688 \text{ (lagging)}$$

18. (d)

$$\text{Excitation emf, } \left(\vec{E}_f\right) = \vec{V} + \vec{I}_a Z_s$$

Armature current, $$I_a = \frac{20 \times 10^3}{\sqrt{3} \times 400} = 28.87\text{ A}$$

$$\vec{E}_f = \frac{400}{\sqrt{3}} + (28.87\angle 36.87^\circ) \times (0.5 + j3)$$

$$\vec{E}_f = 205.85\angle 22.25^\circ\text{ V}$$

$$\text{Voltage regulation} = \frac{|E_f| - |V|}{|V|} \times 100$$

$$= \frac{205.85 - \left(\frac{400}{\sqrt{3}}\right)}{\left(\frac{400}{\sqrt{3}}\right)} \times 100 = -10.86\%$$

19. **(c)**

Power angle can be calculated as,

$$\vec{E}_f' = \vec{V}_t + j\vec{I}_a X_q$$

As rated load is being supplied at unity power factor,

$$\therefore \quad \vec{I}_a = 1\angle 0° \text{ p.u.}$$

$$\vec{E}_f' = 1.0\angle 0° + j1.0\angle 0° \,(0.8)$$

$$= 1.28\angle 38.65° \text{ p.u.}$$

$$\therefore \quad \text{Power angle, } \delta = 38.65°$$

20. **(a)**

$$\text{Full load current} = \frac{25\times 10^3}{\sqrt{3}\times 400\times 0.8} = 45.11 \text{ A}$$

$$\text{Excitation emf } \vec{E}_f = \vec{V} - j\vec{I}_a X$$

$$= \frac{400}{\sqrt{3}} - (45.11\angle 36.87°)(j7)$$

$$= 490.5\angle -31° \text{ V}$$

Rotor angle slip by 0.25 mechanical degree,

$$\theta_e = \frac{P}{2}\theta_m$$

$$\Delta\delta = \frac{4}{2}\times 0.25 = 0.5°$$

$$\text{Synchronizing emf} = 2E_f \sin\frac{\Delta\delta}{2}$$

$$= 2\times 490.5 \sin\left(\frac{0.5}{2}\right) = 4.28 \text{ V}$$

$$\text{Synchronizing current} = \frac{4.28}{7} = 0.611 \text{ A}$$

21. **(a)**

For double layer winding,

No. of slots = No. of coils

Total number of turns = 60 × 10 = 600

$$\text{Turns per phase} = \frac{600}{3} = 200$$

$$\text{Pitch factor } (K_c) = \cos 18° = 0.951$$

$$\text{Distribution factor } (K_d) = \frac{\sin\frac{m\beta}{2}}{m\sin\frac{\beta}{2}}$$

$$m = \frac{60}{4}\times\frac{1}{3} = 5$$

$$\beta = \frac{180}{60/4} = 12°$$

$$K_d = \frac{\sin\frac{5\times 12}{2}}{5\sin\frac{12}{2}} = 0.9567$$

$$\text{Induced emf, } E_{ph} = \sqrt{2}\pi K_w \phi f T_{ph}$$

$$E_{ph} = \sqrt{2}\pi \times 0.9567 \times 0.951 \times 0.015 \times 50 \times 200$$

$$E_{ph} = 606.33 \text{ V}$$

$$E_{L\text{-}L} = 1.05 \text{ kV}$$

22. (c)

Given,

$$V_t = 1.0 \text{ p.u.}$$

$$I_a = 1.0 \text{ p.u. at 0.8 p.f. lagging}$$

$$\phi = \cos^{-1} 0.8 = 36.86°$$

$$X_d = 0.8 \text{ p.u.}$$

$$X_q = 0.5 \text{ p.u.}$$

As we can use the relation,

$$\tan\psi = \frac{V_t \sin\phi + I_a X_q}{V_t \cos\phi + I_a r_a} \quad [\because \text{Here } r_a = 0]$$

$$\tan\psi = \frac{1\times 0.6 + 1\times 0.5}{1\times 0.8 + 0}$$

or $\tan\psi = 1.375$

$$\psi = 53.97°$$

$\because$ Power angle; $\delta = \psi - \phi$ [for generator]

$$= 53.97° - 36.86°$$

$$= 17.11°$$

We can write,

$$\text{No load voltage; } E_f = V_t \cos\delta + I_d X_d$$

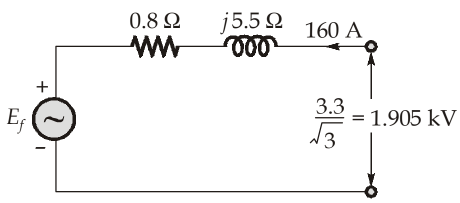
$$= V_t \cos\delta + (I_a \sin\psi) X_d$$

$$= 1 \times \cos 17.11° + (1 \times \sin 53.97°) \times 0.8$$

$$= 1.602 \text{ p.u.} \approx 1.60 \text{ p.u.}$$

23. (c)

Consider the following circuit;



$$\text{Full load current} = 160\angle{-36.86°} \text{ A}$$

$$\text{Synchronous impedance; } Z_s = (0.8 + j\,5.5)\ \Omega$$

$$= 5.56\angle 81.724°\ \Omega$$

From circuit diagram we can write;

$$\vec{E}_f = 1.905 \times 10^3\angle 0° - 5.56\angle 81.724° \times 160\angle -36.86°$$

$$E_f = 1.42\angle -26.22° \text{ kV}$$

Now $\quad P_{mech\ (dev)} = 3 \times 1.42 \times 160 \cos(-36.86° + 26.22°)$

$$= 669.88 \text{ kW}$$

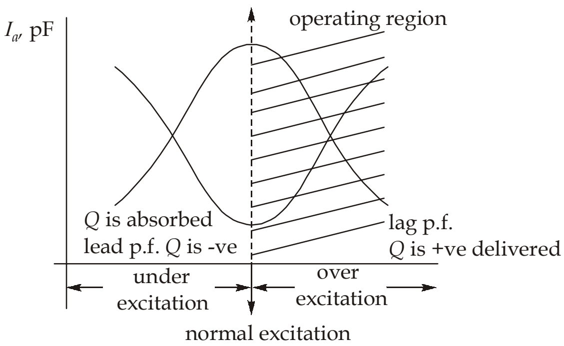
$$\text{shaft output} = 669.88 - 30 = 639.88 \text{ kW}$$

$$\text{Power input} = \sqrt{3} \times 3.3 \times 160 \times 0.8$$

$$= 731.62 \text{ kW}$$

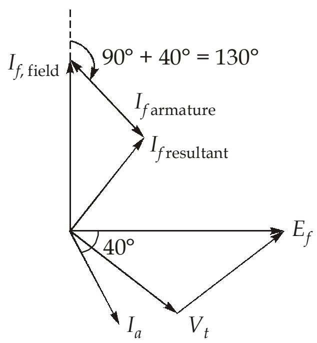
$$\eta_{full\ load} = \frac{\text{Output}}{\text{Input}} \times 100 = \frac{639.88}{731.62} \times 100 = 87.46\%$$

24. (a)



Feeds lagging KVAR to the bus but absorbs the leading kVAR.

25. (d)



26. (b)

Synchronous impedance, $Z_s = (0.5 + j5)\Omega = 5.025\angle 84.29°\ \Omega$

$$I_a = \frac{V\angle 0° - E\angle -\delta}{Z_s\angle\theta}$$

$$S = VI_0^* = V\angle 0\left[\frac{V\angle 0 - E\angle -\delta}{Z_s\angle\theta}\right]^*$$

$$S = \frac{V^2}{Z_s}\angle\theta - \frac{EV}{Z_s}\angle\theta + \delta$$

So from above equation,

$$P = \frac{V^2}{Z_s}\cos\theta - \frac{EV}{Z_s}\cos(\theta+\delta)$$

$$900 \times 10^3 = \frac{2000^2}{5.025}(\cos 84.29°) - \frac{2000\times 3000}{5.025}\cos(84.29° + \delta)$$

$$84.29° + \delta = 133.426°$$

$$\text{Power angle, } \delta = 49.13°$$

27. **(c)**

Take, $V_t = 1\angle 0°$ p.u.

So, $I_a = 1\angle -\cos^{-1}(0.8)$ p.u.

Alternator excitation emf, $\vec{E}_f = \vec{V}_t + \vec{I}_a\vec{Z}_s$

$$\vec{E}_f = 1\angle 0° + [1\angle -\cos^{-1}(0.8)] \times 1.25\angle 90°$$

$$\vec{E}_f = 1 + 1.25\angle 53.13°$$

$$|\vec{E}_f| = \sqrt{(1+1.25\cos 53.13°)^2 + (1.25\sin 53.13°)^2}$$

$$= 2.01 \text{ p.u.}$$

When motor just fall out of step,

$$\delta \approx 90$$

Now for same excitation,

$$2.01\angle 90° = 1\angle 0° + I_a \times 1.25\angle 90°$$

$$\vec{I}_a = \frac{j2.01 - 1}{j1.25} = 1.608 + j0.8$$

$$\vec{I}_a = 1.8\angle 26.45° \text{ p.u.}$$

$$\text{Power factor} = \cos(26.45°) = 0.895 \text{ leading}$$

28. **(c)**

$$E_f^2 = (V_E\cos\phi)^2 + (V_t\sin\phi + I_aX_s)^2$$

$$E_f^2 = V_t^2\left[0.8^2 + \left(0.6 + \frac{I_aX_s}{V_t}\right)^2\right]$$

$$E_f^2 = V_t^2\left[0.8^2 + (0.6+0.2)^2\right]$$

$$E_f = 1.13\ V_t$$

$$\text{Voltage regulation} = \frac{E_f - V_t}{V_t}\times 100 = \frac{1.13V_t - V_t}{V_t}\times 100 = 13\%$$

29. (b)

$$S_{load} = 1200\angle{-\cos^{-1}(0.8)} = 960 - j720$$
$$S_A = 750\angle{-\cos^{-1}(0.9)} = 675 - j326.9$$

Now, $$S_A + S_B = S_{load}$$

$\therefore$ $$S_B = S_{load} - S_A$$
$$= 960 - j720 - 675 + j326.9$$
$$= 285 - j393.1$$
$$S_B = 485.54\angle{-54.05°}$$
$$\cos\phi_B = \cos(-54.05) = 0.587 \text{ (lagging)}$$

30. (a)

Let,synchronous speed of motor = N_{sm}

Also, $$N_{sm} = \frac{120 \times f_m}{P_m}$$

$\therefore$ $$N_{sm} = \frac{120 \times 60}{P_m}$$

Synchronous speed of alternator,

$$N_{sg} = \frac{120 \times f_g}{P_g} = \frac{120 \times 25}{20} = 150 \text{ rpm}$$

Since alternator and motor are directly coupled

$$N_{sg} = N_{sm}$$

(or) $$150 = \frac{120 \times 60}{P_m}$$

$\Rightarrow$ $$P_m = 48$$

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