CLASS TEST

S.No.: 02SK_ABCDEFG_26082024

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Synchronous Machine

ELECTRICAL ENGINEERING

Date of Test : 26/08/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)

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

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

$= 80 \times 6 = 480$

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

Winding factor, $k_w = 0.98$

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

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

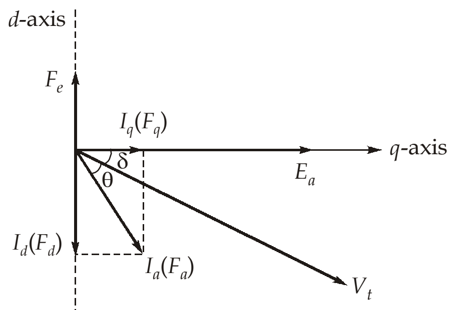
$= 696.19$ V

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

2. (d)

Both statements are correct for starting of synchronous motor. It is recommended to connect an external resistance 7 to 10 times the field resistance to avoid insulation damage.

3. (c)



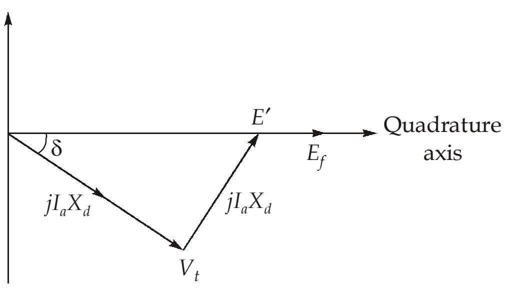
Thus by phasor we can conclude that

- 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 $(90 + \delta)$.

4. (a)

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.

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

5. **(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.

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

6. **(a)**

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

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

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

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

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

7. **(b)**

3rd harmonic voltage in line of Y-connected generator is neutralized. So,

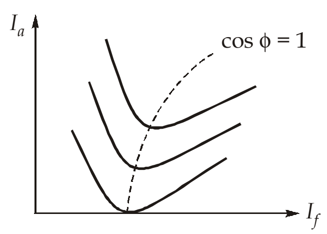
$$V_{L,\text{peak}} = \sqrt{6}V_{ph(\text{rms})} = 231\sqrt{6} = 565.83 \text{ volts}$$

8. **(b)**

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

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

9. **(d)**



10. (a)

By large air-gap length, the reluctance of the air-gap increases, so that the leakage flux decreases hence leakage reactance decreases. So, flux distribution will improved (more sinusoidal).

Because of large air-gap length, armature reaction decreases. So, the voltage regulation will be less.

11. (b)

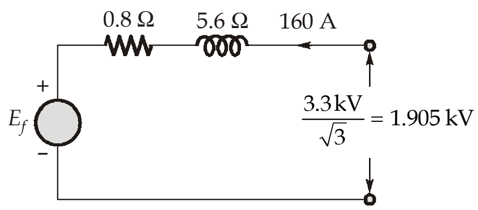
Given,

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

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

$$\vec{E}_{f\,\text{phase}} = 1.905 - 5.656\angle 81.86° \times 0.16\angle -36.9°$$
$$= 1.905 - 0.90496\angle 44.96°$$
$$= 1.417\angle -26.82°\text{ kV or } 2.454\text{ kV (line)}$$

We can draw per phase diagram,



Mechanical power developed,

$$P_{\text{mech (dev)}} = 3E_f I_P \cos(\phi + \delta)$$
$$= 3 \times 1.417 \times 160 \cos(-36.9° + 26.82°)$$
$$= 669.66\text{ kW}$$

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

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

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

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

Power output $= 640.178$ kW

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

12. (b)

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

$I_a = 1$ p.u. 0.8 p.f. lagging

$\phi = \cos^{-1} 0.8 = 36.86°$

Also, $X_d = 0.8$ p.u.

$X_q = 0.6$ p.u.

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

$$\psi = \tan^{-1}(1.5) = 56.309°$$

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

$$= 19.449°$$

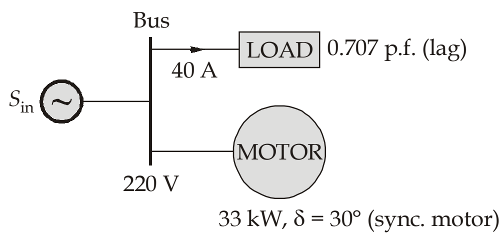
$$E_f = V_t \cos\delta + I_d X_d + I_a r_a = V_t \cos\delta + (I_a \sin\psi) X_d$$

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

$$= 0.9429 + 0.66563$$

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

13. (d)



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

$$= 15.242\angle 45° \text{ kVA}$$

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

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

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

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

14. (a)

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),

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

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

$$\theta_s - \phi = 130.949$$

$$87.134 - \phi = 130.949$$

$$\phi = -43.815°$$

$$\cos\phi = 0.7215$$

15. (b)

For open circuit test,

Given, V_{OC} = 400 V (rms) line voltage

Phase voltage, $V_{OC,\,ph} = \frac{400}{\sqrt{3}} = 230.94$ V

Field current, I_f = 2.5 A

For short circuit test, I_{SC} = 12 A (rms, phase)

I_f = 1.08 A

$$\therefore \quad \text{Base impedance, } Z_{base} = \frac{V_{OC}}{I_{SC}} = \frac{230.94}{12} = 19.245\ \Omega$$

Also, for synchronous impedance at rated voltage saturation is also considered

$$\therefore \quad \text{SCR} = \frac{I_f \text{ for } V_{OC}}{I_f \text{ for } I_{SC}} = \frac{1}{Z_{S(sat)\,p.u.}} = \frac{2.5}{1.8} = 1.3888$$

$$Z_{S(\,sat)p.u.} = \frac{1}{1.3888} = 0.72 \text{ p.u.}$$

$\therefore$ Actual value of Z_S at rated voltage

$$= Z_{S\,(sat)p.u.} \times Z_{base}$$

$$= 0.72 \times 19.245$$

$$= 13.85\ \Omega$$

16. (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,

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

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

$$= 436.36 \text{ volts/phase}$$

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

17. (b)

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

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

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

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

$$= 1.44\angle{-19.44°} \text{ p.u.}$$

$\because$ $E_f = 1.44$ p.u.,

$$\delta = -19.44°$$

As we know,

$$\text{Ful-load torque} = (\text{Maximum torque}) \cdot \sin\delta$$

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

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

18. (b)

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

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

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

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

$$k_d = \frac{\sin\frac{m\beta}{2}}{m\sin\frac{\beta}{2}} \Rightarrow k_d = \frac{0.5}{3 \times 0.174} = 0.96$$

Z = number of conductors in series per phase = $\frac{144 \times 10}{3} = 480$

$$E_{\text{line}} = \sqrt{3} \times 4.44\, f\, N_{ph} \phi_m k_d$$

$$= \sqrt{3} \times 4.44 \times 0.96 \times 0.03 \times \frac{480}{2} \times 50$$

$$= 2657.76 \text{ V}$$

19. **(b)**

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

where P_{sy} = symmetrical power coefficient

P_{sy} α stability α excitation

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

So it is more stable at Q.

20. **(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,

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

$$I_{a(\text{rated})} = \frac{10 \times 10^3}{\sqrt{3} \times 13.8} = 418.4 \text{ A}$$

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

$$I_{\text{sc}} = \frac{418.4}{226} \times 842 = 1558.8 \text{ A}$$

$$Z_{s(\text{adjusted})} = \frac{13.8 \times 10^3/\sqrt{3}}{1558.8} = 5.11\ \Omega$$

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

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

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

21. (a)

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

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

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

This is per phase power.

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

22. (b)

Given, 44 MVA, Y-connected, 3-ϕ salient pole synchronous generator.

It deliver a rated load at 0.8 p.f. lag,

$$V = 10.5\text{ kV},\quad X_d = 1.83\ \Omega$$
$$X_q = 1.21\ \Omega,\ \text{Y-connected}$$

$$\tan\Psi = \frac{V\sin\phi + I_a X_q}{V\cos\phi + I_a R_a}$$

$$V_{\text{ph}} = \frac{V_a}{\sqrt{3}} = 6062.17\text{ V}$$

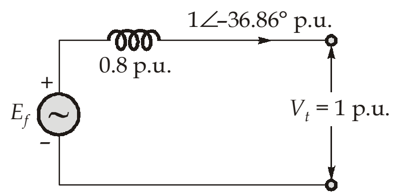
$$I_a = \frac{P}{\sqrt{3}V_L} = \frac{44\times 10^6}{\sqrt{3}\times 10.5\times 10^3} = 2419.3\angle -36.86°\text{A}$$

$$\tan\psi = \frac{(6062.17\times 0.6) + (2419.3\times 1.21)}{(6062.17\times 0.8) + (2419.3\times 0)}$$

$$\psi = 53.546°$$
$$\psi = \delta + \phi$$
$$\delta = 53.546° - 36.86°$$
$$= 16.686° \approx 16.69$$

23. (a)

Consider the circuit diagram drawn below:



From circuit diagram we can write,

$$\vec{E}_f = 1 + j\,0.8\,(1\angle -36.86°)$$

$$\vec{E}_f = 1.61\angle 23.4°\text{ p.u.}$$

Here, $\quad$ power angle, $\delta = 23.4°$

$$\text{Real power; } P_e = \frac{V_t E_f}{X_s}\sin\delta$$

$$\text{Synchronizing power, } \frac{dP_e}{d\delta} = \frac{V_t E_f}{X_s}\cos\delta = \frac{1\times 1.61}{0.8}\cos(23.4°)$$

$$\frac{dP_e}{d\delta} = 1.847 \text{ p.u./electrical radian}$$

or, $$\frac{dP_e}{d\delta} = 1.847\times 10^3 \times \frac{\pi}{180} \text{ kW/electrical degree}$$

$$= 32.236 \text{ kW/electrical degree}$$

or, $$1 \text{ electrical degree} = \frac{P}{2} \text{ mechanical degree}$$

then; $$\frac{dP_e}{d\delta} = 32.236 \times 4 \text{ kW/mechanical degree}$$

$$\frac{dP_e}{d\delta} = 128.944 \text{ kW/mechanical degree}$$

24. (b)

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

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

$$\delta = 24.83°$$

Current is given by,

$$\vec{I} = \frac{\vec{E}_f - \vec{V}}{jX} = \frac{1.25\angle 24.83° - 1\angle 0°}{j0.7}$$

$$I = 0.77\angle{-14.36°}$$

$$\text{Phase angle, } \phi = 14.36°$$

$$\text{Power factor} = \cos\phi = 0.9688 \text{ (lagging)}$$

25. (a)

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

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

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

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

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

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

26. (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,

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

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

$$= 1.28\angle 38.65° \text{ p.u.}$$

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

27. (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,

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

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

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

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

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

28. (a)

For double layer winding,

No. of slots = No. of coils

Total number of turns = 60 × 10 = 600

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

Pitch factor (K_c) = cos 18° = 0.951

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

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

$$\beta = \frac{180}{60/4} = 12°$$

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

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

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

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

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

29. (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,

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

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

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,

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

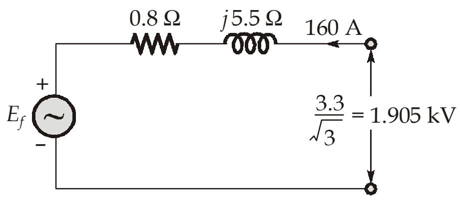
$$= V_t \cos\delta + (I_a \sin\psi) X_d$$

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

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

30. (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

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

$$= 669.88 \text{ kW}$$

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

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

$$= 731.62 \text{ kW}$$

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

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