CLASS TEST

S.No. : 01 SK_EE_EFSGHI_190822

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SYNCHRONOUS MACHINES

ELECTRICAL ENGINEERING

Date of Test : 19/08/2022

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (a)

Given,

$$V_{oc} = 2100 \text{ V}$$
$$I_{sc} = 425 \text{ A}$$

Then synchronous impedance,

$$X_s = \frac{2100}{425} = 4.94\ \Omega$$

Now internal voltage drop $= 4.94 \times 200$
$= 988.24$ V

2. (b)

$$\text{Frequency, } f = \frac{PN}{120} = \frac{6 \times 1000}{120} = 50 \text{ Hz}$$

$$\text{slots per pole} = m = 3$$

$$\text{No. of slots} = \frac{360°}{20} = 18$$

$$\text{No. of turns/phase} = \frac{18 \times 12}{2} = 108$$

$$\text{Slot angle, } \beta = 20°$$

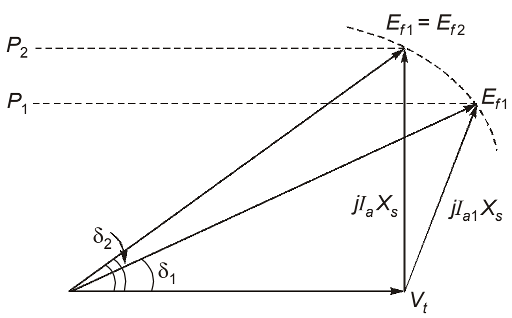
$$\text{then, distribution factor, } K_d = \frac{\sin \frac{m\beta}{2}}{m \sin \beta/2}$$

$$K_d = \frac{\sin \frac{3 \times 20°}{2}}{3 \times \frac{\sin 20°}{2}} = 0.9598$$

$$\text{Emf generated per phase} = 4.44\, f\, \phi\, N_{ph} \cdot K_d$$
$$= 4.44 \times 50 \times 3 \times 10^{-2} \times 108 \times 0.9598$$
$$E_p = 690.36 \text{ V}$$

3. (a)

Consider the below phasor diagram,



If the steam input in increased keeping excitation constant, real power to bus bar will increase, which result in increase in load angle δ ($\delta_2 > \delta_1$).

4. (b)

Given, Load = 600 kW at 0.75 p.f. lagging

$$\text{Load kVA} = \frac{600}{0.75} = 800 \text{ kVA}$$

$$\text{Load kVAR} = \text{Load kVA} \times \sin\phi$$

$$= 800 \times \sqrt{1-(0.75)^2}$$

$$= 529.15 \text{ kVAR}$$

When a synchronous motor is connected to improve the power factor it is over excited. As there is reactive power required from motor so it will operate at zero power factor leading. Which supplied 529.15 kVAR to load.

5. (b)

$$\text{Power input to motor} = \frac{40\text{ kW}}{\eta} = \frac{40\times10^3}{0.9} = 44.44 \text{ kW}$$

$$\text{Armature current, } I_a = \frac{\text{Power input}}{\sqrt{3}\times\text{supply voltage} \times \text{powe factor}}$$

$$= \frac{44.44\times10^3}{\sqrt{3}\times415\times0.75} = 82.43 \text{ A}$$

6. (c)

Both the statements are correct.

7. (c)

Let the original frequency = f_0

Drooping frequency = 4% of f_0 = 0.04 f_0

Let load shared by machine 1 = P_1

Load shared by machine 2 = P_2

For Machine - 1:

For a load of 80 MW, the drop in frequency,

$$= 0.04\, f_0$$

For a load of P MW, the drop in frequency,

$$= \frac{0.04 f_0 \times P}{80}$$

Operating frequency of first machine

$$= \left(f_0 - \frac{0.04}{80} f_0 P_1\right) \quad \text{...(i)}$$

Similarly for Machine - 2

The operating frequency of machine- 2

$$= \left(f_0 - \frac{0.04}{150} f_0 P_2\right) \quad \text{...(ii)}$$

Since both alternators are running parallel, they must operate in same frequency at steady state. From equation (i) and (ii), we get

$$f_0 - \frac{0.04}{80} f_0 P_1 = f_0 - \frac{0.04}{150} f_0 P_2$$

$$P_1 = \frac{8}{15} P_2 \quad \text{...(iii)}$$

Total load shared by machines:

$$P_1 + P_2 = 150 \text{ MW} \quad \text{...(iv)}$$

From equation (iii) and (iv), we get

$$\frac{8}{15} P_2 + P_2 = 150$$

$$P_2 = \frac{150 \times 15}{23} = 97.83 \text{ MW}$$

and, $P_1 = 52.17$ MW

8. (d)

The power taken by driving motor without excitation is corresponding to friction and windage loss:

therefore, $P_{w\&f} = 900$ W

When armature is short circuited, the power corresponds to the copper losses at full load.

Therefore, $P_{cu\,(fl)} = 3000 - 900 = 2100$ W

Half load copper loss,

$$P_{cu}'_{(Hl)} = \frac{1}{4} P_{cu(fl)} = \frac{1}{4} \times 2100 = 525 \text{ W}$$

Now when armature is open circuited;

$$I_a = 0$$

or $P_{cu} = 0$

then only iron losses and rotational losses will be present;

Now, $P_{iron} = 2000 - 900$

$= 1100$ W

Total losses at half load (50%)

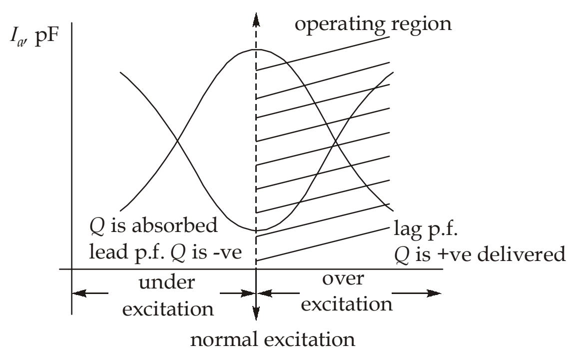
$= 900 + 525 + 1100 = 2525$ W

Efficiency at 50% load

$$\%\eta = \frac{\text{Output}}{\text{Output + losses}}$$

$$\%\eta = \frac{30000 \times 100}{30000 + 2525} = 92.24\%$$

9. (a)



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

10. (a)

Let,synchronous speed of motor = N_{sm}

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

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

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

$$\Rightarrow \quad P_m = 48$$

11. (c)

$$\vec{E}' = \vec{V_t} - j\vec{I_a}X_q$$

$$X_q = 7\ \Omega$$

$$\text{p.u. value of } X_q = \frac{\text{ohmic value}}{\text{base value}}$$

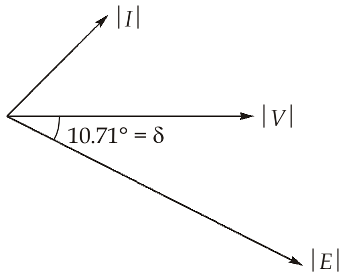
$$\text{Base ohms} = \frac{\left(\frac{440}{\sqrt{3}}\right)}{10} = 25.4\ \Omega$$

$$\text{p.u. value of } X_q = \frac{7}{25.4} = 0.2756 \text{ p.u.}$$

$$\vec{E} = 1 - ((j0.2756) \times 1\angle\cos^{-1}(0.8))$$

$$= 1.18\angle{-10.71°} \text{ p.u.}$$

$$\therefore \quad \text{Torque angle, } \delta = 10.71°$$



Alternative method:

$$\text{Torque angle, } \delta = \tan^{-1}\left[\frac{IX_q\cos\theta}{V + IX_q\sin\theta}\right]$$

$$= \tan^{-1}\left[\frac{10 \times 7 \times \cos(36.87°)}{254 + (10 \times 7\sin(36.87°))}\right]$$

$$\delta = 10.71°$$

12. **(c)**

Active power supplied to load is $= 50$ kW

Reactive power supplied to load,

$$Q = P \tan\phi$$
$$= 50 \tan(\cos^{-1} 0.8)$$
$$= 37.5 \text{ kVAR}$$

Active power supplied by one generator

$$= \frac{50}{2} = 25 \text{ kW}$$

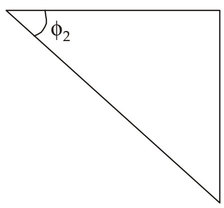
Power factor of generator 1 $= \cos\phi_1 = 0.9$ lag

Reactive power supplied by generator 1

$$= 25 \times \tan(\cos^{-1} 0.9) = 12.10 \text{ kVAR}$$

Reactive power supplid by generator 2

$$= 37.5 - 12.10$$
$$= 25.4 \text{ kVAR}$$



$$\phi_2 = \tan^{-1}\left(\frac{25.4}{25}\right) = 45.45°$$

$$\cos\phi_2 = 0.701 \text{ lagging}$$

Current supplied by machine 2 is,

$$I_2 = \frac{P_2}{\sqrt{3}V_L\cos\phi_2} = \frac{25\times10^3}{\sqrt{3}\times400\times0.701}$$
$$= 51.47 \text{ A}$$

13. **(a)**

$$\vec{E} = \vec{V} + j\vec{I}\vec{X}_s$$
$$= 1 + (j0.8 \times 1\angle{-\cos^{-1}(0.8)})$$
$$= 1.61\angle 23.4° \text{ p.u.}$$

$$\left(\frac{\partial P_e}{\partial\delta}\right)_{\delta=\delta_0} = \frac{EV}{X_s}\cos\delta$$
$$= \frac{1.61\times1}{0.8}\cos(23.4°) = 1.847 \text{ p.u./elec. rad}$$

$$1 \text{ p.u.} = 1000 \text{ kVA}$$

$$\text{Synchronizing coefficient} = \frac{1847}{\left(\frac{180}{\pi}\right)} = 32.23 \text{ kW/elec. degree}$$

14. **(b)**

$$P_m = \frac{V_tE_f}{X_d}\sin\delta = \frac{V_tE_f}{X_d}\sin30°$$

$$T_m = \frac{V_t E_f}{\omega_s X_d}\sin30°$$

$$T_m = \frac{V_t\times1.1E_f}{1.1\omega_s\times1.1X_d}\sin\delta = \frac{V_t E_f}{\omega_s X_d}\sin30°$$

$$\sin\delta = 1.1 \sin 30°$$
$$\delta = \sin^{-1}(0.55)$$
$$\delta = 33.36°$$

15. (b)

Given, $\dfrac{I_a r_a}{V_t} = 1\% = 0.01$

and $\dfrac{I_a X_a}{V_t} = 50\% = 0.50$

Now, $E_f^2 = (V_t\cos\theta + I_a r_a)^2 + (V_t \sin\theta + I_a X_s)^2$

$$= V_t^2\left[\left(\cos\theta + \left(\frac{I_a r_a}{V_t}\right)\right)^2 + \left(\sin\theta + \left(\frac{I_a X_s}{V_t}\right)\right)^2\right]$$

Here $I_a = 0.7\, I_{rated}$

$\therefore$ $(1.2\, V_t)^2 = V_t^2[(\cos\theta + 0.01 \times 0.7)^2 + (\sin\theta + 0.5 \times 0.7)^2]$

$1.44 = 0.014\cos\theta + 0.7\sin\theta + 1.12255$

(or) $0.014\cos\theta + 0.7\sin\theta = 1.44 - 1.12225 = 0.31745$

$$A\cos\theta + B\sin\theta = \sqrt{A^2 + B^2}\sin\left(\theta + \tan^{-1}\left(\frac{A}{B}\right)\right)$$

$\therefore$ $0.70014\sin(\theta + 1.14577°) = 0.31745$

(or) $\sin(\theta + 1.14577°) = 0.4535$

$\theta = 25.824°$

$\therefore$ Power factor $= \cos 25.824° = 0.9$ lag

16. (b)

The open-circuit phase voltage:

$$V_{anl} = \frac{2300}{\sqrt{3}} = 1327.91 \text{ V}$$

The short-circuit phase current:

$$I_{SC} = 150 \text{ A}$$

Thus, $Z_S = \dfrac{1327.91}{150} = 8.85\ \Omega$

and $X_S = \sqrt{8.85^2 - 0.5^2} = 8.84\ \Omega$

The rated full load current is

$$I_a = \frac{500000}{3 \times 1327.91} = 125.51 \text{ A}$$

Let us use the per-phase voltage and the rated current as the base values. That is,

$$V_b = 1327.91 \text{ V}$$
$$I_b = 125.51 \text{ A}$$
$$Z_b = \frac{1327.91}{125.51} = 10.58\ \Omega$$

The per unit quantities when the generator operates at its rated load are

$$\vec{I}_{apu} = 1\angle{-36.87°}$$

$$\vec{V}_{apu} = 1\angle 0°$$

$$\vec{Z}_{spu} = \frac{0.5 + j8.84}{10.58} = 0.047 + j0.836$$

Hence, $\vec{E}_{apu} = 1 + (0.047 + j0.836) \times 1\angle{-36.87°}$

$$= 1.667\angle 22.6°$$

Thus, the generated voltage per phase is

$$\vec{E}_a = 1327.91 \times 1.667\angle 22.6°$$

$$= 2213.63\angle 22.6° \text{ V}$$

$$\%\text{V.R.} = (1.667 - 1) \times 100 = 66.7\%$$

17. (d)

$$\text{Base impedance } (Z_B) = \frac{V_B^2}{S_B} = \frac{400^2}{50000} = 3.2\ \Omega$$

Synchrnous reactance,

$$(X_s)_{pu} = \frac{7.5}{3.2} = 2.34375 \text{ p.u.}$$

When motor is operating at 75% load with 0.8 p.f. leading

$$\vec{E}_{f1} = \vec{V} - j\vec{I}_{a1}X$$

$$= 1\angle 0° - j(0.75\angle\cos^{-1}(0.8)) \times (2.34375)$$

$$= 2.49\angle{-34.4°} \text{ p.u.}$$

Now excitation emf is decreased by 5%

$$E_f \sin\delta = \text{constant}$$

$$E_{f1}\sin\delta_1 = E_{f2}\sin\delta_2$$

$$E_{f2} = 0.95 \times 2.49 = 2.37$$

$$\delta_2 = \sin^{-1}\left(\frac{E_{f1}}{E_{f2}} \times \sin\delta_1\right)$$

$$\delta_2 = \sin^{-1}(0.594)$$

$$\delta_2 = 36.44°$$

$$\text{Current, } \vec{I}_{a2} = \frac{\vec{V} - \vec{E}_{f2}}{jX_s} = \frac{1 - 2.37\angle{-36.44°}}{j2.34375}$$

$$\vec{I}_a = 0.7144\angle 32.78°$$

$$\text{Power factor} = \cos 32.78° = 0.8407 \text{ lagging}$$

18. (a)

For alternator, we can write,

$$E_f^2 = (V_t\cos\phi + I_a r_a)^2 + (V_t\sin\phi + I_a X_s)^2$$

For $r_a = 0$

and $X_s = 0.2$ p.u.

or $E_f^2 = V_t^2 \cos^2\phi + (V_t \sin\phi + I_a X_s)^2$

$$E_f^2 = V_t^2 \left[\cos^2\phi + \left(\sin\phi + \frac{I_a X_s}{V_t}\right)^2\right]$$

$\therefore$ $\frac{I_a X_s}{V_t} = X_{s\,(p.u.)} = 0.2$ p.u.

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

$$E_t = 1.131\ V_t \qquad \text{...(i)}$$

Voltage regulation; V.R. $= \frac{E_f - V_t}{V_t} = \frac{1.13\,V_t - V_t}{V_t} \times 100$

$= 13.1\%$

19. (a)

Given,

5 MVA, 11 kV, $P = 6$,

$f = 50$ Hz

Alternator rated current, $I_a = \frac{5\times10^6}{\sqrt{3}\times11\times10^3} = 262.43$ A

Base impedance $= \frac{V_{phase}}{I_a} = \frac{11\times10^3}{\sqrt{3}\times262.43} = 24.2\,\Omega$

Synchronous reactance, $X_s = 0.4$ p.u. $= 0.4 \times 24.2$

$= 9.68\ \Omega$

$\because$ Mechanical degree $= \text{Electrical radian} \times \frac{2}{P} \times \frac{180}{\pi}$

$= \text{Electrical radian} \times \frac{2}{6} \times \frac{180}{\pi}$

$= \frac{60}{\pi} \times \text{Electrical radian}$

As we know;

$$P_{syn} = \frac{3E_f V_t}{X_s}\cos\delta \ \text{ W/electrical radian}$$

or, $P_{syn} = \frac{\pi}{60} \times \frac{E'_f \cdot V'_t}{X_s}\cos\delta$ W/mech. degree

[$\because$ Here E'_f and V'_t are line voltage]

$$P_{syn} = \frac{\pi}{60} \times \frac{11\times11\times10^6}{9.68}\cos\delta \ \text{ W/mech. degree}$$

at no load, $\delta = 0°$

$P_{syn} = 654.498$ kW/mechanical degree

20. **(c)**

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, $M\dfrac{d^2\delta}{dt^2} = P_a$

$$\frac{d^2\delta}{dt^2} = \frac{P_a}{M}$$

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 $= 1.81° + 10° = 11.81°$

21. **(a)**

$$Z_S = (1 + j10) = 10.05\angle 84.29° \ \Omega$$
$$\theta_Z = 84.29°$$
$$\delta = 180° - \theta_z = 180° - 84.29°$$
$$= 95.71°$$
$$\alpha_z = 90° - \theta_z = 5.71°$$
$$\text{Total power output} = \frac{EV}{Z_S}\sin(\alpha_z + \delta) - \frac{V^2}{Z_s^2}r_a$$
$$= \frac{6.6 \times 6.4}{10.05}\sin(5.71° + 95.71°) - \frac{6.6^2}{10.05^2} \times 1$$
$$= 3688.49 \text{ kW}$$

22. **(c)**

Rated armature current/phase

$$= \frac{150 \times 1000}{\sqrt{3} \times 500} = 173.21 \text{ A}$$
$$\text{Field loss} = \frac{V_f^2}{R_f} = \frac{250^2}{200} = 312.5 \text{ W}$$
$$\text{Short circuit loss} = 3 \times \left(\frac{I_a}{2}\right)^2 \times r_a = 3 \times \left(\frac{173.21}{2}\right)^2 \times 0.03 = 675.04 \text{ W}$$

$$\text{Total loss} = 312.5 + 675.04 + 350 + 500 = 1837.54 \text{ W}$$

$$P_{out} = 150 \times 1000 \times \frac{1}{2} \times 0.8 = 60 \text{ kW}$$

$$\text{Efficiency, } \eta = \left(1 - \frac{1837.54}{60000 + 1837.54}\right) \times 100 = 97.03\%$$

23. (d)

$$\text{Speed droop, } S, D = \frac{n_{nl} - n_{fl}}{n_{fl}} = \frac{f_{nl} - f_{fl}}{f_{fl}} \times 100$$

$$\therefore \quad f_{fl} = \frac{f_{nl}}{\frac{SD}{100} + 1}$$

For generator-A:

$$\frac{f_{nl,A}}{\frac{SD_A}{100} + 1} = \frac{61}{\frac{3.4}{100} + 1} = 58.99 \text{ Hz}$$

For generator-B:

$$\frac{f_{nl,B}}{\frac{SD_B}{100} + 1} = \frac{61.5}{\frac{3}{100} + 1} = 59.71 \text{ Hz}$$

For generator-C:

$$\frac{f_{nl,C}}{\frac{SD_C}{100} + 1} = \frac{60.5}{\frac{2.6}{100} + 1} = 58.97 \text{ Hz}$$

Respective slopes of power frequency curves

$$S_{PA} = \frac{3\text{ MW}}{f_{nl} - f_{fl}} = \frac{3}{61 - 58.99} = 1.492 \text{ MW/Hz}$$

$$S_{PB} = \frac{3\text{ MW}}{f_{nl} - f_{fl}} = \frac{3}{61.5 - 59.71} = 1.676 \text{ MW/Hz}$$

$$S_{PC} = \frac{3\text{ MW}}{f_{nl} - f_{fl}} = \frac{3}{60.5 - 58.97} = 1.961 \text{ MW/Hz}$$

The total load fed by three generators: 7 MW

Let the system frequency be f_s

$$7 \text{ MW} = (1.492)(61 - f_s) + 1.676(61.5 - f_s) + 1.961(60.5 - f_s)$$

$$7 \text{ MW} = (91.012 + 103.074 + 118.640) - 5.129(f_s)$$

$$5.129 f_s = 312.726$$

$$f_s = 60.972 \text{ Hz}$$

24. (b)

For given 3-ϕ, alternator,

For star connection, $E_L = \sqrt{3} E_{ph}$

Given, Maximum fundamental voltage,

$$V_{m1} = 500 \text{ V}$$

$\therefore$ Maximum third harmonic amplitude,

$$V_{m3} = \frac{500 \times 10}{100} = 50 \text{ V}$$

Similarly, maximum fifth harmonic amplitude,

$$V_{m5} = \frac{500 \times 5}{100} = 25 \text{ V}$$

As third harmonics seize to exists in Y-connection.

$$\text{rms line voltage, } E_L = \frac{\sqrt{3}}{\sqrt{2}}\left[500^2 + 25^2\right]^{1/2} = \frac{867.107}{\sqrt{2}}$$

$$= 613.14 \text{ V}$$

25. **(a)**

Terminal voltage, $V_t = 1.0$ p.u.

When the excitation is reduced to zero, the power delivered is reluctance power

$$P_m = V_t^2\left(\frac{X_d - X_q}{2X_d X_q}\right)\sin 2\delta$$

Power is maximum when $2\delta = 90°$

(or) $\delta = 45°$

$$P_{m\,(\max)} = V_t^2\left(\frac{X_d - X_q}{2X_d X_q}\right)$$

$$= 1^2 \times \left(\frac{1.02 - 0.68}{2 \times 1.02 \times 0.68}\right) = 0.245 \text{ p.u.}$$

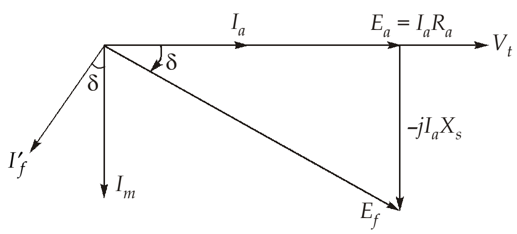
26. **(b)**

$$P_{in} = \sqrt{3} \times 460 \times I_a$$

$$= 3 \times 0.078\, I_a^2 + 125 \times 746$$

$$0.234 I_a^2 - 796.743\, I_a + 93250 = 0$$

$$I_a = 121.365 \text{ A}$$



Let, $V_t = \frac{460}{\sqrt{3}}\angle 0° = 265.6\angle 0°$ V

$$I_a = 121.365\angle 0° \text{ A}$$

$$E_a = V_t - I_a R_a$$
$$= 265.6\angle 0° - 121.365\angle 0° \times 0.078$$
$$= 256.13\angle 0° \text{ V}$$
$$X_S = 0.05 + 1.85 = 1.9\ \Omega$$
$$I_m = \frac{256.13\angle 0°}{1.9\angle 90°} = 134.74\angle{-90°} \text{ A}$$
$$I_f' = I_m - I_a = 134.74\angle{-90°} - 121.365\angle 0°$$
$$= 181.34\angle{-132°} \text{ A}$$
$$\beta = -132°,$$
$$\delta = -132° + 90° = -42°$$

27. (d)

$$\frac{E_{f1}}{E_{f2}} = \frac{f_1}{f_2}$$

$$E_{f2} = \frac{48}{50} \times E_{f1} = 0.96\ E_{f1}$$

$\therefore$ $$X_{S2} = 0.96\ X_{S1}$$

$$\text{V.R.} = 0.01 = \frac{E_{f1} - V_{t1}}{V_{t1}}$$

For negligible armature resistance,

$$V_{t2} = 0.96\ V_{t1} = 0.96 \times 11 = 10.56 \text{ kV}$$

$$\text{V.R.} = \frac{E_{f2} - V_{t2}}{V_{t2}} \times 100$$

$$= \frac{0.96E_{f1} - 0.96V_{t_1}}{0.96V_{t1}} \times 100$$

$$= \frac{E_{f1} - V_{t1}}{V_{t1}} \times 100 = 10\%$$

28. (c)

$$X_S = 4\ \Omega/\text{phase},$$
$$E_f = 540 \text{ V}$$

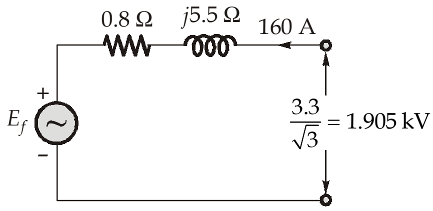
synchronous speed, $$\omega_s = \frac{4\pi f}{P} = \frac{4\pi \times 50}{8} = 25\pi \text{ rad/sec}$$

$$T = \frac{1}{\omega_s} \cdot \frac{E_f V_t}{X_S} \sin\delta, \quad \text{where } V_t = 420 \text{ V}$$

$$\frac{1}{25\pi} \times \frac{540 \times 420}{1} \times \frac{1}{4} \sin\delta = 240$$

$$\sin\delta = 0.3323$$
$$\delta = 19.41°$$

29. (b)



$$Z_s = (0.8 + j5.5)\ \Omega$$
$$= (5.56\angle 81.72°)\ \Omega$$
$$\vec{E}_f = 1.905 - 5.56\angle 81.7° \times 0.16\angle -36.9°$$
$$= 1.42\angle -26.2°\ \text{V}$$

or, E_f = 1.42 kV (phase) or 2.46 kV (line)

$$P_{mech\ (div)} = 3 \times 1.42 \times 160 \cos(-36.9° + 26.2°)$$
$$= 670\ \text{kW}$$

Shaft output = 670 – 30 = 640 kW

$$\text{Power input} = \sqrt{3} \times 3.3 \times 160 \times 0.8$$
$$= 731.6\ \text{kW}$$

$$\text{Efficiency, } \eta = \frac{640}{731.6} = 87.5\%$$

30. (d)

Let, V_b = 10 kV

and MVA_b = 50 MVA

$$Z_d = (0.1 + j1.65)\ \text{p.u.} = 1.653\angle 86.53°\ \Omega$$
$$V = \frac{10}{10}\text{p.u.} = 1.0\ \text{p.u.}$$
$$I_b = \frac{50 \times 10^3}{\sqrt{3} \times 10}\text{A} = 2886.75\ \text{A}$$

Base current, $I_a = \frac{2000}{2886.75}\text{p.u.} = 0.693\ \text{p.u.}$

$$\theta = \cos^{-1} 0.9 = 25.8°\ \text{(leading)}$$
$$E_i\angle\delta = V\angle 0° + I_a Z_d \angle(\alpha + \theta)$$
$$= 1.0\angle 0° + [0.693 \times 1.653\angle(86.53° + 25.8°)]$$
$$= 1.2\angle 61.943°\ \text{p.u.}$$

$\Rightarrow$ $\delta = 61.94°$

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