CLASS TEST - 2016

Electrical Engineering

EE

Electrical Machines

Date : 16/06/2016

ANSWERS

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

1. (a)

Available flux = Flux density × area

$= 1.5 \times (8 \times 12.5 \times 10^{-4})$

$= 1.5 \times 10^{-2}$ Wb

$$\text{Leakage coefficient} = 1.2 = \frac{\text{Available flux}}{\text{Useful flux}}$$

$$\text{Useful flux} = \frac{\text{Available flux}}{1.2}$$

$$= \frac{1.5 \times 10^{-2}}{1.2} = 1.25 \times 10^{-2} \text{ Wb}$$

$$\text{emf} = \frac{\phi z N}{60} \quad (\because \text{ for lap winding P = A})$$

$$= \frac{1.25 \times 10^{-2} \times 1000 \times 600}{60} = 125 \text{ V}$$

4. (c)

Method-I:

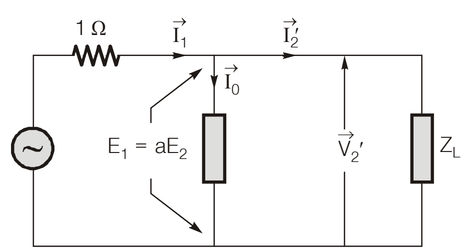
As transformed is ideal, induced emf in secondary winding = load voltage

i.e. $E_2 = V_2 = 110$ Volt

Load current/secondary winding current,

$$I_2 = \left(\frac{4000}{110 \times 0.89}\right) = 40.86 \text{ A}$$

$$\text{Transformation ratio, } a = \frac{2}{1} = 2$$



(Equivalent circuit offered to primary)

Given, $\cos\phi = 0.89$ or, $\phi = 27.12°$

Secondary current referred to primary,

$$I_2' = \frac{I_a}{a} = 20.43 \text{ A}$$

$\therefore \quad \vec{I}_2 = 20.43\angle{-27.12°}$ A,

$E_1 = aE_2 = 2 \times 110 = 220$ Volt

Now, $\quad \vec{I}_1 = \vec{I}_0 + \vec{I}_2'$

Since, input pf required is unity and the load is inductive (lagging), therefore, x must be capacitive reactance.

$$\therefore \quad \vec{I}_1 \angle 0° = \frac{E_1}{-jX} + \vec{I}_2' = \frac{jE_1}{X} \times \vec{I}_2'$$

$$= \left(\frac{j220}{X}\right) + (20.43\angle -27.12°)$$

$$= \frac{j220}{X} + (18.18 - j9.31)$$

$$\text{or,} \quad \vec{I}_1 \angle 0° = \sqrt{(18.18)^2 + \left(\frac{220}{X} - 9.31\right)^2} \angle \theta° \qquad ...(i)$$

$$\text{where,} \quad \theta = \tan^{-1}\left[\frac{\frac{220}{X} - 9.31}{18.18}\right]$$

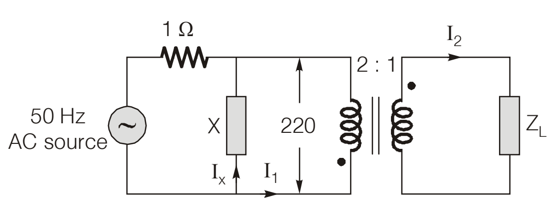
Equating angle of equation (i) on both sides, we get

$$\tan^{-1}\left(\frac{\frac{220}{X} - 9.31}{18.18}\right) = 0°$$

$$\text{or,} \quad \frac{220}{X} - 9.31 = 0$$

or, $\quad X = 23.63\ \Omega$

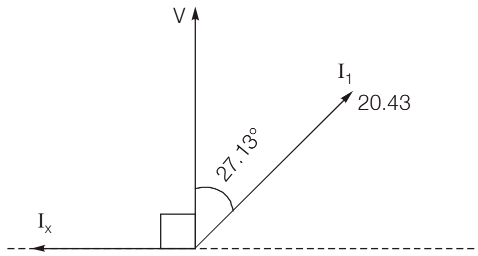
Method-II:



$$I_2 = \frac{4 \times 10^3}{110 \times 0.89} = 40.86\angle -27.13°$$

$$I_1 = \frac{40.86}{2}\angle -27.13°$$

$$= 20.43\angle{-27.73°}$$



For unity pf horizontal component of (I_1) should be cancelled with (I_x).

So, $20.43 \sin(27.13°) = \dfrac{220}{X}$

$X = 23.61\ \Omega$

5. (b)

$$I_{S(base)} = \frac{100}{\sqrt{3}\times 115} = 502\text{ A}$$

Since the transformer supplies a load of 80 MVA at 0.85 pf lagging, so secondary line current of the transformer is

$$I_S = \frac{80}{\sqrt{3}\times 115} = 402\text{ A}$$

$$(I_S)_{pu} = \frac{402}{502}\angle -\cos^{-1}(0.85) = 0.8\angle -31.8°$$

per unit no load voltage of this transformer is

$$V_{NL} = 1\angle 0° + (0.8\angle -31.8°)\ (0.02 + j\,0.055)$$

$$= 1.037\angle 1.6°$$

$$\text{V.R.} = \frac{1.037 - 1}{1} \times 100\ \% = 3.7\ \%$$

10. (b)

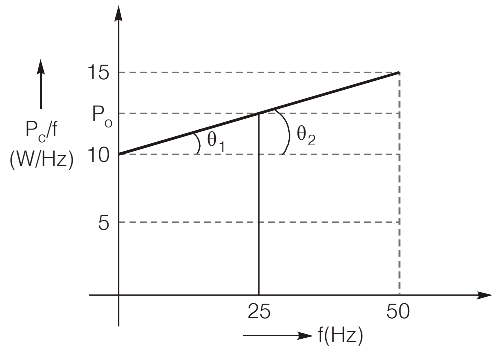
$$N\phi = Li$$

$$1000 \times 10^{-3} = L \times 1$$

$$\Rightarrow \quad L = 1\text{H}$$

$$\Rightarrow \quad W_E = \frac{1}{2}Li^2 = \frac{1}{2}\text{J}$$

11. (b)



Let core loss at 25 Hz be P_o per Hz.

Then, equating the two slopes of figure, we have:

$$\left(\frac{P_o - 10}{25}\right) = \frac{5}{50}$$

or, $P_o = 2.5 + 10 = 12.5$ W/Hz

$\therefore$ Core loss at 25 Hz = 12.5 × 25 = 312.5 Watt

Also, core loss at 50 Hz = 15 × 50 = 750 Watt

Let at (f_1) 25 Hz, eddy current loss = P_{e_1}

and hysteresis loss = P_{h_1}

We know that: $P_e \propto f^2$

$$\therefore \quad \frac{P_{e_2}}{P_{e_1}} = \left(\frac{f_2}{f_1}\right)^2 = \left(\frac{50}{25}\right)^2 = 4$$

$$\therefore \quad P_{e_2} = 4P_{e_1} \quad \ldots(i)$$

Also, $P_h \propto f$

$$\therefore \quad \frac{P_{h_2}}{P_{h_1}} = \frac{f_2}{f_1} = \frac{50}{25} = 2$$

$$\therefore \quad P_{h_2} = 2P_{h_1} \quad \ldots(ii)$$

Now, at f_1 = 25 Hz,

$$P_{e_1} + P_{h_1} = 312.5 \quad \ldots(iii)$$

and at f_2 = 50 Hz

$$P_{e_2} + P_{h_2} = 750 \text{ W}$$

or, $4P_{e_1} + 2P_{h_1} = 750$ W

or, $2P_{e_1} + P_{h_1} = 375$ W ...(*iv*)

(Using equation (*i*) and (*ii*))

Solving equations (*iii*) and (*iv*), we get

$$P_{e_1} = 62.5 \text{ Watt and } P_{h_1} = 250 \text{ Watt}$$

Thus, at 25 Hz, hysteresis loss = 250 W and eddy current loss = 62.5 W.

12. (a)

Armature resistance is assumed negligible. Further field current is ignored in comparison to armature current, i.e.,

$$I_L = I_a$$

As per the data given

$$E = K_e N$$

$$200 = K_e \times 600 \quad \text{...(i)}$$

$$T = K_t I_a$$

$$= K_t \times 30 = K_L \times (600)^2 \quad \text{...(ii)}$$

With a 20 Ω resistor added in the armature circuit

$$(200 - 20I_a) = K_e \times N \quad \text{...(iii)}$$

$$K_t I_a = K_L N^2 \quad \text{...(iv)}$$

Dividing equation (iii) by (i) and (iv) by (ii)

we get, $$\frac{200 - 20I_a}{200} = \frac{N}{600} \quad \text{...(v)}$$

and $$\frac{I_a}{30} = \frac{N^2}{(600)^2} \quad \text{...(vi)}$$

on solving, N = 260.5 rpm

15. (c)

Pole pitch = distance between two adjacent poles

$$= \frac{\text{periphery of the armature}}{\text{number of poles of the generator}}$$

$$= \frac{\pi D}{P} = \frac{\pi \times 0.35}{4} \text{m}$$

$$\frac{\text{Poles arc}}{\text{pole pitch}} = 0.7$$

$$\text{Pole arc} = 0.7 \times \text{pole pitch} = \frac{0.7 \times \pi \times 0.35}{4}$$

$$\text{Area of pole face} = \text{pole arc} \times \text{axial length}$$

$$= \frac{0.7 \times \pi \times 0.35}{4} \times 0.2 = 0.03848 \text{ m}^2$$

$$E = \frac{N P \Phi Z}{60 A}$$

$$250 = \frac{500 \times 4\Phi \times 1200}{60 \times 4}$$

$$\Phi = \frac{250 \times 60 \times 4}{500 \times 4 \times 1200} = 0.025 \text{ Wb}$$

Flux density in the air gap,

$$B = \frac{\text{Flux per pole}}{\text{area of pole shoe}} = \frac{0.025}{0.03848} = 0.65 \text{ T}$$

17. (d)

$$I_{SC} = \frac{5000}{440} = 11.36 \text{ A}$$

$$V_{SC} = I_{SC} \times Z_{eq} = 11.36\,[0.5 + (2)^2 \times 0.2]$$

$$= 11.36\,[\{0.5 + (2)^2 \times 0.2\} + j\,\{0.6 + (2)^2 \times 0.15\}]$$

$$= 11.36\,[1.3 + j1.2]$$

$$= 11.36 \times 1.77 \angle 42.70°$$

$$= 14.77 \angle 42.70° \text{ V}$$

18. (a)

$$a = \frac{3300}{100} = 33$$

I_{2t} = current in the secondary of the teaser transformer

For teaser transformer,

$$P_{2t} = V_{2t} I_{2t} \cos \phi_{2t}$$

$$I_{2t} = \frac{P_{2t}}{V_{2t} \cos \phi_{2t}} = \frac{500 \times 10^3}{100 \times 0.8} = 6250 \text{ A}$$

Since the 2-phase load is balanced, the 3-phase side is also balanced. For the mmf balance of the teaser transformer,

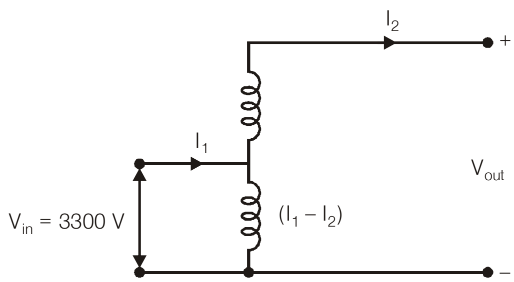
$$I_A \times \frac{\sqrt{3}}{2} T_p = I_{2t} T_s$$

$$I_A = \frac{2}{\sqrt{3}} \frac{T_s}{T_p} I_{2t} = \frac{2}{\sqrt{3}} \times \frac{6250}{33} = 218.7 \text{ A}$$

$$\therefore \quad |I_A| = |I_B| = |I_C|$$
$$= 218.7 \text{ A}$$

Line current in 3-phase sides are I_A, I_B and I_C.

21. (d)



$$V_{in} = 3300 \text{ volts}$$
$$V_{out} = 3300 + 230 = 3530 \text{ V}$$

$$I_2 = \frac{50 \times 10^3}{230} = 217.4 \text{ A}$$

These KVA rating of auto transformer

$$= V_{out} \times I_2$$
$$= (3530)(217.4) = 767.42 \text{ KVA}$$

22. (c)

$R_1 = r_1 + r'_2$ and $X_1 = x_1 + x'_2$

The copper loss obtained during blocked rotor test = 2100 kW

i.e., $3I_1^2 R_1 = 2100$

$$R_1 = \frac{2100}{3(15)^2} = 3.1\,\Omega/\text{phase}$$

$$\therefore \quad r_2' = \frac{R_1}{2} = \frac{3.1}{2} \simeq 1.6\,\Omega/\text{ph}$$

The impedance Z_1 (referred to stator)

$$= \frac{200}{\sqrt{3} \times 15} = 7.7\,\Omega/\text{ph}$$

$$X_1 = x_1 + x_2' = \sqrt{(7.7)^2 - (3.1)^2}$$
$$= 7\ \Omega$$

$$\therefore \quad x_2' = \frac{X_1}{2} = 3.5\ \Omega$$

$$\therefore \quad T = \frac{sE_1^2 r_2'}{r_2'^2 + x_2'^2 s^2}$$

$$\Rightarrow \frac{0.03(E_1^2)(1.6)}{(1.6)^2 + (0.03)^2(3.5)^2} = \frac{E_1^2(0.2)(r')}{(r')^2 + (0.2)^2(3.5)^2}$$

(1970 rpm, s = 0.03; 800 rpm, s = 0.2)

$$r' = 10.7 \text{ or } 0.05\ \Omega$$

extra resistance to be added with rotor is

$$= 10.7 - 1.6$$
$$= 9.1\ \Omega/\text{ph}$$

23. (a)

Phase angle of the main winding current

$$\angle I_m = -\angle Z_m = -\angle(6 + 4j)$$
$$= -33.7°$$

and phase angle of the auxiliary winding current with capacitor in series

$$\angle I_a = -\angle(8 + 6j - j/\omega C)$$
$$= -\tan^{-1}\left(\frac{6 - 1/\omega C}{8}\right)$$

Now, the phase difference between the currents in the main and auxiliary winding.

Now $\alpha = \angle I_m - \angle I_a$

$$90° = -33.7 + \tan^{-1}\left(\frac{6 - 1/\omega C}{8}\right)$$

$$\Rightarrow \quad 123.7 = \tan^{-1}\left(\frac{6 - 1/\omega C}{8}\right)$$

$$\Rightarrow \quad \frac{6 - 1/\omega C}{8} = -1.5$$

$$\Rightarrow \quad \frac{1}{\omega C} = 18$$

$$\Rightarrow \quad C = \frac{1}{2\pi \times 50 \times 18}$$