Exam Score: /40	..........Model Answer.......... إسم الطالب

Try the following Problems

Problem (1)

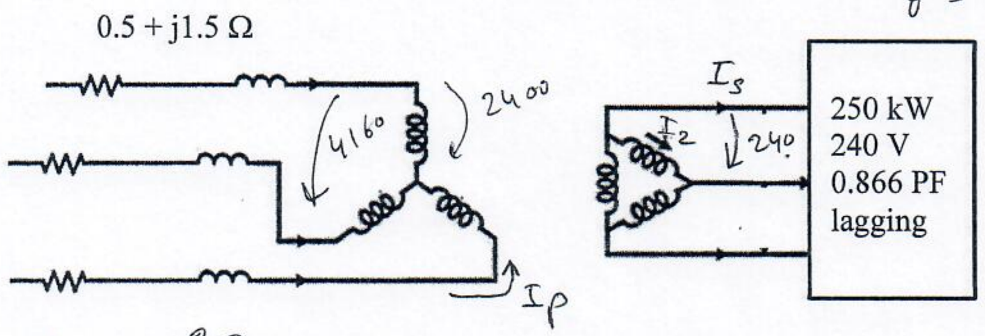
/5

Three single phase 100 kVA, 2400/240 V, 60 HZ transformers are connected to form a three phase, 4160/240 V transformer bank. The equivalent impedance of each transformer referred to its low voltage side is 0.045 + j0.16 Ω. The transformer bank is connected to a three phase source through a three phase feeder with an impedance of 0.5 + j1.5 Ω /phase. The transformer delivers 250 kW at 240 V and 0.866 lagging power factor.

(a) Determine the transformer winding currents.

(b) Determine the sending end voltage at the source.

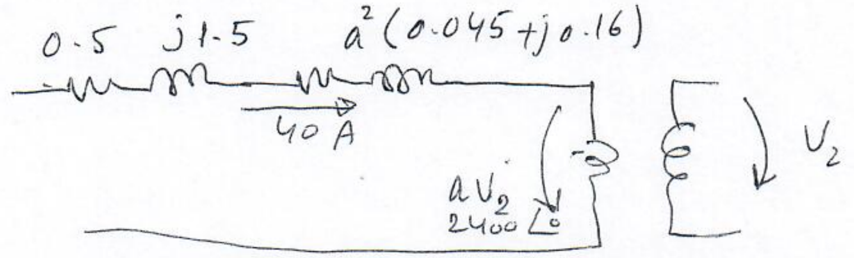
$Pf = 0.866$, $\theta = \cos^{-1} 0.866 = 30^\circ$



$$I_s = \frac{250{,}000}{\sqrt{3} \times 240 \times 0.866} = 694.5\ A \quad \boxed{1}$$

$$I_2 = \frac{I_s}{\sqrt{3}} = \frac{694.5}{\sqrt{3}} = 400\ A \quad \boxed{1}$$

$$a = \frac{2400}{240} = 10 \Rightarrow I_p = 40\ A \quad \boxed{1}$$

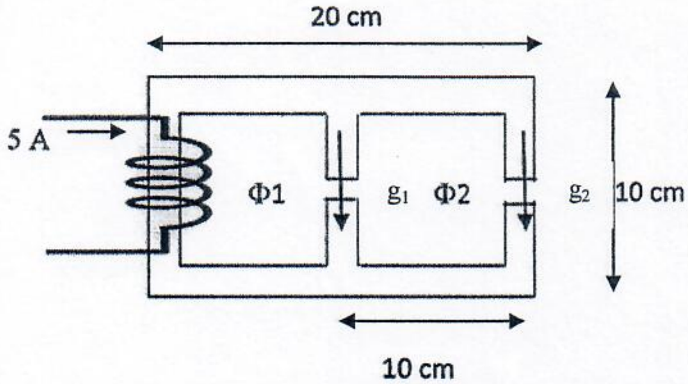


$$V_p = 2400\angle 0 + 40\angle{-30^\circ}\left[0.5 + j1.5 + 100\,(0.045 + j0.16)\right] \quad \boxed{1}$$
$$= 2966.7\angle 9.8^\circ \text{ Volt}$$

Problem (2)

/4

For the magnetic circuit shown, it was found that the magnetic flux $\phi_1 = 0.1\ \phi_2$, assuming infinite iron permeability, find the ratio g_1/g_2



$$\frac{\phi_1}{\phi_2} = \frac{g_2}{g_1}$$

$$0.1 = \frac{g_2}{g_1}$$

$$\boxed{\frac{g_1}{g_2} = 10}$$

[illegible]

Problem (3)

/6

A coil has 100 turns and is rotated at a constant speed of 300 rpm. The axis of rotation is perpendicular to a uniform magnetic flux density of 0.1 T in the vertical direction. The coil has width w = 10 cm, and length l = 20 cm. The plane of the coil is horizontal at t = 0. Calculate:

(a) The maximum flux passing through the coil.
(b) The flux linkage as a function of time.
(c) The instantaneous voltage induced in the coil
(d) The time average value of the induced voltage.
(e) The induced voltage when the plane of the coil is 30° from the vertical.

If the coil terminals are connected to a load = 10 $\angle -45^o$ Ω, find the electrical power output and hence calculate the average input mechanical torque.

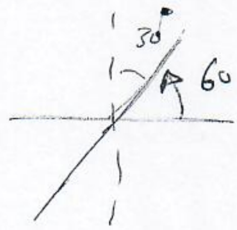
(a) $\phi_p = B w l = 0.1 * 0.1 \times 0.2 = 2 \text{ mwb}$

(b) $\lambda = 100 * 2\times10^{-3} \cos \omega_m t = 0.2 \cos \omega_m t \quad \text{wb-t}$

(c) $e = -0.2\, \omega_m \sin \omega_m t$

$\omega_m = 2 \times \pi \times \frac{300}{60} = 10\pi$

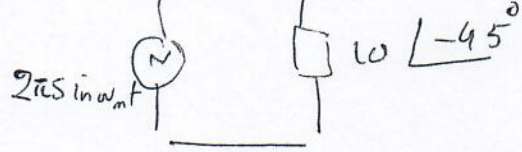
$e = -2\pi \sin \omega_m t \quad \text{Volt}$



(d) $e_{av.} = 0$

(e) $e = e_{max} \cos 60 = e_{max} \sin 30^o$

$= \pi \text{ Volt}$



$I_{rms} = \frac{2\pi/\sqrt{2}}{10} \text{ A}$

$P = I_{rms}^2 * R = \frac{2\pi^2}{100} * \frac{10}{\sqrt{2}} = 0.14\pi^2 \text{ W}$

$P = \omega_m T \quad , \quad T = \frac{0.14\pi^2}{10\pi} = \cancel{4.5 \times 10^{-3}} \text{ N-m}$

0.044

$$\phi_p = \frac{4 \mu_0 N_f I_f l r}{\pi g}$$

Problem (4) $e_{rms} = 2\pi f N_a \phi_p / \sqrt{2}$

/7

In a laboratory experiment, a single phase motor is used to drive a 3-phase, two pole, 60 Hz synchronous generator (Y connected coils). The motor input power is 2.2 kW. The generator has a 500 turns field coil carrying current $I_f = 8$ A. The generator mechanical dimensions are as follows:

gap g = 20 mm machine length l = 1 m

rotor radius r = 30 cm armature coil turns N_a = 24/phase

Assuming a lossless case, find:

(a) The motor speed n (rpm)

(b) The motor torque delivered to the generator

(c) The generator induced rms voltage/phase

(d) The flux ϕ that cuts the aa' stator coil when it makes 30° w.r.t. the field coil.

(e) The voltage induced in the aa' coil at the position specified in part (d)

Knowing that the generator output is connected to a 3 phase Y connected balanced load with PF = 0.8 lagging, find the load impedance.

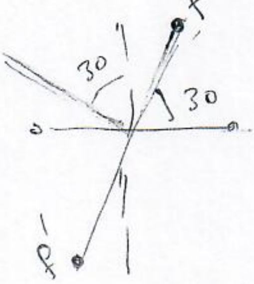
$\frac{n}{60} = 60 \rightarrow n = 3600$ rpm $\boxed{1}$

$T \omega_m = P = 2.2 \times 1000$

$T \times 2\pi \times 60 = 2.2 \times 1000$

$T = \frac{2200}{120\pi} = 5.84$ N.m $\boxed{1}$

$\phi_p = \frac{4 \times 4\pi \times 10^{-7} \times 500 \times 8 \times 1 \times 0.3}{\pi \times 20 \times 10^{-3}} = 96$ mwb



$e_{rms} = \frac{2\pi \times 60 \times 24 \times 96 \times 10^{-3}}{\sqrt{2}} = 614.2V$ $\boxed{1}$

$\phi = \phi_p \cos 30 \simeq 83.1$ mwb $\boxed{1}$

$e = e_{peak} \cos 60 = 434.3$ volt $\boxed{1}$ $\boxed{2}$ $Z = 411.5\angle ?$

$3\, e\, i\, PF = 2200 \Rightarrow i = 1.49 A$ $\frac{e}{i} = Z_L \angle\theta$

Problem (5)

/5

A two pole, three phase, 60 HZ Y connected, synchronous generator has a rotor radius of 10 cm, an air gap length of 0.25 mm, and a rotor length of 40 cm. The rotor field winding has 300 turns, and the stator windings have 80 turns/phase. When connected to a three phase Y connected electrical load, a balanced set of stator currents flow. At t = 0, the current in phase "a" is 15 A, its maximum value. At this same instant, the rotor axis makes an angle of 20 degrees with the reference line (stator axis). The rotor current is constant at 2 A.

Calculate:

(a) The electromagnetic torque **at this instant.**

(b) The induced rms voltage in each phase

(c) The total output electrical power.

$$M = \frac{4\mu_o N_s N_r l r}{\pi g} = 6.14 \text{ H}$$

$$T_e = -M \, i_s \, i_r \sin\theta_m$$

$$i_s \rightarrow \frac{3}{2} I_a$$

(2)

$$= -6.14 \times \frac{3}{2} \times 15 \times 2 \times \sin 20 = -94.5 \text{ N-m}$$

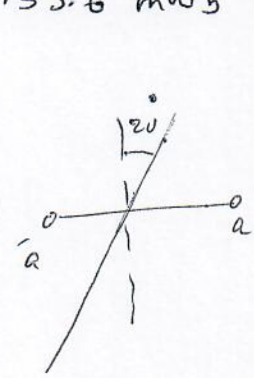
$$\phi_p = \frac{4\mu_o N_r i_r l r}{\pi g} = \frac{4 \times 4\pi \times 10^{-7} \times 300 \times 2 \times 0.4 \times 0.1}{\pi \times 0.25 \times 10^{-3}}$$

$$= 153.6 \text{ mWb}$$

$$e_{rms} = 2\pi f \times N_s \, \phi_p / \sqrt{2}$$

$$= \frac{2\pi \times 60 \times 80 \times 153.6 \times 10^{-3}}{\sqrt{2}} = 3275.65 \text{ Volt}$$

(2)



$$pF = \cos 70^{\circ} = 0.342$$

$$P = 3 \times e_{rms} \times 15 \times PF$$

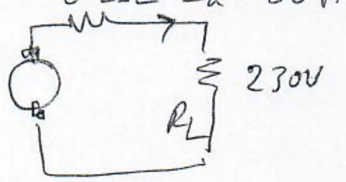
$$= 3 \times 3275.65 \times 15 \times 0.342 = 50.4 \text{ KW}$$

(1)

Problem (6)

/4

A 12 kW, 240 V, 1200 rpm, separately excited DC generator has armature and field winding resistances of 0.2 Ω and 200 Ω respectively. The field current is 1.28 A, when the generator delivers rated current to a resistive load at 230 V (terminal voltage). Find the generator terminal voltage for the same load resistance when the field current increases to 1.3 A.



$$I_a = \frac{12000}{240} = 50 \text{ A}$$

$$E_a = 240 \text{ V}$$
$$= K_a' I_f \omega_m$$

$$K_a' = \frac{240}{1.28 \times 2\pi \times \frac{1200}{60}} = \frac{6}{1.28\pi} = 1.49$$

$$R_L = \frac{230}{50} = 4.6 \, \Omega \quad (1)$$

$$E_{a2} = K_a' I_f \omega_m = 240 \times \frac{1.3}{1.28} = 243.75 \text{ Volt} \quad (2)$$

$$V_t = E_{a2} \frac{R_L}{R_L + R_a} = 243.75 \times \frac{4.6}{4.8} = 233.6 \text{ Volt} \quad (1)$$

Problem (7)

/5

A 20 kW, 400 V, 1200 rpm, separately excited DC generator has armature and field winding resistances of 0.2 Ω and 200 Ω respectively. The machine runs at 1200 rpm.

Case (1):

At no load, the voltage applied to the field circuit is 250V and the terminal voltage is 400 V.

Case (2):

The generator output is then connected to a load impedance of 10 ∠60° Ω, and the field voltage is increased to 260 V.

Find the average torque supplied to the generator in each case.

$$I_{f_1} = \frac{250}{200} = 1.25 \text{ A}$$

$$\omega_m = 2\pi \times \frac{1200}{60} = 40\pi$$

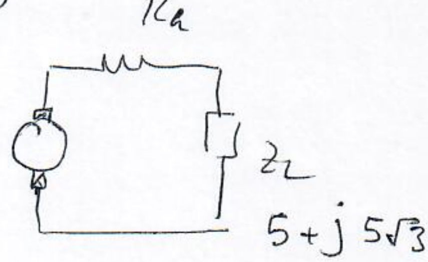
$$E_{a_1} = 400 \text{ V} = K_a' I_f \omega_m$$

$$400 = K_a' \times 1.25 \times 2\pi \times \frac{1200}{60}$$

$$K_a' = \frac{10}{1.25\pi} = 2.55$$

$$I_{f_2} = \frac{260}{200} = 1.3 \text{ A}$$

$$E_{a_2} = \frac{400 \times 1.3}{1.25} = 416 \text{ Volt} \quad (2)$$



$$T_1 = 0 \quad (1)$$

Power consumed in case (2)

$$= \frac{(E_{a_2})^2}{5.2} = 33280 \text{ W} \quad (1)$$

$$T \omega_m = \text{Power}$$

$$T = 264.8 \text{ N.m} \quad (1)$$

Problem (8)

/4

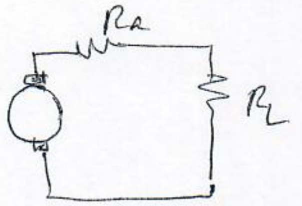
A separately excited DC generator is subject to the following tests:

(i) $I_{f1} = 1.2$ A and running at 1200 rpm

(ii) $I_{f2} = 1.3$ A and running at 1000 rpm

Assuming same load conditions and same machine constant k'_a find the percentage decrease in power delivered to the load.

$$\frac{E_{a1}}{E_{a2}} = \frac{I_{f1}\,\omega_{m1}}{I_{f2}\,\omega_{m2}} = \frac{1.2 \times 1200}{1.3 \times 1000} = \frac{14.4}{13} = 1.11$$



$$\frac{P_1 - P_2}{P_1} \times 100$$

$$\frac{\left(\frac{E_{a1}}{R_a + R_L}\right)^2 R_L - \left(\frac{E_{a2}}{R_a + R_L}\right)^2 R_L}{\left(\frac{E_{a1}}{R_a + R_L}\right)^2 R_L} \times 100$$

$$= \frac{E_{a1}^2 - E_{a2}^2}{E_{a1}^2} \times 100 = \cancel{\left(\frac{E_{a1}}{E_{a2}}\right)^2 - 1}$$

$$= \frac{1 - \left(\frac{E_{a2}}{E_{a1}}\right)^2}{1} \times 100$$

$$= \left[1 - \left(\frac{13}{14.4}\right)^2\right] \times 100 = 18.5\,\%$$