Exam Score: /20

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Open Book

Try the following Problems

(5)

Problem I

Two coils, one mounted on a stator and the other on a rotor, have self and mutual inductances given by;

L_{ss}= 1.0 H L_{rr}= 2.5 H L_{sr}= M cos θ H

the coils are connected in series and carry a current

$$i(t) = I_o \sin \omega t \ A$$

The angle between the axes of the coils is θ.
When the rotor is held fixed at θ = 45°, the time averaged torque is $30\sqrt{2}$ N.m and then the two coils are separated, rotor coil current remains the same and stator coil is short circuited, and θ is fixed at 90°, 45° the resultant timeaveraged torque in this case is 15 N.m. Find M and I_o then if θ changes to 45°, find the new value of the time averaged torque.

Case (1) $T = -M i_s i_r \sin\theta$

$= -M I_o^2 \sin^2 \omega t \sin\theta$

$T_{av.} = \frac{M I_o^2}{2} \sin\theta = 30\sqrt{2}$

$M \frac{I_o^2}{2} \frac{1}{\sqrt{2}} = 30\sqrt{2} \Rightarrow M I_o^2 = 120$ (1) (2)

Case (2) stator S.C $\Rightarrow \lambda_s = L_{ss} i_s + L_{sr} i_r$

$= i_s + M \cos\theta \, i_r$

$\frac{d\lambda_s}{dt} = 0 \Rightarrow \frac{di_s}{dt} + M\cos\theta \frac{di_r}{dt} = 0 \Rightarrow \frac{di_s}{dt} = -M\cos\theta \, I_o \omega \cos\omega$

$i_s = -M\cos\theta \, I_o \sin\omega t$ (1)

$T = -M i_s i_r \sin\theta = +M^2 I_o^2 \sin\theta\cos\theta \sin^2\omega t$

$T_{av.} = \frac{M^2 I_o^2}{4} \sin 2\theta = 0$? ≠ 15 N.m (2)

(7)

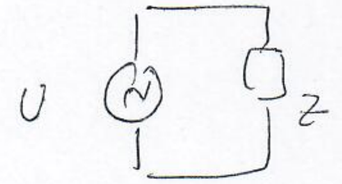
Problem II

Twenty five conducting loops, or turns are connected in series to form a coil. Each turn has a length l = 2.5 m and width w = 20 cm. The coil is rotated at a constant speed of 1200 rpm in a magnetic flux density B directed upward. The coil terminals are connected to a load impedance Z = 10 ∠45°Ω. The power delivered to the load = 100 kW. Determine:

(a) The required flux density.
(b) the input mechanical torque
(c) If the coil is in position of maximum flux linkage at time t = 0, find the magnitude of the output voltage at t = 1/80 sec.

$$\omega_m = \frac{2\pi n}{60} = \frac{2\pi * 1200}{60} = 40\pi \text{ rad/sec}$$

$$Power = \frac{V_{rms}^2}{100} * \frac{10}{\sqrt{2}} = 100 \times 10^3$$



$$V_{rms}^2 = 10^5 * 10\sqrt{2}$$

$$V_{rms} = 1189.2 \text{ Volt} = \frac{B w l \omega_m}{\sqrt{2}} \times N$$

$B =$ ~~26.8 T~~ 1.07 T (3)

(b) $P = T\omega_m = 100 \text{ kW} \Rightarrow T = \frac{10^5}{40\pi} = 795.8$ N.m (2)

(c) $t = \frac{1}{80} \rightarrow \omega t = 40\pi * \frac{1}{80} = \frac{\pi}{2}$

$$V = V_{max} \sin\omega t$$

$$= 1189.2 * \sqrt{2} \sin\frac{\pi}{2} = 1189.2\sqrt{2} = 1681.8 \text{ Volt}$$ (2)

(8)

Problem III

A 3-phase, Y connected, two pole, 60 Hz synchronous generator. 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

The generator output is connected to a 3 phase Y connected load with impedance of magnitude 20 Ω. The generator delivers 40 kVA at 0.7 lagging power factor to this load.

Find:

(a) The number of armature coil turns per phase.

(b) The torque delivered by the turbine when a capacitor bank is connected in parallel to the electrical load to change the power factor to 0.9.

(c) The value of C added.

(d) Estimate the required torque to drive the generator when its terminals are open circuit.

$N_f = 500$

$S = 40\text{ kVA} = 3 V_p I_p = 3 V_p \frac{V_p}{|Z|}$

(2) $V_p = 516.4$ volt $= 2\pi f N_a \Phi_p / \sqrt{2}$

$\Phi_p = 4\mu_0 N_f I_f l r / (\pi g) = \frac{4 \times 4\pi \times 10^{-7} \times 500 \times 8 \times 0.3}{\pi \times 0.02}$

$= 96$ mwb

$516.4 = 2\pi \times 60 \times N_a \times 0.096 / \sqrt{2}$

(1) $N_a \cong 20$ turns , $\omega_m = \frac{2\pi n}{60} = 2\pi f = 120\pi$

(b) $P_T = 40 \times 0.7 = 28$ KW $= \omega_m T$

$T = \frac{28000}{120\pi} = 74.3$ N.m (2)