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The Open University of Sri Lanka
Department of Electrical and Computer Engineering
Diploma in Technology
ECX4238– Electrical Machines
Final Examination - 2011/2012
Duration : Three hours.

CLOSED BOOK

Date: 22nd March 2012 Time: 1400-1700 hrs

This paper contains eight (8) questions. Answer any five (5) questions. All questions carry equal marks. Graph papers will be available on your request.

1) a. A transformer delivers a k fraction of its full-load. The iron loss and the full-load Cu loss of the transformer are P_i and P_{Cu} respectively. Show that maximum efficiency occurs when;

$$k = \sqrt{\frac{P_i}{P_{Cu}}}$$ [6 marks]

b. A 120 kVA, 6000/400 V, Y/Y, 50 Hz, three phase, transformer has an iron loss of 1700 W. The maximum efficiency occurs at ¾ of full-load at unity p.f. Percentage leakage impedance of the transformer is 5.0 %.
Calculate;

i. Full load Cu loss. [4 marks]
ii. Maximum efficiency [4 marks]
iii. Voltage regulation when maximum efficiency occurs. [6 marks]

2) a. Figure Q2 shows the winding connections of a three phase transformer. Draw the phasor diagram to show the EMFs in windings and determine the phase shift between primary and secondary EMFs.

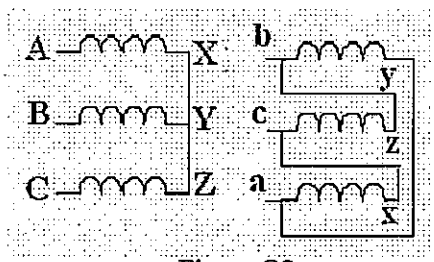

Figure Q2

[7 marks]

b. Group connection of a certain transformer is '21Yy-6'. Explain what this term means. [5 marks]

c. Explain terms ONAN & ONAF, in relation to transformers. [4 marks]

d. A 100 kVA, 50 Hz, 6600/400 V, Y/Δ transformer draws a current of 8 A from the supply. The secondary side is connected to a load having 0.6 p.f. lagging at 400 V. Determine;

i. Phase current of the secondary side. [2 marks]
ii. Output power. [2 marks]

3) a. Explain why a single phase induction motor with one main stator winding does not self start, while a three phase induction motor self starts. [3 marks]

b. A three phase Y connected induction motor draws 2200 W, running on no-load at 400 V. At full-load it draws 60 A at p.f. 0.85 and 400 V. The friction and windage losses are 900 W and can be considered as constant at all speeds and loads. The total Copper loss at full-load is three times as the iron loss. Per-phase stator resistance is 0.2 Ω and no-load Copper loss can be neglected.
At full-load, Calculate;

i. Air gap power. [8 marks]
ii. Slip. [3 marks]
iii. Shaft Power. [3 marks]
iv. Efficiency of the motor. [3 marks]

4) a. Sketch the per-phase equivalent circuit of a three phase induction motor and identify its parameters. [4 marks]

b. A three phase, two pole, 50 Hz, Y connected induction motor is rated at 440 V. The equivalent circuit parameters are: (All referred to the stator side)

$R_1 = 0.075\ \Omega$ $R_2 = 0.065\ \Omega$ $X_M = 7.2\ \Omega$
$X_1 = 0.17\ \Omega$ $X_2 = 0.17\ \Omega$

If the motor starts from stand-still, calculate;

i. Starting current of stator. [4 marks]
ii. Starting current of rotor. [4 marks]
iii. Electrical torque developed at starting. [4 marks]
iv. Current and power factor at no-load. [4 marks]

5) A series wound DC machine is operating as a motor. When it is connected to a 400 V, DC supply, it draws 180 A, delivering 95 kW. The shaft torque is 906 Nm. The Copper losses in armature and field windings are equal. The rotational loss is neglected.

a. Calculate;

i. Efficiency of the motor. [3 marks]
ii. Armature and the field winding resistances. [3 marks]
iii. Speed of the motor. [4 marks]

b. While the supply voltage and input current remains the same as above, a resistance with the same value is connected in parallel to the field winding. Calculate;

i. Shaft torque. [4 marks]
ii. Speed f the motor. [6 marks]

6) An eight-pole, 25 kW, 120 V, DC generator has a simplex lap-wound armature, which has 64 coils with 16 turns per coil. Its rated speed is 2400 rpm. Calculate;

a. Flux per pole required to produce the rated voltage at no-load conditions. [5 marks]
b. Current per path in the armature at the rated load. [5 marks]
c. Induced torque at the rated load. [5 marks]
d. Total armature resistance, if the resistance is 0.011 Ω per turn. [5 marks]

7) a. State the conditions to be fulfilled for parallel operation synchronous generators. [4 marks]

b. Two synchronous generators A and B, rated 200 MW and 150 MW respectively are operating in parallel. The frequencies of the two generators drop by 5 % & 4 % respectively, from no-load to full load. If generators A & B share a common load of 200 MW at 50 Hz, with generator A contributing 140 MW.
Calculate,

i. The speed of each generator at their rated loads. [6 marks]
ii. The maximum load, the two generators can share without over loading any generator. [4 marks]
iii. The power delivered by each generator at the maximum load in *i.* [4 marks]
iv. The frequency at the maximum load. [2 marks]

Hint : Use the percentage frequency - load characteristic of each machine. (Governor Droop characteristic)

8) a. A three phase salient pole synchronous generator has the following parameters.

V	-	Terminal voltage
I	-	Armature current
ϕ	-	Power factor, lagging
E_0	-	Internal induced EMF
X_d	-	Direct axis synchronous reactance
X_q	-	Quadrature axis synchronous reactance
I_d	-	Direct axis component of armature current
I_q	-	Quadrature axis component of armature current
δ	-	Load angle

The armature resistance is negligible.

i. Draw the phasor diagram for the above. [5 marks]
ii. Using the phasor diagram, obtain equations for, *the internal induced EMF, E_0* and the *load angle, δ.* [6 marks]

b. A 11 kV, three phase salient pole synchronous generator has direct and quadrature axis synchronous reactances of 1.8 Ω/phase and 1.1 Ω/phase respectively. The armature resistance can be neglected. The generator is delivering 60 MW and 20 MVAR at rated terminal voltage.
Calculate,

i. Load angle. [6 marks]
ii. Internal induced EMF. [3 marks]