The Open University of Sri Lanka
Department of Electrical and Computer Engineering
Diploma in Technology

ECX 4238 – Electrical Machines
Final Examination – 2007/2008

Date : 12.05.2008 | Time : 0930 - 1230

This paper contains eight questions. Answer any **five** questions. All questions carry equal marks. Show your work clearly.

Q1) a. It is given that "vector group symbol of a transformer is 41Dy11". What do you mean by this?

b. The winding connections of three-phase two windings star-delta connected transformer is shown in figure Q1.

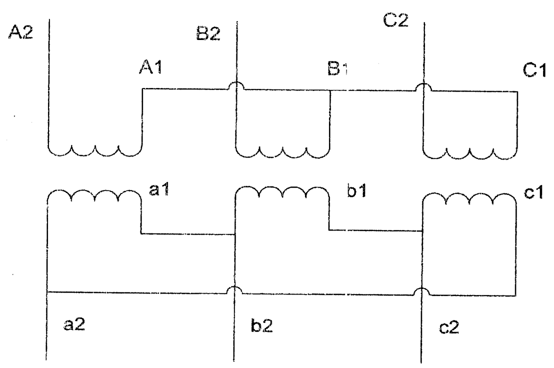

Figure Q1

i. Draw a phasor diagram to show voltages induced in phases at both primary and secondary sides and find phase angle between line-line voltage phasors.

ii. Use the results obtained above to identify vector group symbol of the transformer.

c. A three-phase transformer bank consisting of three single-phase transformers is used to step-down the voltage of a three-phase, 6600 V transmission line. Primary side is connected in star and secondary in delta. The turns ration is 12.If the primary side line current is 10 A, calculate (Neglect the losses)

i. Line current in the secondary side.

ii. Output kVA rating of the transformer.

2) a. Discuss the term "Copper-loss or I^2R-loss" in the transformer.

b. The per phase parameters of three-phase 450 kVA 2400/240 V Δ/Δ transformer are.

$R_p = 0.2\ \Omega$ $R_s = 2x10^{-3}\ \Omega$

$X_p = 0.45\ \Omega$ $X_s = 4.5x10^{-3}\ \Omega$

$R_c = 10\ k\ \Omega$, $X_m = 1.6\ k\ \Omega$ (as seen from 2400 V side)

i. Draw the approximate per phase circuit model as seen from the high voltage side.

ii. Determine the voltage regulation and efficiency when 0.8 lagging power factor rated load is connected to the secondary side of the transformer.

iii. Under these conditions, calculate the high voltage side current and its power factor.

3) a. List the most common types of DC machine.

b. "At starting it is essential to have external resistance in the armature circuit in the DC machine." Explain.

b. A 220 V, 7.5 kW series DC motor is mechanically coupled to a fan. When running at 400 rpm the motor draws 30 A from the main (220 V). The torque required by the fan is proportional to the square of speed. Amature resistance (R_a) and field resistance (R_f) are 0.6 Ω, 0.4 Ω respectively. Neglect armature reactance and rotational losses. Also assume that the magnetization characteristic of the motor to be linear.

i. Determine the power delivered to the fan and torque developed by the motor.

ii. Calculate the external resistance to be added in series to the armature circuit to reduce the fan speed to 200 rpm.

iii. Calculate the power delivered to the fan at this speed in part (ii).

4) a. Draw the power flow diagram of an induction motor.

b. Using the equivalent circuit and the power flow diagram of an induction motor,prove the following:

i. $P_{rcl} = s\,P_{ag}$

ii. $P_m = (1\text{-}s)P_{ag}$

iv. $P_{ag} : P_{rcl} : P_m = 1 : s : (1\text{-}s)$

Where

P_{ag} - air gap power.

P_{rcl} - rotor copper loss

P_m - mechanical power output

s - slip

c. A 4-pole, 415 V, 3-phase, 50 Hz induction motor runs at the speed of 1440 rpm at 0.88 lagging power factor and delivers 10.817 kW to the load. The stator loss is 1060 W, and friction & windage losses are 375 W. Calculate:

i. Slip of the motor

ii. Rotor copper loss

iii. Line current

v. Efficiency

Q5) a. List down the important parameters that influence the motor selection.

b. Why 'induction motors' are so popular over all types of motors?

c. A 440 V, 20 HP, 3-phase induction motor operates at full load, 88 % efficiency and 0.65 power factor lagging. (1 HP = 746 W)

i. Find the current drawn by the motor.

ii. Find the real and reactive power absorbed by the motor.

d. A 3-phase, 400 V, 50 Hz, 6-pole, Y-connected, 19 kW induction motor has the following parameters of its approximate circuit model.

$R_s = 1.4\Omega$ $\quad$ $R_r' = 0.6\Omega$

$X_s = 2\Omega$ $\quad$ $X_r' = 1\Omega$

$X_m = 50\Omega$

The rotational loss is 275 W. For a slip of 0.03 determine

i. The line current, power factor and power input.

ii. The shaft torque and mechanical power output.

iii. The efficiency.

Q6) a. Define the term "unsaturated synchronous reactance"

b. The open-circuit and short-circuit characteristics of 60 Hz, 2300 V (line to line), Y-connected, 100 kVA, 1800 rpm, 3-phase synchronous generator are given in figure Q6.

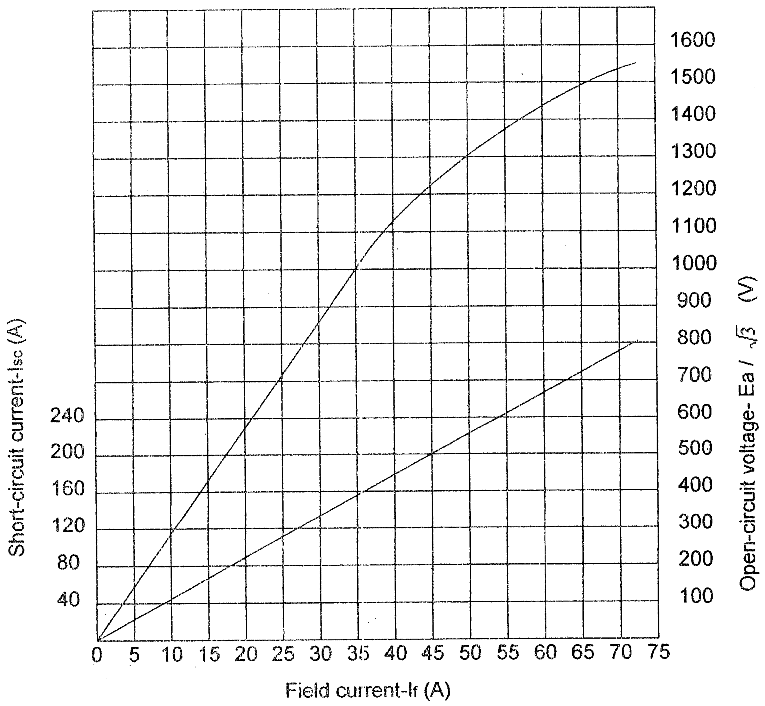

Figure Q6: Open-circuit and short-circuit characteristics of a synchronous machine

Use the graph given to determine:

i. Unsaturated value of synchronous reactance.

ii. Saturated value of synchronous reactance at the rated terminal voltage condition.

iii. The voltage regulation for a 0.8 lagging power factor load using the value of Synchronous reactance determined in part (ii)

Q7) a. What are the conditions that must be satisfied to operate synchronous generators in parallel.

b. Explain briefly how to identify the phase sequence of two synchronous generators in the laboratory.

c. Figure Q7 shows two synchronous generators G1 and G2 operating in parallel. Their turbine governors are preset to deliver 50 MW and 100 MW at 50 Hz to an isolated (each generators has 2 pole)

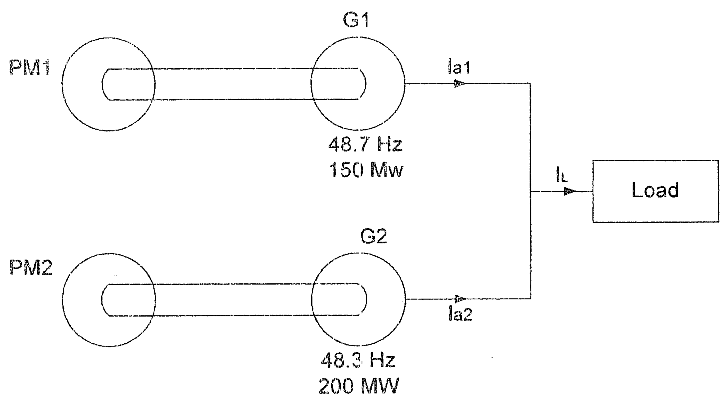

Figure Q7: Parallel operation of two generators

i. Calculate the no-load speed of each generator

ii. Calculate the maximum overall load, the two generators can deliver without overloading any.

iii. Find the corresponding frequency in part (ii)

Q8) a. Prove that per phase power of three-phase synchronous generator is

$$P = \frac{|V_\phi||E_a|}{X_s}\sin\delta$$

Where V_ϕ - external emf (output terminal voltage)

E_a - internal emf

X_s - synchronous reactance

δ - power angle

(Ignore winding resistance)

b. A 100 kVA, 6.6 kV, 50 Hz, Y-connected synchronous generator has a no-load voltage of 11.4 kV (line to line) at a certain field current. If at the same field current, the generator delivers rated load at 0.75 power factor lagging at rated output terminal voltage, calculate:

i. The power angle

ii. The synchronous reactance (armature resistance being negligible)

iii. The voltage regulation.

iv. The Electrical power developed.