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The Open University of Sri Lanka
Department of Electrical and Computer Engineering
Diploma in Technology
ECX4238– Electrical Machines
Final Examination - 2010/2011
Duration : Three hours.

Date: 31st March 2011	Time: 1400-1700 hrs

The 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. Figure Q1 shows the winding connections of a three phase transformer. Draw the phasor diagram to show the e.m.fs in windings and determine the phase shift between primary and secondary emfs.

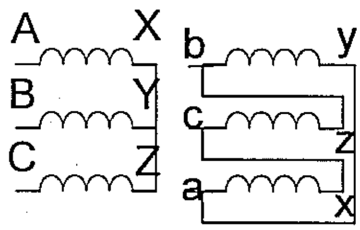

Figure Q1

b. A three - phase 400 V, 50 Hz induction motor is to be fed from a 4000V (line to line) ac supply. The input power to the motor is 150 kVA at 0.85 power factor lagging. It is suggested to connect three, single-phase, 2300/400V, 60 kVA, 50Hz transformers between the supply and input terminals of the motor. Equivalent leakage impedance of each transformer referred to the low voltage side is 0.012+j0.016 Ω. If the motor input voltage (line to line) is to be maintained at 400 V.

i. What should be the primary and secondary winding connections of the three phase transformer bank. Justify your answer. Illustrate the connection using a schematic diagram.

Calculate;

ii. The line currents of LV & HV sides of the transformer.

iii. The primary voltage and voltage regulation.

2) a. What are the conditions that should be satisfied to connect two three phase transformers in parallel?

b. Select one of the conditions listed in (a) and explain brifly the negative effect due to not satisfying above.

c. Two, single phase transformers, A and B have winding impedances referred to the secondary side 0.15+j0.5 Ω and 0.1+j0.6 Ω, respectively. The secondary terminal voltages of A & B at no-load are $E_A = 207\angle 0\ \ V$ and $E_B = 205\angle 0\ \ V$, with equal primary voltages.

i. What is the circulating current at no-load.

If the two transformers are connected in parallel to share a load of (2+j1.5) Ω. Calculate;

ii. The load voltage.

iii. Power factor and the power delivered by each transformer.

3) a. Sketch per-phase equivalent circuit of a three phase induction motor and identify its parameters.

b. A 440 V 50 Hz two pole Y connected induction motor is rated at 75 kW. The equivalent circuit parameters are : (All referred to the stator side)

$R_1 = 0.075\ \Omega$ $R_2 = 0.065\ \Omega$ $X_M = 7.2\ \Omega$

$X_1 = 0.17\ \Omega$ $X_2 = 0.17\ \Omega$

Friction & windage loss = 1.0 kW stator core loss = 1.1 kW

For a slip of 0.04, Determine;

i. The line current
ii. The stator power factor
iii. The stator copper loss
iv. The air-gap power
v. The induced electrical torque
vi. The mechanical power developed
vii. The overall machine efficiency

4) a. In a shunt-wound DC generator, the output voltage is determined by the rotational speed of the armature and the density of the stationary magnetic field flux. For a given armature speed, what prevents the output voltage from "running away" to infinite levels?

b. Give reasons why a shunt wound DC generator may fail to build up its voltage.

c. A shunt wound DC generator has an armature resistance of 0.4 Ω and a field winding resistance of 120 Ω. The generator delivers 5 kW at 230 V at the speed of 1000 rpm. If the generator speed is raised to 1300 rpm, and its terminal voltage is kept constant while delivering 7 kW, Calculate;

i. The additional resistance connected in series to the field winding.
ii. The new armature current.

5) a. Sketch the torque – speed (T-N) characteristic of a three phase induction motor and describe with appropriate illustrations how the T-N characteristic of the motor can be altered by varying the rotor resistance.

b. Draw the power flow diagram of a three phase induction motor and state the factors affecting each of the losses indicated.

c. A 50 kW, 440 V, 50 Hz, 6 pole induction motor has a slip of 6 % when operating at full-load. At this load, the friction and windage losses are 300 W. The stator core loss, stator copper loss and rotor copper loss each equals to twice as the friction and windage loss. Determine:
   i. The load torque
   ii. The air gap power
   iii. The electrical torque developed
   iv. The efficiency of the motor

6) a. Explain the speed control of a separately excited DC motor by changing,
   i. Field voltage
   ii. Armature voltage

b. A separately excited DC motor operates at the speed of 1000 rpm. The variation of armature induced emf (E_A) as a function of field current (I_f) is measured under no-load conditions and are tabulated below:

I_f (A)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
E_A(V)	0	30	60	85	102	115	124	130	134

Armature terminal voltage (V_T) and the supply for field winding (V_F) are 130V and 24 V respectively. Armature resistance is fixed at 0.2 Ω and field winding resistance (R_f) is adjustable. (See figure Q6)

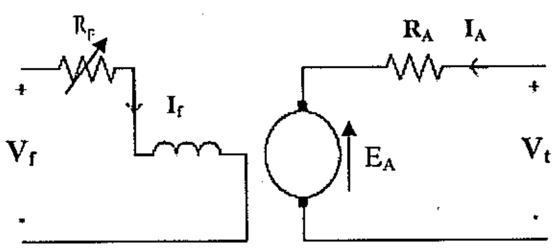

Figure Q6

   i. Calculate the field current if the motor is operated with no-load at 1000 rpm.

The motor drives a load at 1200 rpm and the field resistance is adjusted to *60 Ω*. Calculate:
   ii. Armature back emf.
   iii. Mechanical torque developed by the motor neglecting mechanical losses.
   iv. Overall efficiency, if the motor supplies a mechanical load of 4000W. The mechanical losses are 160W.

7) a. State the conditions to be fulfilled for parallel operation synchronous generators.

b. A 13 kV 10 MVA 0.8 p.f. lagging 60 Hz two pole Y connected steam turbine generator has a synchronous reactance of 12 Ω per phase and an armature resistance of 1.5 Ω per phase. This generator is connected to an infinite bus.

i. What is the magnitude of armature induced emf at rated conditions?
ii. What is the torque angle of the generator at rated conditions?
iii. If the field current is constant, what is the maximum power output of this generator?
iv. How much reactive power will this generator be supplying or consuming, at the absolute maximum possible power?

8) a. Show for a synchronous motor the power angle δ is given by ;

$$Sin\delta = \frac{P_T X_z}{3E_a V_a}$$

Where;
P_T - Total mechanical power developed by the motor
X_s - Synchronous reactance
E_a - Armature induced emf
V_a - Per phase supply voltage

b. A 480 V, 60 Hz, 300 kW 0.8 PF-leading 6 pole Δ-connected synchronous motor has a synchronous reactance of 1.1 Ω and negligible armature resistance. Friction, windage, and core losses are neglegible.

i. If this motor is initially supplying a load of 300kW at 0.8 PF lagging, calculate armature induced e.m.f, the load angle and the line current.
ii. Determine the torque produced by this motor at the above condition.
iii. If armature induced e.m.f is increased by 15 percent, Determine the armature current and the new power factor of the motor.