THE INSTITUTION OF ENGINEERS, SRI LANKA

PART II EXAMINATION –May 2012

ELECTRICAL MACHINES - I

Answer FIVE questions only.
All questions carry equal marks — Time allowed: 03 hours

Q1. (a) Describe briefly the advantages and disadvantages of autotransformer over the traditional two winding transformer. [02]

(b) Three phase 11kV/6kV, 25 kVA, Dy11, 50 Hz, core type transformer has a series impeadance of (0.01+j0.04) pu. Its shunt admittance can be ignored for this calculation. The transformer is to be reconnected as an 11kV/25kV three phase autotransformer.

(i) Draw the vector diagram of line voltages and the connection diagram for the HV and LV windings for the original Dy11 transformer. [02]
(ii) Draw the connection diagram for the autotransformer, indicating clearly the polarity of windings [04]
(iii) Determine the new kVA rating for the autotransformer [04]
(iv) Calculate the input voltage when the transformer is delivering a balanced three phase load of 50 kW at 25kV and 0.85 power factor lagging. [08]

Q2 (a) Three-phase, 100MVA, 11kV cylindrical rotor synchronous generator with a synchronous reactance of 1.5 pu delivers 30 MW and 20 MVAr at rated terminal voltage to a large power system. If the turbine torque is doubled and excitation is raised by 50% what will be new values of real and reactive power delivered to the system? [07]

(b) Three-phase, 100MVA, 11kV salient pole rotor synchronous generator has direct and quadrature axes reactances of 1.7 pu and 1.0 pu respectively. The generator delivers 50 MW of real power to a large power system at 1.0 pu terminal voltage and 2.0 pu internal emf. What is the reactive power output? [07]

(c) Two synchronous generators G1 and G2, rated at 250 MW and 350 MW operate in parallel delivering a common load of 400 MW at 50 Hz with generator G1 providing 40% share. The turbine-governor droops of the two generators are 5% and 4% respectively from no load to full load. Determine the maximum total load that the combination can deliver without overloading any of the two generators. [06]

Q3 (a) Describe with the aid of diagrams, how the speed of an induction machine may be set by an inverter. [05]

(b) A two-pole induction motor to be used with controlled-slip was first tested on a fixed 415 V (line), three-phase, 50 Hz supply. It produced rated torque at a speed of 2900 rpm. The test also showed that it ran with an air-gap flux linkage. $\Psi_{ag} = L_M.I_M = 0.725$ Wb, where I_M is magnetizing current. Its equivalent circuit parameters are:

Stator resistance	R_S	$= 0.5\ \Omega$
Referred rotor resistance	R_R	$= 0.4\ \Omega$
Stator leakage inductance	L_S	$= 10$ mH
Magnetising inductance	L_M	$= 250$ mH

Rotor leakage inductance can be ignored.

Calculate the

(i) Supply frequency required to produce zero torque at a rotor speed of 300 rpm. [03]

(ii) Phase voltage required to produce rated flux linkage under the condition in part (i) [04]

(iii) Supply frequency required for rated torque at a rotor speed of 300 rpm. [04]

(iv) Phase voltage required to produce rated flux linkage under the condition in part (iii) [04]

Q4 A laboratory variable-frequency source is shown in Fig.Q5. The stator of a 3-phase, 4-pole wound-rotor induction motor is supplied from a 415 V, 50 Hz supply, and the rotor is coupled to a DC machine. The 3-phase output is taken from the slip rings. When the rotor is stationary, the open-circuit voltage at the slip rings is 240 V, and when the induction motor runs light the rotor turns clockwise.

(a) For an output frequency of 10 Hz, determine the possible speeds and corresponding directions of rotation, and the open-circuit voltage. [06]

(b) If the losses in both machines are negligible, and the output power from the slip rings at 10 Hz is W, determine the magnitude and direction of the power flow in the AC and DC supplies for each of the possible speeds. [12]

(c) Explain how the choice of operating condition would be restricted if the DC machine was supplied from a 1-quadrant rectifier. [02]

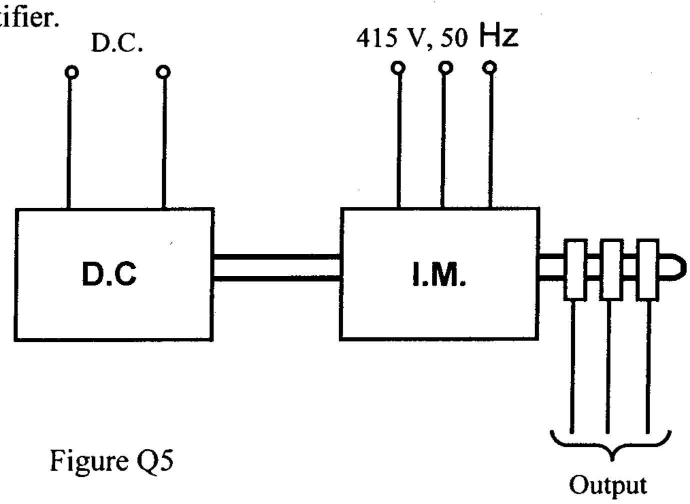

Figure Q5

Q5 (a) Explain why the reduced voltage starting is necessary for large 3-phase cage rotor induction motors? Describe briefly the *star-delta* and the *autotransformer* starting methods. [05]

A 50 Hz, 400 V, 3-phase induction motor draws 120 A, and develops 75 Nm when started direct on line in delta connection. What will be starting current and torque with autotransformer starter at 40% tap? [04]

(b) A 10 kW, 400 V, 3-phase, 4-pole, 50 Hz wound-rotor induction motor develops a maximum torque equal to twice the full-load torque at a slip of 10% at rated voltage and rated frequency, with its slip-rings short-circuited. Stator resistance and rotational losses of the motor are negligible. Determine,

(i) slip and rotor speed at full-load [03]
(ii) full-load torque [03]
(iii) starting torque [03]
(iv) ratio of rotor current at starting to that at full-load [02]

Q6 (a) Estimate the new secondary line voltage for each of the following cases of three phase transformer:

(i) A 400/200 V, *Dz*0 3-phase transformer, reconnected as *Dy*11 transformer with two half sections in the secondary connected in series. [04]

(ii) A 400/200 V, *Dz*0 3-phase transformer, with one of the half sections of one phase of *z* windings wrongly connected with reverse polarity? [04]

(iii) A 400/200V Dy11 transformer, with one of the secondary phases connected wrongly with reverse polarity [04]

(b) A 3-phase, 11/3.3/0.4 kV, *Yyd* transformer delivers 0.5 pu of current to a single phase load connected between one of the lines and the neutral in the secondary (0.4 kV) side. Considering ampere-turn balance, determine current in each winding in the primary and the tertiary. [06]
What will happen to the distribution of current if the tertiary delta is opened? [02]

Q7 (a) Explain briefly the methods of *armature voltage control* and *field voltage control* for a separately excited dc motors. [06]

(b) A 10 kW, 1800 rev/m separately excited dc motor has per unit armature resistance of 0.2 pu. Determine the no-load speed. Hence sketch the torque-speed characteristic for the motor for rated voltage operation
Sketch the operating chart for the motor assuming the maximum permissible speed as 4200 rev/m. What is the maximum safe continuous torque available at 2500 rev/m? [10]

(c) A 220 V separately excited dc motor has an armature resistance of 0.6 Ω. What is the maximum theoretical torque this motor can produce at 2000 rev/m? Why is this theoretical torque not often practical? [04]

Q8 (a) Define *thermal time constant* and *full-load temperature rise* for a general-purpose motor. Explain briefly how you would estimate thermal time constant if the full load temperature rise is known. [05]

(b) An induction motor has maximum permissible temperature rise 12% above its full load temperature rise. Thermal time constant is 60 minutes. If the motor had run on 75% full load for 60 minutes how long can it further run on 150% full load without exceeding safe thermal limits? Assume full load copper loss to be 110% iron losses. State any other assumptions made. [09]

(c) A machine with a shaft-mounted cooling fan was designed to deliver 50 Nm at 3000 rpm. It is intended for use in two applications:

- A speed-controlled conveyor drive in which the machine will sometimes need to deliver 50 Nm at 3000 rpm
- A compressor drive in which the machine must deliver 65 Nm at 3000 rpm for 3 minutes and then rest for 7 minutes before the cycle repeats.

Discuss in outline the issues that would need to be checked to determine if the machine is suitable for these applications. [06]