NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
DEPARTMENT OF ELECTONIC ENGINEERING
BACHELOR OF ENGINEERING (HONS) DEGREE

Final Examination January 2011

TEE 2102 ELECTRICAL MACHINES

Duration of Examination – 3 Hours

INSTRUCTIONS TO CANDIDATES

1. Answer any FIVE questions only.
2. Each question carries 20 marks.
3. Show your steps clearly in any calculation.
4. Start the answers for each question on a fresh page.

Question 1

The diagram in Figure 1 shows a two-pole generator.

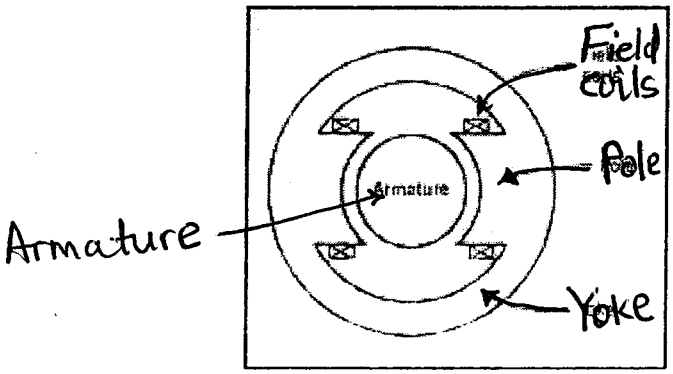

Figure 1

The magnetic circuit of the machine has the following dimensions:

Each pole (cast steel with $\mu_r = 398$):

Magnetic length = 10cm

Cross-section = $400cm^2$

Each air gap:

Length = 0.1cm

Cross section = $400cm^2$

Armature (Silicon Steel with $\mu_r = 110$):
Length = 20cm
Average cross section = $400cm^2$
Yoke (cast steel with $\mu_r = 390$):
Length = 160cm
average cross section = $200cm^2$
Half the exciting winding is on each pole.

a) Draw the magnetic equivalent circuit. [7 marks]

b) How many ampere-turns per pole are required to produce a flux density of 1.1T in the air gaps? [10 marks]

c) Give reasons why the stator and rotor of a DC machine are not laminated. [3 marks]

Question 2

Three single phase 100kVA, 2300/460V, 60Hz transformers are connected to form a three-phase, 2300/460V transformer bank. The equivalent impedance of each transformer referred to the low-voltage side is $0.045 + j0.16\Omega$. The transformer is connected to a three phase source through three phase feeders, the impedance of each feeder being $0.5 + j1.5\ \Omega$. The transformer delivers full load at 460V and 0.85 power factor lagging.

a) Draw a schematic diagram showing the transformer connection and the feeder impedances. [7 marks]

b) Determine the single phase equivalent circuit. [6 marks]

c) Determine the sending end voltage for the three phase source. [3 marks]

d) Determine the transformer winding currents. [4 marks]

Question 3

A 40kW, 200V, 1800rpm shunt motor requires a starter box. During the start up, the armature current is constrained within the range 200 to 400A. The armature circuit resistance is 0.15Ω.

a) Determine the start current if the starter box is not used. [4 marks]

b) Determine the required number of resistors and the value of each in the starter box. [16 marks]

Question 4

A 440V, 60Hz, six pole, three phase induction motor is taking 50kVA at 0.8 power factor and is running at a slip of 2.5%. the stator copper losses are 0.5kW and rotational losses are 2.5kW.

a) Calculate the rotor copper losses [4 marks]

b) Calculate the shaft power [4 marks]

c) Calculate the efficiency [4 marks]

d) Calculate the shaft speed [4 marks]

e) Calculate the shaft torque [4 marks]

Question 5

A three-phase 14kV, 10MVA, 60Hz, two-pole, 0.85 power factor, star connected, synchronous generator has $X_s = 20\Omega$ per phase and $R_s = 2\Omega$ per phase. The generator is connected to an infinite bus.

a) Determine the excitation voltage at the rated condition. Draw the phasor diagram for this condition. [8 marks]

b) Determine the power angle at the rated condition. [5 marks]

c) Determine the speed of the generator. [3 marks]

d) Explain how a synchronous machine can be used to correct power factor. [4 marks]

Question 6

A DC shunt machine (24kW, 240V, 1000rpm) has $R_a = 0.12\Omega$, $N_f = 600$ turns per pole. The machine is operated as a separately excited DC generator and is driven at 1000rpm. When $I_f = 1.8A$, the no load terminal voltage is 240V. when the generator delivers full-load current, the terminal voltage drops to 225V.

a) Determine the generated voltage and developed torque when the generator deliver full load. [8 marks]

b) Determine the voltage drop due to armature reaction. [5 marks]

c) The full load terminal voltage can be made the same as the no load terminal voltage by increasing the field current to 2.2A or by using a series winding on each pole. Determine the number of turns per pole of the series winding required if I_f is kept constant at 1.8A [7 marks]

END OF PAPER