UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, APRIL 1999
Third Year - Program 7
ECE315S - Electromechanical Energy Conversion
Exam Type: C
Examiner : R. Bonert

A complete examination paper consists of the answers to all four problems.
Problem (1) has a weight of 20 points, problems (2),(3) and (4) have a weight of 25 points each.
An aid sheet may be used.

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(1) Dynamometer testing of an induction machine (IM)

An IM has to be tested using a dynamometer. The rated data of the IM are :
18 kW, 1140 rpm, 400 V, 60 Hz, 36 A, PF 0.8
The dynamometer is equipped with another induction machine. The rated data of the dynamometer machine are : 30 kW, 1700 rpm, 600 V, 60 Hz, 38 A, PF 0.85 (power factor)
the maximum allowed speed for the dynamometer is 3600 rpm (120 Hz)

The IM is operated with rated frequency and voltage.
The dynamometer is supplied from a DC/AC three phase converter with sinusoidal PWM providing variable frequency and voltage.

a) Determine the required frequency and voltage for the dynamometer machine to test the IM at its rated operation. (Neglect mechanical losses of both machines)

b) Draw to scale a speed-torque diagram showing the characteristics of the IM and the dynamometer to achieve the described point of operation.

c) Draw onto the diagram from b) the range of continuous operation of the dynamometer, which can be achieved for the described set up.

(2) Dynamometer testing of a permanent magnet DC-machine (PM-DCM)

A permanent magnet DC-machine has to be tested.
The rated data of the DC-machine are :
5 kW, 2000 rpm, 200 V, 30 A, the armature resistance is 0.5 Ω.
A dynamometer with a separately excited DC-machine is available for testing. The rated data of the dynamometer machine are :
8 kW, 1500 rpm, 200 V, 45 A, the armature resistance is 0.3 Ω; the maximum speed of the dynamometer is 3000 rpm and can be reached by field weakening.

A constant voltage 200 V DC-supply is available to operate the PM-DCM and the dynamo-meter. The PM-DCM is started up with a starter resistor and operates at its rated voltage. The armature of the dynamometer machine is connected, as in the laboratory experiments, with a series resistor Rs and a voltage divider resistor Rd to the 200 V system. The excitation of the dynamometer machine is connected to the 200 V system with an adjustable resistor to control the field current.

d) Draw a circuit diagram showing the described test set up.

e) Determine the required resistance Rs, the setting of Rd in % of its value and the excitation in % of the rated excitation to operate the PM-DCM at rated speed and rated torque. Make the following assumptions : Rd is an ideal voltage divider, mechanical losses of both machines are neglected.

f) With the same assumptions as in b) determine Rs, Rd and the excitation to operated the PM-DCM as a generator at rated torque. Calculate also the speed at this point of operation.

g) Draw a speed-torque diagram showing the characteristic of the PM-DCM and the two required characteristics for the dynamometer to achieve the operating points described in b) and c).

(3) Questions about energy conversion

Answer the following questions with a few sentences, statements or drawings giving the most relevant points :

a) Draw the principle circuit of a DC to three phase AC converter providing variable frequency and voltage.
b) Show the principle circuit to convert single phase 60 Hz AC into single phase AC with variable frequency and voltage.
c) What kind of converter(s) is needed to convert 12 V DC into 110 V AC ?
d) Why is it, that it is desirable to operate at a good power factor ?
e) What is a brushless DC-motor ?
f) What are the major differences regarding the electric machine between a stepper motor, a synchronous machine and a brushless DC-motor ?
g) Why are automobiles not electrically driven ?
h) How efficient is the conversion from electrical to mechanical energy ? Classify the different motors.
i) Rank the following motors (highest to lowest) by their specific torques. Specific torque is torque per weight.
j) What determines the size of an electric machine ? What is it, the designer can do to pack more power into a machine with a given speed ?

(4) Design of a DC to DC power supply (boost converter)

A DC to DC power supply should provide a constant output voltage of 5 V. The maximum output current is specified to be 0.1 A at a resistive load.
The input DC-supply is from a 1.2 V NiMH (Nickel Metal Hydride) D-cell type of battery, which has a capacity of 6 Ah.

The chief engineer decided to use a switching power supply switching at 80 kHz. Furthermore the power supply is specified to operate at continuous inductor current between a load current of 10 mA and the maximum output current specified above. The voltage ripple of the output voltage should not exceed 0.5% of the rated output voltage.

a) Determine for the desired power supply the required values of the inductance and the filter capacitor to meet the given specifications.

b) For the given battery voltage and a load current of 0.1 A draw to scale for one complete switching period:
   1) The control signal for the electronic switch
   2) The voltage across the diode
   3) The current in the inductor
   4) The current through the switch
   5) The current through the diode
   6) The current through the load resistor

c) Calculate how long the battery lasts, if the load uses 0.1 A and 80% of the battery capacity is usable.

d) Explain shortly:
   1) what is the start up problem of the boost converter?
   2) what happens if the load is disconnected without stopping the switching?