UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, APRIL 2000
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),(2) and (3) have a weight of 25 points each, and problem (4) has a weight of 30 points.
An aid sheet may be used.

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(1) Design of a DC to DC power supply (buck converter)

A DC to DC power supply should provide a constant output voltage of 5 V. The input voltage is 12V. The rated power is 10 W.
The power supply should operate in continuous current mode down to 10% of the rated current. The voltage ripple of the output voltage should not exceed 1% of the rated output voltage.

Based on available space and components a filter capacitor of 15 uF should be used.

a) Determine for the desired power supply the required value of the switching frequency and the value of the inductance of the filter to meet the given specifications.

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

c) Explain shortly what happens, if the load current falls below 200 mA.

(2) Variable frequency and voltage operation of an induction machine (IM)

State of the art streetcars are equipped with IM drives using a DC to three phase AC converter. Such an IM may have the following rated data :

160 kW, 1140 rpm, 600 V, 60 Hz, 200 A, PF 0.8 (power factor)

the maximum speed of the IM is 2400 rpm at 120 Hz and 600 V

the required inverter provides a variable frequency from 0.5 Hz to 120 Hz and a variable voltage from 5V to 600 V.

a) Determine the required frequency and voltage, if the streetcar is driving uphill and the IM runs at 800 rpm providing 1000 Nm of torque.*(Neglect mechanical losses of the IM)*

b) Determine the speed of the IM, if the streetcar goes down a hill with the same slope and the voltage and frequency supplied to the IM are the same as for uphill operation

c) Determine the required frequency and voltage to accelerate the streetcar at stand still with 1.5 times the rated torque.

d) What is the maximum speed and the maximum torque at that speed , the IM can be operated at continuous operation

(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) Why is sinusoidal PWM used with DC/AC converters?
c) Show the principle circuit to convert single phase 60 Hz AC into single phase AC with variable frequency and voltage.
d) Why is discontinuous current operation in a buck converter undesirable ?
e) Why is it, that it is desirable to operate at a good power factor ?
f) Switchmode DC/AC converters can also be used as AC/DC converters, what is the advantage of using this type of converter compared with a phase controlled rectifier ?
g) What is a two quadrant chopper ?
h) What are the major differences between a drive with a stepper motor and a drive with a brushless DC-motor ?
i) What is a Reluctance Motor ?
j) How efficient is the conversion from electrical to mechanical energy ? Classify the different machines.
k) 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 and with a given volume?

4) Dynamometer testing of a separately excited DC-machine

A DC-machine is tested using a dynamometer. The rated data of the DC-machine are : 2 kW, 1200 rpm, 200 V, 13 A, the armature resistance is 0.8 Ω. The field voltage is 200 V the rated field current is 0.8 A. The maximum speed at reduced flux is limited to 2000 rpm.

A dynamometer with a permanent magnet DC-machine is available for testing. The rated data of the dynamometer machine are :

5 kW, 2000 rpm, 200 V, 30 A, the armature resistance is 0.3 Ω;

The DC-machine is operated with variable armature voltage provided by a two quadrant DC/DC converter.

The dynamometer machine is connected as shown in Figure 1

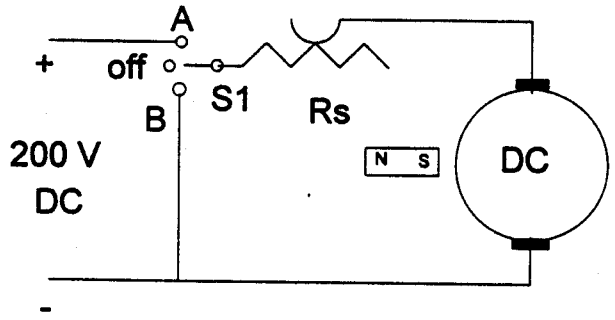

Figure 1, dynamometer connection and controls

The DC-machine should be tested at four different points of operation, these are :

1) rated operation
2) maximum speed and no load
3) same armature and field voltage supply as in 2) but a load requiring rated armature current
4) generator operation with half rated torque, rated armature voltage and rated flux

Neglect for the following calculations the mechanical losses of both machines

a) Determine for each of the 4 points of operation :
- the speed and torque at the point of operation
- the required armature and field voltages for the operation of the DC-machine
- the required settings of the dynamometer controls, switch S1 in position A or B or off, and the value of the resistor Rs in Ohms

b) Draw a speed-torque diagram showing the characteristics of the DC-machine and the required characteristics of the dynamometer to achieve the four required points of operation.

4) announcement 150%

2d rewording of question B5

Determine ~~find~~ the maximum possible speed, if the IM machine is loaded with the maximum possible torque at continuous operation. ?

~~find the maximum speed~~ find the IM can be operated at, ~~if~~ it is providing the maximum ~~torque~~ at this high speed ?