(Confidential) Ref. No. :

M.E. (Electrical)
2nd Semester Final Examination, April/May 2013

Subject : Power Electronics II

Code No. **EE 1013**
Branch: EE
Time : 3 hours Full Marks : 70

(i) The questions are of equal value
(ii) Answer any ***three*** questions taking only ***one*** from each group.
(iii) Graph papers will be supplied.
(iv) One mark reserved for brief and precise answers.

Group A

1. (a) Mention the different configurations of the bipolar controlled switches made of unipolar controlled switches.
(b) Mention the two basic constraints of operation of switches in a Matrix converter
(c) Establish that a Matrix converter can be conceptualized as a back to back Voltage source rectifier and Voltage source inverter.
(d) Describe briefly four step output current direction based commutation strategy.

[4+2+12+5]

2. (a) Show that for a rotor flux oriented vector control drive for an induction motor the electromagnetic torque can be expressed as $T_e = k_t^{'} \times i_{ds}^e \times i_{qs}^e$.
(b) How the rotor flux angle can be estimated using voltage model in direct vector control of an induction motor? .
(c) How the slip is determined in indirect vector control of a squirrel cage induction motor?
(d) Establish that in vector control of salient pole wound rotor synchronous motor the motor operates always in lagging power factor?

[6+6+6+5]

Group B

3. a) A 3-phase Y-connected 420 V, 3.3 kW, 50 Hz Hz, 6-pole Y-connected slip ring induction motor (SRIM) has the following parameter values per phase (referred to stator):
$r_1 = 1.494\ \Omega$, $r_2^{'} = 1.96\ \Omega$, $x_1 = 3.605\ \Omega$, $x_2^{'} = 3.605\ \Omega$, $x_m = 32.93\ \Omega$.
The rated slip for constant voltage operation is around 4%. The total friction, windage and core losses may be assumed to be constant at 340 W and is independent of load. You may assume a suitable value of efficiency. The rated load power factor is 0.75 lag. The stator to rotor effective turns ratio is to be evaluated from the data provided above.
If a speed range of 600-1000 rpm is to be obtained with a static Kramer system decide on the ratings of the converters and the transformer. Also, find the firing-angle range for the feedback path converter. Draw the circuit diagram. Assume a meaningful turns ratio for the rotor side transformer. Draw the phasor diagram at rated speed. Derive in brief the expressions used.

b) The above machine is to be run from a low cost V/f drive without steady-state speed error. Draw the block diagram of the drive system and explain the scheme in details. Is there any particular feature that is required for transient stability of the drive? Which block takes care of the same? Explain with appropriate logic. Draw the graph of the E-f and V-f characteristics of the machine with correct numerical values.

(12+11)

4 a) The machine in Q3(a) above is to be run from a CSI. Make **brief derivations** and evaluate the peak torque, slip for peak torque and the starting torque for the constant stator current model. If rated slip is 4%, find out the rated stator current assuming 0.75 pf under this condition. Evaluate the magnetizing current under rated condition. Compare the values with those for the constant emf model. Show that the CSI fed machine has to be operated in the statically unstable part of the torque-speed characteristic. Hence propose a block diagram for closed loop operation of the CSI fed IM with interdependent slip-speed and dc-link current control. Explain the operation of the closed loop drive in brief. Derive and plot the I_d - ω_{slip} curve with correct numerical values.

b) Draw and explain the operation of a 1-phase ASC-CSI. Clearly indicate the different paths of current flow during the different modes.

c) Develop a simple logic circuit for operation of a 3-phase 6S/4R Switched reluctance motor. (13+6+4)

Group C

5. a) What is a four-quadrant dc motor drive? Explain with relative polarities of speed, torque, voltage, current, power output in all four quadrants.

b) Draw the load voltage, load current, supply current waveforms for a motor load supplied from (i) 1- ϕ Phase controlled converter, (ii) 1- ϕ Chopper, in Forward Motoring (FM) and Forward Regeneration (FR) modes only (assume continuous conduction).

c) How is a (i) three phase phase-controlled converter (ii) a chopper, modelled as a transfer function block? Give reasons in support of your answer.

d) A 250 hp dc motor rated at 500 V and 1250 rpm has $R_a = 0.052\ \Omega$ and $L_a = 2$ mH. It is operated from a fully-controlled three-phase converter fed from a 460 V, 50 Hz., 3- ϕ ac mains. Calculate the rated current and K_b when the field current is maintained at rated value.

e) Show that for a phase-controlled dc motor drive provided with power factor-improving capacitor bank under resonance, the equivalent impedance for the fundamental is the same as that for all harmonics.

(4 + 6 + 6 + 4 + 3)

6. a) What current controllers can be used with a four-quadrant chopper? Give the block diagrams for circuit realization and state the switching logic for each type.

b) Draw the block diagram for closed-loop speed control of phase-controlled converter-fed separately excited dc motor. Assuming a PI-type current controller, derive the transfer function for the current loop. Hence derive an expression for the current loop gain. What are the assumptions involved for a first-order approximation of the current loop?

c) If I_{max} is the maximum allowable current in a dc machine, compare the following between a three phase converter and a two-quadrant chopper:

i. the rms current rating of each switch
ii. the voltage rating of each switch

d) Why are mechanical sensors mounted on motor shafts undesirable in drives? Briefly explain the basic principle of sensorless flux vector control. (6 + 8 + 4 + 5)