Test 1: EE 4002 – Electric Drives Date: 24.02.2022
Answer Any Three out of Four Questions
Total Marks: 45 Time: 90 minutes
(Make reasonable approximations wherever required)

Q1. A three phase star connected 415V (L-L) 50 Hz 4 pole induction motor (IM), has a rotor resistance $R_2 = 0.18\ \Omega$ referred to the stator. It is assumed to have a linear torque-slip characteristic in the slip range 0 to 0.06 (this means that in this operating range all machine parameters except the rotor resistance can be ignored because of low slip) and the slip at rated torque is 0.03 when operated with rated voltage and frequency.

The speed of the induction motor is controlled by an AC drive that employs Sine-Triangle PWM (known as SPWM) to perform V/f control (operate at the rated flux of the IM). The DC bus voltage of the inverter is 750V DC and the switching frequency is 10 kHz. Consider the following operating condition:

The IM produces the rated torque at ½ the rated speed

Determine for the condition mentioned above

(i) The fundamental voltage(RMS, L-L) that the inverter has to produce at the motor terminals and the corresponding stator frequency in Hz

(ii) In the SPWM modulator what has to be the peak of the sinusoidal modulating voltage if the peak of the triangle carrier waveform is 10V for the above mentioned condition

(iii) What are the on time and off time of the three top devices in a switching period in which it has to synthesize the maximum voltage in phase Y (assuming that the same carrier is used in all the three phases) ? Note that phase sequence is R-Y-B.

Marks: 4+2+3*3=15

Q2. The speed of the same induction motor (IM) as referred in Q1 is controlled by an AC drive that employs Space Vector Modulation PWM (known as SVM) to perform V/f control. The switching frequency F_S of the inverter is 10 kHz. Consider the following operating condition for the IM:

2/3rd the rated torque at the rated speed

(i) Find the magnitude $(V)$and frequency (f in Hz) of the voltage space vector ($\bar{V} = V\angle\theta$) that has to be produced by the three phase inverter for the $'k'th$ switching period, where, $\theta = 2\pi f k T_S, T_S = \frac{1}{F_S}$.

(ii) What must be the minimum DC bus voltage V_{dc}that will be required in order to generate the voltage vector of (i) so that there is no low frequency harmonics between the line-line voltages?

(iii) Let $V\angle 0$ be defined as the reference vector when the switch combination of the inverter is such that with respect to DC bus middle point 'O' the R phase voltage is $V_{RO} = \frac{Vdc}{2}$, the Y phase voltage is $V_{YO} = -\frac{Vdc}{2}$ and the B phase voltage is $V_{BO} = -\frac{Vdc}{2}$. Find the ON and OFF duration of the R –phase switch (phase sequence is R-Y-B) of the inverter in the switching period in which the space vector of (i) is located at an angle 115^0 with respect to the reference vector. Assume equal time division of the switch combinations that require either shorting of the three top switches or shorting of the three bottom switches in that switching period.

Marks: 3+3+9=15

Q3. A 3ph, 4 pole, 50Hz, star connected 650 V(L-L) slip ring (wound rotor) induction motor (IM) develops rated torque of 4000N-m at a slip of 4% and maximum torque at a slip of 10%. Ignore all other equivalent circuit parameters except rotor resistance and reactance. Assume that the stator to rotor turns ratio is 1. The slip power recovery drive needs to produce rated torque at all speed between the rated speed and 50% of the rated speed. Consider that the dc link current is harmonic free because the inductance in the dc link has a very large value.

(i) Draw the schematic of a slip power recovery drive system with the provision of a transformer between the 3 phase grid and the thyristor inverter. The grid voltage (V_L)is 650V (L-L) and the voltage at the input to the thyristor inverter is N*V_L .

(ii) For N=1, and when the IM is producing rated torque at 75% the rated speed , find the DC link current, the DC link voltage, the power recovered, the current returned to the grid by the current source inverter, the total current drawn from the grid by the slip power recovery drive and the firing angle of the current source inverter.

Marks: 3+2*6=15

Q4. (i) Sketch the circuit schematic of a Single-phase Full Bridge ASCI (Auto-Sequential-Commutated-Inverter) driving an R-L load. The commutating capacitors $C_{C1}, C_{C2} = C_C$ are assumed to be the same.(ii) Draw the equivalent circuit of each circuit mode during the commutation of load current from -I_d to I_d and formulate the equations that define the capacitor voltage (V_C) and the load current (I_L.) in each circuit mode(iii) Find the expressions of the load current and capacitor voltage in terms of the circuit parameters in each circuit mode.

Marks: 3+6+6=15