**National Exams December 2002**

**98-Elec-B9, Power Electronics and Drives**

3 hours duration

NOTES

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit, with the answer paper, a clear statement of any assumptions made.
2. Any non-communicating calculator is permitted. This is an Open Book examination. Note to the candidates: you must indicate the type of calculator being used, i.e. write the name and model designation of the calculator on the first inside left hand sheet of the exam work book.
3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
4. All questions are of equal value.

**PROBLEM 1**

a- List at least five means of thyristor turn-on. [5 points]

A single-phase, 2300 V (rms,) 60-Hz source supplies a full-wave ac voltage controller. The conduction angle is $\gamma = 155^o$.The controller powers an ac motor operating at a 0.75 power factor, lagging. The average current through each thyristor is 600 A.

b- Find the delay angle $\alpha$ . [5 points]

c- Find the equivalent resistance and inductive reactance of the motor. [10 points]

**PROBLEM 2**

a- Discuss the advantages and disadvantages of twelve-pulse versus six-pulse converters. [5 points]

The ac supply voltage to a controlled half-wave rectifier is 120 V. The load circuit consists of a resistance R= 10 $\Omega$ in series with an inductance L and a dc source $E_c$ (the internal EMF of a dc motor.) The power factor of the RL combination is 0.8, and the ratio $\frac{E_c}{V_m} = 0.2$ . Assume that delay angle $\alpha = 20^o$ .

b- Find an expression that allows us to find the corresponding conduction angle and verify that the solution in this case is $\gamma = 182.845^o$ . [7.5 points]

c- Find the average output voltage, and current. [7.5 points]

**PROBLEM 3**

a- List at least three techniques for inverter operation and explain the operational principles of one technique. [5 points]

b- It is known that the $n^{th}$ Fourier Series coefficient for the output side of a single-phase full wave bridge single pulse modulation inverter is given by:

$$b_n = \frac{4V_d}{n\pi}\sin\frac{n\delta}{2}$$

Show that the ratio of the third harmonic to fundamental component is given by:

$$\frac{b_3}{b_1} = \frac{1}{3}\left[3 - 4\sin^2\frac{\delta}{2}\right]$$

[5 points]

The dc supply to a single-phase full wave bridge single pulse modulation inverter is 220 V. The load consists of an ac motor in parallel with a power factor correcting capacitor. The motor is represented by an R-L series combination whose value at fundamental frequency is given by:

$R = 0.12\,\Omega$ $\qquad\qquad$ $\omega L = j0.09\Omega$

The capacitor is represented at fundamental frequency by:

$$\omega C = 3S$$

c- The modulation angle $\delta$ is selected such that the ratio of the third harmonic to fundamental components of the voltage output is 0.25. Find the ratio of the fifth harmonic to fundamental components of the voltage output. [5 points]

d- Find the fundamental, third, and fifth harmonic components of the inverter output current (feeding the parallel combination of the motor and power factor correcting capacitor. [5 points]

**PROBLEM 4**

a- Explain the meaning of the term forced-commutation, and list at least three factors that need to be taken into consideration when designing a forced commutation circuit. [5 points]

The load on a basic chopper circuit consists of a series combination of R = 0.18 Ω and an inductance L=0.72x10$^{-3}$ H. The period of the chopper is 2.5 ms. The minimum value of the output current is 90 A, and its maximum value is 100 A. It is required to find:

b- The on time of the chopper. [5 points]

c- The value of the dc source voltage. [5 points]

d- The time domain expressions of the chopper output currents, and the values of the output current at t= 1 ms and t=2 ms, respectively [5 points]

**PROBLEM 5**

a- What are the operational differences between an IGBT and a GTO. [5 points]

A three-phase, four-pole induction motor has a total leakage inductance of 1.5 mH, negligible resistance, and operates from a constant volt per Hz drive.

b- Assume that the maximum output torque is 180 N.m., when the supply voltage is 220 V (line-to-line) at a speed of 1500 rpm. Find the required supply frequency. [7.5 points]

c- Assume that we require the maximum output torque to be 200 N.m when the stator frequency is 60 Hz. Find the required supply voltage (line to line.) [7.5 points]

Use the following approximation for the value of maximum developed torque:

$$T_{\max} = \frac{[V_{LL}]^2 P}{4[\omega_i]^2 L_T}$$

Here P is the number of poles, $L_T$ is the total leakage reactance, and

$\omega_i = 2\pi f_i$

**PROBLEM 6**

a- Explain the principle of speed control in a dc drive below base speed and how does it differ from control above base speed.[5 points]

A separately excited dc motor is controlled by using a three phase full wave bridge rectifier circuit connected to the armature terminals. The ac voltage source is 440 V (line-to-line). The motor draws an armature current of 220 A all the time.

b- Find the armature voltage when the firing angle of the rectifier circuit is 55° and speed is 1700 rpm.[5 points]

c- To drive the motor at a speed of 750 rpm, a firing angle of 70° is required. Find the resistance of the armature circuit, the output power and torque under these conditions. [ 5 point]

d- The firing angle is adjusted to 68°. Find the corresponding speed of the motor. [ 5 points]