National Exams December 2003

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- Explain the term "snubbers" in a power electronic circuit and why are they used. [5 points]

A single-phase, full-wave a.c voltage controller is operated from a 120-V, 60-Hz supply with a conduction angle $\gamma = 132^o$. Determine the values of the delay angle α for each of the following conditions:

b- The load power factor is 0.87 lagging.[7.5 points]

c- The ratio of output voltage to input voltage is 0.825. [7.5 points]

PROBLEM 2

a- List and discuss five factors that influence the duration of the turn-off interval of an SCR. [5 points]

The ac supply voltage to a controlled half-wave rectifier is 120 V. The load circuit consists of a resistance R in series with a dc source E_c (the internal EMF of a dc motor.) When the average value of the dc output current is 20 A, the conduction angle is found to be $\gamma = 138^o$, and $\alpha_{\min} = 14^o$

b- Find the value of the dc source E_c, the delay angle α, and the load resistance R [7.5 points]

c- Assume that the delay angle is adjusted to $\alpha = 32^o$, find the average power absorbed by the dc source E_c. What is the motor's horsepower output value under these conditions [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]

c- 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:

$R = 0.14\,\Omega$ $\qquad\qquad$ $\omega L = j0.07\Omega$

The capacitor is represented at fundamental frequency by:

$$\omega C = 2.7S$$

The modulation angle δ is selected such that the ratio of the third harmonic to fundamental components of the voltage output is 0.27. 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 reasons for using series smoothing reactors in inverter circuits. [5 Points]

The voltage input to a basic chopper circuit is V_i = 30 V. The period of the chopper is 3.0 ms. The load consists of a series combination of R = 0.27 Ω and an inductance L=0.45x10^{-3} H. The ratio of minimum to maximum values of the output current is 0.875. It is required to find:

b- The time constant of the load circuit, and the on-time. [5 Points]

c- The maximum and minimum values of the output current. [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=2.7 ms, respectively [5 Points]

PROBLEM 5

List at least three undesirable effects of using high frequency PWM drives. [5 points]

A three-phase, four-pole induction motor has a total leakage inductance of 1.4 mH, negligible resistance, and operates from a constant volt per Hz drive.

a- Assume that the maximum output torque is 245 N.m. at a speed of 1500 rpm, when the frequency supplied to the stator is 60 Hz. Find the required supply voltage (line-to-line), and the motor's line current. [7.5 points]

b- Assume that the motor draws a line current of 180 A, when the stator input frequency is 63 Hz. Find the required supply voltage (line to line,) and the maximum output torque. [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

List the three types of dc drives based on the input supply. What are the variables to be controlled in a dc variable speed drive? [5 points]

A separately excited d.c motor is controlled using a three phase full wave bridge rectifier circuit connected to the armature terminals. The a.c. voltage source is 440 V (line-to-line). The motor draws an armature current of 208 A all the time.

a- Find the firing angle of the rectifier circuit when the armature voltage is 220 V, and speed is 1760 rpm. [5 points]

b- To drive the motor at a speed of 1000 rpm, a firing angle of 76° is required Find the resistance of the armature circuit, the output power and torque under these conditions. [5 point]

c- The firing angle is adjusted to 73°. Find the corresponding speed of the motor. [5 points]