

National Exams May 2005
98-Elec-B9, Power Electronics and Drives
Open Book examination

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- Describe the principle of operation of the ac controller. [5 points]

A single-phase, 575 V (rms,) 60-Hz source supplies a full-wave ac voltage controller. The conduction angle is $\gamma = 160^\circ$. The controller powers an ac motor operating at a 0.85 power factor, lagging. The average current through each thyristor is 60 A.

b- Find the delay angle α . [5 points]

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

PROBLEM 2

a- Explain why is it necessary to use snubers in power electronic circuits [5 points]

The ac supply voltage to a controlled half-wave rectifier is 240 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 30 A, the conduction angle is found to be $\gamma = 145^\circ$, and $\alpha_{\min} = 18^\circ$

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 $\alpha = 30^\circ$, 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- Explain the reasons for using shunt capacitors in inverter circuits. [5 points]

The load on a basic chopper circuit consists of a series combination of $R = 0.1 \Omega$ and an inductance $L = 0.8 \times 10^{-3} \text{ H}$. The period of the chopper is 3 ms. The minimum value of the output current is 80 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 $t = 1 \text{ ms}$ and $t = 2 \text{ ms}$, respectively [5 points]

PROBLEM 4

- a- Explain the principle of operation of pulse width modulation (PWM) for inverter output voltage control. [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 fifth harmonic to fundamental component is given by:

$$\frac{b_5}{b_1} = \frac{1}{5} \left[5 - 20 \sin^2 \frac{\delta}{2} + 16 \sin^4 \frac{\delta}{2} \right]$$

[5 points]

The dc supply to a single-phase full wave bridge single pulse modulation inverter is 220 V. The load is an ac motor. The motor is represented by an R-L series combination whose value at fundamental frequency is given by:

$$R = 8 \Omega$$

$$\omega L = j6 \Omega$$

- c- Find the modulation angle δ such that the ratio of the fifth harmonic to fundamental components of the voltage output is 0.1. Find the ratio of the third harmonic to fundamental components of the voltage output. [5 points]
- d- Find the fundamental and third harmonic components of the inverter output current (feeding the motor). [5 points]

PROBLEM 5

- a- 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 1.5 mH, negligible resistance, and operates from a constant volt per Hz drive.

- b- Assume that the maximum output torque is 350 N.m. at a speed of 1800 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]
- c- Assume that the motor draws a line current of 200 A, when the stator input frequency is 65 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

a- What are the types of ac drives based on the input supply. What are the variables to be controlled in an ac variable speed drive? [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 575 V (line-to-line). The motor draws an armature current of 200 A all the time.

b- Find the armature voltage when the firing angle of the rectifier circuit is 60° and speed is 1750 rpm.[5 points]

c- To drive the motor at a speed of 800 rpm, a firing angle of 75° 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 65° . Find the corresponding speed of the motor. [5 points]