

National Exams May 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 marks]

A single-phase, full-wave a.c voltage controller is operated from a 120-V, 60-Hz supply with a conduction angle $\gamma = 130^\circ$. Determine the values of the delay angle α for each of the following conditions:

b- The load power factor is 0.75 [7.5 marks]

c- The ratio of output voltage to input voltage is 0.8. [7.5 marks]

PROBLEM 2

a- Discuss the advantages and disadvantages of twelve-pulse versus six-pulse converters. [4 Marks]

The a.c. supply voltage to a single-phase full wave controlled rectifier is 120 V. The minimum permissible value of the delay angle is 15° . The load circuit consists of a back e.m.f. E_c in series with a resistance $R = 2 \Omega$. The conduction angle γ is 150° .

b- Find the value of the load's counter e.m.f. E_c . [4 marks]

c- Find the delay angle α . [4 marks]

d- Find the value of the average load current. [4 marks]

e- Find the average power taken by E_c . [4 marks]

PROBLEM 3

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

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 Marks]

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:

$$R = 0.1 \Omega$$

$$\omega L = j0.15 \Omega$$

The capacitor is represented at fundamental frequency by:

$$\omega C = 3.2 S$$

c- The modulation angle δ is selected such that the ratio of the third harmonic to fundamental components of the voltage output is 0.3. Find the ratio of the fifth harmonic to fundamental components of the voltage output. [5 Marks]

- 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 Marks]

PROBLEM 4

- a- Explain the reasons for using series smoothing reactors in inverter circuits. [5 Marks]

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 $R = 0.25 \Omega$ and an inductance $L = 0.5 \times 10^{-3}$ H. The ratio of minimum to maximum values of the output current is 0.8. It is required to find:

- b- The time constant of the load circuit, and the on-time. [5 Marks]
 c- The maximum and minimum values of the output current. [5 Marks]
 d- The time domain expressions of the chopper output currents, and the values of the output current at $t = 1$ ms and $t = 2.8$ ms, respectively [5 Marks]

PROBLEM 5

- a- What are the operational differences between an IGBT and a GTO. [4 Marks]

A three phase, eight pole, 60 Hz, 440-V, induction motor is operated in a constant V/f mode. The stator resistance is 0.1Ω . Assume that operation is at maximum torque of 1150 N.m., and that the rotor resistance is 0.16Ω .

- b- Find the leakage inductance of the motor's equivalent circuit. [4 marks]
 c- Find the minimum frequency which still allows the motor to reach maximum torque. [4 marks]
 d- Assume that the supply to the motor has a frequency of 25 Hz, find the motor speed and applied voltage. [4 marks]
 e- If the shaft speed is 35 rad/s, find the required supply frequency and voltage. [4 marks]

PROBLEM 6

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

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 210 A all the time.

- b- Find the firing angle of the rectifier circuit when the armature voltage is 245 V, and speed is 1750 rpm. [5 Marks]
 c- To drive the motor at a speed of 1000 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 68° . Find the corresponding speed of the motor. [5 Marks]

Marking Scheme

PROBLEM 1

(a) 5 marks (b) 7.5 marks (c) 7.5 marks

PROBLEM 2

(a) 4marks (b) 4 marks (c) 4 marks (d) 4 marks (e) 4 marks

PROBLEM 3

(a) 5 marks (b) 5 marks (c) 5 marks (d) 5 marks

PROBLEM 4

(a) 5 marks (b) 5 marks (c) 5 marks (d) 5 marks

PROBLEM 5

(a) 4marks (b) 4 marks (c) 4 marks (d) 4 marks (e) 4 marks

PROBLEM 6

(a) 5 marks (b) 5 marks (c) 5 marks (d) 5 marks