

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

A single-phase, 2300 V (rms,) 60-Hz source supplies a full-wave ac voltage controller. The conduction angle is $\gamma = 155^\circ$. 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 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 a free-wheeling diode in power electronic circuits [5 points]

The a.c. supply voltage to a controlled half-wave rectifier is 120 V. The load circuit consists of a resistance $R = 8 \Omega$ in series with an inductance L and a d.c. source E_c . The power factor of the R-L combination is 0.85 and the ratio of the counter emf E_c to the maximum ac voltage V_m is given by $E_c/V_m = 0.18$. Assume that the delay angle $\alpha = 30^\circ$

b- Find an expression that allows us to find the corresponding conduction angle, and verify that the solution in this case is very close to $\gamma = 170^\circ$ [7.5 points]

c- Find the average value of the 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:

$$R = 0.12 \Omega$$

$$\omega L = j0.09 \Omega$$

The capacitor is represented at fundamental frequency by:

$$\omega C = 3S$$

c- The modulation angle δ 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 reasons for using series smoothing reactors in inverter circuits. [5 Points]

The voltage input to a basic chopper circuit is $V_i = 24$ V. The period of the chopper is 2.4 ms. The load consists of a series combination of $R = 0.12 \Omega$ and an inductance $L = 0.35 \times 10^{-3}$ H. The ratio of minimum to maximum values of the output current is 0.75. 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 value of the output current at $t = 1$ ms [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- Give a list of 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.

- b- Find the firing angle of the rectifier circuit when the armature voltage is 220 V, and speed is 1760 rpm. [5 points]
 c- 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]
 d- The firing angle is adjusted to 73° . Find the corresponding speed of the motor. [5 points]