

National Exams December 2010
07-Elec-B8, 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- Refer to the SCR characteristic shown in figure (1). Which of the statements A or B is correct? What do the points X1 and X2 identify? [5 Points]

A 120-V, 60-Hz single phase source supplies a single-phase, full-wave ac voltage controller operating with a conduction angle $\gamma = 135^\circ$.

- b- The controller supplies an ac motor whose power factor varies from 0.45 at starting to 0.85 at full load. Determine the corresponding values of the delay angle α . [7.5 points]
- c- Determine the ratio of the output voltage to input voltage corresponding to the conditions of part (a.) [7.5 points]

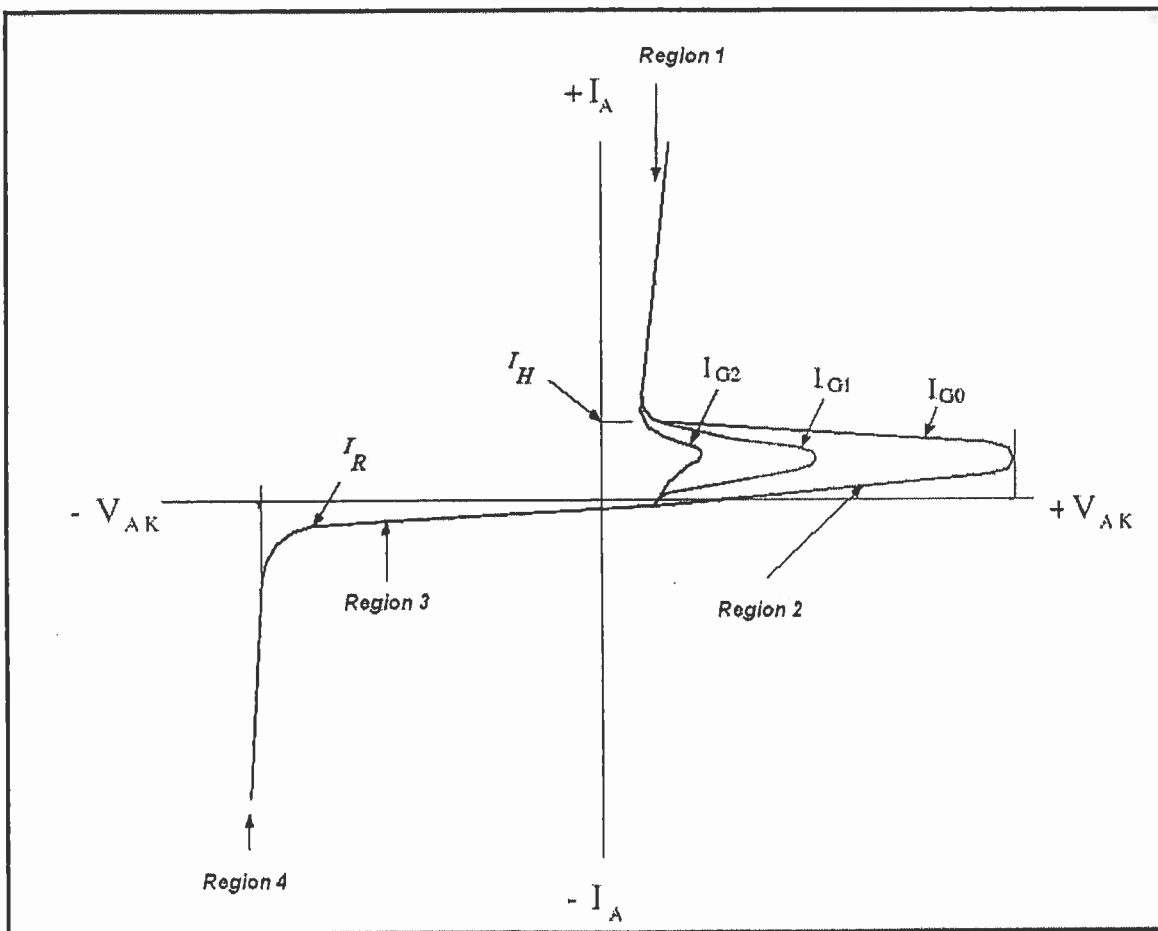


Figure (1) SCR Characteristics

PROBLEM 2

a- Explain the principle of operation of basic chopper circuits and the effects of varying the on-time on operational modes of the chopper. [5 points]

The load on a basic chopper circuit consists of a series combination of $R = 12 \Omega$, an inductance $L = 15 \times 10^{-3} \text{ H}$ and a back emf $E_c = 18 \text{ V}$. The period of the chopper is $T = 0.25 \text{ ms}$. The dc supply voltage is 220 V .

- b- Find the critical value of the on-time for which the minimum value of the load current is zero. [5 point]
- c- Find the value of the maximum load current corresponding to the conditions of part (b) [5 points]
- d- Assume that $t_{on} = 0.5 T$, determine the minimum and maximum values of the instantaneous load current. [5 points]

PROBLEM 3

- a- Explain how harmonics arise in an electric power distribution system, and list three ways of mitigating their effects. [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 third harmonic component is given by:

$$\frac{b_5}{b_3} = \frac{3}{5} \left[\frac{5 \sin \frac{\delta}{2} - 20 \sin^3 \frac{\delta}{2} + 16 \sin^5 \frac{\delta}{2}}{3 \sin \frac{\delta}{2} - 4 \sin^3 \frac{\delta}{2}} \right]$$

[5 points]

The dc supply to a single-phase, full wave bridge, single pulse modulation inverter is 240 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:

$$R = 8 \Omega$$

$$\omega L = j10 \Omega$$

- c- The modulation angle δ is selected such that the ratio of the fifth harmonic to third harmonic components of the voltage output is 0.4. Find the ratio of the third 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 motor). [5 points]

Useful Trig Identities:

$$\sin 3\theta = 3 \sin \theta - 4 \sin^3 \theta$$

$$\sin 5\theta = 5 \sin \theta - 20 \sin^3 \theta + 16 \sin^5 \theta$$

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 $V_1 = 24$ V. The period of the chopper is 2.2 ms. The load consists of a series combination of $R = 2 \Omega$ and an inductance $L = 0.5 \times 10^{-3}$ H. The ratio of minimum to maximum values of the output current is 0.5. Determine the following:

- 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 $t = 1.5$ ms, respectively [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 1.2 mH, negligible resistance, and operates from a constant volt per Hz drive.

- b- Assume that the maximum output torque is 200 N.m. at a speed of 1500 rpm, when the line to line voltage supplied to the stator is 200 V. Find the required supply frequency. [7.5 points]
 c- Assume that we require the maximum output torque to be 240 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- What are the 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 three-phase, full wave, bridge rectifier circuit feeds the armature terminals of a separately excited dc motor. The ac voltage source is 230 V (line-to-line). The motor draws an armature current of 120 A all the time.

- b- Find the armature voltage when the firing angle of the rectifier circuit is 42.5° and speed is 1750 rpm. [5 points]
 c- To drive the motor at a speed of 1250 rpm, a firing angle of 57.5° 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]