National Exams May 2016

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 $\gamma = 130^o$.

b- The controller supplies an ac motor whose power factor varies from 0.5 at starting to 0.85 at full load. Determine the corresponding range 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 (b.) [7.5 points]

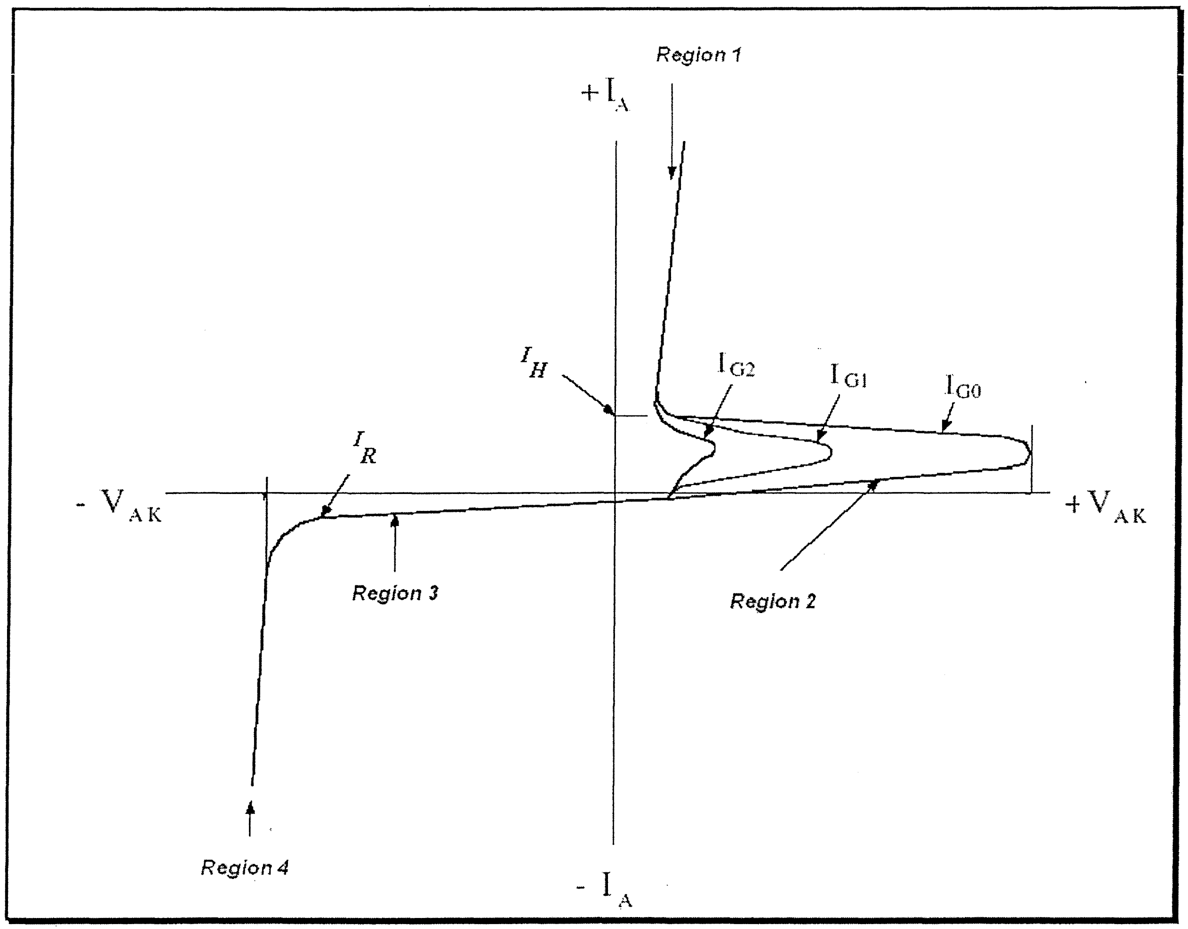

Figure (1) SCR Characteristics

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 = 10 Ω, an inductance L= 15×10^{-3} H and a back emf E_c= 18 V. The period of the chopper is T= 0.20 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 three harmful effects of harmonics in electric power distribution systems. [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 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 = 7.5 Ω $\qquad\qquad$ $\omega L = j10\Omega$

c- The modulation angle δ is selected such that the ratio of the fifth harmonic to third harmonic components of the voltage output is 0.2. 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 functions of clamping capacitors and smoothing reactors in inverter circuits. [5 Points]

b- The voltage input to a basic chopper circuit is V_i = 30 V. The load consists of a series combination of R = 0.2 Ω and an inductance such that the time constant is 1.5 ms. The maximum value of the output current is 90 A and the ratio of the on-time to time constant is 0.9. It is required to find the period of the chopper. [5 Points]

c- The minimum value of the output current. [5 Points]

d- Suppose now that the resistance of the load circuit is increased to 0.4 Ω while the inductance is kept constant at its original value. Find the maximum and minimum values of the output current if the period and on time remain unchanged. [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 1.75 mH, negligible resistance, and operates from a constant volt per Hz drive.

b- Assume that the maximum output torque is 275 N.m. at a speed of 1800 rpm, when the line to neutral supply voltage supplied to the stator is 200 V. Find the required line frequency, and the motor's line current. [7.5 points]

c- Assume that the maximum output torque drops to 240 N.m when the stator input frequency is 65 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- Explain the principles of operation of a three phase full wave bridge rectifier and how it is applied for speed control of a separately excited dc motor above and below rated speed [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 220 V (line-to-line). The motor draws an armature current of 165 A all the time.

b- Find the armature voltage when the firing angle of the rectifier circuit is 45° and speed is 1750 rpm.[5 points]

c- To drive the motor at a speed of 1200 rpm, a firing angle of 55° 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]