National Exams May 2011

07-Elec-B8, 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- Refer to the SCR characteristic shown in figure (1). Explain the significance of regions 1 to 4 on the characteristic. [5 Points]

A single-phase, full-wave a.c voltage controller is operated from a 120-V, 60-Hz supply with a conduction angle $\gamma = 135^{o}$. Determine the values of the delay angle α for each of the following conditions:

b- The load power factor is 0.707.[7.5 points]

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

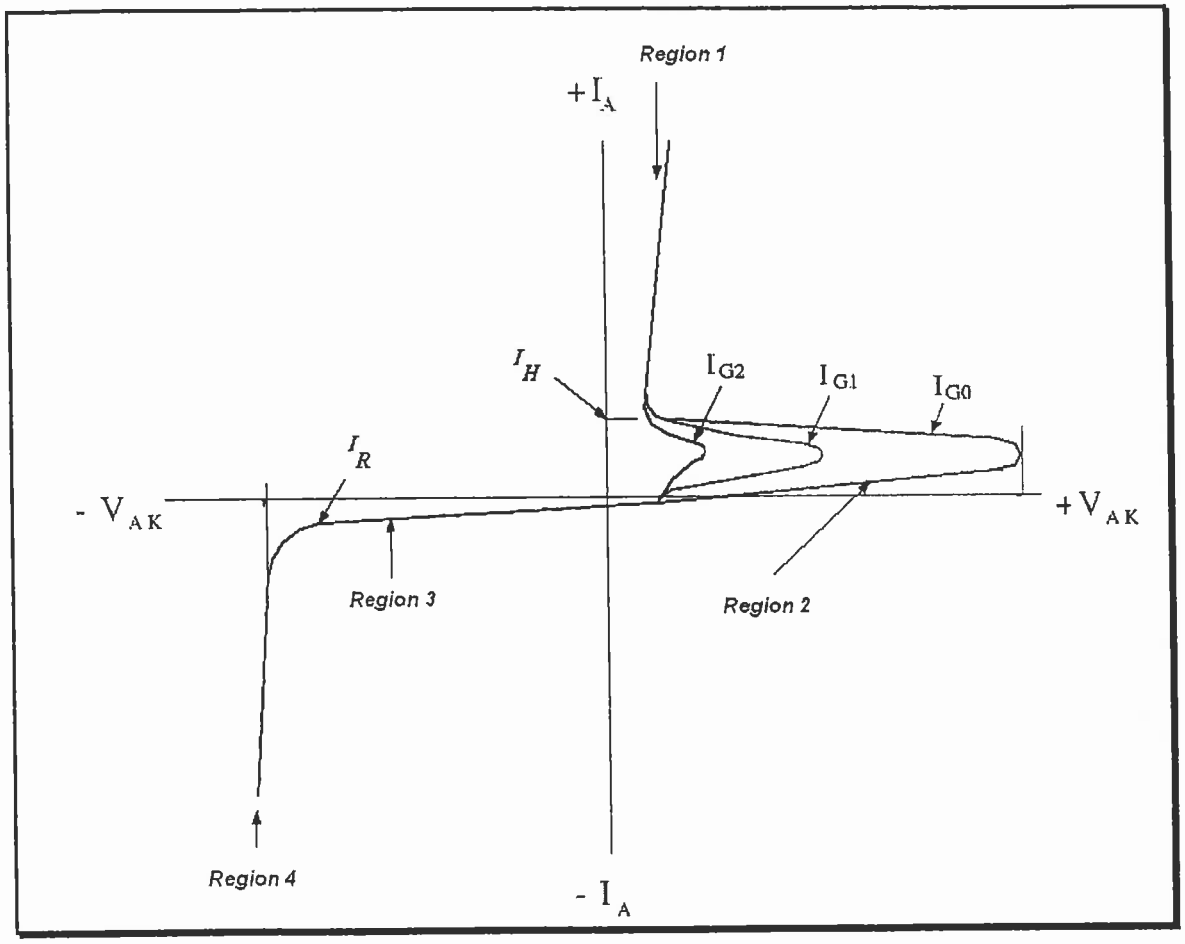

Figure (1) SCR Characteristics

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 28 A, the conduction angle is found to be $\gamma = 145^o$, and $\alpha_{min} = 18^o$

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 $\alpha = 30^o$, 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 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 = 0.1 Ω and an inductance $L=0.3\times10^{-3}$ 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 4

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]

c- 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:

$R = 0.12\,\Omega$ $\qquad\qquad$ $\omega L = j0.06\Omega$

The capacitor is represented at fundamental frequency by:

$$\omega C = 2.7S$$

The modulation angle δ is selected such that the ratio of the third harmonic to fundamental components of the voltage output is 0.27. 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 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 0.1 Ω. Assume that operation is at maximum torque of 1150 N.m., and that the rotor resistance is 0.16 Ω.

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- 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 dc motor is controlled by using a three phase full wave bridge rectifier circuit connected to the armature terminals. The ac voltage source is 440 V (line-to-line). The motor draws an armature current of 205 A all the time.

b- Find the armature voltage when the firing angle of the rectifier circuit is 57.5° and speed is 1750 rpm.[5 points]

c- To drive the motor at a speed of 700 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 points]