National Exams December 2005

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- 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 single-phase, 230 V (rms,) 60-Hz source supplies a full-wave a.c voltage controller. The controller powers a 20-hp motor, whose power factor is 0.8. The corresponding conduction angle is $\gamma = 160°$.

b- Find the delay angle α . [5 Points]

c- Find the effective (rms) output voltage of the controller. [5 Points]

d- Assume that the efficiency of the motor is 0.92; find the average current through each of the thyristors of the controller. [5 Points]

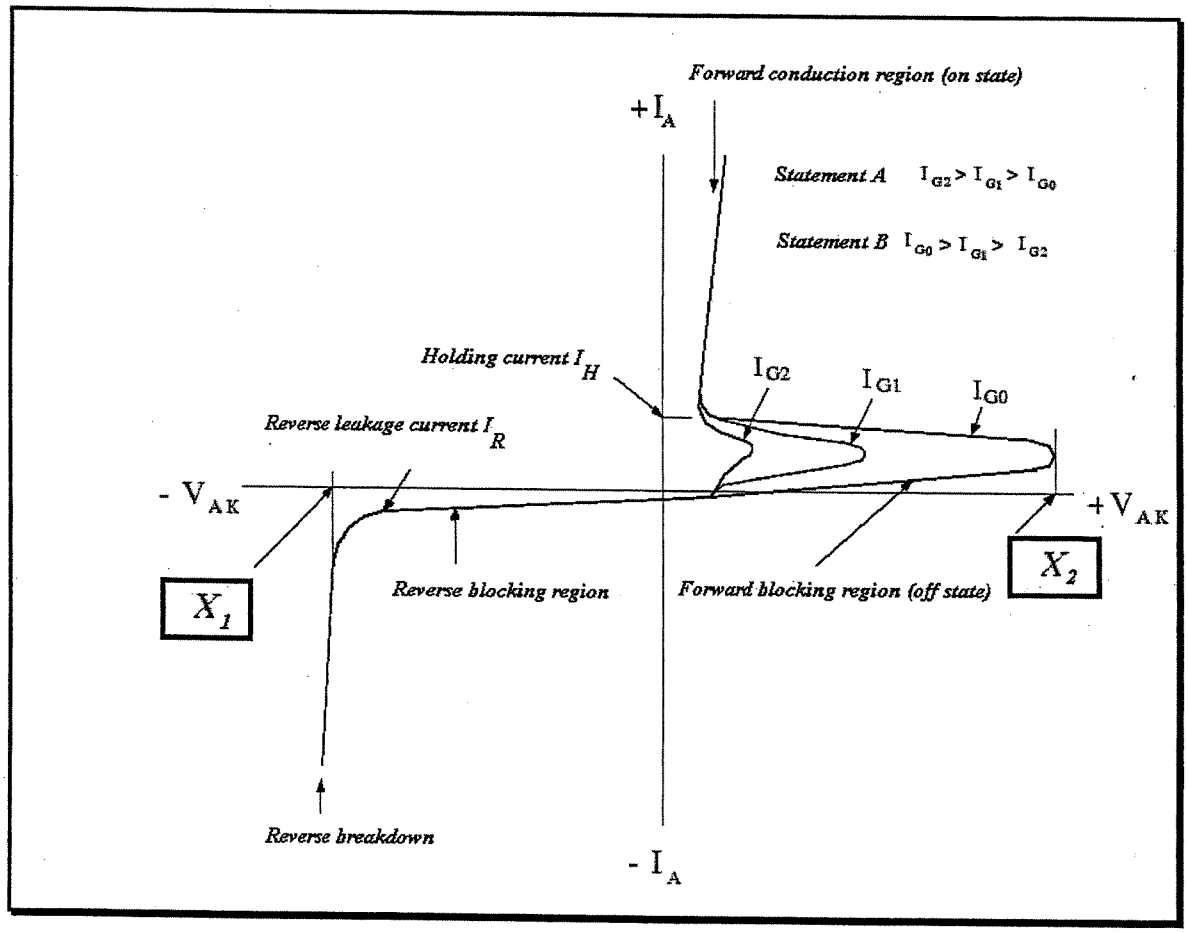

Figure (1) SCR Characteristics

PROBLEM 2

a- Discuss three ways of reducing third harmonic produced by converters. [4 Points]

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 20°. The load circuit consists of a back e.m.f. E_c in series with a resistance R = 2.5 Ω. The conduction angle γ is 145°.

b- Find the value of the load's counter e.m.f. E_c. [4 Points]
c- Find the delay angle α. [4 Points]
d- Find the value of the average load current. [4 Points]
e- Find the average power taken by E_c. [4 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 1.8 ms. The load consists of a series combination of R = 0.25 Ω and an inductance $L=0.36\times10^{-3}$ H. The ratio of minimum to maximum values of the output current is 0.6. 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 values of the output current at t= 1 ms and t=2 ms, respectively [5 Points]

PROBLEM 4

a- Explain the principle of operation of sinusoidal pulse width modulation (PWM) for inverter output voltage control. [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 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:

$$R = 4\,\Omega \qquad\qquad \omega L = 8\Omega$$

c- The modulation angle δ is selected such that the ratio of the third harmonic to fundamental components of the voltage output is 0.24. 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 motor). [5 Points]

PROBLEM 5

a- What are the operational differences between an IGBT and a Power MOSFET? [4 Points]

A three phase, eight pole, 60 Hz, 440-V, induction motor is operated in a constant V/f mode. The stator resistance is 0.12 Ω. Assume that operation is at maximum torque of 1250 N.m., and that the rotor resistance is 0.18 Ω.

b- Find the leakage inductance of the motor's equivalent circuit. [4 Points]
c- Find the minimum frequency which still allows the motor to reach maximum torque. [4 Points]
d- Assume that the supply to the motor has a frequency of 25 Hz, find the motor speed and applied voltage. [4 Points]
e- If the shaft speed is 36 rad/s, find the required supply frequency and voltage. [4 Points]

PROBLEM 6

a- What are the types of ac drives based on the input supply. What are the variables to be controlled in an ac 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 600 V (line-to-line). The motor draws an armature current of 210 A all the time.

b- Find the armature voltage when the firing angle of the rectifier circuit is 60° and speed is 1750 rpm.[5 Points]

c- To drive the motor at a speed of 800 rpm, a firing angle of 65° 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 55°. Find the corresponding speed of the motor. [5 Points]