National Exams May 2009

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 single-phase, 230 V (rms,) 60-Hz source supplies a full-wave a.c voltage controller. The controller powers a 100-hp motor, whose power factor is 0.85. 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 0.96; find the average current through each of the thyristors of the controller. [5 Points]

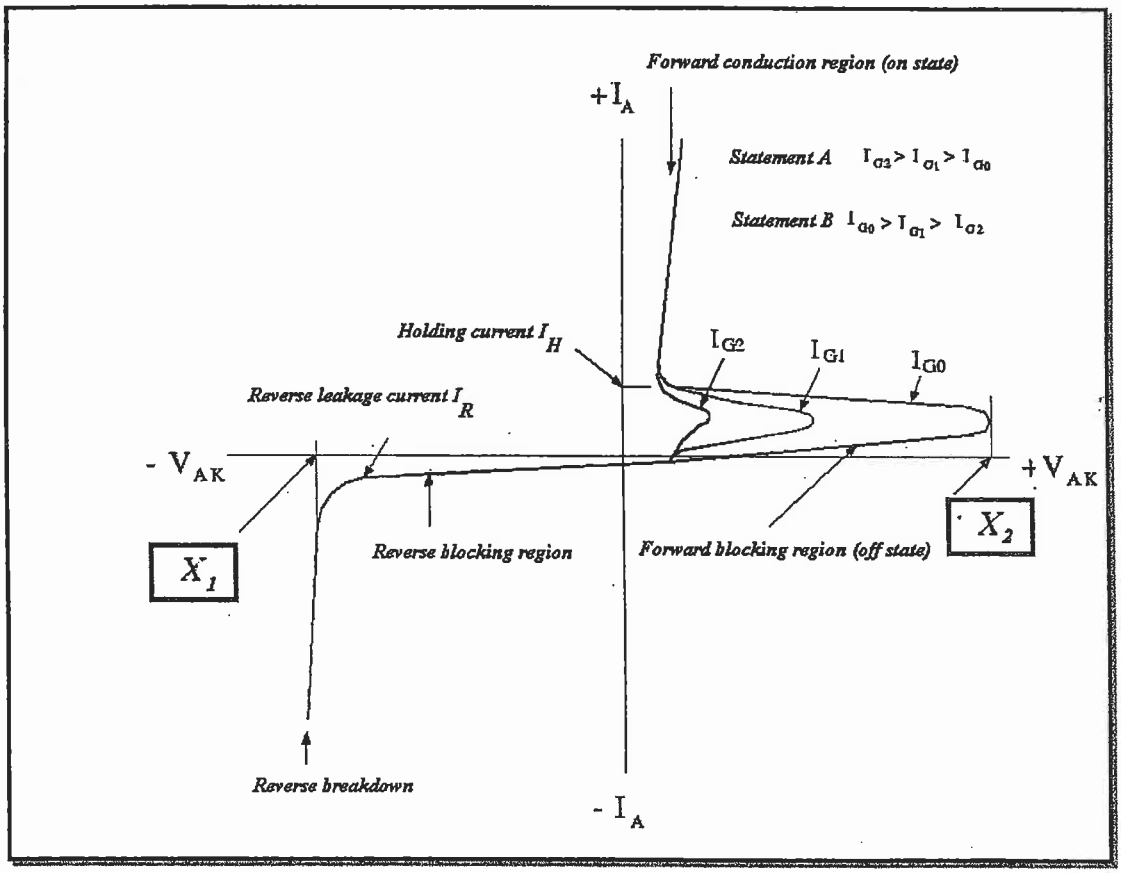

Figure (1) SCR Characteristics

PROBLEM 2

a- List and discuss five factors that influence the duration of the turn-off interval of an SCR. [5 points]

The ac supply voltage to a half-wave controlled rectifier is 120 V. The load circuit consists of a resistance R in series with an inductance L. The power factor of this load is 0.707.

b- Find the value of the delay angle α when the conduction angle is $\gamma = 145^o$. Find the load resistance R when the average value of the dc output current is 25 A. [7.5 points]

c- Assume that the conduction angle is adjusted to $\gamma = 150^o$, find delay angle α and the average value of the dc output current under the conditions of part (b) [7.5 points]

PROBLEM 3

a- Explain the differences between current-fed inverters and voltage-fed inverters. [5 points]

b- The n^{th} Fourier Series coefficient on the output side of a single-phase full wave bridge single pulse modulation inverter is:

$$b_n = \frac{4V_d}{n\pi}\sin\frac{n\delta}{2}$$

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 modulation angle δ is selected such that the ratio of the third harmonic to fundamental components of the voltage output is 0.325.

c- Find the first and third harmonic components of the output voltage. [5 Points]

The load connected to the output side of the inverter consists of a 2.5 hp ac motor operating at 0.7 pf at fundamental frequency. A power factor correcting capacitor is connected in parallel with the motor to improve the power factor to 0.85 at fundamental frequency.

d- Find the impedance of the motor at fundamental frequency and the third harmonic component of the motor current. [5 Points]

PROBLEM 4

a- Explain functions of clamping capacitors and smoothing reactors in inverter circuits. [5 Points]

The voltage input to a basic chopper circuit is V_i = 30 V. The load consists of a series combination of R = 0.3 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 on-time is 2.4 ms. It is required to find:

b- 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- Explain the consequences of decreasing the supply frequency to an induction motor below the rated value while maintaining the value of the supply voltage constant at rated value. [5 points]

A three phase, eight pole, 60 Hz, 440-V, induction motor is operated in a constant V/f mode. The stator resistance is 0.14 Ω. Assume that operation is at rated frequency and voltage to deliver maximum torque of 1000 N.m., and that the rotor resistance is 0.21 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 for operation at maximum torque. [4 Points]

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 45° and speed is 1700 rpm.[5 points]

c- To drive the motor at a speed of 1000 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]