National Exams May 2014

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 75-hp motor, whose power factor is 0.8. The corresponding conduction angle is $\gamma = 160^o$.

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]

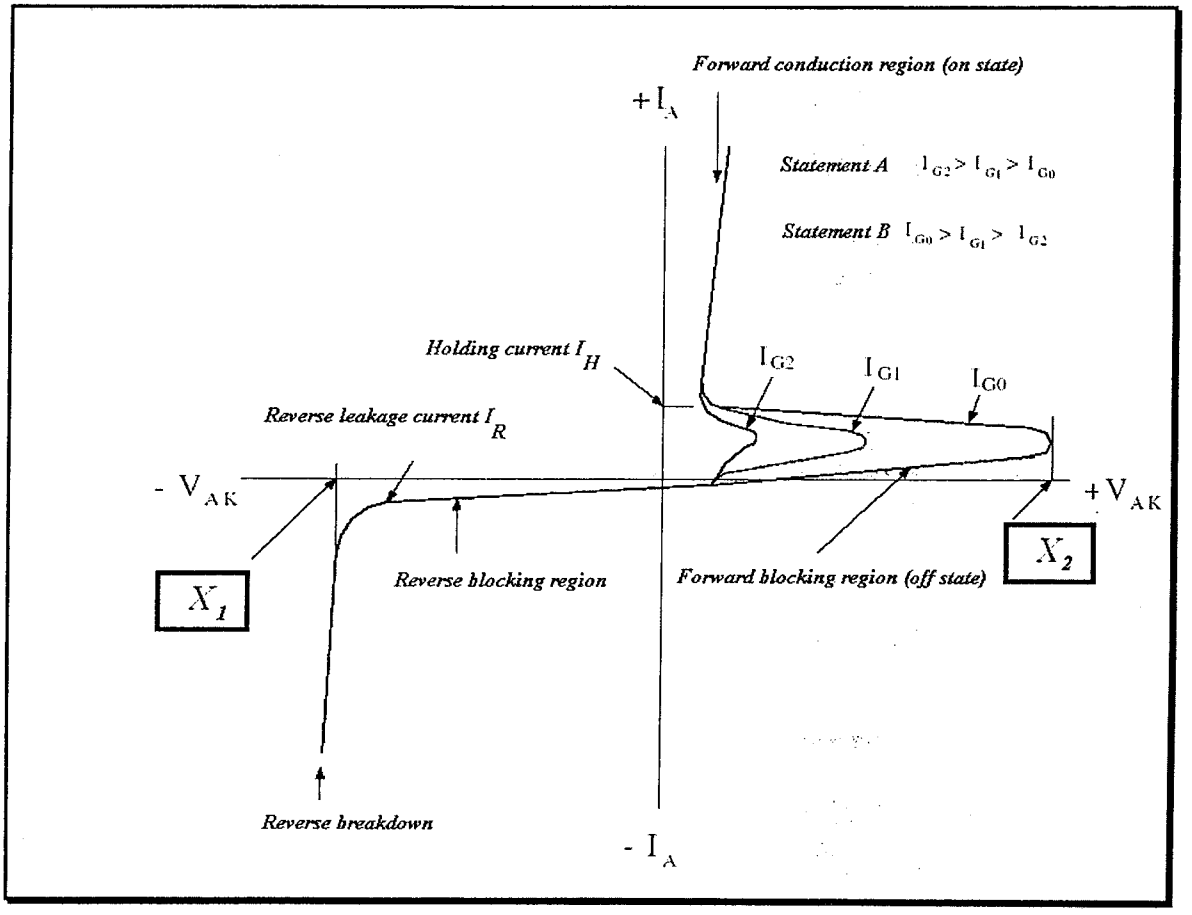

Figure (1) SCR Characteristics

PROBLEM 2

a- 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 = 9.6 Ω, an inductance L= $12\text{x}10^{-3}$ H and a back emf E_c= 20 V. The period of the chopper is T= 0.25 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 maximum value of the instantaneous load current. [5 points]

PROBLEM 3

a- Explain the differences between current-fed inverters and voltage-fed inverters. [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:

$$R = 8\,\Omega \qquad \omega L = j6\Omega$$

c- The modulation angle δ is selected such that the ratio of the fifth harmonic to third harmonic components of the voltage output is 0.3. 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 principle of operation of a basic single phase half wave controlled rectifier supplying a resistive load [5 points]

b- Explain how the operation of a basic single phase half wave controlled rectifier is affected if the load consists of resistance plus inductance in series with a dc voltage source. [5 points]

Consider a half-wave controlled rectifier supplying a resistive load. The rectifier operates initially at a delay angle $\alpha_o = 18^o$ while the maximum value of the ac input wave is $V_{\max 0}$. The maximum value of the ac input wave is changed to $0.85V_{\max 0}$. Determine the corresponding relative change in the dc output voltage when the delay angle is changed to the following values.

c- $\alpha_1 = 8^o$, $\alpha_2 = 12^o$ and $\alpha_3 = 30^o$ [5 points]

d- Repeat part (b) for a three-phase controlled rectifier operating in continuous current mode [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 Y-connected induction motor with negligible no-load losses has the following parameters:

$R_s = 0.2\Omega$ $R_r = 0.2\Omega$

$X_s = 1.2\Omega$ $X_r = 1.5\Omega$ $X_m = 12\Omega$

The motor is controlled by a current source inverter and the input current is kept constant at 40 A. When the frequency is 50 Hz, the developed torque is 180 N.m. The approximate equivalent circuit corresponding to this mode of operation is given in Fig. (2.) Determine:

b- The slip and rotor speed. [7.5 points]

c- The terminal voltage per phase and the power factor. [7.5 points]

Use the following torque formula for constant current operation:

$$T = \frac{3\left[X_m I\right]^2 (R_r / s)}{s\omega_s\left[\left(R_s + \frac{R_r}{s}\right)^2 + (X_m + X_s + X_r)^2\right]}$$

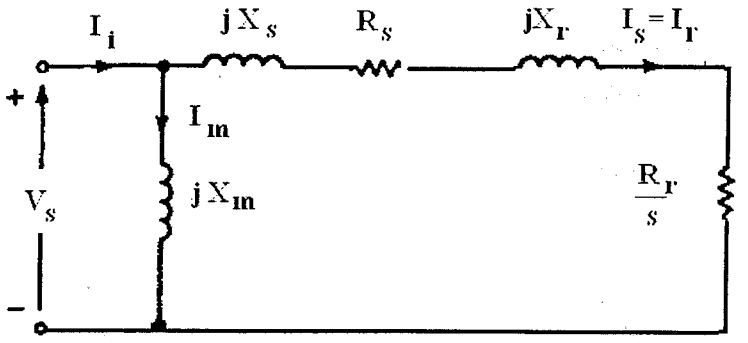

Figure (2) Approximate equivalent circuit for Constant current operation of a three phase induction motor

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 200 A all the time.

b- Find the armature voltage when the firing angle of the rectifier circuit is 39° and speed is 1720 rpm.[5 points]

c- To drive the motor at a speed of 1000 rpm, a firing angle of 57° is required. Find the resistance of the armature circuit, the output power and torque under these conditions. [5 points]

d- The firing angle is adjusted to 65°. Find the corresponding speed of the motor. [5 points]