National Exams December 2008

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 120-V, 60-Hz single phase source supplies a single-phase, full-wave ac voltage controller operating with a conduction angle $\gamma = 135^{o}$.

b- The controller supplies an ac motor whose power factor varies from 0.4 at starting to 0.8 at full load. Determine the corresponding values 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 (a.) [7.5 points]

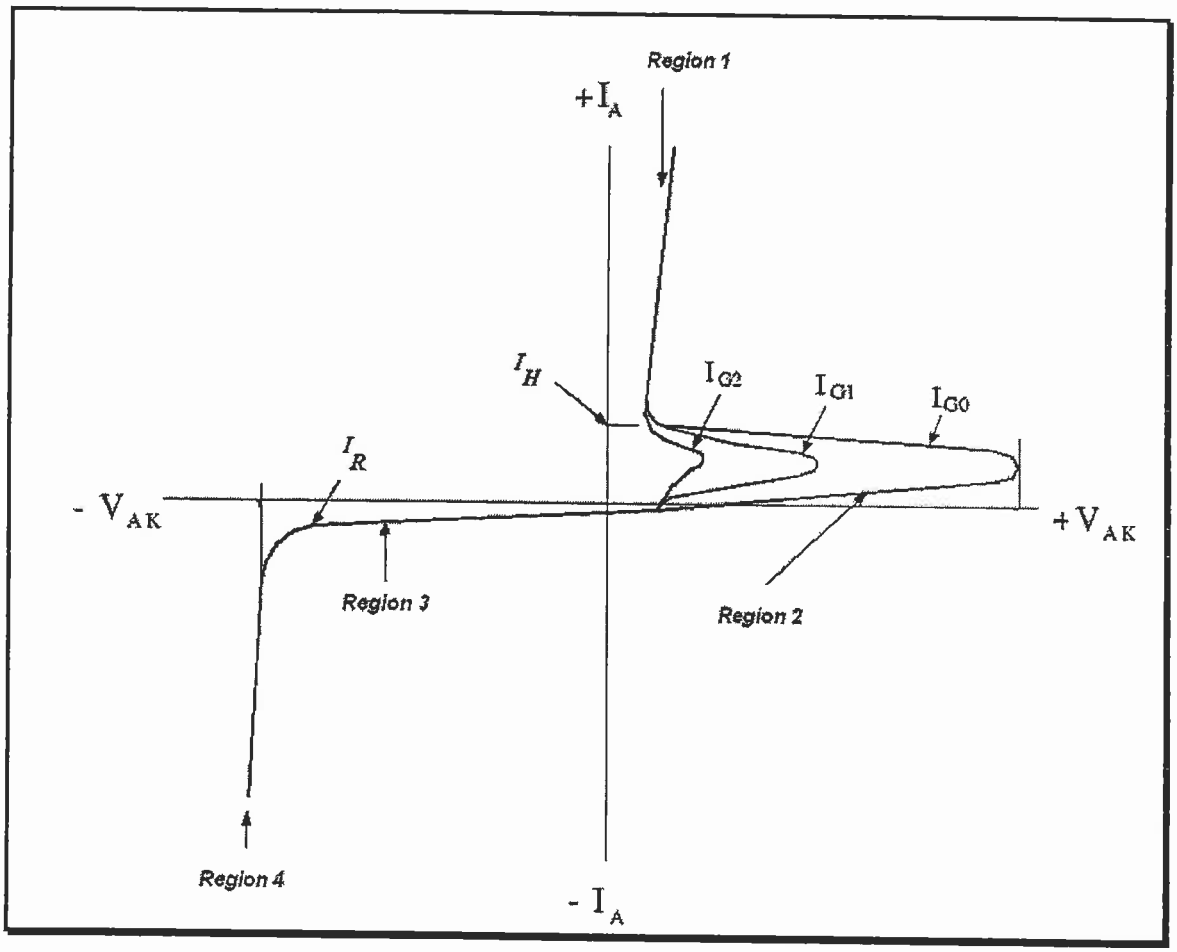

Figure (1) SCR Characteristics

PROBLEM 2

a- Discuss three causes of harmonics in the electric power distribution system. [4 Points]

The a.c. supply voltage to a single-phase full wave controlled rectifier is 120 V. The load circuit consists of a 30 V counter (back) e.m.f. E_c in series with a resistance R = 2.25 Ω. The conduction angle γ is maintained at 135°.

b- Find the minimum permissible value of the delay angle. [4 Points]
c- Find the delay angle α. [4 marks]
d- Find the value of the average load current. [4 Points]
e- The minimum value of α is changed to 12°. Find the value of the average load current. [4 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:

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

c- The modulation angle δ is selected such that the ratio of the fifth harmonic to third harmonic components of the voltage output is 0.25. 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]

The voltage input to a basic chopper circuit is V_i = 24 V. The period of the chopper is 1.6 ms. The load consists of a series combination of R = 0.2 Ω and an inductance L=0.35x10^{-3} H. The ratio of minimum to maximum values of the output current is 0.7. 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 5

a- List at least three undesirable effects of using high frequency PWM drives. [5 points]

A three-phase, 50 Hz , eight-pole Y-connected induction motor with negligible no-load losses has the following parameters:

$$R_s = 0.2\Omega \qquad R_r = 0.3\Omega$$

$$X_s = 1.\Omega \qquad X_r = 1.5\Omega \qquad X_m = 10.42\Omega$$

The motor is controlled by a current source inverter and the input current is kept constant at 30 A. The developed torque is 120 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:

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

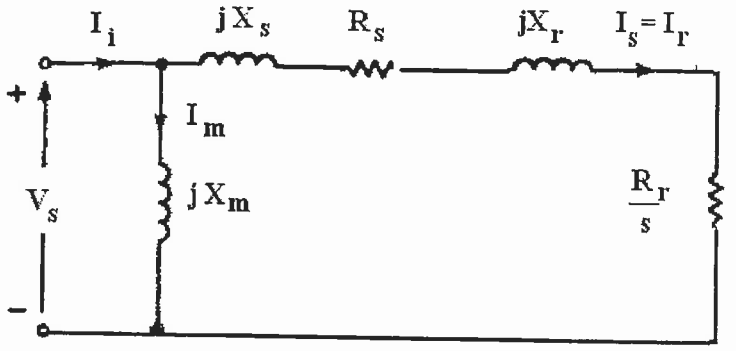

Figure (2) Approximate equivalent circuit for Constant current operation of a three phase induction motor

PROBLEM 6

a- 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 155 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]