National Exams December 2015 Front Page

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). 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]

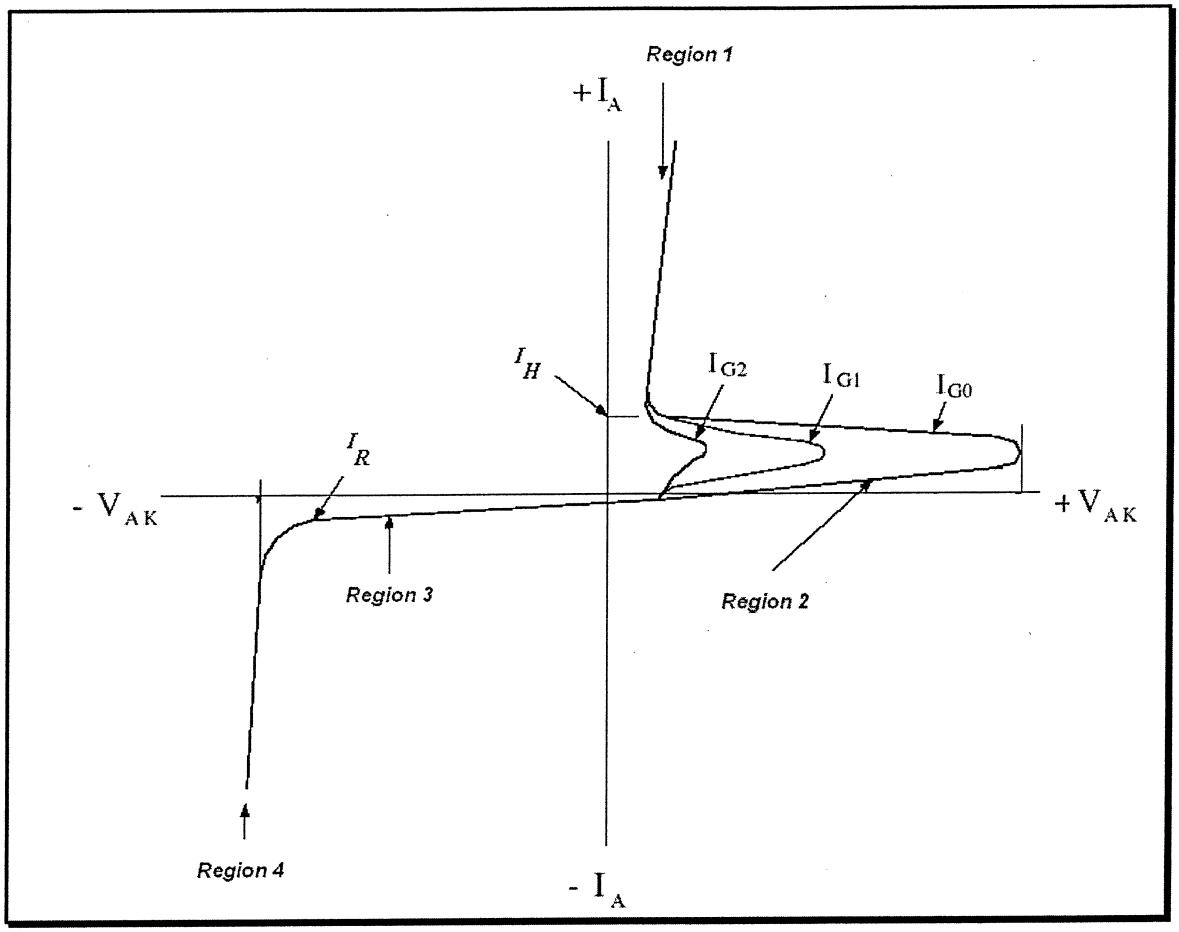

Figure (1) SCR Characteristics

PROBLEM 2

a- Discuss three ways in which harmonics are introduced 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 minimum permissible value of the delay angle is 15°. The load circuit consists of a back e.m.f. E_c in series with a resistance R = 2 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 marks]
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 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]

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:

$R = 0.12\,\Omega$ $\qquad\qquad$ $\omega L = j0.09\Omega$

The capacitor is represented at fundamental frequency by:

$$\omega C = 3S$$

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

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

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

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:

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

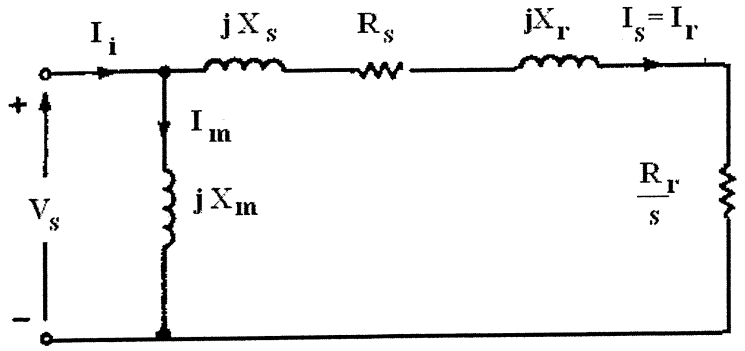

Figure (2) Approximate equivalent circuit for Constant current operation of a three phase induction motor

PROBLEM 6

a- 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]