National Exams May 2012

07-Elec-B8, 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- Explain the term "snubbers" in a power electronic circuit and why are they used. [5 points]

A single-phase, 2300 V (rms,) 60-Hz source supplies a full-wave ac voltage controller. The conduction angle is $\gamma = 157^o$ .The controller feeds an ac motor operating at a 0.72 power factor, lagging. The average current through each thyristor is 650 A.

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

c- Find the equivalent resistance and inductive reactance of the motor. [10 points]

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 = 11 Ω, an inductance L= 12x10^{-3} H and a back emf E_c= 19.8 V. The period of the chopper is T= 0.2 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 minimum and maximum values of the instantaneous load current. [5 points]

PROBLEM 3

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 nth Fourier Series coefficient for the output side voltage 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 in parallel with a capacitor. The motor is represented by an R-L series combination whose value at fundamental frequency is given by:

R = 2.4 Ω $\qquad\qquad$ $\omega L = 12\Omega$

The admittance of the capacitor at fundamental frequency is $\omega C = 3S$

c- The modulation angle δ is selected such that the ratio of the third harmonic to fundamental components of the voltage output is 0.22. 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]

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- 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 = 2.15 Ω. The conduction angle γ is maintained at 133°.

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 11°. Find the value of the average load current. [4 Points]

PROBLEM 5

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

A three-phase, four-pole induction motor has a total leakage inductance of 1.6 mH, negligible resistance, and operates from a constant volt per Hz drive.

b- Assume that the maximum output torque is 275 N.m. at a speed of 1500 rpm, when the frequency supplied to the stator is 60 Hz. Find the required supply voltage (line-to-line), and the motor's line current. [7.5 points]

c- Assume that the motor draws a line current of 210 A, when the stator input frequency is 64 Hz. Find the required supply voltage (line to line,) and the maximum output torque. [7.5 points]

Use the following approximation for the value of maximum developed torque:

$$T_{max} = \frac{[V_{LL}]^2 P}{4[\omega_i]^2 L_T}$$

Here P is the number of poles, L_T is the total leakage reactance, and

$\omega_i = 2\pi f_i$

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 41° and speed is 1720 rpm.[5 points]

c- To drive the motor at a speed of 1000 rpm, a firing angle of 58° 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]