National Exams May 2010

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- Explain the effect of load inductances on the output voltage of an ac controller. [5 points]

A single-phase, 220 V (rms,) 60-Hz source supplies a full-wave a.c voltage controller. The controller powers a 20-hp motor whose power factor angle is $\phi = 20^o$. The corresponding conduction angle is $\gamma = 160^o$.

b- Verify that the delay angle is $\alpha = 40^o$. [5 points]

c- Find the effective (rms) output voltage of the controller. [5 points]

d- Assume that the efficiency of the motor is 0.87; find the average current through each of the thyristors of the controller. [5 points]

PROBLEM 2

a- Explain why is it necessary to use snubbers in power electronic circuits [5 points]

The ac supply voltage to a controlled half-wave rectifier is 220 V. The load circuit consists of a resistance R in series with a dc source E_c (the internal EMF of a dc motor.) When the average value of the dc output current is 32 A, the conduction angle is $\gamma = 145^o$, and $\alpha_{min} = 21^o$

b- Find the value of the dc source E_c, the delay angle α, and the load resistance R [7.5 points]

c- Assume that the delay angle is adjusted to $\alpha = 30^o$, find the average power absorbed by the dc source E_c. What is the motor's horsepower output value under these conditions [7.5 points]

PROBLEM 3

a- Explain how harmonics arise in an electric power distribution system, and list three ways of mitigating their effects. [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 240 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:

$R = 6\,\Omega$ $\qquad\qquad$ $\omega L = j4\Omega$

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 meaning of the term forced-commutation, and list at least three factors that need to be taken into consideration when designing a forced commutation circuit. [5 points]

The load on a basic chopper circuit consists of a series combination of R = 0.25 Ω and an inductance $L=0.8\times10^{-3}$ H. The period of the chopper is 2.5 ms. The minimum value of the output current is 90 A, and its maximum value is 100 A. It is required to find:

b- The on time of the chopper. [5 points]

c- The value of the dc source voltage. [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- What are the operational differences between an IGBT and a GTO. [4 points]

A three phase, eight pole, 60 Hz, 440-V, induction motor is operated in a constant V/f mode. The stator resistance is $0.125\,\Omega$. Assume that operation is at maximum torque of 1350 N.m., and that the rotor resistance is $0.175\,\Omega$.

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 35 rad/s, find the required supply frequency and voltage. [4 points]

PROBLEM 6

a- Give a list of the three 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 separately excited d.c motor is controlled using a three phase full wave bridge rectifier circuit connected to the armature terminals. The a.c. voltage source is 440 V (line-to-line). The motor draws an armature current of 212 A all the time.

b- Find the firing angle of the rectifier circuit when the armature voltage is 220 V, and speed is 1760 rpm. [5 points]

c- To drive the motor at a speed of 900 rpm, a firing angle of 78° 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 73°. Find the corresponding speed of the motor. [5 points]