National Exams May 2017

16-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 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 $\gamma = 162.5^o$. The controller powers an ac motor operating at a 0.875 power factor, lagging. The average current through each thyristor is 625 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- List and discuss five factors that influence the duration of the turn-off interval of an SCR. [5 points]

The ac supply voltage to a half-wave controlled rectifier is 120 V. The load circuit consists of a resistance R in series with an inductance L. The power factor of this load is 0.707.

b- Find the value of the delay angle α when the conduction angle is $\gamma = 147^o$. Find the load resistance R when the average value of the dc output current is 25 A. [7.5 points]

c- Assume that the conduction angle is adjusted to $\gamma = 152^o$, find delay angle α and the average value of the dc output current with R = 1.1 Ω [7.5 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 = 10 Ω $\omega L = j12.5\Omega$

c- The modulation angle δ is selected such that the ratio of the fifth harmonic to third harmonic components of the voltage output is 0.225. 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 reasons for using series smoothing reactors in inverter circuits. [5 Points]

The voltage input to a basic chopper circuit is V_i = 28 V. The period of the chopper is 2 ms. The load consists of a series combination of R = 1.8 Ω and an inductance L=0.45x10^{-3} H. The ratio of minimum to maximum values of the output current is 0.75. Determine the following:

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=1.5 ms, respectively [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. [20 points]

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

$R_s = 0.25\Omega$ $X_s = 1.2\Omega$

$R_r = 0.25\Omega$ $X_r = 1.2\Omega$ $X_m = 10.4\Omega$

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. (1.) Complete the table given below:

Input current	Slip	Terminal voltage	Developed Torque
40	?	?	180
45	0.04	?	?
50	?	?	125

Use the following torque formula for constant current operation:

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

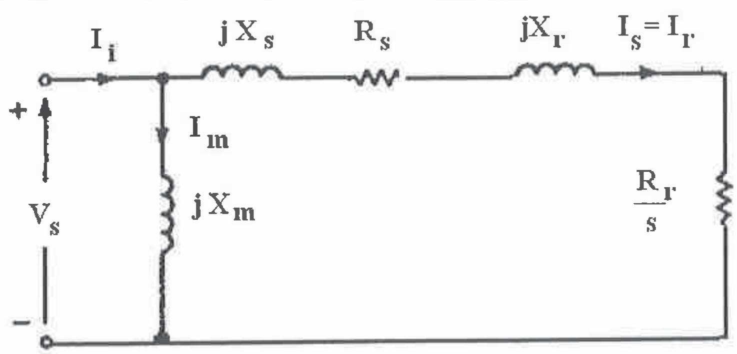

Figure (1) approximate equivalent circuit for Constant current operation of a three phase induction motor

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? [20 points]

A three-phase, full wave, and bridge rectifier circuit feeds the armature terminals of a separately excited dc motor. The ac voltage source is 230 V (line-to-line). Complete the table given below

Case	Supply voltage to rectifier V_{ac}	Rectifier output DC voltage V_{dc}	Rectifier firing angle α	Motor armature resistance R_a	DC motor input current I_a	Motor back emf E_b	Shaft speed in rpm n_s	Motor output torque T_a
A	230	?	45°	R^*_a?	125	?	1720	?
B	230	?	60°	R^*_a?	125	?	1000	?
C	230	?	65°	R^*_a	125	?	?	?
D	230	?	?	R^*_a	100	?	?	?