

National Exams December 2016
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 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 $\gamma = 162.5^\circ$. The controller powers an ac motor operating at a 0.85 power factor, lagging. The average current through each thyristor is 575 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 $\gamma = 147^\circ$. 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 $\gamma = 152^\circ$, find delay angle α and the average value of the dc output current with $R = 1.1 \Omega$ [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:

$$R = 8 \Omega$$

$$\omega L = j6 \Omega$$

- c- The modulation angle δ is selected such that the ratio of the fifth harmonic to third harmonic components of the voltage output is 0.225. 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 $V_i = 24$ V. The period of the chopper is 2 ms. The load consists of a series combination of $R = 1.8 \Omega$ and an inductance $L = 0.45 \times 10^{-3}$ 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. [5 points]

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

$$R_s = 0.2 \Omega$$

$$R_r = 0.22 \Omega$$

$$X_s = 1.1 \Omega$$

$$X_r = 1.5 \Omega$$

$$X_m = 10.417 \Omega$$

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.) 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:

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

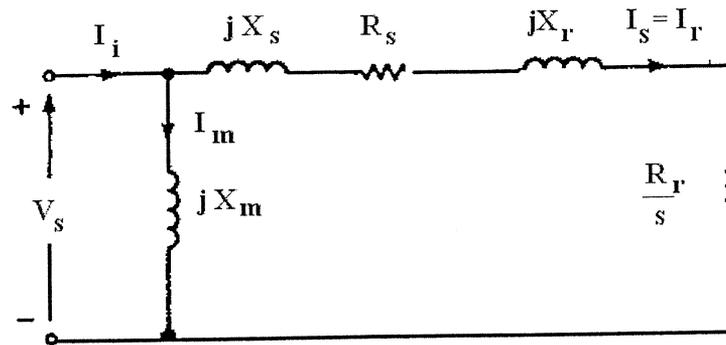


Figure (1) approximate equivalent circuit for Constant current operation of a three phase induction motor

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? [5 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). The motor draws an armature current of 150 A all the time.

b- Find the armature voltage when the firing angle of the rectifier circuit is 43° 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 point]

d- The firing angle is adjusted to 65° . Find the corresponding speed of the motor. [5 points]