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2601/304

**POWER ELECTRONICS, MACHINES
AND UTILIZATION**

June/July 2019

Time: 3 hours



THE KENYA NATIONAL EXAMINATIONS COUNCIL

**DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING
(POWER OPTION)**

MODULE III

POWER ELECTRONICS, MACHINES AND UTILIZATION

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

Answer booklet;

Non programmable electronic calculator;

Drawing instruments.

*This paper consists of **EIGHT** questions in **TWO** sections; **A** and **B**.*

*Answer **THREE** questions from section **A** and **TWO** questions from section **B** in the answer booklet provided.*

All questions carry equal marks.

Maximum marks for each part of a question are as indicated.

*Candidates should answer the questions in **English**.*

This paper consists of 6 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

SECTION A: MACHINES AND UTILIZATION

Answer **THREE** questions from this section.

1. (a) State **four** advantages of individual drives over group drives. (4 marks)

(b) A constant speed motor has the following duty cycle:

- Load rising linearly from 300 kW to 500 kW in 4 minutes;
- Uniform load of 350 kW for 2 minutes;
- Regenerative power returned to supply reducing linearly from 350 kW to zero in 3 minutes;
- Remains idle for 3 minutes.

If the duty cycle is repeated indefinitely, determine the suitable size of a continuously rated motor for the duty-cycle. (11 marks)

(c) The initial temperature of a machine is 40 °C. The machine has a final steady temperature rise of 90 °C and a heating time constant of 2.5 hours. If the ambient temperature is 20 °C, determine the temperature of the machine after 1.4 hours. (5 marks)

2. (a) The power developed by a d.c shunt motor is given by:

$$P_d = E_b I_a \text{ Where:}$$

E_b is the armature back e.m.f and I_a is the armature current, show that the torque (T) developed is proportional to $I_{sh} I_a$. (5 marks)

(b) With the aid of a labelled diagram, explain the rheostatic (armature) speed control method of a d.c shunt motor. (5 marks)

(c) The Hopkinson's test on two similar d.c shunt machines at full load gave the following results:

- Line voltage : 230 V
- Line current excluding field currents : 15 A
- Motor armature current : 75 A
- Armature resistance of each machine is : 0.3 Ω
- Field currents : 1.5 A and 2 A

Determine the motor's efficiency. (10 marks)

3. (a) With the aid of labelled construction and stator coil supply connection diagrams, describe the construction of a variable reluctance stepper motor. (10 marks)
- (b) A 10 kW, 4 - pole, 220 V, 50 Hz reluctance motor has a torque angle of 28° when operating under rated load conditions. Determine the:
- (i) load torque;
- (ii) torque angle if the voltage drops to 210 V. (5 marks)
- (c) With reference to electric traction, describe the d.c system of tract electrification. (5 marks)
4. (a) Explain:
- (i) 'cogging' in three-phase induction motors;
- (ii) how changes in supply voltage and frequency affect the performance of an induction motor. (4 marks)
- (b) A 415 V, 50 Hz, 4 - pole, three-phase, star-connected induction motor has the following parameters referred to stator:
- $$R_1 = 0.1\Omega \quad R'_2 = 0.15\Omega$$
- $$X_1 = 0.4\Omega \quad X'_2 = 0.45\Omega$$
- The motor has stator core loss of 1120 W and rotational loss of 1500 W. It draws a no-load current (line) of 24 A at a power factor of 0.09 (lag). If the motor operates at a slip of 4%, determine the:
- (i) input line current and its power factor;
- (ii) electromagnetic torque in Nm;
- (iii) output power;
- (iv) efficiency. (16 marks)
5. (a) With the aid of a labelled diagram, explain the operation of a vapour absorption refrigeration system. (12 marks)
- (b) State **three**:
- (i) conditions to be fulfilled before an incoming alternator is connected to an infinite bus - bar .
- (ii) advantages of stationary armature as applied to synchronous machines. (6 marks)

- (c) List **two** methods of starting a synchronous motor.

(2 marks)

SECTION B: POWER ELECTRONICS

Answer **TWO** questions from this section.

6. (a) Figure 1 shows a symbol of a semiconductor device:

- (i) name the device;
- (ii) draw its equivalent circuit;
- (iii) with the aid of voltage-current (V/I) characteristic curve, describe the operation of the device. (10 marks)

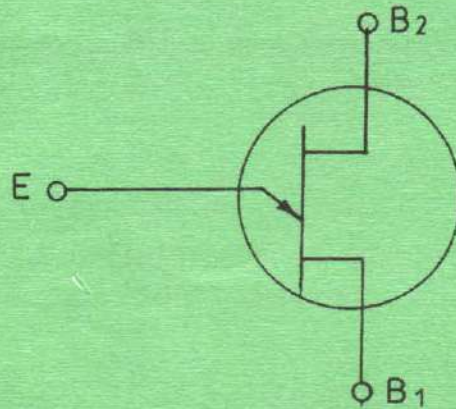


Fig.1

- (b) (i) State **two** advantages of multi-phase rectifier circuits.
- (ii) Show that the expression of output d.c voltage of an n pulse half-wave controlled rectifier with overlap is given by:

$$V_{dc} = \frac{nV_{max}}{2\pi} \sin \frac{\pi}{n} \{ \cos \alpha + \cos(\alpha + \gamma) \}.$$

Where:

α = firing angle;

γ = overlap angle.

(10 marks)

7. (a) State **three** applications of cycloconverters.

(3 marks)

(b) Figure 2 shows an inverter circuit:

- (i) identify the type of inverter;
- (ii) describe the operation of the circuit.

(9 marks)

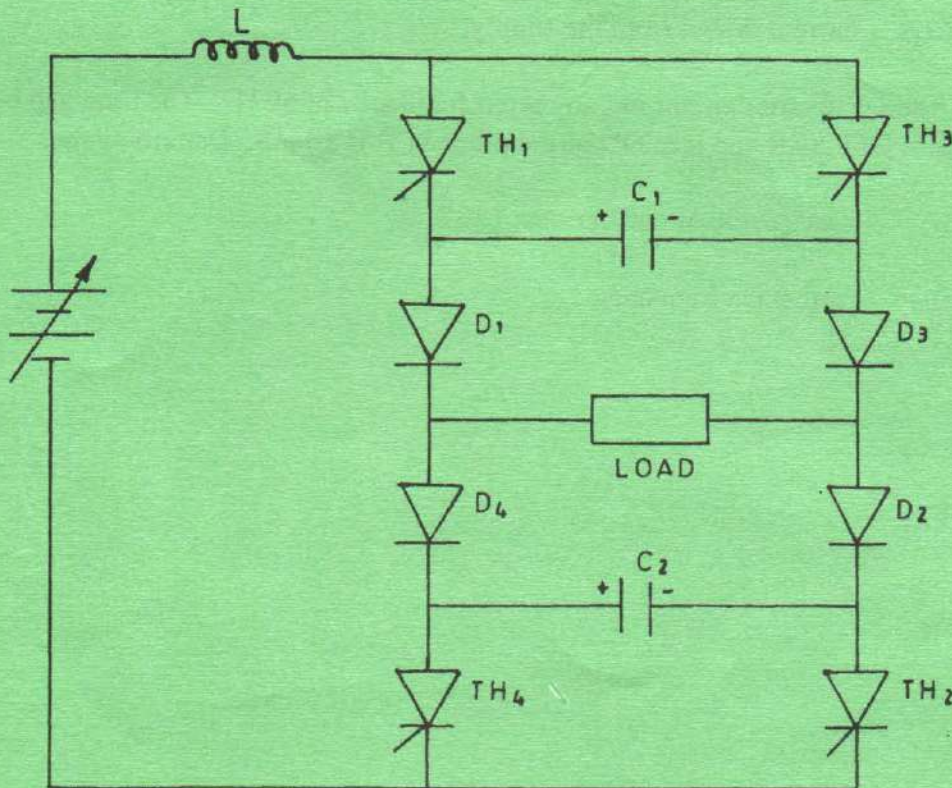


Fig. 2

(c) A single phase 230 V, 50 Hz supply feeds a separately excited d.c motor through two single phase semi-converters. One for the field and one for the armature. The firing angle for the semi-converter for field is zero. The field resistance is 200Ω and armature resistance is 0.3Ω . The load torque is 50 NM at 900 r.p.m. The voltage constant is 0.8 V/A rad/sec and the torque constant is 0.8 N-m/A^2 . Assuming that armature and field current are continuous and constant, determine the:

- (i) field current;
- (ii) firing angle of converter in the armature circuit.

(8 marks)

8. (a) With the aid of diagrams, derive the expression for depth of heat penetration in induction heating.

(8 marks)

- (b) An insulating slab of area 80 cm^2 and 2 cm thick is heated from 20°C to 50°C by dielectric heating in 7 minutes. The supply frequency is 20 MHz and 10% of the heat input to the slab is wasted. Assuming a relative permittivity of 6.5, density of 0.55 g/cm^3 , specific heat capacity of $1.0465 \text{ J/g}^\circ\text{C}$ at a power factor of 0.04, determine the:
- (i) applied voltage;
 - (ii) current drawn from the supply. (8 marks)
- (c) A series inverter circuit has an output frequency of 50 Hz. The time gap between turn OFF SCR and turn ON of the other SCR is 10 mS. Determine the:
- (i) time period of oscillations;
 - (ii) resonance frequency. (4 marks)

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