...of three-phase

2521/304
2601/304
POWER ELECTRONICS, MACHINES
AND UTILIZATION
Oct./Nov. 2022
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:
Non-programmable electronic calculators;
Drawing instruments.
*This paper consists of **TWO** sections; **A** and **B**.*
*Answer **FIVE** questions choosing **THREE** questions from section **A** and **TWO** questions from section **B** in the answer booklet provided.*
Maximum marks for each part of a question are as indicated.
Candidates should answer the questions in English.
Take: $\varepsilon_0 = 8.85 \times 10^{-12}\ F/M$

This paper consists of 7 printed pages.

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

Turn over

SECTION A: MACHINES AND UTILIZATION

*Answer **THREE** questions from this section.*

1. (a) (i) State **two** constructional features differentiating variable reluctance and permanent magnet stepper motors.

(ii) With aid of a labelled diagram, explain the operation of a variable reluctance motor. (8 marks)

(b) With reference to synchronous motors, state **two**:

(i) effects of hunting;
(ii) methods of reducing hunting.

(4 marks)

(c) A 132 kV, three phase, star connected synchronous motor draws a full load current of 100 A at 0.85 p.f leading. The armature resistance is 3.2 Ω and a synchronous reactance of 32 Ω per phase. If the stray losses are 400 W, determine the:

(i) E.m.f. induced E_f;
(ii) power input;
(iii) power output.

(8 marks)

2. (a) With reference to motor rating, explain each of the following duty cycles:

(i) intermittent periodic;
(ii) continuous.

(4 marks)

(b) The temperature rise of a motor is 50°C after 1 hour and 75°C after 2 hours of starting from initial conditions. If the temperature falls from final steady value of 60°C in 1.5 hours when disconnected, the ambient room temperature is 30°C. Determine the:

(i) heating time constant τ;
(ii) final steady temperature rise;
(iii) cooling time constant τ_c.

(12 marks)

(c) For each of the following, state **two**:

(i) merits of using electric drive in rail traction system;
(ii) requirements of electrical traction systems.

(4 marks)

3. (a) (i) State **two** drawbacks of the stator resistance starting method of three-phase induction motors.

(ii) Highlight **two** differences between the approximate equivalent circuit of an induction motor and a power transformer. (4 marks)

(b) A 400 V, 25 hp, 60 Hz, 4 pole, star-connected induction motor has the following per phase impedances referred to stator circuit.

$R_1 = 0.64\,\Omega$ $R_2' = 0.33\,\Omega$

$X_1 = 1.11\,\Omega$ $X_2' = 0.46\,\Omega$

$X_m = 28\,\Omega$

The rotational losses are 1200 W at a slip of 2%.

Determine the:

(i) synchronous speed N_s;
(ii) rotor mechanical shaft speed N_r;
(iii) total referred impedance Z_T;
(iv) stator current I_1.

(12 marks)

(c) With aid of labelled block diagrams, explain each of the following types of drives:

(i) group;
(ii) multi-motor.

(4 marks)

4. (a) With reference to alternators, state **two** advantages of stationary armature windings. (2 marks)

(b) Two 3-phase, star connected alternators A and B supply a total load of 20 MVA at 0.8 lagging p.f at a line voltage of 6.6 kV. The two alternators are rated at 10 MVA, 6.6 kV each. Machine A is operating on full load at 0.85 lagging power factor (p.f.)

(i) Sketch the connection diagram.

(ii) Determine the:

(I) total load current;
(II) current and power factor of machine B.

(7 marks)

(c) (i) Explain the functions of each of the following refrigerant properties in air conditioning and refrigeration:

(I) fluid viscosity;
(II) evaporating pressure.

(ii) With aid of a labelled diagram, explain the function of the parts of a centrifugal compressor air conditioning system.

(11 marks)

5. (a) State **two** merits of back to back test on D.C machines. (2 marks)

(b) With aid of a circuit diagram, show that using the swin burne test method on d.c motor, the efficiency of a motor is given by the expression:

$$\eta = \frac{VI - [(I - I_{sh})^2 r_a + W_c]}{VI}$$

where V is the supply voltage
I is the supply current
I_{sh} is the shunt motor current
r_a is the armature resistance
W_c is constant losses.

(8 marks)

(c) Figure 1 shows the Hopkinson test circuit diagram on two similar shunt machines which gave the following data:

Line voltage = 120 V, Line current = 50 A,
Armature current = 240 A,
Field current for motor and generator are 4A and 4.5 A respectively
Armature resistance of each machine is 0.04 Ω, brush drop = 1 V/brush.

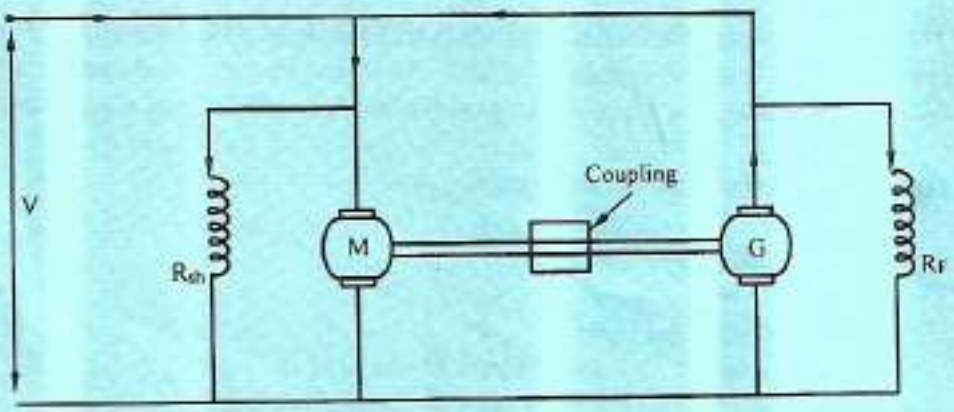

Fig. 1

Determine the:

(i) motor copper losses;
(ii) general copper losses.

(10 marks)

SECTION B: POWER ELECTRONICS

Answer TWO questions from this section.

6. (a) With reference to power MOSFET, explain each of the following regions in the voltage current (V-I) characteristic.

(i) cut-off region;
(ii) active region;
(iii) ohmic region. (6 marks)

(b) With aid of a labelled V-I characteristic curve, describe the operation of a Triac. (7 marks)

(c) A controlled half-wave rectifier has a peak supply voltage of 300 V and a 100 Ω load. For a firing angle of 30°, determine the:

(i) average load voltage;
(ii) average load current;
(iii) load power.

(7 marks)

7. (a) (i) With reference to thyristor inverters, distinguish between line and forced commutation.

(ii) Figure 2 shows a circuit diagram of a series inverter. Determine the:

(I) resonance frequency;
(II) time period of oscillations.

(7 marks)

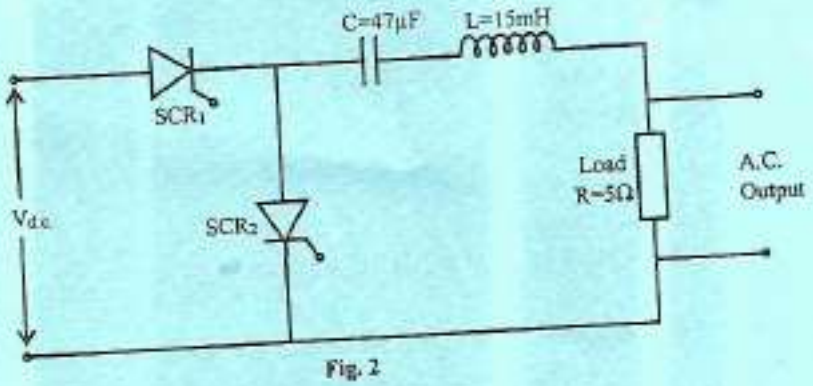

Fig. 2

(b) (i) State **two** areas of application of cycloconverters.

(ii) Figure 3 shows a circuit diagram of a step-down cycloconverter. Describe its operation such that the output frequency f_o equals $\frac{1}{4}$ the supply frequency f_s. (8 marks)

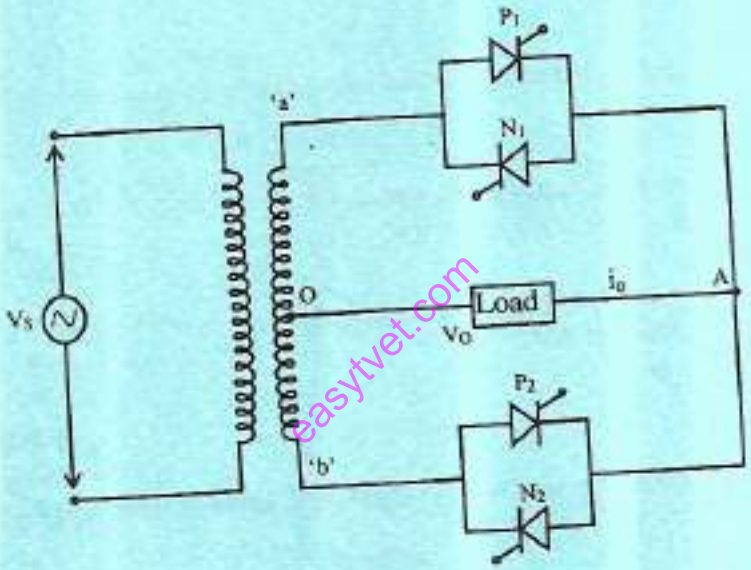

Fig. 3

(c) With aid of labelled torque-speed characteristic curves, explain how the speed of an induction motor may be controlled by varying the frequency. (5 marks)

8. (a) With aid of a labelled diagram, explain the working principle of indirect resistant heating. (5 marks)

(b) In a dielectric heating process, the capacitance formed between the two electrodes is 4.5 μF. If the supply voltage is 900 V and the current flowing through the capacitor is 80 A, determine the supply frequency. (4 marks)

(c) The speed of a separately-excited d.c motor is controlled by a chopper. The circuit has a supply voltage of 110 V, armature circuit resistance of 0.5 Ω and motor constant of 0.05 V/rpm. If the motor drives a constant load torque requiring an average current of 20 A and assuming motor current is continuous, determine the:

(i) range of speed control;
(ii) range of duty cycle.

(9 marks)

(d) State **two** advantages of using thyristors over motor-generator set during speed control of d.c drives. (2 marks)

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