2521/305
2601/305
ELECTRICAL POWER SYSTEMS AND
ELECTROMAGNETIC FIELD THEORY
June/July 2020
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING (POWER OPTION)

MODULE III

ELECTRICAL POWER SYSTEMS AND ELECTROMAGNETIC FIELD THEORY

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Answer booklet;
Non programmable Scientific calculator.
This paper consists of ***EIGHT*** *questions in* ***TWO*** *sections;* ***A*** *and* ***B.***
Answer any ***THREE*** *questions from section* ***A*** *and any* ***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 5 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: ELECTRICAL POWER SYSTEMS

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

1. (a) Explain why an actual surge is less severe than a theoretical one. (2 marks)

   (b) An overhead transmission line having an inductance of 10.5 mH and a capacitance of 0.048 μF is connected in series with a cable having an inductance of 2.4 mH and a capacitance of 1.6 μF. If a surge voltage of 300 kV travels along the overhead transmission line towards the junction, determine the:

   (i) voltage;
   (ii) current.

   (6 marks)

   (c) (i) State **two** assumptions made when analysing the performance of short transmission lines.

   (ii) A three phase, 11 kV, 50 Hz, 16 km long overhead transmission line supplies a load of 1000 kW at 0.8 power factor lagging. If the line resistance and inductance are 0.03 Ω and 0.7 mH per phase per km respectively, determine the:

   (I) sending end voltage;
   (II) voltage regulation;
   (III) transmission efficiency.

   (12 marks)

2. (a) State **three** merits of synchronous phase modifier when used in overhead transmission lines. (3 marks)

   (b) Explain how the following factors affect corona power loss:

   (i) system voltage;
   (ii) density of air;
   (iii) conductor surface.

   (6 marks)

   (c) (i) State **three** factors that determine the choice of span length of an overhead transmission line.

   (ii) An overhead transmission line at a river crossing is supported by two towers of heights 45 m and 75 m above water level with a span length of 300 m. If the weight of the conductor is 0.92kg/m and the working tension is 2040 kg, determine the clearance between the conductor and water level mid way between the towers.

   (11 marks)

Clear = H- Sag

3. (a) State **two** types of:

(i) unsymmetrical faults that occur on a power system;
(ii) symmetrical components.

(4 marks)

(b) With the aid of phasor diagrams, show that the negative phase sequence component of current for a three phase unbalanced system is given by:

$I_{R2} = \frac{1}{3}(\vec{I_R} + \lambda^2\vec{I_Y} + \lambda\vec{I_B})$, where λ is the operator and $\vec{I_R}, \vec{I_Y}$ and $\vec{I_B}$ are the currents in the red, yellow and blue phases. (7 marks)

(c) The voltages across a three-phase unbalanced load are $V_R = 150\angle 0^\circ V, V_Y = 150\angle -90^\circ V$ and $V_B = 300\angle 180^\circ V$. Determine the sequence components of voltages in the red phase. (9 marks)

4. (a) With reference to power system stability, define the following terms:

(i) transfer reactance;
(ii) steady-state limit.

(2 marks)

(b) Figure 1 shows a synchronous generator connected to a synchronous motor through a series impedance (R + jx) Ohms. Show that the maximum power delivered to the synchronous motor is given by

$P_m = \frac{|E_m||E_g|}{X}$, where E_m is the internal voltage of the motor, E_g is the internal voltage of the generator and X is the total series reactance. (8 marks)

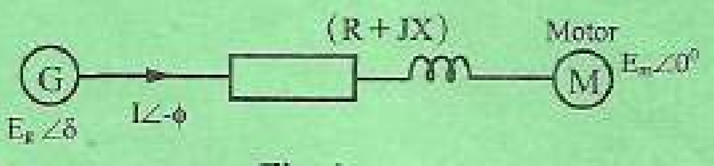

Fig. 1

(c) A generator operating at 50 Hz delivers 1.0 p.u power to an infinite bus through a transmission line in which the resistance is ignored. A fault takes place reducing the amount of power transferable to 0.45 p.u whereas before the fault this power was 1.85 p.u, and after clearance of the fault the power is 1.15 p.u. Use equal area criterion to determine the critical clearing angle. (10 marks)

5. (a) State **three**:

(i) requirements of line protection;

(ii) factors to be considered when selecting a protective system for a transformer.

(6 marks)

(b) With the aid of a labelled diagram, explain the operation of Merz-price circulating current system as used in alternators. (6 marks)

(c) A three phase, 6.6 kV star connected alternator is protected by Merz-price circulating current system. If the current ratio of the current transformer is 300/1 A, the synchronous reactance of the alternator is 5.0 Ω/phase, the minimum operating current for the relay is 0.5 A and the neutral point is earthed through a 2.0 Ω non-inductive resistor, calculate the:

(i) percentage of each stator winding which is protected against earth fault when the machine is operating at normal voltage.

(ii) maximum resistance to provide protection for 95% of the stator winding.

(8 marks)

SECTION B: ELECTROMAGNETIC FIELD THEORY

*Answer any **TWO** questions from this section.*

6. (a) (i) Define 'dot-product' as used in electromagnetic field theory.

(ii) Three electromagnetic field quantities are represented by:

$$\vec{M} = 2a_x - a_z$$
$$\vec{N} = 2a_x - a_y + 2a_z$$
$$\vec{T} = 2a_x - 3a_y + a_z$$

Determine $\vec{N} \cdot (\vec{T} \times \vec{M})$.

(5 marks)

(b) Explain **three** conditions that must be satisfied in the application of Coulomb's law in electrostatics. (3 marks)

(c) (i) State the divergence theorem.

(ii) A vector field in cylindrical co-ordinate system

$\vec{A} = 30\ell^{-1}\hat{a}_\ell - 2z\,\hat{a}_z$ exists over the surface of the cylinder bounded by $\ell = 2, z = 0$ *and* $z = 5$. Evaluate both sides of the equation using divergence theorem.

(12 marks)

7. (a) Define the following terms as used in magnetic fields:

(i) magnetic flux density;
(ii) magnetic field intensity.

(2 marks)

(b) (i) List **three** current distribution configurations in a magnetic field.

(ii) Write the expression for the boundary condition for the normal component of magnetic flux density B, between two different media of relative permeabilities μ_{r1} and μ_{r2} respectively in a magnetostatic field.

(iii) Show that the constant of discontinuity of the normal component of magnetic field strength H across the boundary in b (ii) is given by:

$$\frac{H_{N2}}{H_{N1}} = \frac{\mu_{r1}}{\mu_{r2}}.$$

(7 marks)

(c) (i) Write Maxwell's equations for time varying fields in free space.

(ii) An electromagnetic field in free space has a magnetic flux density

$\vec{B} = B_m\, e^{j(\omega t + \beta z)\hat{a}_y}$. Using Maxwell's equations, show that

$$E_x = \frac{-\omega}{\beta}\, B_m\, e^{j(\omega t + \beta z)\hat{a}_x}.$$

(11 marks)

8. (a) (i) Write an expression for a pure progressive wave.

(ii) Express the wave equation $\nabla^2 E = \mu\varepsilon \dfrac{\partial^2 \vec{E}}{\partial t^2}$ in three dimensions.

(4 marks)

(b) (i) Draw a labelled diagram of a transverse electromagnetic wave.

(ii) Show that in a region where volume charge density

$$\ell_v = 0,\ \frac{\partial^2 \vec{E}_x}{\partial x^2} + \frac{\partial^2 \vec{E}_y}{\partial y^2} + \frac{\partial^2 \vec{E}_z}{\partial z^2} = 0.$$

(7 marks)

(c) A plane electromagnetic wave having a frequency of 10 MHz travels through a lossless medium of relative permittivity (ε_r) and permeability (μ_r) of 3 and 2 respectively. Determine the:

(i) velocity of propagation;
(ii) wavelength;
(iii) intrinsic impedance of the medium.

(9 marks)

THIS IS THE LAST PRINTED PAGE.