2521/305
2601/305
ELECTRICAL POWER SYSTEMS AND ELECTROMAGNETIC FIELD THEORY
Oct./Nov. 2022
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 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.

SECTION A: ELECTRICAL POWER SYSTEMS

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

1. (a) (i) State **three** demerits of induction type over current relay in protection systems.

(ii) Outline **three** limitations of the Mertz-Price protection scheme.

(6 marks)

(b) With aid of a labelled diagram, describe the operation of the differential bus-bar unit protection system. (6 marks)

(c) A conductor of diameter 3 cm is placed centrally through a porcelain bushing of relative permittivity 5. The internal and external diameters of the procelain bushing are 4 cm and 10 cm respectively. The voltage between the conductor and an earthed clamp surrounding the porcelain is 25 KV r.m.s. Determine the:

(i) maximum gradient on the surface of conductor; g_1 max;

(ii) corona value at g_1 max.

(8 marks)

2. (a) Define the following with respect to overhead transmission lines:

(i) crest;
(ii) front.

(2 marks)

(b) A three phase transmission line has conductors each of diameter 3 cm, spaced 2 m apart in an equilateral formation. A voltage wave of 11 kV travels along the lines. Determine the:

(i) inductance per unit length;
(ii) capacitance per unit length;
(iii) natural impedance;
(iv) line current.

(8 marks)

(c) (i) Draw the labelled vector diagrams of the positive, negative and zero sequence component in reference to overhead line faults.

(ii) Derive the expression for the zero component in (i).

(10 marks)

3. (a) (i) Explain the effect of wind and ice loading on conductor sag and tension.

(ii) Describe **two** factors which affect sag on overhead lines.

(7 marks)

(b) Figure 1 shows an overhead transmission line over unequal levels of gradient 1:20 supported by two towers P_1 and P_2. The conductor weight is 0.85 kg/m. The maximum breaking stress is 3000 kg, with a safety factor of 2. The conductor is fixed 20 m below the top of each tower.

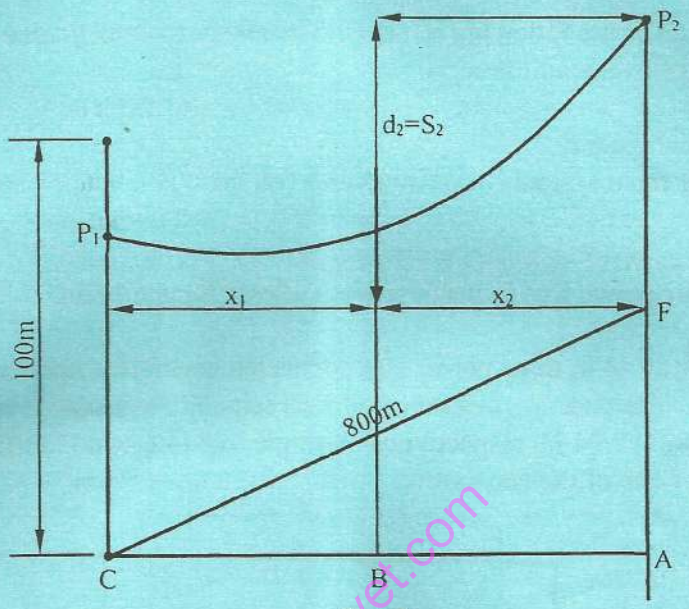

Fig. 1

Determine the:

(i) vertical distance between the two supports;
(ii) horizontal distance between the two supports;
(iii) sag S_2 referenced to tower P_2. (8 marks)

(c) State **five** merits of limiting the phase to ground fault by use of resistance grounding method. (5 marks)

4. (a) State **three** methods used to improve power system transient stability. (3 marks)

(b) Derive an expression for moment of inertia for synchronous machine in power systems stability analysis. (5 marks)

(c) A generator operating at 50 Hz, delivers 2 p.u MW power. A three phase fault occurs reducing the maximum power to 0.6 p.u MW. Before the fault, the power is 2.8 p.u MW and after clearing the fault the power drops to 2.2 p.u MW. Determine the;

(i) ratio of maximum power during and after fault, K_1;
(ii) ratio of maximum power after and before the fault, K_2;
(iii) maximum rotor angle δm;
(iv) initial power angle δ_0;
(v) critical clearing angle δ_c.

(8 marks)

(d) Explain each of the following terms with reference to time graded over current protection of overhead lines:

(i) radial feeder;
(ii) ring main system.

(4 marks)

5. (a) Outline **four** power line faults in power systems transmission. (2 marks)

(b) Two 33 kV, 20 MW, three phase, star connected generators operate in parallel as shown in figure 2. The positive, negative and zero sequence reactances are j 0.08 p.u, j 0.06 p.u and j 0.04 Pu respectively. A single line to ground fault occurs at the terminals of one of the generators.

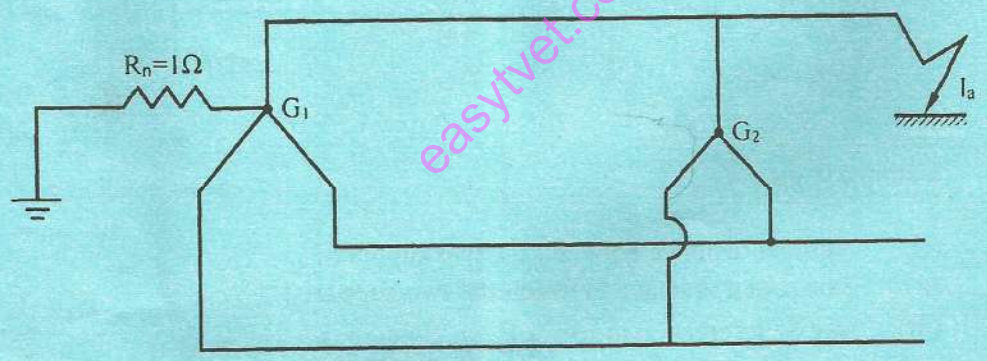

Fig. 2

Determine the:

(i) actual positive sequence reactance;
(ii) actual negative sequence reactance;
(iii) impedance;
(iv) fault current;
(v) current in the grounding resistor.

(8 marks)

(c) Explain **two** effects of voltage variations in power systems. (2 marks)

(d) A 200 km long, three phase, 50 Hz transmission line delivers 30 MW at a power factor 0.85 lagging to a 66 kV balanced load. The resistance of the line is $0.08\,\Omega/km$. The conductor diameter is 2 cm equilaterally spaced 3 m between the centres. Using the nominal T method, determine the:

(i) impedance per phase;
(ii) capacitive susceptance;
(iii) receiving end current in complex form;
(iv) voltage drop V_1 across the capacitor.

(8 marks)

SECTION B: ELECTROMAGNETIC FIELD THEORY

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

6. (a) Distinguish between electric and magnetic dipoles with reference to electromagnetic fields. (2 marks)

(b) Figure 3 shows a point charge of $60\,\mu C$ at point (0, 0, 10) m. Determine the:

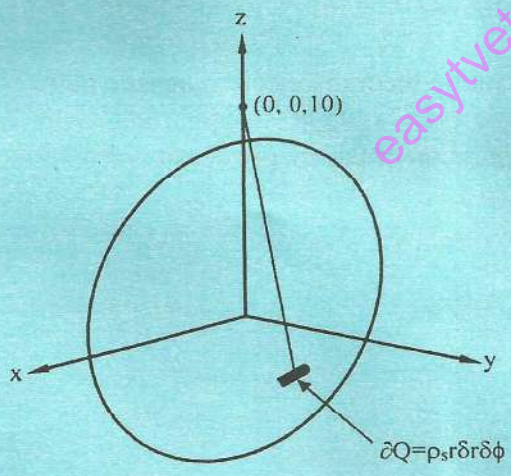

Fig. 3

(i) charge density;
(ii) force on the charge due to a circular plate of charge $600\,\pi\mu C$ at a radius $r \leq 10\,m$, z = 0 m.

(8 marks)

(c) State the Amperes circuital law. (2 marks)

(d) (i) Outline **three** types of radiations detected by electromagnetic detectors.

(ii) With aid of a diagram, explain the construction of the Geiger-Muller counter detector in electromagnetics. (8 marks)

7. (a) Describe electromagnetic shielding. (2 marks)

(b) A uniform wave propagating in free space strikes a lossy medium with a dielectric constant of 20 and conductivity $0.8\,m\,S/m$. The frequency of the wave polarized in the x-direction is 200 kHz. Determine the;

(i) angular frequency, ω;
(ii) propagation constant, Y;
(iii) intrinsic impedance η;
(iv) phase velocity, μp.

(8 marks)

(c) (i) Outline **three** sources of electromagnetic radiations.

(ii) A conductor of length 10 cm carries a current of 2 A in a vertical direction. A point P is placed 1 m away from the conductor in the x - direction.

(I) sketch the arrangement;
(II) determine the angle between vertical axis and point P;
(III) magnetic field at point P using Biot - Savart law.

(10 marks)

8. (a) (i) Describe the energy conservation theory in electromagnetic fields.

(ii) Write the Mathematical expression of the energy density of:

(I) electric field;
(II) magnetic field.

(4 marks)

(b) Figure 4 shows an electromagnetic wave propagating across two media. The magnetic field density of the wave is given by the expression:

$$B_1 = (1.5\,a_x + 0.9\,a_y + 0.6\,a_z)\,T$$

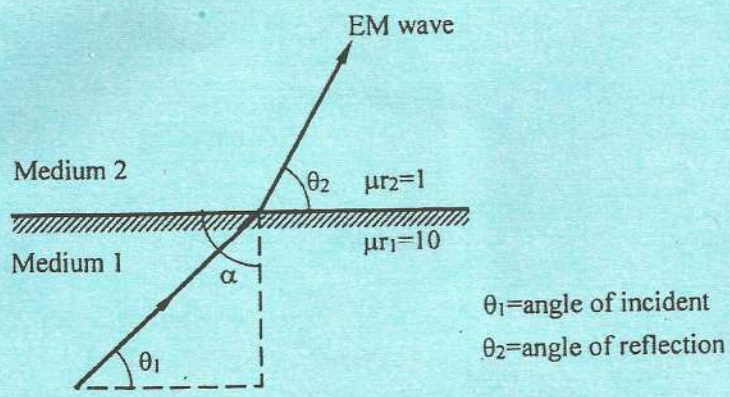

Fig. 4

Determine the:

(i) expression for magnetic field intensity in plane 1, H_1 in medium 1;
(ii) angle of incident θ_1;
(iii) angle of reflection θ_2.

(6 marks)

(c) Distinguish between velocity of wave propagation and wave length with reference to electromagnetic waves. (2 marks)

(d) The electric field intensity of a uniform plane wave in free space is given by the expression:

$$E = 98\cos(\omega t + 8z)\overrightarrow{a_x}$$

Determine the:

(i) wave frequency;
(ii) wave length;
(iii) electric field intensity;
(iv) average power density.

(8 marks)

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