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MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

THIRD YEAR SECOND SEMESTER EXAMINATIONS

FOR THE DEGREE OF

BACHELOR OF SCIENCE
IN
ELECTRICAL AND COMMUNICATIONS ENGINEERING

COURSE CODE: ECE 327

COURSE TITLE: ELECTRICAL MACHINES III

DATE: THURSDAY, APRIL, 28TH, 2022. **TIME: 3:00 – 5:00 PM**

INSTRUCTIONS TO CANDIDATES

ANSWER QUESTION ONE AND ANY OTHER TWO QUESTIONS.
QUESTION ONE CARRIES 30 MARKS AND ALL OTHERS 20 MARKS EACH.

TIME: 2 Hours

Question One (30 marks)

(a) State two differences between the windings of the three-phase induction motor and single-phase induction motor. **[2 marks]**

(b) (i) Explain the working principle of a synchronous motor. **[6 marks]**

(ii) State and explain three applications of synchronous motors. **[3 marks]**

(c) A three-phase, Y-connected synchronous generator supplies current of 10A having phase angle of 20° lagging at 400 V. Find the load angle and the components of armature current I_d and I_q if $X_d = 10\ \Omega$ and $X_q = 6.5\ \Omega$. Assume armature resistance is negligible. **[3 marks]**

(d) A 180-V, 50-Hz, 4-pole, single-phase induction motor is rotating in the clockwise direction at a speed of 1210 rpm. Determine:

(i) its per-unit slip in the direction of rotation and in the opposite direction.
(ii) the effective rotor resistance in each branch if the rotor resistance at standstill is 10Ω.
[5 marks]

(e) Draw the graph of current against time showing the ac component of a symmetrical short circuit current occurring in a synchronous generator and indicate the different periods. Write the formula for I (t). **[4 marks]**

(f) A 75kW, three-phase, Y connected, 50 Hz, 440 V cylindrical rotor synchronous motor operates at rated condition with 0.8 power factor leading. The motor efficiency excluding field and stator losses is 95% and $X_S = 2.5\Omega$ Calculate:

(i) the mechanical power developed,
(ii) the armature current,
(iii) the back emf,
(iv) the power angle,
(v) the maximum or pull-out torque of the motor. **[7 marks]**

Question Two (20 marks)

(a) Draw and label the equivalent circuit of a single-phase induction motor (without core losses). Write equations for impedances of forward and backward running rotor. **[6 marks]**

(b) (i) Draw the equivalent circuit of a synchronous generator. **[2.5 marks]**

(ii) Write the armature circuit equation of an alternator and draw its phasor diagram at lagging power factor load. **[3.5 marks]**

(c) A 100MVA, 13.5kV, 60Hz, star connected synchronous generator is operating at the rated voltage and no-load when a three-phase fault develops at its terminals. Its parameters per unit to the machines own base are given as:

$$X_S = 1.0, \quad X' = 0.25, \quad X'' = 0.12, \quad T' = 1.105, \quad T'' = 0.045$$

If the initial dc component averages 50% of initial ac component, calculate:

(i) the ac component in the generator after the fault occurs,

(ii) the total current (ac and dc) just after the fault occurs,

(iii) the ac component after 5 seconds. **[8 marks]**

Question Three (20 marks)

(a) Mention six disadvantages of single-phase induction motors. **[3 marks]**

(b) (i) Explain the armature reaction that occurs when a generator is supplied with a load at lagging, leading and at unity power factor. **[3 marks]**

(ii) Draw the phasor diagram of an alternator loaded with a load of zero power factor leading (show all three phases of E and I). **[2 marks]**

(iii) Using the diagram in (ii), write the equations for instantaneous values of currents I_A, I_B and I_C and fluxes Φ_A, Φ_B and Φ_C at time $\omega t = 0$, when the alternator is supplying current at a leading power factor. **[3 marks]**

(c) A 3000 kVA, 6-pole alternator runs at 1000rpm in parallel with other machines on 3300V bus-bars. The synchronous reactance is 25%. Calculate the synchronizing power for one mechanical degree of displacement and the corresponding synchronizing torque.**[4 marks]**

(d) (i) Define the term compounding curves. **[1 mark]**

(ii) Draw V-curves of a synchronous motor for full-load, half-load and no-load. Compare the field current for leading power factor of 0.8 at full-load and no-load. **[3 marks]**

(iii) Sketch the graph between power factor and field current at half load. **[1 mark]**

Question Four (20 marks)

(a) State and explain methods used for synchronizing alternators. **[3 marks]**

(b) (i) State four methods used to make a single-phase induction motor self-starting. **[2 marks]**

(ii) Explain the working principle of a shaded pole single-phase induction motor.**[4 marks]**

(iii) State two advantages, two disadvantages and two applications of a shaded pole single-phase induction motor. **[3 marks]**

(c) State four conditions that must be satisfied for the proper synchronization of alternators. **[4 marks]**

(d) A three-phase, star connected alternator supplies a load of 10MW at a lagging power factor of 0.85 and at a terminal voltage of 11kV. Its resistance is 0.1Ω per phase and synchronous reactance is 0.66Ω per phase. Calculate the line value of e.m.f generated. **[4 marks]**

Question Five (20 marks)

a) Draw the speed-torque characteristic of a single-phase induction motor. Show the resultant torque, torque due to forward field and torque due to backward field. **[3 marks]**

b) State and explain two methods of starting a synchronous motor. **[4 marks]**

c) (i) Define the term locked rotor torque. **[1 mark]**

(ii) State the purpose of the phase splitter. **[1 mark]**

d) The main and auxiliary windings of a hypothetical 140 V, 50 Hz, split-phase induction motor have the following locked-rotor parameters:

$$R_{mw} = 4\Omega, \quad X_{mw} = 5.5\Omega, \quad R_{aw} = 11.2\Omega, \quad X_{aw} = 9.8\Omega$$

The motor is connected to a 140 V system. Determine:

(i) the locked rotor current in each winding,

(ii) the phase-displacement angle between the main and auxiliary currents,

(iii) the locked rotor torque in terms of the machine constant. **[6 marks]**

e) (i) State the two types of rotors of a synchronous machine. **[1 mark]**

(ii) Mention four characteristics for each of the stated rotors. **[4 marks]**