MACHAKOS UNIVERSITY

University Examinations for 2022/2023 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

THIRD YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL & ELECTRONIC ENGINEERING)

EEE 315: ELECTRICAL MACHINES III

DATE: **TIME:**

INSTRUCTIONS: This examination paper contains five questions. Answer **Question ONE** and any other **TWO Questions**. Question ONE carries 30 Marks and ALL the other questions carry 20 Marks each.

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Give three applications of synchronous machines (3 marks)

b) Draw a complete well labelled per phase equivalent circuits with their corresponding phasor diagrams for both the synchronous motor and generator (8 marks)

c) What are the two methods which are normally used to start a synchronous motor? (2 marks)

d) The following test data are obtained for a 3φ, 195MVA, 15kV, 60Hz star-connected synchronous machine used in a ship.

Open circuit test:

$I_f(A)$	150	300	450	600	750	900	1200
(V_{L-L} (kV)	3.75	7.5	11.2	13.6	15	15.8	16.5

Short-circuit test:

$\boldsymbol{I_f}$ = 750A; I_a = 7000A

The armature resistance is very small.

i) Draw the open-circuit characteristic, the short-circuit characteristic, the air gap line, and the modified air gap line. (3 marks)

ii) Determine the unsaturated and saturated values of the synchronous reactance in ohms and also in pu. (4 marks)

iii) Find the field current required if the synchronous machine is to deliver 100MVA at rated voltage, at 0.8 leading power factor. (3 marks)

e) A 3-phase, 11kV, 10MW, star connected synchronous generator has a synchronous impedance of (0.6 +j10.0) Ω per phase. If the excitation is such that the open circuit voltage is 12kV, Determine;

i) Maximum output of the ship generator. (3 marks)

ii) Current and pf at the maximum output. (4 marks)

QUESTION TWO (20 Marks)

a) A 3Ø, 5MVA, 11kV, 60Hz synchronous machine has a synchronous reactance of 10 Ohms per phase and a negligible stator resistance. The machine is connected to the 11kV, 60Hz bus and is operated as a synchronous condenser.

Neglect rotational losses:

i) For normal excitation, find the stator current, Draw the phasor diagram. (4 marks)

ii) If the excitation is increased by 150 percent of the normal excitation, find the stator current and power factor, Draw the phasor diagram. (4 marks)

iii) If the excitation is decreased to 50 per cent of the normal excitation, find the stator current and power factor, draw the phasor diagram. (4 marks)

b) If the rotational losses are 80kW, find the stator current and excitation voltage for a normal excitation, Draw the phasor diagrams. (8 marks)

QUESTION THREE (20 MARKS)

a) A 3Ø, 5MVA, 11kV, 60Hz synchronous machine has a synchronous reactance of 10 ohms per phase and a negligible stator resistance. The machine is connected to the 11kV, 60Hz bus and is operated as a synchronous condenser.

Neglect rotational losses.

i) For normal excitation, find the stator current, Draw the phasor diagram (4 marks)

ii) If the excitation is increased by 150 percent if the normal excitation, find the stator current and power factor, Draw the phasor diagram. (4 marks)

iii) If the excitation is decreased to 50 per cent of the normal excitation, find the stator current and power factor, draw the phasor diagram. (4 marks)

b) If the rotational losses are 80kW, find the stator current and excitation voltage for a normal excitation, Draw the phasor diagrams. (8 marks)

QUESTION FOUR (20 MARKS)

A 3Ø, 5kVA, 208V, four pole, 60 Hz, star connected synchronous machine has a negligible stator winding resistance and a synchronous reactance of 8 ohms per phase at the rated terminal voltage.

The machine is first operated as a generator in parallel with a 3Ø,208V, 60Hz supply.

i) Determine the excitation voltage and the power angle when the machine is delivering rated kVA at 0.8pf lagging. Draw the phasor diagram for this condition. (6 marks)

ii) If the filed excitation current is now increased by 20 percent (without changing the prime mover power), find the stator current, power factor, and reactive kVA Supplied by the machine. (10 marks)

iii) With the field current as in (i) the prime mover is slowly increased. What us the steady-state (or static) stability limit? Power factor, and reactive power at this maximum power transfer condition? (4 marks)

QUESTION FIVE (20 MARKS)

A 3phase, 2000kVA, 11kV, 1800rpm synchronous generator has a resistance of 1.5ohms and a synchronous reactance of 15 ohms per phase

a) The field current is adjusted to obtain the rated terminal voltage at open circuit.

i) Determine the excitation voltage (E_f). (2 marks)

ii) If a short circuit is applied across the machine terminals, find the stator current. . (2 marks)

b) The synchronous machine is next to connected to an infinite bus. The generator is made to deliver the rated current at 0.8 power factor lagging.

i) Determine the excitation current (E_f) (2 marks)

ii) Determine the percentage increase in the field current relative to the field current in part (a) (2 marks)

iii) Determine the maximum power the synchronous machine can deliver for the excitation current of part (b). Neglect (R_a) (2 marks)

c) In a factory, a 3phase, 4kV 400kVA synchronous machine is installed along with other induction motors. The following are the loads on the machines:

Induction motor: 500kVA at 0.8 PF lagging

Synchronous motor: 300kVA at 1.0 PF

i) Compute the overall power factor of the factory' (4 marks)

ii) To improve the factory pf, the synchronous machine is over-excited (to draw leading current) without change in its load. Without overloading the motor, to what extent can the factory pf be improved? Find the current and power factor of the synchronous motor for this condition. (6 marks)