MACHAKOS UNIVERSITY

University Examinations for 2021/2022

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

THIRD YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 315: ELECTRICAL MACHINES III

DATE: 9/12/2021 **TIME: 8.30-10.30 AM**

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) What are the required conditions to be met before the incoming synchronous generator is connected to the infinite bus? (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 data are obtained for a 3phase, 10MVA, 14kV, Star connected synchronous machine. (10 marks)

$I_f A$	Open Circuit voltage(kV) (line-line)	Airgap line voltage(kV) (line-line)	short circuit current(A)
100	9.0		
150	12.0		
200	14.0	18	490
250	15.3		
300	15.9		
350	16.4		

The armature resistance is 0.07 Ohm per phase.

i) Find the unsaturated and saturated values of the synchronous reactance in ohms and also in pu.

ii) Find the field current required if the synchronous generator is connected to an infinite bus and delivers rated MVA at 0.8 lagging power factor

iii) If the generator, operating as in part (ii), is disconnected form the infinite bus without changing the field current, find the terminal voltage.

e) The following open Circuit Characteristics (OCC) was obtained in a case of a 3-phase, 6000V synchronous Machine(SM) running at normal speed:

Field current,	*A:*	*14*	*18*	*23*	*30*	*43*
Terminal Voltage, V:		*4000*	*5000*	*6000*	*7000*	*8000*

The field current is 17A when armature is short circuited and the full load current is flowing. Using synchronous impedance method, determine the voltage regulation of the SM supplying the full load of 200kVA at 0.707 lagging: (7 marks)

QUESTION TWO (20 MARKS)

a) A 1000kW, 3-phase, star connected, 3.3kV, 24-pole, 50Hz synchronous motor has a synchronous reactance of 3.24Ω per phase; the resistance being negligible.

i) The motor is fed from infinite bus-bars at 3.3kV, Its field excitation is adjusted to result to unity pf operation at rated load. Compute the maximum power and torque that the motor can deliver with its excitation remaining constant at this value. (8 marks)

ii) The motor is now fed from a 1200 kVA, 3-phase star-connected, 3.3 kV, 2-pole, 50 Hz synchronous generator with a synchronous reactance of 4.55Ω per phase, the resistance being negligible. Compute the field excitations of motor and generator set when is operating at rated terminal voltage of unity pf and the motor is delivering full-load power. The field excitations of both the machines remaining constant, the motor load is gradually raised. Compute the maximum power and torque that the motor can deliver. Also compute the terminal voltage when the motor is delivering maximum power. (6 marks)

b) A 3300 V, star-connected synchronous motor is operating at constant terminal voltage and constant excitation. Its synchronous impedance is 0.8 + j5Ω. It operates at a power factor of 0.8 leading when drawing 800 kW from the mains. Find its power factor when the input is increased to 1200 kW, excitation remaining constant. (6 marks)

QUESTION THREE (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 is the steady-state (or static) stability limit, Power factor, and reactive power at this maximum power transfer condition**?** (4 marks)

QUESTION FOUR (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 FIVE (20 MARKS)

a) A 3∅, 60Hz, supply and a two 3Φ synchronous machines are available. Determine, the speed and the suitable number of poles, for each of the synchronous machine to provide. (5 marks)

i) A 3∅,180Hz supply

ii) A 3∅, 500Hz Supply

b) A 3∅, synchronous condenser has $X_{s=}1.2pu$. The maximum field current is limited to 2.5 times the rated field current. The rated field current produces rated terminal voltage at open circuit. Determine the maximum reactive power that the synchronous condenser can provide. (5 marks)

c) A 3∅,20kVA, 208V. four-pole star-connected synchronous machine has a synchronous reactance of X_s =1.5 ohm per phase. The resistance of the stator winding is negligible. The machine is connected to a 3∅, 208V infinite bus, Neglect rotational losses.

i) The field current and the mechanical input power are adjusted so that the synchronous machine delivers 10kW at 0.8 lagging power factor. Determine the excitation voltage (E_f) and the power angle (δ). (5 marks)

ii) The mechanical input power is kept constant, but the field current is adjusted to make the power factor unity. Determine the percentage change in the field current with respect to its value in part (i) (5 marks)