MACHAKOS UNIVERSITY COLLEGE

SECOND SEMESTER EXAMINATION 2018/2019

FOURTH YEAR SUPPLEMENTARY EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONICS ENGINEERING

EEE 315 ELECTRICAL MACHINES III

DATE: 21ST AUGUST, 2019 **TIME: 8.00 A.M - 10.00 P.M**

INSTRUCTIONS

This paper consists of **FIVE** questions.

Answer **QUESTION 1** and ANY **OTHER TWO** questions.

Question 1 carries 30 marks and is COMPULSORY.

---

1. (a) The following data are taken from the open- and short-circuit characteristics of a 45-kVA 3-phase Y-connected 220-V (line-to-line) 6-pole 60-Hz synchronous machine. From the open-circuit characteristic

Line-to-line voltage = 220 V Field current = 2.84A

From the short-circuit characteristic

Armature current (A)	118	152
Field current(A)	2.20	2.84

From the air-gap line

Field current = 2.20A Line-to-line voltage = 202 V

Calculate:

(i) the unsaturated value of the synchronous reactance

(ii) its saturated value at rated voltage

(iii) the short-circuit ratio

Express the synchronous reactance:

(iv) in ohms per phase

(v) in per unit on the machine rating as a base

(6 marks)

(b) For the 45-kVA 3-phase Y-connected synchronous machine of Question 1(a), at rated armature current (118A) the short-circuit load loss (total for three phases) is 1.80 kW at a temperature of 25ºC. The dc resistance of the armature at this temperature is 0.0335 Ω/phase. Calculate the armature effective resistance in per unit and in ohms per phase at 25ºC.:

(i) in per unit

(ii) in ohms per phase at 25ºC.

(6 marks)

(c) A 1492 kVA 1.0-power-factor 3-phase Y-connected 2300-V 30-pole 60-Hz synchronous motor has a synchronous reactance of 1.95Ω/phase. Neglecting all losses:

(i) calculate the maximum torque in newton-meters which this motor can deliver if it is supplied with power from a constant-frequency source, commonly called an *infinite bus*, and it its field excitation is constant at the value which could result in 1.00 power factor at rated load.

(ii) Instead of the infinite bus of part (i) suppose that the motor is supplied with power from a 3-phase Y-connected 2300-V 1750-kVA 2-pole 3600-r/min turbine generator whose synchronous reactance is 2.65 Ω/phase. The generator is driven at rated speed, and the field excitations of generator and motor are adjusted so that the motor runs at 1.00 power factor and rated terminal voltage at full load. The field excitations of both machines are then held constant, and the mechanical load on the synchronous motor is gradually increased. Calculate:

a) the maximum motor torque under these conditions, and
b) the terminal voltage when the motor is delivering its maximum torque.

(6 marks)

(d) Data are given in Figure Question 1(d) with respect to the losses of the 45-kVA synchronous machine of part(a) and part(b). Calculate its efficiency when running as a synchronous motor at a terminal voltage of 230 V and with a power input to its armature of 45 kW at 0.80 power factor, leading current. The field current measured in a load test taken under these conditions is $I_f(\text{test}) = 5.50\text{A}$.

(6 marks)

(e) A 100-MVA, 13.5 kV, Y-connected, 3-phase 60-Hz synchronous generator is operating at the rated voltage and no load when a three-phase fault develops at its terminals. Its reactances per unit to the machine's own base are:

$X_s = 1.0 \qquad X' = 0.25 \qquad X'' = 0.12$

and its time constants are:

$T' = 1.10s \qquad T'' = 0.04s$

The initial dc component in this machine averages 50 % of the initial ac component.

(i) What is the ac component of current in this generator the instant after the fault occurs?
(ii) What is the total current (ac plus dc) flowing in the generator right after the fault occurs?
(iii)What will the ac component of the current be after 2 cycles? After 5 cycles?

(6 marks)

2. (a) A 150 kW 2300-V 3-phase 60-Hz 28-pole 257-r/min synchronous motor is initially operating unloaded. Calculate the maximum shaft load which can be suddenly applied to the motor. Assume a synchronizing power, P_s = 11.0 kW/elec deg, to be the initial slope of the power-angle curve followed under these conditions. Ignore damping.

(10 marks)

(b) A 2-pole, 50 Hz, 11kV, turbo-generator has a rating of 60 MW, power factor 0.85 lagging. It's rotor has a moment of inertia of 8,800 kg-m2. Calculate:

(i) its inertia constant in MJ per MVA and
(ii) its momentum in MJ-s/electrical degree.

(10 marks)

3. (a) A 100 MVA synchronous generator operates on full load at a frequency of 50Hz. The load is suddenly reduced to 50 MW. Due to time lag in governor system, the steam valve begins to close after 0.4 seconds. Calculate the change in frequency that occurs in this time. Given: H = 5 kW-s/kVA of generator capacity.

(10 marks)

(b) A generator is delivering rated power of 1.0 per unit to an infinite bus through a lossless network. A 3-phase fault under this condition reduces P_{max} to 0 per unit. The value of P_{max} before fault is 2.0 per unit and 1.5 per unit after fault clearing. If the fault is cleared in 0.05 second, calculate rotor angles at intervals of 0.05 second from t = 0 second to 0.1 second. Assume H = 7.5 MJ/MVA and frequency to be 50 Hz.

(10 marks)

4. (a) A 50 Hz, 4-pole turbo-generator rated 20 MVA, 13.2 kV has an inertia constant of H = 9.0 kW-s/kVA. Calculate the kinetic energy stored in the rotor at synchronous speed. Calculate the acceleration if the input less the rotational losses is 25,000 hp and the electric power developed is 15,000 kW. If the acceleration computed for the generator is constant for a period of 15 cycles, calculate the change in torque angle in that period and the rpm at the end of 15 cycles. Assume that the generator is synchronized with a large system and has no accelerating torque before the 15-cycle period begins.

(10 marks)

(b) A 50 Hz, 4-pole turbo-generator rated 100 MVA, 11kV has an inertia constant of 8.0MJMVA.

(i) Calculate the stored energy in the rotor at synchronous speed
(ii) If the mechanical input is suddenly raised to 80 MW for an electrical load of 50 MW, calculate the rotor acceleration neglecting mechanical and electrical losses.

(10 marks)

5. (a) With the aid of suitable diagrams, explain the *equal area criterion*.

(10 marks)

(b) A 480 V, 50 Hz, Y-connected, 6-pole synchronous generator is rated at 50 kVA at 0.8 p.f lagging. It has a synchronous reactance of 1.0Ω per phase. Assume that this generator is connected to a steam turbine capable of supplying up to 45 kW. The friction and windage losses are 1.5 kW, and the core losses are 1.0 kW.

(i) Sketch the capability curve for this generator, including the prime-mover power limit.
(ii) Can this generator supply a line current of 56 A at 0.7 p.f lagging? Why or why not?
(iii) What is the maximum amount of reactive power this generator can produce?
(iv) If the generator supplies 30kW of real power, what is the maximum amount of reactive power that can be simultaneously supplied?

(10 marks)

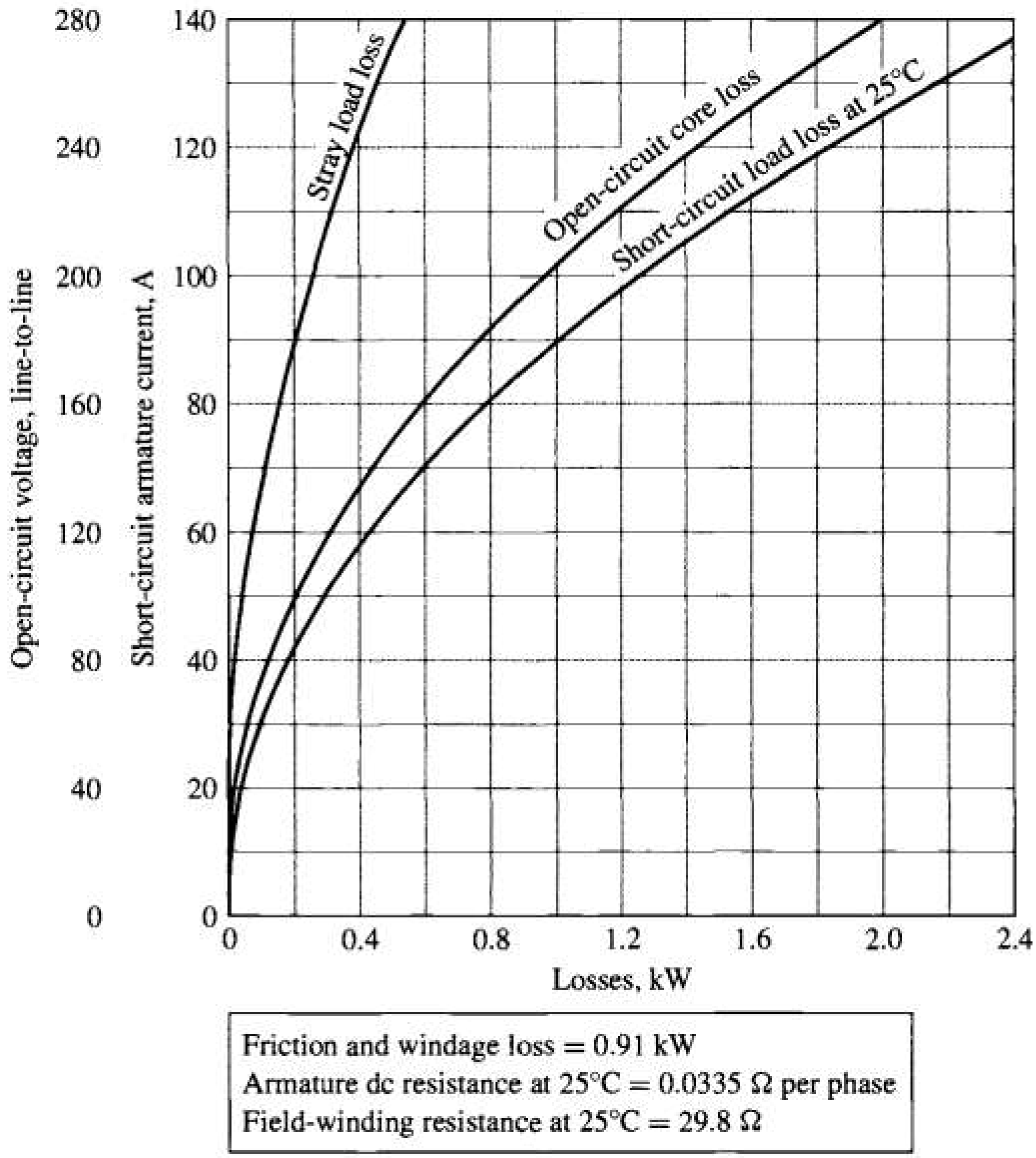

Figure Question 1(d)