Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	ELECTRICAL MACHINES
COURSE CODE	:	BEV 20803
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **FIVE (5)** PAGES

Q1 (a) Describe **FOUR (4)** reasons why inveter is required to start an induction motor.

(4 marks)

(b) Based on your understanding, explain the technical consequences when rotor of an induction motor is locked.

(3 marks)

(c) A factory manufactures plastic bags using an air compressor equipped with 3-phase AC induction motor as part of the blowing process. The motor comes with specifications of 415 V, 50 Hz, 1200 rpm, 25 hp wound-rotor type is having the following equivalent circuit parameters:

$R_1 = 0.25\ \Omega$ $X_1 = 1.2\ \Omega$ $R_2 = 0.2\ \Omega$ $X_2 = 1.1\ \Omega$ $X_M = 35\ \Omega$

(i) Draw and label the per-phase equivalent circuit.

(3 marks)

(ii) Find the number of poles of the motor.

(2 marks)

(iii) Calculate V_{TH} , Z_{TH} and draw its Thevenin equivalent circuit.

(7 marks)

(iv) Determine the starting torque of the motor.

(3 marks)

(v) Evaluate the external resistance required during maximum torque at starting.

(3 marks)

Q2 (a) Provide a concise overview of **TWO (2)** typical methods used to deliver DC power to the field circuit on the rotor of a synchronous generator.

(4 marks)

(b) A 2400 V, 100 kVA, 0.85 pf lagging, 50 Hz, 2 pole generator has a synchronous reactance, X_S and armature resistance R_A, of 1.2 Ω and 0.15 Ω, respectively. The friction and windage losses are 24 kW and its core losses are 20 kW. The field circuit has a DC voltage of 200 V and the maximum I_F of 12 A. The maximum measured field current I_F at no load, to make terminal voltage V_T equal to 2400 V is 4.5 A.

(i) Calculate the internal generated voltage of this machine at the rated condition.

(5 marks)

(ii) Determine the input power.

(4 marks)

(iii) Determine the torque supplied by the generator's prime mover.

(3 marks)

(iv) Draw the per phase equivalent circuit if the generator is connected to Δ-connected load with an impedance of $12\angle 30°$ Ω/phase.

(2 marks)

(v) Determine and sketch the phasor diagram of this generator.

(7 marks)

Q3 (a) By using simple words and figures, explain briefly and compare the main difference between under-excited and over-excited during steady state operation of synchronous motor.

(4 marks)

(b) Suggest **THREE (3)** basic approaches to start the synchronous motor.

(3 marks)

(c) A synchronous motor located at chips factory in Sri Gading, Batu Pahat runs over a continuous range of speeds from 150 r/min to 600 r/min. The speed changes are to be accomplished by controlling the system frequency with a solid-state drive. The 50 Hz, eight-pole, Y-connected synchronous motor which operates at 480-V, 80-kW, 0.85-PF leading also has a synchronous reactance of 2.5 Ω and a negligible armature resistance.

(i) Find the minimum and maximum frequency for the motor to provide the speed range from 150 r/min to 600 r/min.

(4 marks)

(ii) Calculate the internal generated voltage, E_A and the maximum power during motor's rated condition.

(8 marks)

(iii) Propose the maximum internal generated voltage, E_A at the minimum speed of the motor.

(2 marks)

(iv) Propose the maximum supplied power at minimum speed of the motor by assuming applied voltage, V_ϕ is derated by the same amount as E_A.

(4 marks)

Q4 (a) A shunt DC motor is supplied with voltage of 220 V and draws a current of 4 A at no load operation. During full load operation it draws a current of 22 A at the speed of 2200 rpm. Given the armature resistance and shunt field winding resistance of 0.2 Ω and 200 Ω, respectively.

(i) Calculate the field current, armature current and no-load back emf voltage.
(3 marks)

(ii) Determine the power developed, copper loss and input power during no-load operation.
(3 marks)

(iii) Evaluate the power developed, copper loss and input power during full-load operation.
(5 marks)

(iv) Find the output power and efficiency of the DC motor under full load operation.
(2 marks)

(v) Determine the developed torque useful torque.
(3 marks)

(vi) Estimate the no-load speed and speed regulation.
(2 marks)

(b) (i) Explain briefly **FOUR (4)** applications of DC generators
(4 marks)

(ii) List **THREE (3)** types of self-excited DC generators
(3 marks)

-END OF QUESTIONS –

APPENDIX A

Formula

$$P_{SCL} = 3I^2R$$

$$P_{AG} = P_{IN} - P_{iron\ loss} - P_{SCL}$$

$$P_{RCL} = sP_{AG}$$

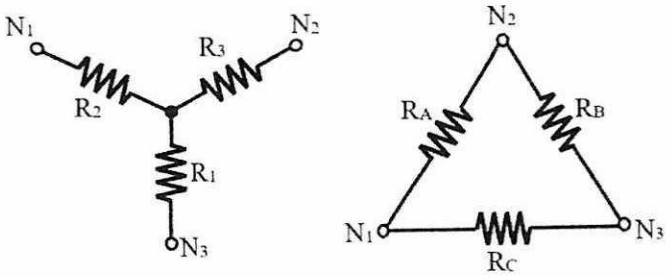
$$P_{CONV} = P_{AG} - P_{RCL}$$

$$P_{CONV} = P_{AG}(1-s)$$

$$P_{CONV} = \frac{P_{RCL}(1-s)}{s}$$

$$P_{out} = P_{CONV} - P_{F\&W} - P_{stray}$$

$$\tau_{ind} = \frac{P_{AG}}{\omega_{sync}}$$



$$R_1 = \frac{R_B R_C}{R_A + R_B + R_C} \qquad R_A = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

$$R_2 = \frac{R_C R_A}{R_A + R_B + R_C} \qquad R_B = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

$$R_3 = \frac{R_A R_B}{R_A + R_B + R_C} \qquad R_B = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$