Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	ELECTRICAL MACHINES
COURSE CODE	:	BEJ 20403
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER ALL QUESTIONS 2.THIS FINAL EXAMINATION IS CONDUCTED VIA **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 **SIX (6)** PAGES

Q1 (a) A 2400 V, 1100 kVA, 0.85 power factor (PF) lagging, six-poles, Y-connected synchronous generator has a synchronous reactance of 1.2 Ω and an armature resistance of 0.05 Ω. At 60 Hz, its friction and windage losses are 25 kW, and its core losses are 15 kW. The field circuit has a DC voltage of 220 V, and the maximum I_F is 10 A. The resistance of the field circuit is adjustable over the range from 22 to 200 Ω. The Open Circuit Characteristic (OCC) of this generator is shown in **Figure Q1(a)**.

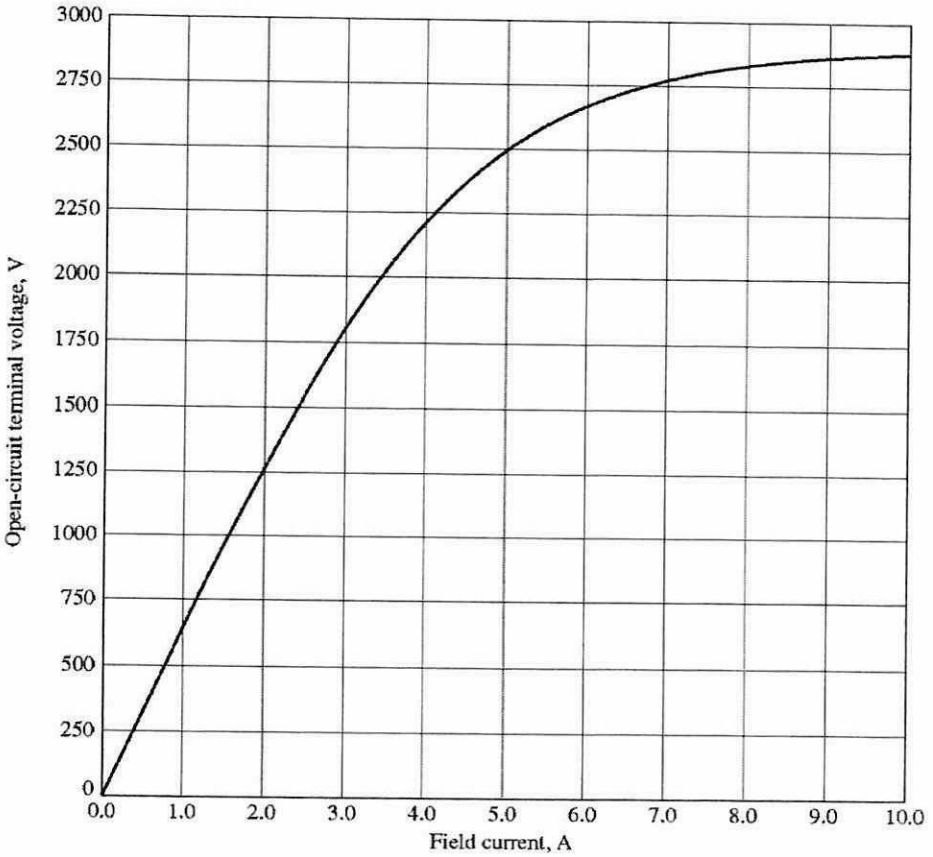

Figure Q1(a)

(i) Calculate the internal generated voltage, E_A of this machine at rated conditions.

(7 marks)

(ii) Determine the required field current to make V_T equal to 2400 V when the generator is running at rated conditions.

(2 marks)

(iii) If this machine is operating at rated conditions, determine the input torque, τ_{APP} that must be applied to the shaft of this generator

(7 marks)

(iv) Calculate the efficiency of the generator.

(2 marks)

(b) A three-phase Δ -connected synchronous generator is rated at 120 MVA, 15 kV, 0.80 PF leading and 50 Hz. Its synchronous reactance is 1.2 Ω, and its resistance may be ignored. Analyze the voltage regulation of this generator.

(7 marks)

Q2 (a) A 208 V 45 kVA, 0.8-PF-leading, Δ-connected, 60 Hz synchronous machine has a synchronous reactance of 2.5 Ω and a negligible armature resistance. Its friction and windage losses are 1.5 kW and its core losses are 1.0 kW. Initially, the shaft is supplying a 15 hp load, and the motor's power factor is 0.80 leading.

(i) Sketch the phasor diagram of this motor, and find the values of I_A, I_L and E_A?

(15 marks)

(ii) Assume that the shaft load is now increased to 30 hp. Find I_A, I_L and E_A after the load change.

(8 marks)

(iii) Calculate the new motor power factor?

(2 marks)

Q3 (a) Explain the purpose of brushes and rotor in a DC motor.

(4 marks)

(b) List out and briefly describe **THREE (3)** types of losses in a DC motor.

(6 marks)

(c) A DC shunt motor with compensating windings as shown in **Figure Q3(c)** has a rating of 70 hp, 270 V and 1350 rpm with an armature resistance of 0.05 Ω. The field circuit, $R_{adj} + R_F$ has a total resistance of 30Ω which produces a no-load speed of 1400 rpm while the shunt field winding has 1500 turns per pole.

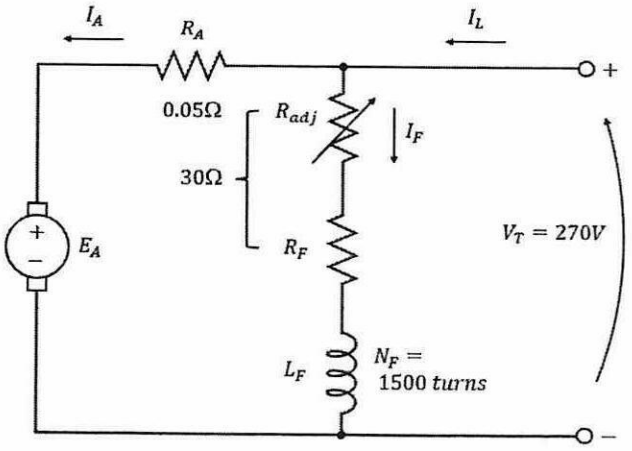

Figure Q3(c)

(i) Find the induced torque if the input current is 100 A and 200 A.

(10 marks)

(ii) Plot the torque-speed characteristic curve of the motor by using the result obtained in **Q3(c)(i)**. Analyze your findings.

(5 marks)

Q4 (a) DC machines are generators that convert mechanical energy to DC electric energy while motors convert DC electric energy to mechanical energy. With the assistance of related figures, draw and explain the concept of rotating DC machines.

(10 marks)

(b) Consider the separately excited DC generator and the magnetization curve as shown in **Figure Q4(b).** The following data are known about the machine:

$$R_A = 0.18\,\Omega \qquad R_F = 24\,\Omega \qquad R_{adj} = 0 \; to \; 25\,\Omega$$

$$V_F = 120\,V \qquad N_F = 1000 \; turns \; per \; pole$$

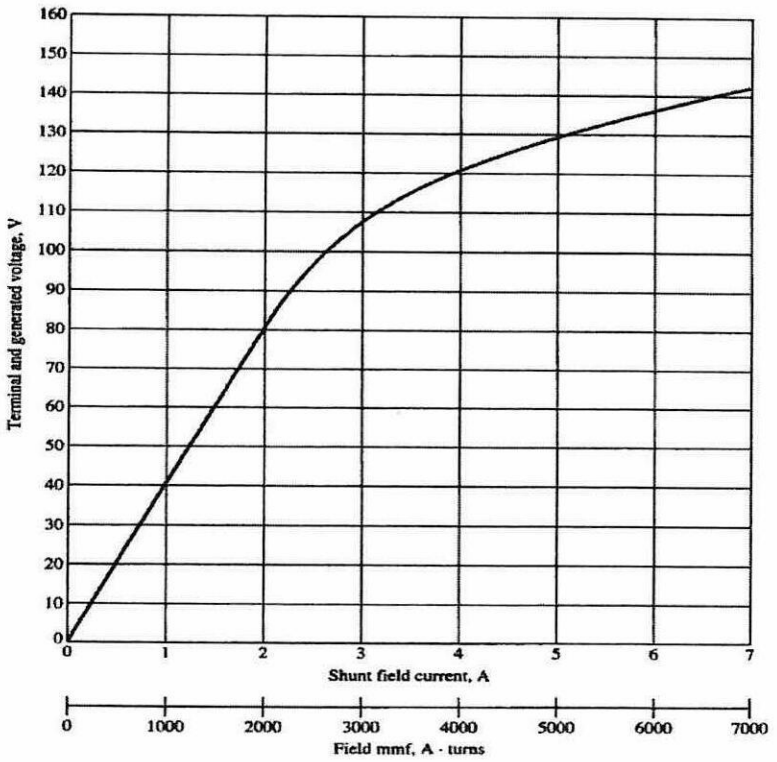

Figure Q4(b)

Its field current is rated at 5A. The generator is rated at 6kW, 120 V, 50A and 1800 rpm. Assuming no armature reaction. Answer the following questions about this generator.

(i) If this generator is operating at no load, analyze the range of voltage adjustment that can be achieved by changing R_{adj}.

(10 marks)

(ii) If the armature current of the generator is 50 A, the speed of the generator is 1700 rpm, and the terminal voltage is 106V. Determine the field current that must be flowing in the generator.

(5 marks)

End of Questions

APPENDIX A

FORMULAE

Synchronous Generators

$$V_{\emptyset} = E_A - jX_s I_A - R_A I_A$$

$$f_e = \frac{n_m P}{120}$$

$$P_{in} = \tau_{app}\omega_m$$

$$V_R = \frac{E_A - V_{\emptyset}}{V_{\emptyset}} \times 100\%$$

Synchronous Motor

$$\tau_{ind} = \frac{3V_{\emptyset}E_A \sin\delta}{\omega_m X_s}$$

DC Motor

$$V_T = E_A + I_A R_A$$

$$\frac{E_{A1}}{E_{A2}} = \frac{n_{m1}}{n_{m2}}$$

$$\tau_{ind} = \frac{E_A I_A}{\omega_m}$$

DC Generator

$$E_A = V_T + I_A R_A$$