Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	ELECTRICAL MACHINES
COURSE CODE	:	BEJ 20403
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JULY/ AUGUST 2023
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 **SEVEN (7)** PAGES

Q1 (a) List **TWO (2)** types of rotors used in synchronous generator.

(2 marks)

(b) A 2500 V, 1200 kVA, 0.80 power factor (PF) lagging, four-pole, Δ-connected synchronous generator has a synchronous reactance of 1.4 Ω and an armature resistance of 1.2 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(b)**.

(i) Calculate the internal generated voltage, $\boldsymbol{E_A}$ of this machine at rated conditions.

(7 marks)

(ii) Determine the required field current to make V_T equal to 2500 V when the generator is running at rated conditions.

(2 marks)

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

(6 marks)

(c) A three-phase Y-connected synchronous generator is rated at 140 MVA, 14.5 kV, 0.85 PF leading and 70 Hz. Its synchronous reactance is 1.2 Ω, and its resistance may be ignored. Analyze the voltage regulation of this generator.

(8 marks)

Q2 (a) List **THREE (3)** reason if a 3-phase synchronous motor fails to start.

(3 marks)

(b) A 2500 V, 50 Hz, 1200 hp 0.89 PF leading four-poles Y-connected synchronous motor has a synchronous reactance of 1.9 Ω and negligible armature resistance. Ignore its friction, windage, and core losses for the purposes of this problem.

(i) If this motor is initially supplying 1200 hp at 0.80 PF lagging, determine the magnitudes and angles of $\boldsymbol{E_A}$ and $\boldsymbol{I_A}$.

(6 marks)

(ii) Based on **Q2(b)(i)**, sketch the phasor diagram of this motor.

(3 marks)

(iii) Calculate the torque that this motor is producing, $\boldsymbol{\tau_{ind}}$ and the maximum possible induced torque for this motor, $\boldsymbol{\tau_{ind,max}}$.

(7 marks)

(iv) If the magnitude of the internal generated voltage, $|E_A|$ is increased by 30 percent, determine the new magnitude of the armature current and its new PF.

(6 marks)

Q3 (a) List **FOUR (4)** types of DC motor.

(4 marks)

(b) Sketch and label the power flow and losses of 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.

(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) Explain the difference between field flux production in series generator, shunt generator, and separately excited generator.

(6 marks)

(b) Describe the difference between DC generators and DC motors.

(4 marks)

(c) The magnetization curve for a separately excited DC generator is shown in **Figure Q4(c)**. The generator is rated at 6 kW, 130 V, 50 A, and 1600 r/min. Its field circuit is rated at 5 A. The following data are known about the machine:

$$R_A = 0.18\ \Omega \qquad R_F = 20\ \Omega \qquad R_{adj} = 0\ to\ 40\ \Omega$$

$$V_F = 130\ V \qquad N_F = 1000\ turns\ per\ pole$$

(i) Determine the range of voltage adjustments that can be achieved by changing R_{adj} if this generator is operating at no load.

(4 marks)

(ii) Analyze the maximum and minimum no-load voltages in the generator if the field rheostat is allowed to vary from 0 to 40 Ω and the generator's speed is allowed to vary from 1400 to 2000 r/min.

(6 marks)

(iii) Analyze the field current that must be flowing in the generator if the armature current of the generator is 50 A, the speed of the generator is 1500 r/min, and the terminal voltage is 106 V.

(5 marks)

End of Questions

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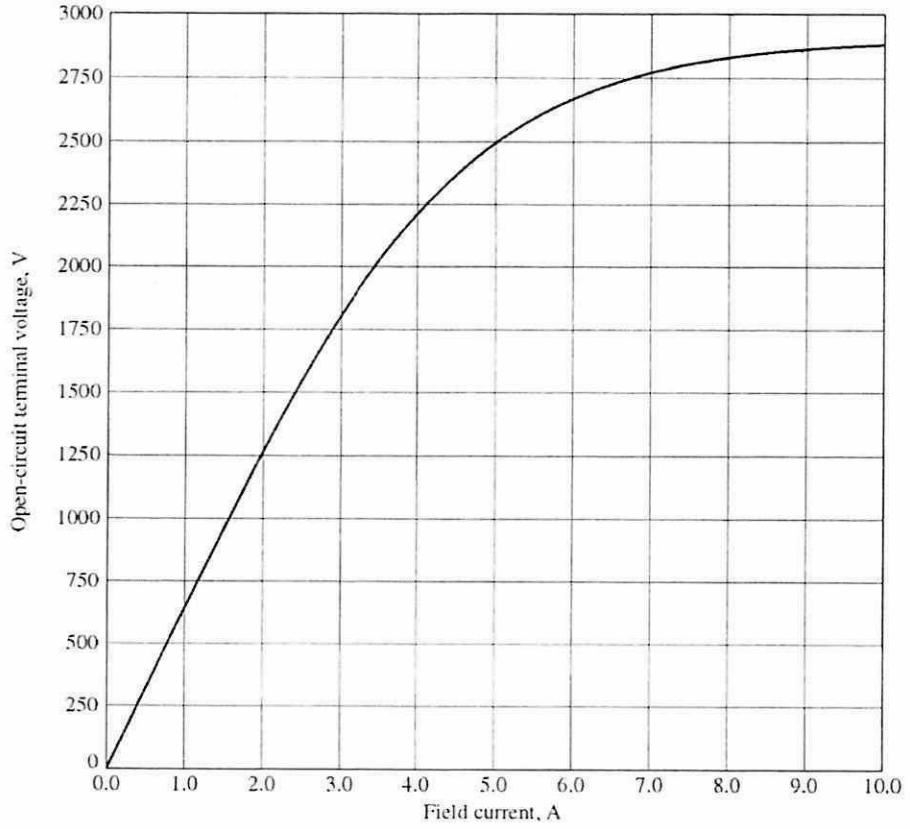

Figure Q1(b)

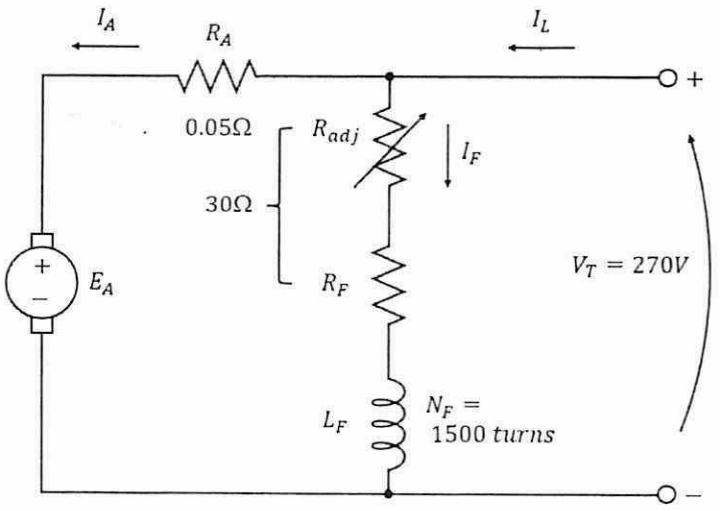

Figure Q3(c)

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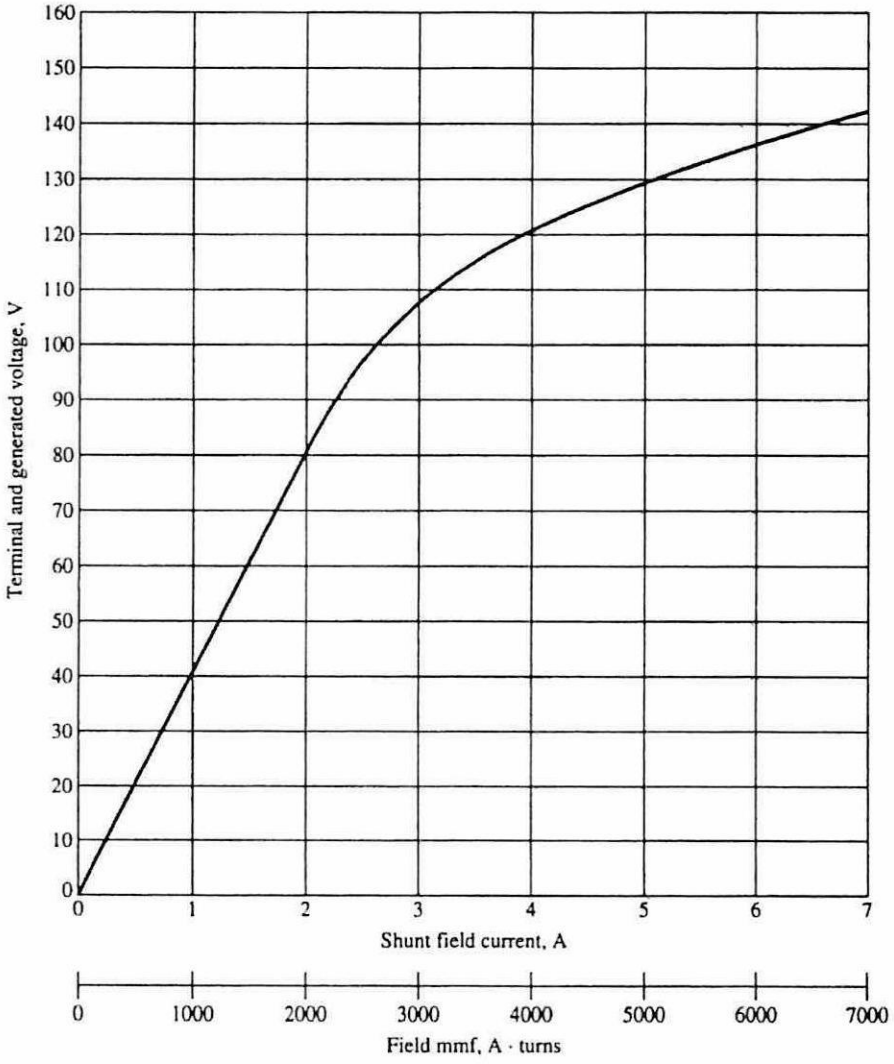

Figure Q4(c)

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LIST OF EQUATIONS

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

$$E_A = V_T + I_A R_A$$