Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2014/2015

COURSE NAME	:	ELECTRICAL MACHINE AND DRIVES
COURSE CODE	:	BNR 31403
PROGRAMME	:	BND
EXAMINATION DATE	:	DISEMBER 2014/JANUARY 2015
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

Q1 (a) Magnetic fields are the fundamental mechanism by which energy is converted from one form to another in motors, generators and transformers. Identify **FOUR (4)** basic principles of magnetic fields commonly used in these devices.

(4 marks)

(b) The flow of magnetic flux induced in the ferromagnetic core can be made analogous to an electrical circuit hence the name magnetic circuit. Demonstrate both analogy circuits with suitable figures.

(4 marks)

(c) Describe Faraday's Law and illustrate the application that related to the Faraday's Law.

(5 marks)

(d) A ferromagnetic core is shown in Figure **Q1(d)**. The depth of the core is 5cm. The other dimensions of the core are also shown in the Figure **Q1(d)**.

(i) Calculate the total reluctances.

(5 marks)

(ii) Find the value of the current that will produce a flux of 0.005 Wb.

(3 marks)

(iii) With the current calculated in **Q1(d)** , what is the flux density at the top of the core?

(2 marks)

(iv) What is the flux density at the right side of the core? Assume that the relative permeability of the core is 1000.

(2 marks)

Q2 (a) State **TWO (2)** types of cores used in power transformer construction and sketch both of them in single phase and three phase application.

(4 marks)

(b) The secondary winding of a transformer has a terminal voltage of $v_s(t) = 282.8 \sin 377t$ V. The turns ratio of the transformer is 100:200 ($a = 0.50$). Then, the secondary current of the transformer is $i_s(t) = 7.07 \sin(377t - 36.87°)$A. The impedances of this transformer referred to the primary side are shown in Figure **Q2(b)**.

(i) Calculate the primary current of this transformer?

(12 marks)

(ii) Determine the voltage regulation and efficiency?

(9 marks)

Q3 (a) Based on the rotor design of three-phase AC induction motors, classify **TWO (2)** types of induction motors and state its applications.

(4 marks)

(b) Induction motor can be basically described as rotating transformer with three-phase system of voltages and currents input. Induction motor also can be simplified with equivalent circuit system. Thus, based on the equivalent circuit system of induction motor, sketch the complete power-flow diagram of the induction motor?

(9 marks)

(c) A 50-kW, 440-V, 50-Hz, 6-pole induction motor has a slip of 6% when operating at full-load conditions. At full-load conditions, the friction and windage losses are 300 W, and the core losses are 600 W. Find the following values for full-load conditions:

(i) The shaft speed , n_m

(4 marks)

(ii) The output power in watts

(2 marks)

(iii) The load torque τ_{load} in newton-meters

(2 marks)

(iv) The induced torque τ_{ind} in newton-meters

(2 marks)

(v) The rotor frequency in hertz

(2 marks)

Q4 (a) Define the principles of synchronous generator and sketch the basic synchronous generator with load supplied.

(3 marks)

(b) Illustrate and label the power-flow diagram of synchronous generator in own definition.

(5 marks)

(c) Develop a table showing the speed of magnetic field rotation in AC machines of 2, 4, 6, 8, 10, 12, and 14 poles operating at frequencies of 50, 60, and 400 Hz.

(5 marks)

(d) A 2300-V 1000-kVA 0.8-PF-lagging 60-Hz two-pole Y-connected synchronous generator has a synchronous reactance of 1.1 Ω and an armature resistance of 0.15 Ω. At 60 Hz, its friction and windage losses are 24 kW, and its core losses are 18 kW. The field circuit has a dc voltage of 200 V, and the maximum I_F is 10 A. The resistance of the field circuit is adjustable over the range from 20 to 200 Ω.The OCC of this generator is shown in Figure **Q4(d)**.

(i) How much field current is required to make terminal voltage,V_T equal to 2300 V when the generator is running at no load?

(2 marks)

(ii) What is the internal generated voltage of this machine at rated conditions?

(7 marks)

(iii) How much field current is required to make V_T equal to 2300 V when the generator is running at rated conditions?

(3 marks)

Q5 (a) Describe briefly about synchronous motor?

(2 marks)

(b) Draw the full equivalent circuit of three-phase (3ϕ) synchronous motor.

(5 marks)

(c) Explain using phasor diagrams, what happens to a synchronous motor as its field current is varied. Derive a synchronous motor V curve from the phasor diagram.

(8 marks)

(d) 480-V 100-kW 0.85-PF leading 50-Hz six-pole Y-connected synchronous motor has a synchronous reactance of 1.5 Ω and a negligible armature resistance. The rotational losses are also to be ignored. This motor is to be operated over a continuous range of speeds from 300 to 1000 r/min, where the speed changes are to be accomplished by controlling the system frequency with a solid-state drive.

(i) Justify the suitable frequency range must be varied to provide by motor speed control?

(3 marks)

(ii) Calculate how large is internal generated voltage, E_A at the motor's rated conditions?

(5 marks)

(iii) What is the maximum power the motor can produce at the rated condition?

(2 marks)

Q6 (a) List **FIVE (5)** major types of DC generators and classify according to the manner in which their field flux is produced.

(10 marks)

(b) From the Kirchhoff's voltage law (KVL), plot the derivation of the terminal characteristic of a shunt DC generator characteristic graph.

(5 marks)

(c) Elaborate detail about series DC generator with graphical analysis and equivalent circuits.

(10 marks)

Q7 (a) List **FIVE (5)** major types of DC motors in general application.

(5 marks)

(b) In order for a DC motor to function properly on the job, it must have some special control and protection equipment associated with it. Discuss the purposes of this equipment.

(3 marks)

(c) Demonstrate the complete equivalent circuit of a separately excited DC motor by parameter of I_F, I_L and V_T

(7 marks)

(d) As illustrated in Figure **Q7(d)**, a 50-Hp, 250-V, 1200 r/min DC shunt motor with compensating windings has an armature resistance (including the brushes, compensating windings, and interpoles) of 0.06 Ω. Its field circuit has a total resistance $R_{adj} + R_F$ of 50 Ω, which produces a no-load speed of 1200 r/min. There are 1200 turns per pole on the shunt field winding.

(i) Evaluate the speed of this motor when its input current is 100 A.

(5 marks)

(ii) Evaluate the speed of this motor when its input current is 200 A.

(5 marks)

- END OF QUESTION

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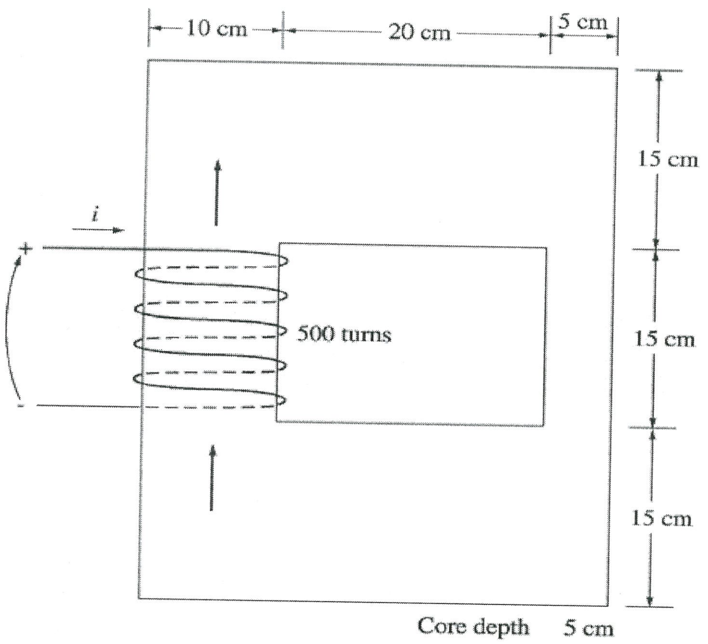

Figure Q1(d) : Ferromagnetic core

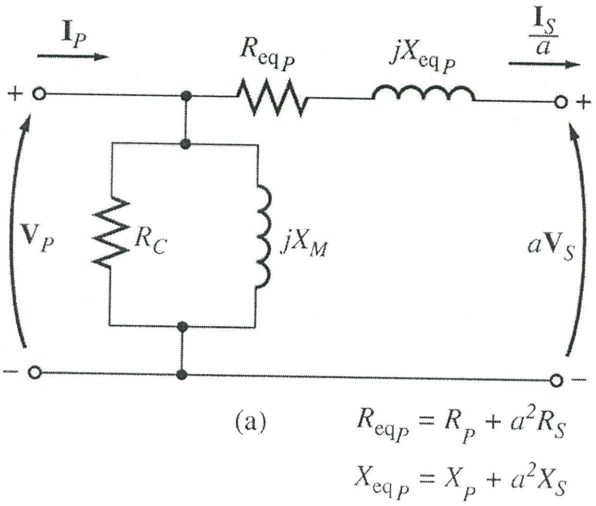

Figure Q2(b) : Approximate equivalent circuit referred to the primary side

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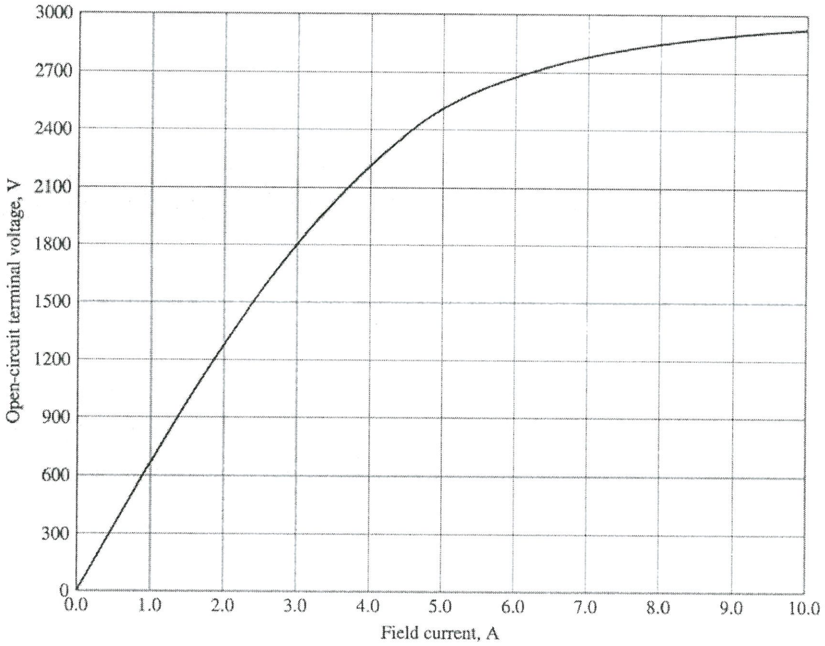

Figure Q4(d) : Open-Circuit Characteristic

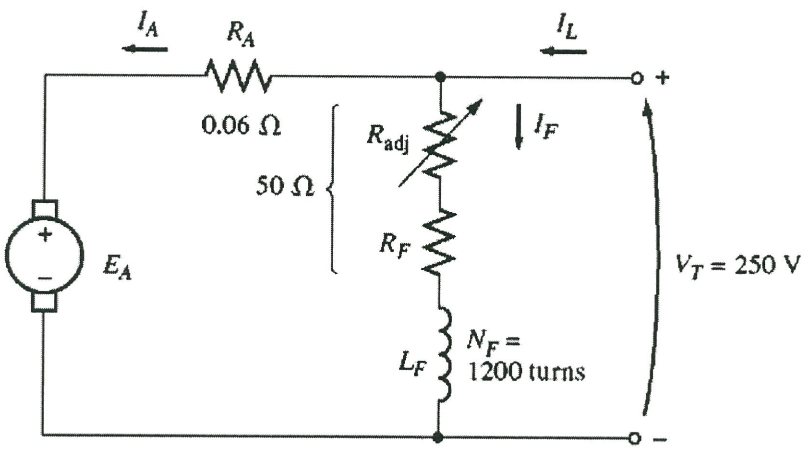

Figure Q7(d) : Shunt Motor

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LIST OF FORMULA

General

$S_{1\text{-}\phi} = V_\phi I_A$	Y connected : $V_\phi = \frac{V_T}{\sqrt{3}}$ $I_\phi = I_L$
$P_{1\text{-}\phi} = V_\phi I_A \cos\theta$	Δ connected : $V_\phi = V_T$ $I_\phi = \frac{I_L}{\sqrt{3}}$
$Q_{1\text{-}\phi} = V_\phi I_A \sin\theta$	1hp = 746 W
$S_{3\emptyset} = 3V_\emptyset I_\emptyset = \sqrt{3}V_T I_L$	efficiency, $\eta = \frac{P_{out}}{P_{out}+P_{loss}}$ x 100
$P_{3-\emptyset} = 3V_\emptyset I_\emptyset \cos\theta = \sqrt{3}V_T I_L \cos\theta$	$Q_{3-\emptyset} = 3V_\emptyset I_\emptyset \sin\theta = \sqrt{3}V_T I_L \sin\theta$

Synchronous Generator and Synchronous Motor

$P = \frac{3V_\varphi E_A \sin\delta}{X_S}$	$\tau_{ind} = \frac{3V_\varphi E_A \sin\delta}{\omega_m X_S}$	$P_{max} = \frac{3V_\varphi E_A}{X_S}$	$\tau_{max} = \frac{3V_\varphi E_A}{\omega_m X_S}$

Shunt/Separately Excited DC Motor

$\tau_{ind} = \frac{E_A I_A}{\omega_m}$	$I_F * = I_F - \frac{\mathcal{F}_{AR}}{N_F}$	$\frac{E_A}{E_{A0}} = \frac{\eta}{\eta_0}$

Induction Motor

$f_r = sf_e$	$n_{sync} = \frac{120f_e}{P}$	$n_m = (1-s)n_{sync}$

$$\tau_{ind} = \frac{3V_{TH}^2\, {}^{R_2}/_{s}}{\omega_{sync}\left[\left(R_{TH}+{}^{R_2}/_{s}\right)^2 + (X_{TH}+X_2)^2\right]}, \text{where...,} \left\{ \begin{array}{l} V_{TH} = V_\emptyset \frac{jX_M}{R_1+jX_1+jX_M} \\ Z_{TH} = \frac{jX_M(R_1+jX_1)}{R_1+j(X_1+X_M)} \end{array} \right\}$$

$s_{max} = \frac{R_2}{\sqrt{R_{TH}^2 + (X_{TH}+X_2)^2}}$	$\tau_{max} = \frac{3V_{TH}^2}{2\omega_{sync}\left[R_{TH} + \sqrt{R_{TH}^2 + (X_{TH}+X_2)^2}\right]}$