The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Electrical and Computer Engineering

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Study Programme	:	Bachelor of Science Honours in Engineering
Name of the Examination	:	Final Examination
Course Code and Title	:	**EEX5348 Electrical Machines and Drives**
Academic Year	:	2024/25
Date	:	06th February 2026
Time	:	1400-1700h
Duration	:	3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Five (5)** questions in **Four (4)** pages.
3. Answer **all** questions.
4. All questions carry equal marks.
5. Answer for each question should commence from a new page.
6. This is a Closed Book Test (CBT).
7. Any type of calculator is allowed to use.

Question 1

a. Explain the principle of electronic commutation in a Brushless DC motor. (3 marks)

b. A Brushless DC motor drive system is given in Figure Q1. Identify each component in drive system and explain its functions.

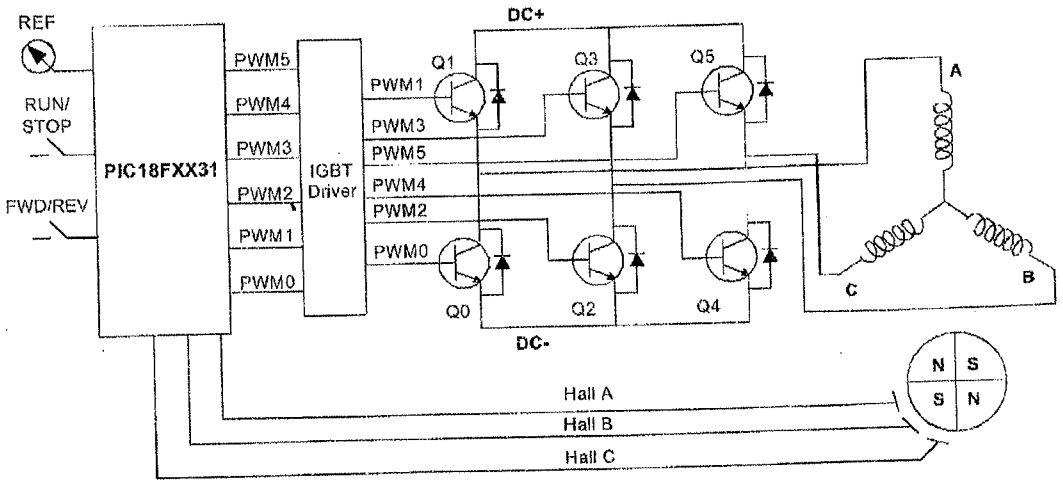


Figure Q1

(5 marks)

c. BLDC motor shown in Figure Q1 provides following Hall sensor outputs as given in Table Q1 and the corresponding active IGBTs during motor rotation. Fill the phase current section of the table Q1 considering the active transistors at each time. Use the symbols 'DC+', 'DC-' and '0ff' when filling these gaps.

Table Q1

Sequence #	Hall Sensor Input			Active PWMs		Phase Current		
	A	B	C			A	B	C
1	0	1	1	PWM5(Q5)	PWM2(Q2)			
2	1	1	1	PWM1(Q1)	PWM2(Q2)			
3	1	1	0	PWM1(Q1)	PWM4(Q4)			
4	1	0	0	PWM3(Q3)	PWM4(Q4)			
5	0	0	0	PWM3(Q3)	PWM0(Q0)			
6	0	0	1	PWM5(Q5)	PWM0(Q0)			

(4 marks)

d. A three-phase BLDC motor is supplied from a DC link inverter and operates under 120° electronic commutation. Assume ideal inverter operation and neglect mechanical losses.

The motor parameters are given below:

Rated DC link voltage, $V_{dc} = 300\,\text{V}$

Number of poles, $P = 8$

Phase resistance, $R = 0.6\,\Omega$

Back-EMF constant, $K_e = 0.09\,\text{V/radS}^{-1}$

Torque constant, $K_t = 0.09\,\text{Nm/A}$

Rated phase current, $I = 10\,\text{A}$

i. Determine the back EMF per phase at 3000 rpm.

ii. Calculate the electromagnetic torque developed by the motor at rated current.

iii. Estimate the mechanical output power of the motor at this operating condition.

iv. Briefly explain how PWM control of the inverter can be used to control the speed of the BLDC motor while maintaining the developed torque.

(8 marks)

Question 2

a. Compare DC motor drives and AC motor drives with respect to the following aspects. Give a brief explanation for each case.

i. Control complexity

ii. Maintenance requirements

iii. Performance characteristics

iv. Typical application (4 marks)

b. A separately excited dc motor is required to be controlled by a three phase half-controlled thyristor bridge. The motor parameters are as follows,

Motor voltage constant = 0.25 V/rpm

Armature resistance = 0.2 Ω

Armature rated current= 100 A

A 400V, three-phase, 50 Hz supply is available to power up the drive system.

i. Draw the power circuit diagram of the proposed DC drive system, clearly showing all essential components. (6 marks)

ii. The motor draws a no-load armature current of 5 A when the firing angle is 45°. Determine the no-load speed of the motor, stating clearly any assumptions made. (6 marks)

iii. Determine the firing angle required to obtain a motor speed of 1500 rpm when the motor operates at rated armature current. (4 marks)

Question 3

a. Draw the cross-sectional view of a 2-phase, 4-pole stator, 6-tooth rotor hybrid stepper motor. Determine the basic step angle from the geometry. Clearly mark the step angle on your diagram. (5 marks)

b. Briefly explain the difference between unipolar and bipolar stepper motor drives, highlighting their drive requirements, efficiency, and torque characteristics. (6 marks)

c. Explain the role of detent torque and holding torque in a stepper motor. (3 marks)

d. Draw and explain the torque–speed characteristics of a stepper motor, clearly indicating the start–stop (pull-in) range and the slewing (pull-out) range. (4 marks)

e. A variable reluctance stepper motor has 4 phases, 8 stator poles, and a 6-tooth rotor. Calculate its step angle and the total number of steps per mechanical revolution. (2 marks)

Question 4

a. Draw a transient current waveform of a synchronous generator following a three-phase short-circuit at the terminals, labeling:

- Sub-transient current-I"
- Transient current -I'
- Steady-state current -I

(4 marks)

b. A 11 kV ,50 Hz, three-phase synchronous generator has the following parameters:
   - Sub-transient reactance $X_d'' = 0.2$ p.u.
   - Transient reactance $X_d' = 0.3$ p.u.
   - Synchronous reactance $X_d = 1.0$ p.u.
   - Rated current $I_L = 500$ A

   i. Calculate the initial fault current immediately after a three-phase short-circuit.
   ii. Calculate the fault current after a few cycles (transient current).
   (6 Determine the steady-state fault current. (6 marks)

c. A synchronous motor operating at rated voltage experiences a sudden 50% increase in load. Discuss qualitatively how the rotor angle and torque behave during the transient period. (6 marks)

d. Discuss the industrial applications of synchronous motor drives, highlighting the reasons for their selection in each application. (4 marks)

Question 5

a) Explain why single-phase induction motors require additional starting mechanisms while three-phase induction motors are inherently self-starting. (2 marks)

b) It is necessary to maintain a constant V/f ratio during speed control of Induction motor. Explain the reason. (2 marks)

c) With the aid of clearly labelled torque–speed characteristic curves, explain the effect of the following speed control methods on three phase wound rotor induction motor performance:

   i. Supply frequency control (V/f control)
   ii. Rotor resistance control

   (8 marks)

d) A 440 V, 50 Hz, 4 pole three-phase squirrel cage induction motor develops a torque of 100 Nm at a speed of 1200 rpm. If the stator supply frequency is reduced by half, calculate

   i. The stator supply voltage required for maintaining the same flux in the machine

   ii. The new speed at a torque of 100 Nm.

   (6 marks)

e) Justify why frequency control using power electronic converters has become the preferred method for speed control of induction motors in modern industrial applications. (2marks)

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