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

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| Study Programme | : Bachelor of Technology Honours in Engineering |
| Name of the Examination | : Final Examination |
| Course Code and Title | : **EEX5348** |
| | **Electrical Machines and Drives** |
| Academic Year | : 2021/2022 |
| Date | : 30th January 2023 |
| Time | : 0930-1230hrs |

## General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Five (5)** questions in **Three (03)** pages.
3. Answer **all questions**, All the questions carry **equal marks**.
4. Answer for each question should commence from a new page.
5. Relevant figures and tables are provided with the question paper
6. This is a Closed Book Test **(CBT).**
7. Answers should be in clear hand writing.
8. Do not use red colour pen.

## Question 01

**a)** Sketch typical line current waveform produced by a synchronous generator, following a sudden three-phase short circuit at its terminals (at the time t=0), indicating all the necessary details. Assume the generator was operating at no-load condition prior to the short circuit. **[3 marks]**

**b)** For the short-circuited synchronous generator in (a) above, write down an expression for the instantaneous current in phase A. Define all the terms in your expression. **[3 marks]**

**c)** Briefly explain the self-synchronous/self-control mode of speed control in a synchronous motor. **[3 marks]**

**d)** What is the significance of synchronous motor V-curves? Draw the variation of V curves with the increasing load and show the locus of unity power factor. **[4 marks]**

**e)** What are the differences between continuous and intermittent duty loads? **[3 marks]**

Briefly explain why a motor with lower rating can be selected for delivering a larger power output for a short time duty. **[4 marks]**

## Question 02

**a)** Sketch the internal structure of the BLDCM and briefly explain how the motor operates. **[4 marks]**

**b)** Write a short description about the permanent magnet materials that can be used for BLDC motor rotor construction considering different applications. **[3 marks]**

**c)** Draw the induced voltage waveforms of three phases against rotor position angle for a trapezoidal brushless DC motor. Hence deduce the current waveforms for three phases that will develop constant torque independent of the rotor position. **[6 marks]**

**d)** A BLDCM has the following data.

Rotor radius = 8cm
Rotor axial length = 30cm
Airgap flux density due to rotor magnets = 0.9T
Number of turns per phase = 36 turns
Stator resistance per phase = 0.6 Ohm
Stator Inductance per phase = 12 mH
Friction Torque = 1 Nm for all speeds

It was found that the steady state speed of the motor is 1141.5 rpm when delivering a load of load-torque 65Nm. Calculate the DC supply voltage at the input terminals. State any assumptions you made. **[7 marks]**

## Question 03

a) Suppose a company is seeking your advice on a selection of motor for a CNC machine. The available choices are stepper motors and servo motors. What will be your choice? Validate your answer with valid arguments. **[4 marks]**

b) What is the difference between full switching sequence and half switching sequence of stepper motors? **[4 marks]**

c) Draw the cross-section of 8/6 Pole Four Phase variable reluctance stepper motor. Hence calculate the basic step angle. **[3 marks]**

d) Sketch the torque speed characteristics of a stepper motor showing pull-in and pull-out regions. **[2 marks]**

e) How does the static position error occur in the stepper motor drives? With an aid of suitable diagrams, briefly explain a way of determining static position error. **[4 marks]**

f) Open loop control strategy is widely used to control the stepper motors in low-cost applications. But this control mechanism is not much suitable for the high-end applications since this yield erratic motor behavior sometimes. Briefly explain the reason for this erratic motor behavior which present in open loop control strategy in some occasions. **[3 marks]**

## Question 04

A separately excited dc motor is required to be controlled by a two quadrant DC motor drive. The motor parameters are as follows,

Motor torque constant = 1.1Nm/A
Armature resistance = 0.7Ω
Armature Inductance = 2mH
Switching Frequency = 20kHz

A 220V DC source is available to power up the DC drive system. You can assume the friction torque as 1Nm for all the speeds.

**a)** Draw the power circuit of your proposed DC drive system including all the necessary components **[2 marks]**

**b)** Check whether the proposed drive system is always working under continuous armature current mode and comment on the results. **[2 marks]**

c) Determine the maximum possible no-load speed that can be obtained by using your proposed drive system. **[3 marks]**

d) Determine the required duty factor range which you need to operate to set the motor speed in 800rpm - 1000rpm range, while driving a load of load torque 35Nm. Also calculate the range of percentage peak-peak current ripple under this operating conditions. **[6 marks]**

e) Suppose your motor is operating at 800rpm. Calculate the initial rate of fall of speed, if you reduce the existing duty factor by 25% (stepwise). Note that the moment of inertia of connected load is 0.6 kg $m^2$. What will be the final steady state speed value with new duty factor? **[7 marks]**

## Question 05

a) With an aid of a suitable diagram, briefly explain about the stable working region of an induction motor on its Torque/Speed characteristics. **[4 marks]**

b) A three phase, 400V, 50Hz, six pole induction motor runs on load at 950rpm at rated voltage and rated frequency input. Take initial voltage boost of 10% of rated voltage. If the load-torque is constant for all speeds, determine the voltage and frequency combination required to drive the load at 150rpm. **[5 marks]**

c) A three-phase induction motor has following data,

Number of poles = 6
Rated Frequency = 50Hz
Rated Power = 15kW
Rated Voltage = 400V
Rated Current = 20A
Full Load Slip = 4%
Breakdown Slip = 10%

The motor is used in a variable speed drive covering a speed range from 0 to 6500rpm. Determine the speed ranges corresponding to constant torque, constant power and high-speed regions. **[6 marks]**

d) For the motor in section (c) above, calculate the boundary of safe torque against the speed indicating the values in the graph, over the full range of speed. **[5 marks]**