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

Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX4332 Electrical Power**
Academic Year	: 2023/2024
Date	: 4th March 2025
Time	: 0930-1230hrs
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 five questions. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. No charts/ codes are provided.
6. This is a Closed Book Test (CBT).
7. Answers should be in clear handwriting.
8. Do not use Red colour pen.

Question 01

Assume you are an engineer of a garment factory. The factory is supplied with three-phase 400V, 50Hz power from the utility and operates using three-phase induction motors, DC motors, and fluorescent lamps. The power factor of the factory is 0.75 lag, which is below the recommended level for industrial operations.

(a) Identify and explain the causes of the low power factor in this factory, considering the electrical appliances that are in use. **[3 marks]**

(b) Discuss the economic and operational impacts of running an industrial factory at a low power factor. How does power factor correction improve overall factory performance? **[4 marks]**

(c) If the factory operates with an apparent power of 500 kVA, calculate the required capacitive reactive power (kVAR) to improve the power factor to 0.95. **[4 marks]**

(d) To achieve the power factor improvement in part (c), a start-connected three-phase capacitor bank is introduced. Calculate the per-phase capacitance required for installation in the factory. **[3 marks]**

(e) Describe the other power factor correction methods that can be implemented in this factory. Provide a brief explanation of each method. **[3 marks]**

(f) The factory experiences a highly dynamic load variation, an automatic power factor correction (APC) device is recommended to be installed in the factory. Explain how it works and compare its advantages with the fixed capacitor bank solution mentioned in part (d). **[3 marks]**

Question 02

(a) With a neat diagram, explain the flux distribution in a DC machine before and after armature reaction occurs. **[3 marks]**

(b) A DC generator is experiencing a decrease in generated voltage. Explain how armature reaction contributes to this issue and briefly explain two appropriate corrective measures to mitigate its effects. **[3 marks]**

(c) A 4-pole DC series motor has a wave-connected armature winding with 600 conductors. The total winding resistance of the motor is 0.8 Ω. When supplied with 250V DC, the motor delivers 10 kW of output power and draws a current of 50 A. Given that the flux per pole is 3 mWb, calculate the developed torque and the shaft torque under these operating conditions. **[6 marks]**

(d) A 250V DC series motor has a total resistance of 0.4 Ω and operates at 2000 rpm while drawing 20 A of current.

i. Determine the additional series resistance required to limit the speed to 4000 rpm when the armature current is reduced to 5 A. Assume that flux is proportional to the armature current. **[4 marks]**

ii. Determine the additional series resistance required to limit the speed to 1000 rpm when the armature current increases to 30 A. Assume that the flux at 30 A is 20% greater than the flux at 20 A **[4 marks]**

Question 03

(a) Describe the potential of wind power in Sri Lanka and the major challenges in large-scale implementation. **[4 marks]**

(b) Government policy proposes a 70% renewable energy mix by 2030. Evaluate the feasibility of this policy based on the current energy infrastructure and available resources in Sri Lanka. **[4 marks]**

(c) A load variation throughout a day of a certain consumer metered at 400/230 kV, 50 Hz is shown in Table Q3.

Table Q3

Time (hours)	**0000-0600**	**0600-1300**	**1300-1700**	**1700-2400**
Total Load (kW)	28	40	42	28
Type of Loads	Lighting Load only	Lighting Load +	Lighting Load +	Lighting Load only
		12 kW induction motor load operating at 0.85 p.f	14 kW induction motor load operating at 0.9 p.f.	

i. Draw the daily load curve and determine the load factor of the above consumer.

ii. What is the maximum demand?

iii. What is the applicable tariff structure for this consumer?

iv. Determine this consumer's monthly electricity bill.

v. Calculate the size of the capacitance/phase that needs to be installed between 0600- 1300 hrs to improve the power factor to 0.95. Capacitors are star-connected.

[12 marks]

Note: A month consists of 30 days. Tariff rates offered from the utility are given in APPENDIX 1 in page 4

Question 04

(a) Briefly describe the economic and practical benefits of using an auto-transformer in power transmission and distribution. **[2 marks]**

(b) A single-phase auto-transformer has a primary voltage of 230V and a secondary voltage of 115V. If the output power is 10 kVA, calculate the power transferred inductively and conductively **[5 marks]**

(c) Describe the Short Circuit (SC) test on a transformer and explain how copper losses are determined

(d) A distribution line has a 20 kVA, 2000/200V, 50 Hz single-phase transformer. The transformer was subjected to the Open-Circuit Test and Short-Circuit Test and the following readings were obtained.

Open-Circuit Test (LV side): 200 V, 4 A, 120 W

Short-Circuit Test (HV side): 60 V, 10 A, 300 W

Determine the following for a transformer:

i. the equivalent circuit parameters of the transformer.
ii. the full-load efficiency and voltage regulation at 80% lagging power factor.
iii. the load at which maximum efficiency occurs and the maximum efficiency of the transformer at 0.8 lagging power factor.

[13 marks]

Question 05

(a) Briefly explain the role of Hall-effect sensors in BLDC motor operation **[2 marks]**

(b) Draw a clear control diagram for a Brushless DC (BLDC) motor, showing and labeling all key components. **[5 marks]**

(c) A ceiling fan using a capacitor-start induction motor fails to start but hums when switched on. Briefly describe the possible causes and suggest appropriate troubleshooting steps to fix the issue. **[3 marks]**

(d) In remote areas where only single-phase power is available, what type of single-phase induction motor would be best suited for small agricultural pumps? Justify your selection based on starting torque, efficiency, and maintenance. **[3 marks]**

(e) A 1 HP single-phase induction motor operates under varying load conditions in a washing machine. Explain how the motor speed and efficiency change as the load changes. **[3 marks]**

(f) Identify the type of single-phase induction motor shown in Figure Q5. Explain its advantages and discuss its common applications. **[4 marks]**

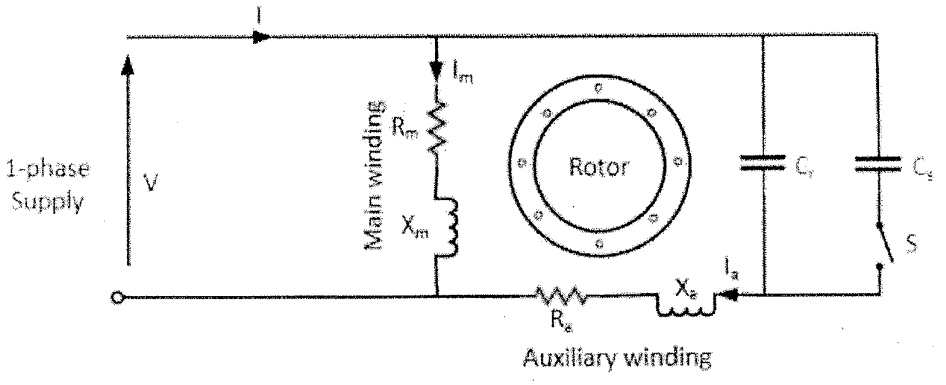


Figure Q5

APPENDIX 1

Tariff rates offered from the utility for Q#3

Customer Category	Energy charge (Rs/kWh)			Fixed Charge (Rs/ month)	Maximum Demand Charge per month (Rs /kVA)
	Peak (1830hr-2230hr)	Off-Peak (2230hr-0530hr)	Day (0530hr-1830hr)		
IP-1	For VDMC ≤ 300 kWh/month- 13.50			300	-
	For VDMC > 300 kWh/month- 21.50				-
IP-2	37.00	25.50	30.50	5,000	1,500
IP-3	36.00	24.50	30.00	5,000	1,400

Note: VDMC – Volume Differentiated Monthly Consumption

Rate 1 – Supply at 400/230 V Contract demand <= 42 kVA

Rate 2 – Supply at 400/230 V Contract demand > 42 kVA

Rate 3 – Supply at 11 kV & above

*As per the Social Security Contribution Levy (SSCL) Act No. 25 of 2022, SSCL is charged at a rate of 2.5% from the monthly electricity bills of CEB customers

*The above tariff revision is hereby published in terms of Section 30 (2) (d) of the Sri Lanka Electricity Act, No. 20 of 2009.