Unit 4021: Electrical Machines

Unit Code: **M/651/0740**

Level: **4**

Credits: **15**

Introduction

Electrical machines are used to convert electrical energy to and from mechanical energy. These are found in manufacturing, transport, consumer appliances, medical and other sectors. People will come across them every day in their home and at work. Electric machines are bidirectional electromechanical energy conversion devices that can be looked in two ways; as a motor which converts electrical energy to mechanical energy; or as a generator which converts mechanical energy to electrical energy. Transducers and actuators are also energy converters and can be found in a wide range of industrial and domestic applications.

This unit introduces students to the construction, modelling and characteristics of a range of electromagnetic machines and their practical application.. Among the topics included in this unit are: principles underlying the operation and construction of brushed DC, induction, and synchronous machines (motors and generators), electromagnetic transducers and actuators; and operating characteristics of electrical machines such as voltage, current, speed, torque, power rating, electromagnetic interference (EMI) and efficiency.

On successful completion of this unit, students will be able to gain knowledge and understanding of the operating characteristics of different types of electrical machines and their practical applications in the industry.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Investigate the different types and operation of electrical machines

LO2 Explore the operation and the various starting methods of induction machines

LO3 Explore the operation and the various starting methods of synchronous machines

LO4 Analyse the operating characteristics, construction and applications of electromagnetic transducers and actuators.

Essential Content

LO1 Investigate the different types and operation of electrical machines

Constructional features:

Construction, application and characteristics and operation of machine types such as: DC brushed, single phase induction, three phase induction, universal, types of synchronous (BLDC/BLAC, wound rotor)

Stator, rotor, windings, commutator/slip rings, bearings, case, cooling.

Typical applications of a range of electrical machines (generators/motors), possible modes of operation (torque, speed, position), and how they are chosen for a specific application (based on key performance parameters: torque-speed characteristic, losses, efficiency, size, cost, etc.).

Brushed and brushless DC machines:

Brushed versus brushless; advancements and case studies.

Brushed DC machine equivalent circuit model, analysis of the circuit, testing/characterising.

LO2 Explore the operation and the various starting methods of induction machines.

Methods and applications:

Characteristics and testing (characterisation) of induction machines (locked rotor and no-load tests)

Equivalent circuit model of one phase with magnetising branch approximation.

Starting methods

Direct On-Line (DOL)

Star/Delta

Variable Frequency Drives (VFD)

Operation, key characteristics, and parameters:

Voltages, power, speed, torque, inertia, EMI, efficiency, and safety (including health and safety policies, procedures and regulations, compliance, risk assessment process and procedures)

Protection devices.

LO3 **Explore the operation and the various starting methods of synchronous machines**

Operation and characteristics of synchronous machines:

Characteristics and testing of synchronous machines (too much load can cause them to lose sync and torque)

Focus on two types: Permanent Magnet Synchronous Machines (PMSM – Brushless AC) and the wound rotor for larger applications (grid power generation)

Starting methods (Closed loop control of PMSM with a VFD)

Practical applications

Equivalent circuit model

Voltages, power, speed, torque, inertia, EMI, efficiency

Cooling and protection.

LO4 **Analyse the operating characteristics, construction and applications of electromagnetic transducers and actuators.**

Operating characteristics:

Construction, application, characteristics and testing of electromagnetic transducers and actuators

Transducer types (active, passive, sensor), actuator types (solenoids, linear, rotary including stepper motors)

Practical applications

Voltage and current requirements, hysteresis, and speed of operation.

Torque/force

Insulation Protection (IP) rating

Contact types

Back Electromotive Force (EMF), EMI and efficiency.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate the different types and operation of electrical machines.		
P1 Examine the types of electrical machine used in industry. **P2** Discuss suitable applications for electrical machines in industry. **P3** Investigate key parameters of a brushed DC machine.	**M1** Illustrate the operation of the brushed DC machine, considering the equivalent circuit.	**D1** Assess the appropriateness of different types of electrical machine for an actual operational requirement.
LO2 Explore the operation and the various starting methods of induction machines		
P4 Explore the operating principles of the three-phase induction machine. **P5** Analyse the different methods of starting three- and single-phase induction machines.	**M2** Demonstrate the characterisation of the three-phase induction machine, considering the equivalent circuit.	**D2** Critically evaluate the efficiency of available induction machines and make a recommendation for a specific operational requirement.
LO3 Explore the operation and the various starting methods of synchronous machines		
P6 Explain the operating principles of a permanent magnet synchronous machine. **P7** Explore a synchronous machine for a specific application, considering their operating characteristics.	**M3** Justify the use of a wound-rotor synchronous machine in a specific application.	**D3** Assess the performance and efficiency of permanent-magnet synchronous machines and make a recommendation for a specific operational requirement.
LO4 Analyse the operating characteristics, construction and applications of electromagnetic transducers and actuators		
P8 Analyse the operation, types and uses of electromotive transducers and actuators, by examining features that support their suitability for specific applications.	**M4** Justify the selection of suitable transducers for specific industrial applications.	**D4** Critically analyse the practical application of transducers and actuators in an industrial situation and make recommendations to improve their operating effectiveness.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Boldea I. and Tutelea L.N. (2021) *Electrical Machines: Steady State and Performance with MATLAB*. 2nd Ed. CRC Press

Boldea I. and Tutelea L.N. (2021) *Electrical Machines: Two Volume Set.* 2nd Ed. CRC Press

Chapman S.J. (2011) *Electric Machinery Fundamentals*. 5th Ed. McGraw-Hill

De Silva, C.W. (2015) *Sensors and Actuators: Engineering System Instrumentation*. 2nd Ed. CRC Press

Fucha E.F. and Masoum M.A.S. (2023) *Power Quality in Power Systems, Electrical Machines, and Power-Electronic Drives*. 3rd Ed. Academic Press

Gibbons P.(Editor) (2023) *Electrical Machines: Analysis and Applications* (Hardback). Clanrye International.

Gieras J.F. (2020) *Electrical Machines: Fundamentals of Electromechanical Energy Conversion*. CRC Press

Guru B.S. and Hiziroglu H.R. (2001) *Electric Machinery and Transformers*. 3rd Ed. Oxford university Press

Hughes, A. (2013) *Electric Motors and Drives: Fundamentals, Types and Applications*. 4th Ed. Newnes

Krishnan R. (2001) *Electric Motor Drives: Modeling, Analysis, and Control* Paperback – Illustrated. Pearson.

Alassouli H.M. (2021) *Lecture Notes for Electrical Machines Course*. Self-published.

Sarma M.S. (1997) *Electrical Machines: Steady-State Theory and Dynamic Performance*. 2nd Ed. CL Engineering

Sehgal R., Gupta N., Tomar A., Sharma M.D. and Kumaran V. (2022) *Smart Electrical and Mechanical Systems.* 1st Ed. Academic Press

Wildi T. (2014) *Electrical Machines, Drives and Power Systems*. 6th Ed. Pearson New International Edition.

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Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

CES Transactions on Electrical Machines and Systems

Electrical Machines and Control 1007-449X

Electrical machines and Electromechanics

Electrical Machines & Power Systems

International Journal of Electrical Machines & Drives

International Journal of Electrical Power & Energy Systems

Journal of Electrical Engineering & Technology

Links

This unit links to the following related units:

Unit 5010: Further Electrical Machines and Drives.