Unit 5010: Further Electrical Machines and Drives

Unit Code: H/651/0864

Level: 5

Credits: 15

Introduction

Electric machines are used to convert electrical power to mechanical power or vice-versa. They are an indispensable part of engineering processes and are the workhorse in both commercial and industrial applications.

The aim of this unit is to continue developing the skills in the use and application of electrical machines, particularly direct current (DC) and alternating current (AC) drives.

Among the topics included in this unit are: an introduction to electrical machines and drives, and their characteristics, starting and braking, loading conditions, ratings, and their control.

On successful completion of this unit students will be able to learn about the operation of different motors used in industry, different types of industrial drives used in various disciplines, assessing the importance of electrical machines and their drives for a given industrial application, and analysing their performances and suggest appropriate solutions using a variety of possible methods.

Prior learning: It is recommended to complete *Unit 4021 Electrical Machines* before studying this unit.

Learning Outcomes

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

LO1 Synthesise knowledge and skills on the principles of operation and the characteristics of electrical machines and their industrial applications

LO2 Examine the fundamentals of power electronics converters

LO3 Analyse the operation and characteristics of DC drives and their industrial applications

LO4 Analyse the operation and characteristics of AC drives and their industrial applications

Essential Content

LO1 **Synthesise knowledge and skills on the principles of operation and the characteristics of electrical machines and their industrial applications**

Principles of operation and characteristics of electrical machines and their industrial applications:

Electrical machines, concepts of electrical machines and their classification

Principles of operation of DC machines and their characteristics

Principles of operation of three-phase induction machines and their characteristics

Principles of operation of synchronous machines and their characteristics

Introduction to special machines

Four-quadrant torque-speed operation, inertia, and friction characteristic of electrical machines.

Simulation using Matlab/Simulink or similar commercially available software

Methods and practices for operations and control: Administrative controls; operational controls; geometry, location, access; hazards and control measures in practice: commissioning, decommissioning, monitoring and repair of electrical machines; storage and transport; sustainability factors in industrial applications; associated documentation control processes (including access, authorisation, location, format) and standard operating procedures (SoPs); relevant use of data collection systems, data input/output formats within the context of industrial use of electrical machines.

Electrical machines and Industry 4.0: Use and benefits from increased connectivity, performance optimisation, integration and impact on organisations. Example applications such as data driven condition monitoring and multidrive systems.

LO2 **Examine the fundamentals of power electronics converters**

Fundamentals of power electronics converters used in power processing units for electric drives:

Electronic switches (transistors); MOSFETs, IGBTs and how they are driven including practical considerations

Concepts of electrical drives and their classification

DC to DC converters, AC to DC converters (Rectifiers), DC to AC converters (Inverters), AC to AC converters (Cyclo-converters)

Simulation using Matlab/Simulink or similar commercially available software.

LO3 **Analyse the operation and characteristics of DC drives and their industrial applications**

Operation and characteristics of DC drives and their industrial applications:

DC drives and their application to emerging areas such as smart grids and renewable energy sources

Operating modes of DC drives; single-phase drives, three-phase drives, Pulse Width Modulation (PWM), two/four quadrant operation drives

Application; closed loop control of DC drives

Simulation using Matlab/Simulink or similar commercially available software

Practical experience in using equipment, where available

Safety first culture in industrial application design − health and safety policies, procedures and regulations, compliance, individual/team responsibilities, risk assessment and risk mitigation.

LO4 **Analyse the operation and characteristics of AC drives and their industrial applications**

Operation and characteristics of AC drives and their industrial applications:

AC drives and their industrial applications such as process control, smart grids and renewable energy sources

Induction motor drives: voltage, and frequency control (V/f with RL compensation), and closed loop speed control

Synchronous motor drives: closed loop speed control (Field Oriented Control, FOC) of synchronous motor drives

Simulation using Matlab/Simulink or similar commercially available software

Practical experience in using equipment, where available.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Synthesise knowledge and skills on the principles of operation and the characteristics of electrical machines and their industrial applications</td><td rowspan="2">D1 Critically evaluate the performance of a given electrical machine for a specific application using Matlab, Simulink or similar software.</td></tr>
<tr><td>P1 Evaluate different types of electrical machines and their industrial applications.
P2 Illustrate the principle of operation of electrical machines with the aid of circuit diagrams and waveforms.
P3 Synthesise knowledge and skills on the construction, operation and characteristics of a given electrical machine.</td><td>M1 Utilise Matlab and Simulink or similar software for modelling and simulation of a given electrical machine.
M2 Analyse the characteristics of a given electrical machine from its equivalent circuits.</td></tr>
<tr><td colspan="2">LO2 Examine the fundamentals of power electronics converters</td><td rowspan="2">D2 Critically evaluate the performance of a MOSFET half-bridge DC/AC converter using Matlab/ Simulink software, using different MOSFETs.</td></tr>
<tr><td>P4 Illustrate, with the aid of a circuit diagram and waveforms, the operation of a MOSFET half-bridge switch.
P5 Illustrate, with the aid of a circuit diagram and waveforms, the operation of a full-wave rectifier with smoothing.
P6 Examine with the aid of a circuit diagram, how an H-bridge converts DC to AC.</td><td>M3 Demonstrate how Matlab and Simulink (or similar software) are used for modelling and simulation of a MOSFET half-bridge switch.
M4 Evaluate the key performance characteristics of a MOSFET half-bridge switch.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Analyse the operation and characteristics of DC drives and their industrial applications		
P7 Discuss the operating modes of DC drives and control parameters. **P8** Analyse the importance of DC drives in industrial applications. **P9** Conceptualise with the aid of diagrams how an H-bridge can be used to drive a DC machine at different speeds and directions. **P10** Illustrate, with the aid of diagrams the implementation of closed loop control of DC drives.	**M5** Develop an open loop block diagram (using Matlab Simulink or similar software) of a DC motor and derive the relationship between the input and the output of the system. **M6** Investigate the parameters influencing the output characteristics of a DC machine, driven by an H-Bridge when load is applied.	**D3** Critically analyse the impact of a given DC drive on the operation and performance of a specific industrial process control system.
LO4 Analyse the operation and characteristics of AC drives and their industrial applications		
P11 Analyse the operating modes of AC drives, their control parameters, and their importance in industrial applications. **P12** Illustrate, with the aid of circuit diagrams and waveforms, the principles of operation of three-phase AC drives. **P13** Propose, with the aid of diagrams, how an H-Bridge can be used to drive a single-phase AC machine.	**M7** Develop an open loop block diagram of an induction motor (using Matlab Simulink or similar software) and derive the relationship between the input and the output of the system. **M8** Investigate how AC drive circuits are used to control the speed of induction and synchronous motors.	**D4** Critically analyse the impact of a given AC drive on the operation and performance of a specific industrial process control system.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

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

Bose B.K. (2001) *Modern Power Electronics and AC Drives Hardcover*. Printice Hall.

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 Se*t. 2nd Ed. CRC Press.

El-Sharkawi M.A. (2018) *Fundamentals of electric drives*. 2nd Ed., CL Engineering.

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

Franchi C.M. (2022) *Electrical Machine Drives – Fundamental Basics and Practice*. CRC Press.

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

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

Rashid M.H. (2012) *Power Electronics: Circuits, Devices and Applications*. 4th Ed. Prentice Hall.

Rashid, M.H. (2001) *Power Electronics Handbooks*. 1st Ed. Academic Press.

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

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 Drives – A Section of Machines

Electrical Machines and Electromechanics

Electrical Machines & Power Systems

Fundamentals of Electrical Drives

International Journal of Electrical Machines and Drives

International Journal of Electrical Power and Energy Systems

Journal of Electrical Engineering and Technology

Modern Electrical Drives: Trends, Problems, and Challenges

Links

This unit links to the following related units:

Unit 4021: Electrical Machines.