Unit 31: Features and Applications of Electrical Machines

Level:	**3**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning:	**60**

Unit introduction

All electrical machines use applications of electro-magnetic principles where electric currents create magnetic fields, which either attract or repel each other. This is the basis of all electric motors, whether they operate on alternating current (AC), direct current (DC) or are universal motors that operate on both.

Transformers are devices that also use the principle of electromagnetism. These are generally very efficient and their output power can be almost 100 per cent of the input power, depending on the application.

This unit has been designed to help learners understand the complexities of electromagnetism and its applications to everyday electrical devices, systems and apparatus. Learners will consider a range of machines, their application and their control. In addition, the unit will help learners understand relevant electrical hazards, legislation, regulation and standards.

Note that the use of 'e.g.' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'e.g.' needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1 Know the electrical hazards and the legislation, regulations and standards related to working with electrical apparatus

2 Understand features and applications of alternating current (AC) machines

3 Understand features and applications of direct current (DC) machines

4 Know how electrical machine control circuits and systems operate.

Unit content

- 1 **Know the electrical hazards and the legislation, regulations and standards related to working with electrical apparatus**

  Electrical hazards: safe working procedures e.g. isolation (safe isolation, switch off, lock off, display notices, testing for dead with test lamp and proving unit), earthing, interlocking, warning notices, permit to work; risk assessment when working on electrical apparatus e.g. hazard evaluation and recording of risk, controlling risk; personal protective equipment (PPE) e.g. insulated gloves, mats, tools, barriers

  Legislation, regulations and standards: e.g. Health and Safety at Work Act 1974, The Electricity at Work Regulations 1989, Personal Protective Equipment at Work Regulations 1992, Electrical Equipment (Safety) Regulations 1994, Machinery Directives, HSE publications e.g. GS38, Codes of Practice, British and International Standards, BS7671 17th Edition IEE Wiring Regulations

- 2 **Understand features and applications of alternating current (AC) machines**

  Alternating current (AC) motors: single and polyphase; construction, principles of operation, starting characteristics and torque; types (induction motors, split-phase, capacitor start, capacitor start and run, shaded pole, universal, variable frequency drives); applications of AC motors e.g. conveyor belt drives, pumps, machine shop equipment, fixed loads, variable loads

  AC generator: types e.g. single-phase, polyphase; construction and principles of operation; applications e.g. stand-by generators, remote site generators, vehicle alternators with regulation and rectification

  Transformers: principles of operation; efficiency and losses; construction of single and double wound; types e.g. step up, step down, safety isolating transformer; applications e.g. incoming mains step down, portable transformer for hand tools, safety isolating transformer for electrical test-bench work, machine power supplies

- 3 **Understand features and applications of direct current (DC) machines**

  Direct current (DC) motors: types e.g. series, shunt, compound (long and short shunt), brushless; construction, principles of operation, starting characteristics and torque; applications e.g. motor vehicle starters and window operation, toys and models, industrial drives, crane hoists, fixed loads, variable loads

  DC generators: construction and principles of operation; production and control of DC voltages and current; applications e.g. motor vehicles, speed control/feedback systems (tacho-generators)

- 4 **Know how electrical machine control circuits and systems operate**

  Stop/start/retain relay control: relay/contactor with retaining/latching contact; start, stop, overload, 'inch' (non-latching) control; remote stop/start; safety relays for production/manufacturing equipment e.g. several guards closed sensors, oil level detectors, temperature sensors, body heat (passive infra-red) detectors; control circuits e.g. AC machine control (direct on line (DOL), star-delta, soft start and other solid state techniques such as triac, inverter drives, slip ring rotor resistance control, auto transformer, power factor correction), DC machine control (starting methods and speed control such as face plate, solid state systems); emergency stop e.g. closed contact device to stop the machine/system from running or starting and turn power off under emergency conditions; emergency stopping e.g. dynamic braking by either DC injection braking or timed phase reversal, solenoid operated mechanical brakes, instantly stopping the machine

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 describe hazards that may exist when working with two different pieces of electrical apparatus		
P2 describe control measures that should be used to reduce the risk of harm to self and others when working with two different pieces of electrical apparatus		
P3 describe aspects of legislation, regulations and standards that relate to work being carried out on two different pieces of electrical apparatus		
P4 explain the features, characteristics and application of two different types of AC motor	M1 explain the operational features of a speed control system for an AC machine	D1 compare the applications of a DC and an AC motor for two contrasting modern electrical installations
P5 explain the features, characteristics and an application of one type of AC generator		

P6 explain the features, characteristics and application of two different types of transformer		
P7 explain the features, characteristics and application of two different types of DC motor	M2 explain the operational features of a speed control system for a DC machine	
P8 explain the features, characteristics and an application of a DC generator		
P9 describe the operation and use of a stop/start/retain relay control circuit for an AC or DC machine.	M3 explain the use of a safety relay system and how its use addresses the issues raised in relevant legislation, regulations and standards.	D2 compare the construction and operation of two different types of stop/start/ retain relay control circuit for either an AC or a DC machine.

Essential guidance for tutors

Assessment

P1, P2 and P3 are linked and are likely to be achieved through investigations based on the same two different items of electrical equipment, e.g. transformers, isolators, AC and DC motors. Evidence could be presented in the form of a written report or as a presentation to a group using appropriate visual aids.

When describing hazards and control measures for P1 and P2, learners should include all the aspects identified in the unit content.

For P3, learners should include relevant quotes from their sources and specific references and it is important that these are shown to be specific to the work being undertaken and not just general quotes.

For P4, the learner needs to carry out investigations based on two different types of AC motor (e.g. induction, split-phase, capacitor start, capacitor start and run, shaded pole, universal, variable frequency drives, single or polyphase motors). Ideally, these should be combined into one single investigation of two different motors rather than two separate investigations. This will avoid the need to assess the criterion twice before it can be reported as achieved. Learners need to describe the features, characteristics (e.g. construction, principles of operation, starting characteristics and torque) and a typical application for each type of AC motor considered. Evidence could include written descriptions plus relevant drawings, circuit diagrams, photographs and exploded views (as appropriate), annotated to aid the description.

P5 and P6 require a similar approach. However, it is important to note that while P5 only requires one AC generator to be considered, for P6, like P4 above, learners must describe two different types of transformer (e.g. step up, step down or safety isolating transformers).

P7 and P8 simply replicate the criteria for P4 and P5 but for two different DC motors (e.g. series, shunt, compound (long and short shunt), brushless) and one DC generator. As above, P7 should be done as one activity to avoid splitting the criterion.

P9 requires learners to be able to describe the operation and use of a stop/start/retain relay control circuit. This can be an AC or DC machine and can be chosen by the tutor or the learner. The choice of AC or DC control circuit is only limited by the need to draw as extensively as possible from the unit content to cover such aspects as safety relays and emergency stop/stopping requirements. The assignment should be based on a practical investigation if possible and learners should provide a careful description of the circuit that they have investigated. This should include an itemised list of components (together with a description of the function of each component) and should be supported by a suitably annotated circuit diagram.

To achieve M1 and M2, learners should be able to explain the operational features of the speed control systems for an AC machine and a DC machine respectively. Learners will need to consider the speed control aspects of machines within specific applications, which will draw from and build upon their knowledge and understanding developed through P4–P8.

For M3, learners need to explain the use of a safety relay system and how the system addresses the issues raised in relevant legislation, regulations and standards. The system considered could be the same as that described for P9. Learners must be able to set the circuit within a particular context or application and demonstrate that they understand the importance of the circuit within that application.

Learners must also have recognised the relationship of such a circuit to the requirements of relevant legislation, regulations and standards. Note that there is a further link from the work undertaken for P9 and M3 to that required for D2 (see notes below) and this might form the basis of a single assignment.

To satisfy D1, learners should show that they can bring together their understanding of P4 to P8 by comparing the applications of a DC and an AC motor for two contrasting modern electrical installations. Learners should investigate two sufficiently complex and contrasting installations that enable them to draw from and show that they can apply the understanding that they have gained at pass and merit level. Typical applications might be a variable-speed motor drive for an electric vehicle and a high-torque constant-speed drive used in an industrial conveyor belt.

Learners should justify the type of DC and AC motor as well as its supply configuration (e.g. triac speed controller) and output drive systems (e.g. gearbox or belt reduction system). They should also make reference to the operating principles and actual machine characteristics (e.g. starting torque, on-load torque, efficiency).

D2 builds on the work undertaken for P9 and M3. As such, the circuit considered for P9 could be one of the stop/start/retain relay control circuits that is used for comparison and against which a second is compared. However, centres may prefer to get learners to consider two completely different relay control circuits to provide them with a wider range of experience.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3	Electrical Hazards and Legislation and Regulations	A technician has been asked to show potential electrical hazards to a new learner and explain the legislation and regulations with which they need to be familiar.	A written report or a presentation
P4, P5, P6, P7, P8, M1, M2, D1	AC and DC Electrical Machines	A technician has been asked to write a report explaining and comparing the key features of a range of new AC and DC machines.	A written report
P9, M3, D2	Machine Control Circuits and Systems	A technician has been asked to describe the operation of a stop/start/ retain relay control to a new member of staff.	A written report

Essential resources

Centres will need a workshop equipped with electrical machines and associated switchgear and control equipment. Learners will require access to a range of AC and DC motors and generators. A selection of different types of transformer (e.g. step-down, step-up, isolating variable voltage) will also be required. In addition, to permit testing of motor speed controllers, learners will require one or more variable speed controllers (for both AC and DC motors) together with variable loads and machine braking systems.

Learners will also require access to appropriate statutory and non-statutory regulations, health and safety legislation as well as catalogues, data sheets and relevant equipment specifications.

Indicative reading for learners

Textbooks

Bird, J – *Electrical and Electronic Principles and Technology* (Routledge, 2013) ISBN9780415662857

Hughes A – *Electric Motors and Drives: Fundamentals, Types and Applications* (Newnes, 2013) ISBN 9780080983325

Schultz G – *Transformers and Motors* (Newnes, 1997) ISBN 9780750699488