Unit 61: Features and Applications of Electrical Machines

Unit code: D/600/7115

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit provides learners with knowledge and an understanding of the features and applications of a range of electrical machines and the hazards, legislation and regulations related to working with electrical apparatus.

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.

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 alternating current (AC) machines

3 Understand 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 eg 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 eg hazard evaluation and recording of risk, controlling risk; personal protective equipment (PPE) eg insulated gloves, mats, tools, barriers

Legislation, regulations and standards: eg 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, Codes of Practice, British and International Standards, BS7671 17th Edition IEE Wiring Regulations

2 Understand 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 eg conveyor belt drives, pumps, machine shop equipment, fixed loads, variable loads

AC generator: types eg single-phase, polyphase; construction and principles of operation; applications eg 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 eg step up, step down, safety isolating transformer; applications eg incoming mains step down, portable transformer for hand tools, safety isolating transformer for electrical test-bench work, machine power supplies

3 Understand direct current (DC) machines

Direct current (DC) motors: types eg series, shunt, compound (long and short shunt), brushless; construction, principles of operation, starting characteristics and torque; applications eg 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 eg 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 eg several guards closed sensors, oil level detectors, temperature sensors, body heat (passive infra red) detectors; control circuits eg 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 eg closed contact device to stop the machine/system from running or starting and turn power off under emergency conditions; emergency stopping eg 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 identify the hazards that may exist when working with two different pieces of electrical apparatus [SM4]	**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
P2 list the 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	**M2** explain the operational features of a speed control system for a DC machine	**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.
P3 describe the aspects of legislation, regulations and standards that relate to work being carried out on two different pieces of electrical apparatus [IE4]	**M3** explain the use of a safety relay system and how its use addresses the issues raised in relevant legislation, regulations and standards.	
P4 explain the features, characteristics and application of two different types of AC motor		
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		

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:**
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.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

Few learners will have had prior experience in this area of work, so it will be essential to provide a formal introduction to the unit content. This introduction should emphasise the safety aspects of working with electricity and electrical machines and should also make learners aware of the relevant statutory and non-statutory regulations. Although these aspects can be developed as learners progress through learning outcome 1, it is important at the outset to make learners aware of the hazards that may be encountered and implications of the regulations that apply to electrical equipment and applications.

It is likely that most centres will want to deliver the learning outcomes sequentially. One approach to delivery could be a series of practical investigations supplemented by appropriate theory. For example, learning outcome 2 could be covered using a series of investigations based on alternating current motors (capacitor start, shaded pole and induction types), alternating current generators (single-phase and polyphase types) and transformers.

Wherever possible, investigations should be based on examples of real machines. Learners should always be encouraged to relate theoretical principles delivered by formal class teaching to practical applications.

Learning outcome 3 can be delivered using a similar approach, based on a set of practical investigations supplemented by relevant theory. Once again, learners should be introduced to typical practical applications of electrical machines (such as vehicle starter motors, industrial drives, toys and models) and be encouraged to relate these to the appropriate theory, which can be delivered by formal class teaching.

In all cases, the approach used should take into account the needs of individual learners and the range of industries that the centre has links with or is preparing the learner for. Whichever approach is taken should be sufficiently varied to provide learners with a knowledge and understanding of electrical machines and their associated control circuits and systems in real-world settings.

Learning outcome 4 requires learners to investigate typical electrical machine control circuits and systems. Learners need to appreciate why these systems are required as well as how they are implemented. Practical examples should be provided for learners to investigate and these could be supported by visits to local industry where a wider range of techniques will usually be available. As a minimum, learners should be provided with direct experience of a simple start/stop/retain control circuit for both a DC and an AC machine. They should also be made aware of how this system addresses relevant health and safety legislation.

Delivery of this unit can provide opportunities for learners to work individually or in groups when planning or investigating electrical machines. In all cases, tutors should ensure that each learner has the correct personal protective equipment and that machines and their associated control systems are safe for inspection and operation. It is important that close attention is paid when learners are using machines or working on machine control systems to ensure a safe working environment and that they operate systems in a safe manner.

Note that the use of 'eg' 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 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain the importance and use of safe working procedures for working with electrical apparatus • describe the control measures used to reduce risk of harm to self and others • explain the key legislation, regulations and standards that apply to working with electrical apparatus. *Practical workshop activities:* • carrying out risk assessment for different types of electrical equipment.
Prepare for and carry out **Assignment 1: Electrical Hazards and Legislation and Regulations** (P1, P2, P3).
Whole-class teaching: • explain the key features, characteristics, operation and applications of different types of AC motor • explain the key features, characteristics, operation and applications of AC generators • explain the key features, characteristics, operation and applications of different types of transformer. *Practical workshop activities:* • practical investigation of a range of different AC machines.
Whole-class teaching: • explain the key features, characteristics, operation and applications of different types of DC motor • explain the key features, characteristics, operation and applications of DC generators. *Practical workshop activities:* • practical investigation of a range of different DC machines.
Prepare for and carry out **Assignment 2: AC and DC Electrical Machines** (P4, P5, P6, P7, P8, M1, M2, D1).
Whole-class teaching: • explain the purpose, use and operation of stop/start/retain relay controls for AC and DC machines. *Practical workshop activities:* • practical investigation of a range of different electrical machine control circuits and systems.
Prepare for and carry out **Assignment 3: Machine Control Circuits and Systems** (P9, M3, D2).
Feedback on assessment and unit evaluation.

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, eg 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 identifying hazards and listing 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 (eg 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 (eg 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 (eg 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 (eg 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 belt conveyor.

Learners should justify the type of DC and AC motor as well as its supply configuration (eg triac speed controller) and output drive systems (eg gearbox or belt reduction system). They should also make reference to the operating principles and actual machine characteristics (eg 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 Edexcel 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 apprentice 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.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with:

Level 1	Level 2	Level 3
		Electrical and Electronic Principles
		Electrical Technology

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 (eg 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.

Employer engagement and vocational contexts

Much of the work for this unit can be set in the context of learners' work placements or be based on case studies of local employers. Further information on employer engagement is available from the organisations listed below:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI – University of Warwick) – www.warwick.ac.uk/wie/cei/
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbooks

Hughes A – *Electric Motors and Drives: Fundamentals, Types and Applications* (Newnes, 2005) ISBN 0750647183

Schultz G – *Transformers and Motors* (Newnes, 1997) ISBN 0750699485

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	analysing and evaluating information when relating the relevant aspects of legislation, regulations and standards to working with electrical apparatus
Self-managers	anticipating, taking and managing risks when identifying the hazards that may exist when working with electrical apparatus.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Reflective learners	setting goals with success criteria for their development and work
Team workers	collaborating with others when working in groups to investigate a range of electrical machines.

Functional Skills – Level 2

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	describing the hazards, control measures and aspects of legislation, regulation and standards that apply to working with electrical apparatus
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	Researching and investigating the hazards, control measures and aspects of legislation, regulation and standards that apply to working with electrical apparatus
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining the features, characteristics and applications of AC and DC machines.