Unit 64: Electrical Applications

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

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 Understand electrical hazards, legislation, regulation and standards

2 Understand alternating current machines

3 Understand direct current machines

4 Understand electrical machine control circuits and systems.

Unit content

1 **Understand electrical hazards, legislation, regulation and standards**

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 16th Edition IEE Wiring Regulations

2 **Understand alternating current 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 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 **Understand electrical machine control circuits and systems**

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

Grading grid

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

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 and list the control measures that should be used to reduce the risk of harm to self and others P2 describe the aspects of legislation, regulations and standards that relate to work being carried out on two different pieces of electrical apparatus P3 describe the features, characteristics and application of two different types of AC motor P4 describe the features, characteristics and an application of one type of alternating current generator P5 describe the features, characteristics and application of two different types of transformer	M1 explain the operational features of a speed control system for an AC machine M2 explain the operational features of a speed control system for a 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.	D1 compare the applications of a DC and an AC motor for two contrasting modern electrical installations 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.

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:**
P6 describe the features, characteristics and application of two different types of DC motor P7 describe the features, characteristics and an application of a DC generator P8 describe the operation and use of a stop/start/retain relay control circuit for an AC or DC machine.		

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.

Assessment

P1 and P2 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 might 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, learners should include all the aspects identified in the unit content.

For P2, 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 P3, 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 for this criterion might include the written descriptions plus relevant drawings, circuit diagrams, photographs and exploded views (as appropriate), annotated to aid the description.

The criteria P4 and P5 require a similar approach. However, it is important to note that while P4 only requires one AC generator to be considered, for P5, like P3 above, learners must describe two different types of transformer (eg step up, step down or safety isolating transformers).

P6 and P7 simply replicate the criteria for P3 and P4 but for two different DC motors (eg series, shunt, compound (long and short shunt), brushless) and one DC generator. As above, P6 should be done as one activity to avoid splitting the criterion.

P8 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 the merit criteria, 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 P3–P7.

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 P8. 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 P8 and M3 to that required for D2 (see notes below) and this might form the basis a single assignment.

In order to satisfy D1, learners should be to able show that they can bring together their understanding of P3 to P7 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 be able to 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 upon the work undertaken for P8 and M3. As such, the circuit considered for P8 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.

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

This unit provides some of the underpinning knowledge for the SEMTA Level 3 NVQ in Electrical and Electronic Engineering.

The unit can be linked to *Unit 5*: *Electrical and Electronic Principles* and *Unit 52*: *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.

Indicative reading for learners

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

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

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Tutors should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Application of number Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• describing the features, characteristics and application of different types of AC and DC motors and generators • describing the features, characteristics and application of different types of transformer.	N3.1 Plan an activity and get relevant information from relevant sources. N3.2 Use this information to carry out multi-stage calculations to do with: a amounts or sizes b scales or proportion c handling statistics d using formulae. N3.3 Interpret the results of your calculations, present your findings and justify your methods.

Communication Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• identifying hazards that may exist when working with electrical machines • describing relevant aspects of legislation, regulations and standards • describing the features, characteristics and application of different types of AC and DC motors and generators • describing the features, characteristics and application of different types of transformer • describing the operation and use of a stop/start/retain relay control circuit.	C3.2 Read and synthesise information from at least **two** documents about the same subject. Each document must be a minimum of 1000 words long. C3.3 Write **two** different types of documents each one giving different information about complex subjects. One document must be at least 1000 words long.
Information and communication technology Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• researching and preparing reports to describe relevant aspects of legislation, regulations and standards • researching and preparing reports to describe the features, characteristics and application of different types of AC/DC motors and generators • researching and preparing reports to describe the features, characteristics and application of different types of transformer • preparing reports to describe the operation of stop/start/retain relay control circuits.	ICT3.1 Search for information, using different sources, and multiple search criteria in at least one case. ICT3.2 Enter and develop the information and derive new information. ICT3.3 Present combined information such as text with image, text with number, image with number.