Next Generation Higher National Unit Specification

Electrical Transformers, Motors and Machine Systems (SCQF level 8)

Unit code: J7BT 48

SCQF level: 8 (24 SCQF credit points)

Valid from: session 2023 to 24

Prototype unit specification for use in pilot delivery only (version 1.0) February 2024

This unit specification provides detailed information about the unit to ensure consistent and transparent assessment year on year.

This unit specification is for teachers and lecturers and contains all the mandatory information required to deliver and assess the unit.

This edition: February 2024 (version 1.0)

Unit purpose

This unit provides learners with knowledge and understanding, as well as practical application, of electrical power machines and drive systems. It covers:

- the constructional features and applications of transformers
- electrical machines and drives, and their characteristics
- starting and braking, loading conditions, ratings, and the control of these

Entry to the unit is at your centre's discretion. However, we recommend that learners have one or more of the following:

- broad knowledge and understanding of electrical power systems at SCQF level 7, for example passes in SCQF level 7 units covering electrical principles
- relevant SCQF level 7 qualifications, for example Advanced Higher Physics or Engineering Science, or a Higher National Certificate in a related engineering subject
- relevant or equivalent workplace experience

The unit provides learners with suitable knowledge and skills to progress to:

- employment in a wide range of engineering jobs requiring electrical knowledge
- technical apprenticeships
- further study

Unit outcomes

Learners who complete this unit can:

1 analyse the construction and operation of single-phase and three-phase transformers
2 analyse the applications of induction and synchronous motors
3 analyse the functions and applications of transducers and actuators, including power electronics
4 analyse the operations of direct current (DC) and alternating current (AC) drives in industrial applications
5 analyse motor characteristics for industrial loads
6 analyse protection arrangements for motors and ancillary equipment

Evidence requirements

You should assess the unit holistically, using a portfolio of evidence generated by learners. They must produce a reflective report for each outcome, evaluating the knowledge and skills they have gained.

Learners must generate evidence under unsupervised, open-book conditions. It must be in an appropriate written or oral recorded format.

You can find further information in the ‘Additional guidance’ section.

To successfully achieve the unit, learners must provide a sample of evidence from the ‘Knowledge and skills’ section.

Even though the evidence requirements are assessed on a sample basis, you must teach all content in the ‘Knowledge and skills’ section and it must be available for assessment. Learners should not know which items they will be assessed on in advance. You must use a different sample for each assessment occasion.

Outcome 1

For this outcome, you must assess five of the nine items:

- Examine transformer core type construction, B-H curves, eddy current losses within the core, applied voltage and induced voltage production of harmonics.
- Draw a full transformer equivalent circuit and a simplified equivalent circuit.
- Calculate equivalent resistance and reactance open and short circuit tests.
- Calculate the transformer efficiency for full load, half load and different power factor voltage regulation.
- Describe conditions necessary for parallel operation of single-phase transformers.
- Produce vector diagrams, vector symbols and phase displacements.
- Describe conditions for parallel operation of three-phase transformers with regard to tap changing and transformer cooling classifications.
- Describe effects of short circuit faults.
- Describe the use of gas-oil actuated (Buchholz) relay circuit breakers surge protection.

Outcome 2

For this outcome, you must assess four of the seven items:

- Explain with the aid of annotated diagrams different starting methods.
- Identify starting circuitry for different motors.
- Label constructional components of different motors.
- Justify the selection of a motor for a specific industrial application.
- Demonstrate different characteristics by testing of induction and synchronous motors.
- Evaluate the relationship of voltages, current, frequency, power, speed, torque, inertia, electromagnetic interference (EMI) and efficiency.
- Make recommendations of cooling and protection devices for machines.

Outcome 3

For this outcome, you must assess eight of the twelve items:

- Analyse the practical application of transducers (active, passive, sensor) and actuator types (solenoids, linear, rotary).
- Calculate the voltage and current requirements of two actuators and two transducers.
- Describe hysteresis and eddy current losses.
- Simulate torque and speed characteristics.
- Choose correct ingress protection (IP) for a type of environment.
- Describe back electromotive force (EMF), EMI and efficiency.
- Highlight characteristics of electrical machines suitable for industrial applications.
- State concepts of electrical machines and their classification.
- Operate DC machines in a controlled environment and record characteristics.
- Operate three-phase induction machines under controlled conditions and record their characteristics.
- Operate synchronous machines and record characteristics.
- Simulate using suitable software:
  - DC to DC converters (choppers)
  - AC to DC converters (rectifiers)
  - DC to AC converters (inverters)
  - AC to AC converters (cyclo-converters)

Outcome 4

For this outcome, you must assess five of the seven items:

- Describe the use of different hardware modes of DC drives:
  - single-phase drives
  - three-phase drives
  - chopper drives
  - two/four quadrant operation drives

- Identify applications using closed-loop control of DC drives.
- Draw the speed-torque characteristic of an AC motor suitable for driving conveyors, centrifugal pumps or other suitable applications.
- Select two AC drives and match to their industrial application such as smart grid and renewable energy sources.
- Describe induction motor drives: voltage controls, frequency controls, current controls, voltage, current and frequency control, and closed-loop control induction motor.
- Describe synchronous motor drives: frequency control and closed-loop control of synchronous motor drives.
- Simulate using suitable software any one DC drive and one AC drive application.

Outcome 5

For this outcome, you must assess three of the five items:

- Describe electrical protection arrangements of power transmission systems.
- Describe starting/braking arrangements for electric motors.
- Discuss factors that affect the selection of power transmission systems (nature of load — torque demand on motor, resonance with natural frequency of system, backlash, cost).
- Explain how the following types of transmission systems can be used with electric motors:
  - flexible couplings
  - chain and sprocket drive
  - pulley and belt drive
  - clutches
  - gearboxes
- For the above types of transmission systems:
  - use manufacturers' catalogues and internet sources to explore different drive types
  - perform calculations involving the sizing of drives

Outcome 6

For this outcome, you must assess six of the nine items:

- Explain the need for electrical protection in a motor drive system.
- Identify overcurrent and earth leakage as the main forms of electrical protection.
- Describe, using manufacturers' catalogues and internet sources as support, protection components, their main constructional features and key performance characteristics as used in electrical protection systems:
  - fuses
  - relays circuit
- Explain, with the aid of annotated diagrams, at least two types of motor starting arrangements.
- Explain, with the aid of annotated diagrams, at least two types of motor braking arrangements.

- Identify braking circuitry.
- Identify factors influencing choice of braking method in terms of performance and cost.
- Explain different braking methods used with DC and AC motors (regenerative, reverse current and DC dynamic braking).
- Investigate the selection of motor and ancillary equipment for a given industrial load.

Knowledge and skills

The following table shows the knowledge and skills covered by the unit outcomes:

Knowledge	Skills
Outcome 1 Learners should understand: ♦ the construction characteristics of transformers ♦ the operation of single-phase transformers on load ♦ the operation of three-phase transformers ♦ transformer protection	**Outcome 1** Learners can: ♦ examine transformer core type construction, B-H curves, eddy current losses within the core, applied voltage and induced voltage production of harmonics ♦ draw a full transformer equivalent circuit and a simplified equivalent circuit ♦ calculate equivalent resistance and reactance open and short circuit tests ♦ calculate the transformer efficiency for full load, half load and different power factor voltage regulation ♦ describe parallel operation of single-phase transformers ♦ produce vector diagrams, vector symbols and phase displacements ♦ describe conditions for parallel operation of three-phase transformers with regard to tap changing and transformer cooling classifications ♦ describe effects of short circuit faults ♦ describe the use of gas-oil actuated (Buchholz) relay circuit breakers surge protection

Knowledge	Skills
Outcome 2 Learners should understand: ♦ the starting methods and applications of three-phase induction motors and synchronous machines ♦ the types of generators available in industry by assessing their practical applications	**Outcome 2** Learners can: ♦ explain, with the aid of annotated diagrams, different starting methods ♦ identify starting circuitry ♦ label constructional components of different motors ♦ justify the selection of a motor for a specific industrial application ♦ demonstrate different characteristics by testing induction and synchronous motors ♦ evaluate the relationship of voltages, current, frequency, power, speed, torque, inertia, EMI and efficiency ♦ recommend cooling and protection devices for machines

Knowledge	Skills
Outcome 3 Learners should understand: ♦ the operating characteristics of electromagnetic transducers and actuators ♦ the principles of operation and the characteristics of electrical machines and their industrial applications ♦ the fundamentals of power electronics converters used in power processing units for electric drives	**Outcome 3** Learners can: ♦ analyse the practical application of transducers (active, passive, sensor) and actuator types (solenoids, linear, rotary) ♦ calculate the voltage and current requirements of two actuators and two transducers ♦ describe hysteresis and eddy current losses ♦ simulate torque and speed characteristics ♦ choose correct IP for the type of environment ♦ describe EMF, EMI and efficiency ♦ highlight characteristics of electrical machines suitable for industrial applications ♦ state concepts of electrical machines and their classification ♦ operate DC machines in a controlled environment and record characteristics ♦ operate three-phase induction machines under controlled conditions and record their characteristics ♦ operate synchronous machines and record characteristics ♦ simulate, using suitable software: — DC to DC converters (choppers) — AC to DC converters (rectifiers) — DC to AC converters (inverters) — AC to AC converters (cyclo-converters)

Knowledge	Skills
Outcome 4 Learners should understand: ♦ the fundamentals of DC drives and their industrial applications ♦ the fundamentals of AC drives and their industrial applications	**Outcome 4** Learners can: ♦ describe the use of different hardware modes of DC drives: single-phase drives, three-phase drives, chopper drives, two/four quadrant operation drives ♦ identify applications using closed-loop control of DC drives ♦ draw the speed-torque characteristic of an AC motor suitable for driving conveyors, centrifugal pumps or other suitable applications ♦ select two AC drives and match to their industrial application, such as smart grid and renewable energy sources ♦ describe induction motor drives: voltage controls, frequency controls, current controls, voltage, current and frequency controls, and closed-loop control induction motors ♦ describe synchronous motor drives: frequency control and closed-loop control of synchronous motor drives ♦ simulate, using suitable software, one DC drive and one AC drive application

Knowledge	Skills
Outcome 5 Learners should understand: ♦ the factors that influence the choice of a motor to drive a given industrial load ♦ different forms of motor to load power transmission systems	**Outcome 5** Learners can: ♦ use a block diagram showing the need for power transmission system electrical protection and starting/braking arrangements ♦ discuss factors that affect the selection of power transmission systems (nature of load — torque demand on motor, resonance with natural frequency of system, backlash, cost) ♦ explain how the following types of transmission systems can be used with electric motors: — flexible couplings — chain and sprocket drive — pulley and belt drive — clutches — gearboxes ♦ for the types of transmission systems listed above: — use manufacturers' catalogues and internet sources to explore different drive types — perform calculations involving the sizing of drives

Knowledge	Skills
Outcome 6 Learners should understand: ♦ different electrical protection arrangements used with electrical motors ♦ starting and braking arrangements associated with electrical motors ♦ the selection of motor and ancillary equipment for a given industrial load	**Outcome 6** Learners can: ♦ explain the need for electrical protection in a motor drive system ♦ identify overcurrent and earth leakage as the main forms of electrical protection ♦ describe, using manufacturers' catalogues and internet sources as support: — protection components (fuses and relay circuits) — their main constructional features — key performance characteristics as used in electrical protection systems ♦ explain, with the aid of annotated diagrams, at least two types of motor starting arrangements ♦ explain, with the aid of annotated diagrams, at least two types of motor braking arrangements ♦ identify braking circuitry ♦ identify factors influencing choice of braking method in terms of performance and cost ♦ explain different braking methods used with DC and AC motors (regenerative, reverse current and DC dynamic braking) ♦ investigate the selection of motor and ancillary equipment for a given industrial load

Meta-skills

Throughout the unit, learners develop meta-skills to enhance their employability in the engineering sector.

Self-management

This meta-skill includes:

- integrity (self-awareness, ethics, self-control), which learners demonstrate through their portfolio or investigation reports
- adapting (critical reflection, self-learning), which learners demonstrate through their portfolio or investigation reports
- initiative (decision making, self-motivation, responsibility), which learners demonstrate as they complete their learning activities and projects

Social intelligence

This meta-skill includes:

- communicating (receiving information, listening, giving information), which learners demonstrate by accessing the unit material through a virtual learning environment (VLE), keeping an e-portfolio and writing technical reports
- collaborating (team working, collaboration), which learners demonstrate as they engage with you and other learners throughout the unit

Innovation

This meta-skill includes:

- curiosity (information sourcing, questioning, observation), which learners demonstrate as they complete their learning activities and projects
- sense-making (holistic thinking, analysis), which learners demonstrate as they carry out individual or group learning activities and projects
- critical thinking (deconstruction, logical thinking, judgement), which learners demonstrate as they carry out individual or group learning activities and projects

Literacies

Learners develop core skills in the following literacies:

Numeracy

Learners develop numeracy skills by performing engineering calculations when they evaluate engineering devices and circuits.

Communication

Learners develop communication skills by studying the course material and engaging with lecturers and other learners.

Digital

Learners develop digital skills and computer literacy by using engineering software and recording evidence using digital assets.

Delivery of unit

This unit is part of the Higher National Diploma (HND) in Engineering. The framework includes mandatory and optional units, and you can tailor the selected combination of units to specific engineering pathway needs.

While the exact time allocated to this unit is at your centre's discretion, the notional design length is 120 hours. The amount of time you allocate to each outcome is also at your discretion.

You should give learners the opportunity to participate in tutorial sessions to enable them to practise and apply the theorems and laws that are crucial to this unit. If you incorporate the unit into other group awards, we recommend you deliver it in the context of the specific occupational area or areas that the group award covers.

Additional guidance

The guidance in this section is not mandatory.

Content and context for this unit

We recommend you deliver this unit after learners have gained experience in electrical principles, electromagnetic theory, power supply systems and complex number notation.

Outcome 1 covers constructional characteristics of transformers, analysing the operations of single and three-phase transformers, and explaining transformer protection.

Outcome 2 covers the practical aspects of electrical machines, particularly the construction application characteristics of DC and AC drives.

Outcome 3 outlines the role of electrical machines as actuators in industrial control loops. They are an indispensable part of engineering processes, and the workhorse in both commercial and industrial applications.

Outcome 4 covers electrical machines and drives, and their characteristics. It looks at starting and braking, loading conditions, and ratings, and the control of all of these. On completing this outcome, learners can:

- explain the operation of different motors used in industry
- describe the different types of industrial drives used in various disciplines
- assess the importance of electrical machines and their drives for a given industrial application
- analyse their performances
- suggest appropriate solutions using a variety of possible methods

Outcome 5 covers the factors that influence the choice of motor needed for different industrial tasks. Learners also distinguish between the different forms of motor load and drive systems.

Outcome 6 analyses different protection arrangements used with electrical motors, as well as starting and braking arrangements.

Approaches to assessment

You assess the unit holistically using a portfolio of evidence that learners generate. Select the most appropriate assessment style according to the learning set out in the unit. You should assess learners using a variety of methods to help them develop a broad range of transferable skills. Learners must generate evidence under unsupervised, open-book conditions.

Equality and inclusion

This unit is designed to be as fair and as accessible as possible with no unnecessary barriers to learning or assessment.

You should take into account the needs of individual learners when planning learning experiences, selecting assessment methods or considering alternative evidence.

Guidance on assessment arrangements for disabled learners and/or those with additional support needs is available on the assessment arrangements web page: www.sqa.org.uk/assessmentarrangements.

Information for learners

Electrical Transformers, Motors and Machine Systems (SCQF level 8)

This information explains:

- what the unit is about
- what you should know or be able to do before you start
- what you need to do during the unit
- opportunities for further learning and employment

Unit information

This unit provides you with knowledge and skills specific to electrical engineering. It is part of the Higher National Diploma (HND) in Engineering, which is aimed at learners who want to become engineering technicians or, after further study, engineers. It provides you with suitable knowledge and skills to progress to further study or employment in a wide range of engineering industries, such as oil and gas, process, utilities, and renewables.

Before starting the unit, we recommend that you have a broad knowledge and understanding of electrical power systems at SCQF level 7, for example, you have passed an SCQF level 7 unit covering electrical principles.

On completion of the unit, you can:

1 analyse the construction and operation of single-phase and three-phase transformers
2 analyse the applications of induction and synchronous motors
3 analyse the functions and applications of transducers and actuators, including power electronics
4 analyse the operations of direct current (DC) and alternating current (AC) drives in industrial applications
5 analyse motor characteristics for industrial loads
6 analyse protection arrangements for motors and ancillary equipment

Outcome 1 covers constructional characteristics of transformers, analysing the operations of single and three-phase transformers, and explaining transformer protection.

Outcome 2 covers the practical aspects of electrical machines, particularly the construction application characteristics of DC and AC drives.

In outcome 3 you learn that electric machines are the most common devices used to perform the actuator function in an industrial control loop. They are an indispensable part of engineering processes, and the workhorse in both commercial and industrial applications.

Outcome 4 introduces you to electrical machines and drives, and their characteristics, starting and braking, loading conditions, and ratings, and the control of these.

When you have completed this outcome, you can:

- explain the operation of different motors used in industry
- describe the different types of industrial drives used in various disciplines
- assess the importance of electrical machines and their drives for a given industrial application
- analyse their performances
- suggest appropriate solutions using a variety of possible methods

Outcome 5 covers the factors that influence the choice of motor needed for different industrial tasks. You also distinguish between the different forms of motor load and drive systems.

Finally, outcome 6 analyses different protection arrangements used with electrical motors, as well as starting and braking arrangements.

There is a holistic approach to assessment, where you produce a reflective report for each outcome, evaluating the knowledge and skills you have gained. You produce evidence under open-book, unsupervised conditions.

Meta-skills

Throughout the unit, you can develop meta-skills to enhance your employability in the engineering sector. Meta-skills include self-management, social intelligence and innovation.

Self-management

You develop the meta-skills of integrity, adapting and initiative as you study the course material, and do learning activities and projects.

Social intelligence

You develop your communication skills by accessing the unit material through a virtual learning environment (VLE), keeping an e-portfolio and writing technical reports. You also develop your collaboration skills when engaging with lecturers and other learners throughout the unit.

Innovation

You develop the meta-skills of curiosity, sense-making and critical thinking when carrying out learning activities and projects.

Administrative information

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Superclass: XK

History of changes

Version	Description of change	Date

Note: please check SQA's website to ensure you are using the most up-to-date version of this document.