Next Generation Higher National Unit Specification

Electrical Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves (SCQF level 8)

Unit code: J7BV 48

SCQF level: 8 (24 SCQF credit points)

Valid from: session 2023–24

Prototype unit specification for use in pilot delivery only (version 1.0) November 2023

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: November 2023 (version 1.0)

Unit purpose

This unit provides learners with knowledge and understanding of the application of electrical power utilisation systems. It covers:

- the demands, sources and construction of electrical power generation and distribution systems
- interconnections of power systems and their protection to explain the critical processes and the effects of failure and the importance of electrical safety
- the characteristics of transmission lines
- the performance of a transmission line with a matched termination
- the performance of a transmission line with various terminations
- network response problems when complex waves are applied
- the effectiveness of forms of engineering activity to promote sustainable development, with consideration of the economics of components, power systems and alternative energy sources
- new and emerging methods to optimise energy usage, conversion and storage techniques

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, Advanced Higher Physics or Engineering Science, or a Higher National Certificate (HNC) in a related engineering subject
- relevant, equivalent work experience

The unit provides learners with suitable knowledge and skills to progress to further study or employment in a wide range of engineering industries.

Unit outcomes

Learners who complete this unit can:

1 understand sources and construction of electrical power generation and distribution systems
2 understand interconnections of power systems and their protection
3 calculate phasor voltages and currents at two points
4 understand the physical arrangements of an overhead transmission line
5 understand power systems and alternative energy sources
6 discuss new and emerging methods to optimise energy usage

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.

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 six of the nine items:

- Describe energy demands of a power generation and transmission system.
- Describe total power demands of a defined country over a working week.
- Identify average, minimum and maximum demands, and overall annual energy consumption, of domestic, industrial, transport and other systems.
- Identify and quantify energy losses.
- Calculate percentage of delivered total energy that is in the form of electrical energy.
- Compare the demands of a G20 industrial economy with that of a developing economy.
- Analyse the trends of energy supply-and-demand data to predict future energy requirements and budgets.
- Identify the contribution supplied by each of the significant primary sources of energy of a defined country.
- Investigate the influence of long-term governmental policy on managing the energy budget.

Outcome 2

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

- Compare the distribution of power using DC and single-phase and polyphase AC transmission systems.
- Illustrate techniques of AC systems, including identification of a range of loads and their respective power factors.
- Investigate consequences of loads with poor power factor and the advantages of applying power factor corrections.
- Recognise the effects of perturbations and harmonics within AC systems and describe methods to measure and reduce harmonics.
- Demonstrate the need to protect the power distribution network from the effects of overload or damage, and identify the requirements of a robust protection system.
- Evaluate the impedance of an AC transmission line, its power losses and its effect on the power delivered, including:
  - calculating inductance and capacitance for two types of transmission line
  - performing calculations to determine each of the following secondary parameters: Zo, γ, α, β and v

Outcome 3

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

- Calculate incident, reflected and transmitted values of:
  - voltage, current and power for one of the following mismatched terminations: ZL > ZO, ZL < ZO
  - sketch incident, reflected and transmitted waves for one of the following terminations: ZL > ZO, ZL < ZO
- Construct an accurate scaled drawing for a repetitive, low duty cycle, voltage pulse on a line with one of the following terminations: open circuit, short circuit or matched.
- Calculate rms voltage and current values from given complex wave equations containing a fundamental and two harmonics.

Outcome 4

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

- Explain the different ways in which the series and shunt parameters can be specified, directly or indirectly.
- Calculate the regulation of a transmission line.
- Calculate the efficiency of power delivery of a transmission line.
- Demonstrate the short transmission line model and its limitations, and perform short line calculations.
- Explain the need to include the shunt admittance of the line for medium length lines.
- Perform calculations using three different medium length line models.
- Explain the causes of the Ferranti effect on unloaded lines and cables.

Outcome 5

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

- Outline efficiency, costs, security and environmental implications of energy production using coal, oil and natural gas.
- Define ‘renewable’ in relation to sources of energy.
- Evaluate the efficiency, costs, security and environmental implications of energy production using renewable sources of mechanical kinetic energy, including wave, tidal, large- and small-scale hydro, and wind.
- Evaluate the efficiency, costs, security and environmental implications of energy production using solar heating, solar photovoltaics, biomass, fuel cells and geothermal techniques.
- Investigate the current state of research into nuclear, fusion and fission energy, and other novel forms of energy.

Outcome 6

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

- Describe techniques for optimising the generation of electricity in power stations and small-scale generators by using varied and distributed generation systems, and managing the generation of power techniques for optimising energy usage and conversion.
- Evaluate technologies and techniques for improving the efficiency or reducing the energy consumption of equipment in common use, including lighting, heating, transport and industrial processes.
- Describe energy storage techniques.
- Demonstrate the need for energy storage techniques as part of an energy management programme.
- Compare and contrast characteristics of short-term and long-term energy storage techniques and their connection to the power grid, including hydro, battery, super capacitor, flywheel and thermal.
- Compare and contrast emerging battery technologies and battery management techniques.

Knowledge and skills

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

Knowledge	Skills
Outcome 1 Learners should understand: ♦ the demands, sources and construction of electrical power generation and distribution systems	**Outcome 1** Learners can: ♦ describe energy demands of a power generation and transmission system ♦ describe total power demands of a defined country over a working week ♦ identify average, minimum and maximum demands and overall annual energy consumption of domestic, industrial, transport and other systems ♦ identify and quantify energy losses ♦ calculate ratio of delivered total energy that is in the form of electrical energy ♦ compare the demands of a G20 industrial economy with that of a developing economy ♦ analyse the trends of energy supply-and-demand data to predict future energy requirements and budgets ♦ identify the contribution supplied by each of the significant primary sources of energy of a defined country ♦ investigate the influence of long-term governmental policy on managing the energy budget

Knowledge	Skills
Outcome 2 Learners should understand: ♦ the interconnections of power systems and their protection to explain the critical processes and the effects of failure and the importance of electrical safety	**Outcome 2** Learners can: ♦ compare the distribution of power using DC, and single-phase and polyphase AC transmission systems ♦ illustrate techniques of AC systems, including identification of a range of loads and their respective power factors ♦ investigate consequences of loads with poor power factor and the advantages of applying power factor corrections ♦ recognise the effects of perturbations and harmonics within AC systems and describe methods to measure and reduce harmonics ♦ demonstrate the need to protect the power distribution network from the effects of overload or damage, and identification of the requirements of a robust protection system ♦ evaluate the impedance of an AC transmission line, its power losses and its effect on the power delivered, including: — calculating inductance and capacitance for two types of transmission line — performing calculations to determine each of the following secondary parameters: Zo, γ, α, β and v

Knowledge	Skills
Outcome 3 Learners should understand: ♦ phasor voltages and currents at two points	**Outcome 3** Learners can: ♦ calculate incident, reflected and transmitted values of: — voltage, current and power for one of the following mismatched terminations: ZL > ZO, ZL < ZO — sketch incident, reflected and transmitted waves for one of the following terminations: ZL > ZO, ZL < ZO ♦ construct an accurate scaled drawing for a repetitive, low duty cycle, voltage pulse on a line with one of the following terminations: open circuit, short circuit or matched ♦ calculate rms voltage and current values from given complex wave equations containing a fundamental and two harmonics
Outcome 4 Learners should understand: ♦ the physical arrangements of an overhead transmission line and how this results in the series and shunt elements of the line model	**Outcome 4** Learners can: ♦ explain the different ways in which the series and shunt parameters can be specified, directly or indirectly ♦ calculate the regulation of a transmission line ♦ calculate the efficiency of power delivery of a transmission line ♦ demonstrate the short transmission line model and its limitations, and perform short line calculations ♦ explain the need to include the shunt admittance of the line for medium length lines ♦ perform calculations using three different medium length line models ♦ explain the causes of the Ferranti effect on unloaded lines and cables

Knowledge	Skills
Outcome 5 Learners should understand: ♦ the effectiveness of forms of engineering activity to promote sustainable development, with consideration of the economics of components, power systems and alternative energy sources	**Outcome 5** Learners can: ♦ outline efficiency, costs, security and environmental implications of energy production using coal, oil and natural gas ♦ define 'renewable' in relation to sources of energy ♦ evaluate the efficiency, costs, security and environmental implications of energy production using renewable sources of mechanical kinetic energy, including wave, tidal, large- and small-scale hydro, and wind ♦ evaluate the efficiency, costs, security and environmental implications of energy production using solar heating, solar photovoltaics, biomass, fuel cells and geothermal techniques ♦ investigate current research into nuclear, fusion and fission energy, and other novel forms of energy

Knowledge	Skills
Outcome 6 Learners should understand: ♦ new and emerging methods to optimise energy usage, conversion and storage techniques	**Outcome 6** Learners can: ♦ describe techniques for optimising the generation of electricity in power stations and small-scale generators by using varied and distributed generation systems, and managing the generation of power techniques for optimising energy usage and conversion ♦ evaluate technologies and techniques for improving the efficiency or reducing the energy consumption of equipment in common use, including lighting, heating, transport and industrial processes ♦ describe energy storage techniques ♦ demonstrate the need for energy storage techniques as part of an energy management programme ♦ compare and contrast characteristics of short-term and long-term energy storage techniques and their connection to the power grid, including hydro, battery, super capacitor, flywheel and thermal ♦ compare and contrast emerging battery technologies and battery management techniques

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 and self-control): learners evidence this through their portfolio or investigation reports
- adapting (critical reflection and self-learning): learners evidence this through their portfolio or investigation reports
- initiative (decision making, self-motivation and responsibility): learners demonstrate this during learning activities or projects

Social intelligence

This meta-skill includes:

- communicating (receiving information, listening and giving information): learners evidence this when accessing the unit material through a virtual learning environment (VLE), keeping an e-portfolio and writing technical reports
- collaborating (team working): learners demonstrate this when engaging with their lecturers and other learners throughout the unit

Innovation

This meta-skill includes:

- curiosity (information sourcing, questioning and observation): learners demonstrate this during learning activities or projects
- sense-making (holistic thinking and analysis): learners demonstrate this during learning activities or projects that they complete either individually or in groups
- critical thinking (deconstruction, logical thinking and judgement): learners demonstrate this during learning activities or projects that they complete either individually or in groups

Literacies

Numeracy

Learners develop numeracy skills by performing calculations related to the transmission systems.

Communication

Learners develop communication skills by studying the course material, completing unit assessments and engaging with their lecturers and other learners.

Digital

Learners develop digital skills and computer literacy by accessing the course material through a VLE.

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.

Additional guidance

The guidance in this section is not mandatory.

Content and context for this unit

Outcome 1

You could cover:

- sources and construction of electrical power generation and distribution systems
- demands of a power generation and transmission system
- total power demands of a defined country over a working week, identifying average, minimum and maximum demands
- overall annual energy consumption of domestic, industrial, transport and other systems, identifying and quantifying energy losses
- the extent of delivered energy that is in the form of electrical energy
- a comparison between the demands of a G20 industrial economy with that of a developing economy
- analysis of the trends of energy supply-and-demand data to predict future energy requirements and budgets
- identification of the contribution to the energy supplied by each of the significant primary sources of energy of a defined country
- the influence of long-term governmental policy on managing the energy budget

Outcome 2

You could cover:

- interconnections of power systems and their protection to explain the critical processes and the effects of failure, and the importance of electrical safety
- construction of power generation and transmission systems
- comparisons between the distribution of power using DC, and single-phase and polyphase AC transmission systems
- amplitude and phase of voltages and currents in three-phase systems with resistive and complex loads
- power factor and power measurement techniques of AC systems, including identification of a range of loads and their respective power factors
- consequences of loads of poor power factor and the advantages of applying power factor corrections
- calculation of power factor correction components
- recognition of the effects of perturbations and harmonics within AC systems and describing methods to measure and reduce harmonics
- the need to protect the power distribution network from the effects of overload or damage, and the identification of the requirements of a robust protection system
- evaluation of the impedance of an AC transmission line, its power losses and its effect on the power delivered to a load

Outcome 3

You could cover:

- calculating phasor voltages and currents at two points
- calculating power associated with complex waves
- calculating electrical quantities in an R – L – C series circuit or an R – L // C parallel circuit subject to a complex waveform with a fundamental and two harmonics
- selective resonance
- the effects of harmonics on measurement of voltage and current in single-phase and electronic circuits

Outcome 4

You could cover:

- the physical arrangements of an overhead transmission line and how this results in the series and shunt elements of the line model
- the different ways in which the series and shunt parameters can be specified, directly or indirectly
- calculating the regulation of a transmission line
- calculating the efficiency of power delivery of a transmission line
- the short transmission line model and its limitations, and how to perform short line calculations
- the need to include the shunt admittance of the line for medium length lines
- perform calculations using three different medium length line models
- the causes of the Ferranti effect on unloaded lines and cables

Outcome 5

You could cover:

- power systems and alternative energy sources
- forms of engineering activity to promote sustainable development, with consideration of the economics of components, power systems and alternative energy sources
- efficiency, costs, security and environmental implications of energy production using coal, oil and natural gas
- the definition of ‘renewable’ in relation to sources of energy
- the efficiency, costs, security and environmental implications of energy production using renewable sources including wave, tidal, large- and small-scale hydro, and wind
- the efficiency, costs security and environmental implications of energy production using solar heating, solar photovoltaics, biomass, fuel cells and geothermal techniques
- the current state of research into nuclear, fusion and fission energy and other novel forms of energy

Outcome 6

You could cover:

- new and emerging methods to optimise energy usage
- techniques for optimising the generation of electricity in power stations and small-scale generators by using varied and distributed generation systems
- techniques for optimising energy usage and conversion
- evaluating technologies and techniques for improving the efficiency or reducing the energy consumption of equipment in common use, including lighting, heating, transport and industrial processes
- energy storage techniques
- the need for energy storage techniques as part of an energy management programme
- characteristics of short-term and long-term energy storage techniques and their connection to the power grid, including hydro, battery, super capacitor, flywheel and thermal
- emerging battery technologies and battery management techniques

Approaches to delivery

We recommend you deliver outcomes 1 to 4 in order. You can then deliver outcomes 5 and 6 in any order.

You should deliver the unit in a learning space or through a VLE. You should teach primarily using problem-based learning (PBL) techniques such as case studies and mini projects, supported by other methods.

Approaches to assessment

We recommend that you assess the unit holistically by reviewing case study reports and mini projects.

Learners should demonstrate evidence of all knowledge and skills in the context of one or more overarching complex electrical engineering scenarios.

For case studies and mini projects, you can assess knowledge and skills through coursework exercises. Learners should produce product evidence (for example, in the form of a coursework report) under open-book, unsupervised and untimed 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 Engineering: Utilisation of Electrical Power, Transmission Lines and Complex Waves (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. It also provides you with knowledge and skills to prepare you for further study.

Before starting the unit, we recommend that you have knowledge and understanding of power systems. For example, you may have passed units covering machines and power systems at SCQF level 7.

On completion of the unit, you can:

1 understand sources and construction of electrical power generation and distribution systems
2 understand interconnections of power systems and their protection
3 calculate phasor voltages and currents at two points
4 understand the physical arrangements of an overhead transmission line
5 understand power systems and alternative energy sources
6 discuss new and emerging methods to optimise energy usage

In outcome 1, you learn about electrical generation and the trends in demands of a defined country. You identify and quantify energy losses, and calculate the extent of delivered energy that is in the form of electrical energy. You compare the demands of a G20 industrial economy with that of a developing economy. You learn about data predicting, future energy requirements and budgets, to identify the contribution supplied by each of the significant primary sources of energy of a defined country. You also investigate the influence of long-term governmental policy on managing the energy budget.

In outcome 2, you learn about different transmissions with AC and DC voltages, and the interconnections used to transmit power over long distances. You look at the pros and cons of each system. This outcome also covers the configurations of distribution networks with protection systems that are used to ensure quality and safety of supply.

In outcome 3, you learn about the effects of inductance capacitance on a network and how a wave is distorted by harmonics.

In outcome 4, you learn how to calculate efficiency of power delivery of a transmission line. You learn about the short transmission line model and its limitations, and how to perform short line calculations. You understand the need to include the shunt admittance of the line for medium length lines to be able to perform calculations using three different medium length line models. You also understand the causes of the Ferranti effect on unloaded lines and cables.

In outcome 5, you learn to promote sustainable development, looking at alternative power sources and considerations of the economics of renewable energy. This outcome also covers the environmental implications of energy production.

In outcome 6, you use your knowledge of energy systems compatibility, looking at technologies for storage of large amount of energy. You evaluate technologies and techniques for improving the efficiency or reducing the energy consumption of equipment in common use, for example:

- pumped hydro
- super capacitor
- flywheel
- thermal
- emerging battery technologies

You are assessed by completing mini projects, technical reporting and critical self-evaluation. You collate assessment evidence in your portfolio.

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

This meta-skill includes:

- integrity (self-awareness, ethics and self-control): you evidence this through your portfolio or investigation reports
- adapting (critical reflection and self-learning): you evidence this through your portfolio or investigation reports
- initiative (decision making, self-motivation and responsibility): you demonstrate this during learning activities or projects

Social intelligence

This meta-skill includes:

- communicating (receiving information, listening and giving information): you evidence this when accessing the unit material through a virtual learning environment (VLE), keeping an e-portfolio and writing technical reports
- collaborating (team working and collaboration): you demonstrate this when engaging with your lecturers and other learners throughout the unit

Innovation

This meta-skill includes:

- curiosity (information sourcing, questioning and observation): you demonstrate this during learning activities or projects
- sense-making (holistic thinking and analysis): you demonstrate this during learning activities or projects that you complete either individually or in a group
- critical thinking (deconstruction, logical thinking and judgement): you demonstrate this during learning activities or projects that you complete either individually or in a group

Administrative information

Published: November 2023 (version 1.0)

Superclass: XJ

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.