SQA Advanced Unit Specification: general information

Unit title: Electrical Design Systems: An Introduction

Unit code: HV2W 47

Superclass: XJ

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Version: 01

Unit purpose

This Unit has been designed to allow candidates to develop their knowledge, understanding and skills of a range of services provided by the distribution of power and network communication cabling throughout an electrical installation. More specifically candidates will study earthing systems and how protection from touch voltages is achieved. This Unit also introduces candidates to the design procedures involved in selecting conductors to supply single and three-phase equipment located in small modern electrical distribution systems.

On completion of the Unit the candidate should be able to:

1 Examine the principles of protective earthing systems.
2 Apply electrical design procedures when selecting current carrying conductors.
3 Investigate structured distribution data cable systems for communication networks.

Recommended prior knowledge and skills

Entry to this Unit is at the discretion of the centre, however candidates should have a basic knowledge and understanding of electrical systems, equipment and protective devices, or have technical experience of electrical systems within building services. This may be evidenced by possession of *Electrical Installation* Units from the National Certificate(s) in Electrical Engineering.

Credit points and level

1 SQA Credit at SCQF level 7: (8 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from National 1 to Doctorates.*

Core Skills

Opportunities to develop aspects of Core Skills are highlighted in the Support Notes of this Unit specification.

There is no automatic certification of Core Skills or Core Skill components in this Unit.

Context for delivery

If this Unit is delivered as part of a Group Award, it is recommended that it should be taught and assessed within the subject area of the Group Award to which it contributes.

Assessment

The assessment for this Unit is in two parts.

An assessment lasting one and a half hours, which should be conducted under controlled supervised conditions and should follow after the delivery of Outcomes 1 and 2.

An investigation should be completed for the design specification of standard network cabling for voice and data communication systems for a small modern building. Candidates will be expected to produce a report of between 1,000–1,200 words or equivalent that includes diagrams and appendices on the specification for the network system.

Teaching and learning and assessments do not have to be presented to the candidates in any specific order.

SQA Advanced Unit Specification: statement of standards

Unit title: Electrical Design Systems: An Introduction

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The sections of the Unit stating the Outcomes, Knowledge and/or Skills, and Evidence Requirements are mandatory.

Where evidence for Outcomes is assessed on a sample basis, the whole of the content listed in the Knowledge and/or Skills section must be taught and available for assessment. Candidates should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

Outcome 1

Examine the principles of protective earthing systems.

Knowledge and/or Skills

- System earthing of low voltage transformer secondary windings
- Earth electrode types and application
- Equipment earthing protective systems
- Touch and step voltage protective measures

Outcome 2

Apply electrical design procedures when selecting current carrying conductors

Knowledge and/or Skills

- Design current for load centres incorporating single and three-phase equipment
- Protective devices for power and semiconductor applications
- External factors that affect cable effectiveness
- Select cable conductor sizes to comply with design procedures

Evidence Requirements for Outcomes 1 and 2

Evidence for the Knowledge and/or Skills items in Outcomes 1 and 2 should be provided on a sample basis. The evidence may be presented in response to specific questions. Each candidate will need to demonstrate that they can answer questions correctly based on a sample under the knowledge and skills items shown in both Outcomes.

The assessment should incorporate two Knowledge and/or Skills items from each Outcome. In any assessment of the Outcomes, Knowledge and/or Skills item four from both Outcomes must always be selected along with any one of the other three knowledge/skills statements in each Outcome.

In order to ensure that candidates will not be able to foresee what items they will be questioned on, a different Knowledge and/or Skills item from each Outcome, as well Knowledge and/or Skills item four in both Outcomes, should be sampled each time the Outcomes are assessed. Candidates must provide a satisfactory response to all items.

Where sampling takes place, a candidates response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

Outcome 1

- Explain that the purpose of earthing transformer windings is to minimise disturbances to the power system from overvoltages that can damage conductor and motor insulation connected to the system.
- Describe the types of earth electrodes for power systems and methods of reducing surface voltage gradients and risks from step voltages.
- Describe how equipment earthing can achieve protection against electric shock.
- Evaluate Touch Voltage Curves and determine if protection against electric shock can be achieved from calculations of earth fault loop impedance values and disconnection times of protective devices.

Outcome 2

- Determine the design current for TP&N electrical installations and the reasons for balancing the current across three phases.
- Explain the operation and function of protective devices for electric motors and fuses for semi conductor applications.
- Describe how PVC, XLPE (low smoke zero halogen) and magnesium oxide conductor insulations are selected to overcome external influences.
- Calculate the design current and select conductor sizes for three-phase and single-phase loads and confirm that the circuits comply with the voltage drop constraint.

The assessment for Outcomes 1 and 2 must be combined together to form one assessment paper. This assessment should be taken at a single assessment event lasting one and a half hours and carried out under supervised, controlled conditions. Assessment should be conducted under closed-book conditions and as such candidates should not be allowed to bring any additional material to the assessment. Candidates should be permitted to use scientific calculators during the assessment. Centres must provide candidates with all the relevant reference design material to satisfactorily complete the assessment.

Assessment Guidelines for Outcomes 1 and 2

The assessment paper should be composed of an appropriate balance of short answer and structured questions that may incorporate sketches/diagrams to demonstrate enhanced understanding. Centres should devise only the charts, reference tables and diagrams or drawings necessary for candidates to satisfactorily complete the assessment.

Outcome 3

Investigate structured distribution data cable systems for communication networks.

Knowledge and/or Skills

- Local Area Networks (LAN)
- Structured cabling for data and communication networks
- Extended star topology installation systems
- Configuration of patch panel arrangements
- Attenuation to crosstalk ratio (ACR)

Evidence Requirements for Outcome 3

All Knowledge and/or Skills items in Outcome 3 should be assessed. The evidence should be presented in response to an assignment in which candidates are set the task of investigating the requirements and outlining the basic design of a communication network for a small modern operation.

The candidate assignment can be judged to be satisfactory where the evidence provided is valid, relevant and sufficient to meet the requirements for each item by showing that he/she can:

- identify the economic function of a LAN and describe the type of information that can be transmitted.
- describe the different types and specific design applications of structured data cables.
- describe the operation of the network.
- describe the process for Patch Panel wiring for data applications.
- explain ways of ensuring the Attenuation to Crosstalk ratio (ACR) complies with the required parameters of BS EN standards.

Candidates should produce a report of between 1,000–1,200 words or equivalent that includes diagrams and appendices on the specification for the network system. Candidates should have access to course notes, relevant textbooks, instruction manuals, supplier's and manufacturers' catalogues and the use of the Internet whilst doing this assignment.

Assessment Guidelines for Outcome 3

Centre may wish to issue candidates with suitable guideline notes giving advice on the best way to source information and structure their reports.

SQA Advanced Unit Specification: support notes

Unit title: Electrical Design Systems: An Introduction

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

This Unit has been written in order to allow candidates to develop their knowledge, understanding and skills in the following areas:

1 The principles of protective earthing systems.
2 Applying electrical design procedures when selecting current carrying conductors.
3 Investigating structured distribution data cable systems for communication networks.

This Unit has been developed to provide SQA Advanced Certificate/SQA Advanced Diploma in Engineering candidates with a fundamental knowledge, understanding and skills in electrical design principles including the function of protective systems. It is a 1-credit Unit at SCQF level 7 (8 SCQF credit points at SCQF level 7). The Unit can also be offered on a free-standing basis.

In designing this Unit the Unit writer has identified the range of topics expected to be covered by lecturers. The writer has also given recommendations as to how much time should be spent on each Outcome. This has been done to help lecturers decide what depth of treatment should be given to the topics attached to each of the Outcomes. Whilst it is not mandatory for centres to use this list of topics it is strongly recommended that they do so to ensure continuity of teaching and learning, and assessment across the three Outcomes.

A list of topics is shown below.

Outcome 1: Examine the principles of protective earthing systems (15 hours)

- Review lv transformer single and three phase voltage levels
- Explain the function of system earthing where the neutral is connected to ground at one or more points to minimise disturbances from high transient overvoltages
- Describe that at certain frequencies, the system inductance is resonant with the system capacitance to earth in **ungrounded** power distribution systems
- Identify that repeated re-striking of an arc from line to ground in the unearthed system can result in seriously high overvoltages
- Explain that the dangers of overvoltages are detrimental to the insulation of conductors and motor windings connected to the system
- Explain that system earthing prevents variations between line voltages and the neutral from floating as it is held at a reference potential of zero volts
- Compare earth electrodes and describe grid and mesh installation methods for connecting power systems to earth
- Describe that the requirements of sub-station earthing are to control potential gradients and dissipate large currents without drying out the earth surrounding the electrode

- Explain that equipment earthing enables circuit protection to operate quickly and minimises the duration of the dangers from touch voltages
- Explain, with the aid of diagrams, that equipment earthing requires a low impendence to earth, high reliability and be able to carry the high earth fault currents without damage from overheating
- Outline the physiological effects of earth leakage current and electric shock
- Explain that the value of touch voltage U_t is dependant on the resistance of the circuit protective conductor R_2
- Apply the potential divider rule to determine the value of touch voltage between exposed adjacent conductive parts of equipment in a system
- Touch voltage U_t can be determined by:

$$U_t = U_{OC}\left[\frac{R_2}{Z_e + R_1 + R_2}\right] \text{Volts}$$

- Explain how touch voltage tolerance curves relate to dry and wet conditions
- Calculate earth fault loop impedance value Z_S using given data and from the fault current I_a, and compare the duration of the disconnection time of the protective device with touch voltage time curve and confirm risk from electric shock is minimised
- Explain the method of reducing the magnitude of touch voltages within an electrical installation is by creating an equipotential zone

Outcome 2: Apply electrical design procedures when selecting current conductors (15 hours)

- Explain the function of a distribution system and the reasons for balancing currents across three phases when designing load centres
- Calculate the maximum design current by applying diversity and how further trimming can be implemented in small installations
- Interpret a line diagram of a small TP&N switchgear arrangement for a low voltage intake position and outline how isolation, control and protection is achieved
- Calculate the design current for a variety of single and three phase loads
- Describe how initial starting or transient currents can affect the type of protective device required
- Explain the application and operating design characteristics when using charts for protective fuses in semi conductor applications
- Describe the external factors which can have an adverse effect on the type of cable to be selected for specific applications (eg dampness, ingress of moisture, impact damage and dust)
- Outline the operational conditions which can affect different types of cables current carrying capacity (eg grouping and extremes of temperature)
- Identify the relevant installation characteristics and applications of PVC, XLPE, Low Smoke and Fume and MI cables
- Describe installation methods to provide live circuit conductors with protection from impact damage and vibration
- Calculate the final circuit conductor sizes for three phase induction motor applications and discharge lighting installations by ensuring the voltage drop constraints are complied with

Assessment: Written Test — 1.5 hours

Outcome 3: Investigate structured distribution data cable systems for communication networks (10 hours)

- Outline BS EN standards for CAT 5 and CAT 5E, and proposed CAT 6 and CAT 7 standards for cabling systems
- Explain that structured cabling is the wired infrastructure within modern buildings to carry high-speed digital communication signals
- State that information is transmitted and received as data, video or voice communications within a local area network, known as a LAN
- Explain that cabling is installed to interconnect computers (sharing common software) and other devices including printers, scanners etc to provide a connection to a telecommunication facility
- Communication racks may include RJ45 Patch Panels and network devices including hubs, routers and electrical devices to switch between different communication functions
- Explain how flood wiring and Star Topology cabling provides a flexible system
- Applications of balanced STP or UTP twisted pair copper cables (shielded or unshielded) and fibre optic cables
- Methods of providing backbone cabling and horizontal cabling from the floor distributor to the TCO (Telecommunication Connection Outlet) using low smoke zero halogen cables which may be specified for fire safety reasons
- Illustrate, with the aid of wire maps, how the effectiveness of high-speed data transfer is affected by incorrect terminating techniques
- Explain how attenuation can affect a signal travelling within a cable
- Describe the skin effect phenomenon and methods of overcoming signal loss when transferring on high frequency
- Describe methods of minimising interference within a cable from cross talk
- Attenuation to cross talk ratio (ACR) headroom margins match required parameters
- Consider how propagation delay, delay skew, return loss and characteristic impedance can affect successful transmission of data

Assessment: Investigative Assignment

Guidance on the delivery and assessment of this Unit

This Unit has been designed to incorporate sufficient time to allow lecturers/assessors to present all of the electrical design procedure content contained in the Unit. There is also sufficient time for candidates to take appropriate measurements and undertake appropriate analysis on electrical installations to consolidate their learning.

It is strongly recommended that candidates are encouraged to examine the various equipment, earthing and network system components within their learning environment. Design charts, graphs, tables and touch voltage curves should be integrated within the learning and where possible actual measured values should be used to strengthen knowledge and understanding of design and safety requirements. It is essential candidates are able to relate theory to practice of functional design procedures. During the delivery of the Unit, lecturers should be selective in the data and manufacturers reference material that is necessary for candidates to satisfactorily complete the relevant Outcome. Lecturers should use their teaching and formative assessment strategies to encourage candidates to clearly link the design requirements for functional requirements and essential safety factors to reducing the risk of electric shock and temperature rise which could result in a fire. This approach should help to develop candidates' critical thinking skills.

With the expansion of data cable networks an overview of the requirements of the hardware and procedures required to fault find should be clearly outlined and consolidated with reference to the Internet and other relevant technical support systems.

Candidates will have opportunities to develop their Written Communication skills principally through the preparation of the written report for Outcome 3. Candidates will also have an opportunity to develop their Use of Numbers skills through the various cable calculations they will undertake as part of the Unit. They may also have opportunities to develop their Using Graphical Information skills by interpreting and using various forms of circuit and wiring diagrams and communication network representations throughout the Unit.

Information on Evidence Requirements and assessment guidelines is given after Outcomes 2 and 3 in the higher national Unit specification, statement of standards section. The written assessment should take place after Outcomes 1 and 2 have been completed. Outcome 3 can be delivered independently and the assignment presented to the candidates for completion throughout the remaining time allocated to the Unit.

Open learning

This Unit can be delivered by open learning which may incorporate some degree of online support. However with regards to assessment, planning will be required by the centre to ensure the sufficiency and authenticity of candidate evidence.

Arrangements will be required to be put in place for the combined written assessment paper for Outcomes 1 and 2 to ensure it is conducted under controlled and supervised conditions.

To keep administrative arrangements to a minimum, it is recommended for distance learning candidates that the date for the assessment paper date is organised well in advance.

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or e-checklists. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003), SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

Opportunities for developing Core Skills

There may be opportunities to gather evidence towards the following listed Core Skill components in this Unit, although there is no automatic certification of Core Skills or Core Skill components.

Written Communication	SCQF level 6
Using Number	SCQF level 6
Using Graphical Information	SCQF level 5
Critical Thinking	SCQF level 6

Equality and inclusion

This unit specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence.

Further advice can be found on our website www.sqa.org.uk/assessmentarrangements.

History of changes to Unit

Version	Description of change	Date

SQA acknowledges the valuable contribution that Scotland's colleges have made to the development of SQA Advanced Qualifications.

FURTHER INFORMATION: Call SQA's Customer Contact Centre on 44 (0) 141 500 5030 or 0345 279 1000. Alternatively, complete our Centre Feedback Form.

General information for candidates

Unit title: Electrical Design Systems: An Introduction

In Outcome 1 of the Unit you will learn about distribution voltages and the safety requirements that are required for an electrical system. You will also study functional earthing requirements and circuit protective systems which will give you the opportunity to understand in greater detail how this important safety factor is applied for the effective operation of electrical equipment. You will also identify the apparent dangers of Touch Voltages between adjacent earthed metalwork and methods used to minimise these dangers.

In Outcome 2 you will examine the basic principles of calculating load current and the importance of balance within a 3-phase distribution system. You will assess 1-phase and 3-phase loads and select cables for equipment taking into account design constraints. You will then identify the external factors (environmental and operational) which have to be considered when selecting a cable from given options for single and three phase electrical loads. You will be encouraged to use manufacturers' catalogues and data sheets to ensure the cable selected is suitable and adequately protected for its operating conditions.

In Outcome 3 you will examine structured cable systems to carry high-speed digital communications within modern buildings. You will study the relevant design parameters, and how they have to be complied with to ensure effective transfer of data. You will also review methods of minimising interference within a cable from crosstalk and how propagation delay can affect successful transmission networks.

Assessment for this Unit will comprise of a one and a half hour written test, conducted under controlled, supervised conditions, after the delivery of Outcomes 1 and 2 followed by an investigative assignment in which you will have the opportunity to identify the requirements for a network to carry high speed digital data and voice for a small modern building.