SQA Advanced Unit Specification

General information for centres

Unit title: Synchronous Machines

Unit code: HV4W 48

Unit purpose: This unit is designed to introduce candidates to the construction and principle of operation of synchronous machines, and to develop the skills and knowledge necessary to evaluate their operating characteristics.

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

1. describe the construction and operation of synchronous machines
2. analyse the operating characteristics of a synchronous generator
3. analyse the operating characteristics of a synchronous motor

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

**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.*

Recommended prior knowledge and skills: Candidates should have a broad knowledge of field theory and basic electrical circuits. This may be evidenced by possession of the following SQA Advanced Units: HT83 47 Electrical Machine Principles, HT7K 47 Three Phase Systems and HP46 47 DC and AC Principles. However, entry requirements are at the discretion of the centre.

Core skills: There may be opportunities to gather evidence towards the listed core skills or core skills components in this unit, although there is no automatic certification of core skills or core skills components:

- Written Communication (reading) at SCQF level 6
- Numeracy at SCQF level 6
- Using Information Technology at SCQF level 5
- Critical Thinking at SCQF level 6
- Reviewing and Evaluating at SCQF level 6

Context for delivery: This unit was developed for the SQA Advanced Diploma in Electrical Engineering. If this unit is to be used in another 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: Assessment for Outcomes 1, 2 and 3 should be combined together into one assessment paper which should last two hours. The paper should be composed of a suitable balance of short-answer, restricted-response and structured questions. The assessment should be conducted under controlled, supervised conditions.

SQA Advanced Unit Specification: statement of standards

Unit title: Synchronous Machines

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

Describe the construction and operation of synchronous machines.

Knowledge and/or skills

- Constructional features of a synchronous machine
- Principle of operation of a synchronous machine when operating as a motor
- Principle of operation of a synchronous machine when operating as a generator
- Methods of excitation

Outcome 2

Analyse the operating characteristics of a synchronous generator.

Knowledge and/or skills

- Operating characteristics of a synchronous generator
- Use of an equivalent circuit in order to evaluate the performance of a synchronous generator
- Operation of a synchronous generator connected to an infinite bus
- Synchronisation procedures for synchronous generators

Outcome 3

Analyse the operating characteristics of a synchronous motor.

Knowledge and/or skills

- Operating characteristics of a synchronous motor
- Use of an equivalent circuit in order to evaluate the performance of a synchronous motor
- Starting methods for synchronous motors
- Practical applications of synchronous motors

Evidence requirements for the unit

Evidence for the knowledge and /or skills in Outcomes 1, 2 and 3 will be provided on a sample basis. The evidence may be presented in response to specific questions. Each candidate will need to demonstrate that she/he can answer correctly questions based on a sample of the items shown under the knowledge and skills items in all three outcomes. In any assessment of the outcomes, **all** of the knowledge and/or skills items should be assessed from Outcome 1, **three out of four** knowledge and/or skills items should be sampled from Outcome 2 and **three out of four** knowledge and skills items from Outcome 3.

In order to ensure that candidates will not be able to foresee what items they will be questioned on, a different sample of three out of four knowledge and/or skills items from Outcome 2 and three out of four knowledge and/or skills items from Outcome 3 are required each time the unit is assessed. Where sampling takes place, a candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each sample by showing that the candidate is able to:

Outcome 1

- identify the constructional features of a synchronous machine
- evaluate the principles of operation of a synchronous machine when operating as a motor
- evaluate the principles of operation of a synchronous machine when operating as a generator
- describe methods of excitation

Outcome 2

- evaluate the operating characteristics of the synchronous generator
- demonstrate the use of an equivalent circuit to evaluate the performance of the synchronous generator
- describe the operation of a synchronous generator connected to an infinite bus
- evaluate synchronisation procedures for synchronous generators

Outcome 3

- evaluate the operating characteristics of the synchronous motor
- demonstrate the use of an equivalent circuit in order to evaluate the performance of the synchronous motor
- describe starting methods for synchronous motors
- describe practical applications of synchronous motors

Evidence should be generated through assessment undertaken in controlled, supervised conditions. Assessment should be conducted under closed-book conditions and as such candidates should not be allowed to bring any textbooks, handouts or notes to the assessment. Candidates will be permitted to use scientific calculators during the assessment.

Assessment guidelines

The assessment for Outcomes 1 to 3 should be combined together to form one assessment paper. This single assessment paper should be taken at a single assessment event lasting two hours. Such a paper should be composed of an appropriate balance of short-answer, restricted-response and structured questions.

Administrative information

Unit code: HV4W 48

Unit title: Synchronous Machines

Superclass category: XL

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

For further information, please call SQA's Customer Contact Centre on 44 (0) 141 500 5030 or 0345 279 1000. Alternatively, complete our Centre Feedback Form.

SQA Advanced Unit Specification: support notes

Unit title: Synchronous Machines

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 knowledge, understanding and skills in the following areas:

- The construction and operation of synchronous machines
- The operating characteristics of a synchronous generator
- The operating characteristics of a synchronous motor

This unit has been devised as an optional unit within the SQA Advanced Diploma in Electrical Engineering.

In designing this unit, the unit writer has identified the range of topics expected to be covered by lecturers. The writers have 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. While 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 across the Electrical Engineering units.

A list of topics is given below. Lecturers are advised to study this list of topics in conjunction with the 'Guidance on the delivery and assessment of this unit' topic below so that they can get a clear indication of the standard of achievement expected of candidates in this unit.

1. Describe the construction and operation of synchronous machines (12 hours)

- Analyse constructional features of synchronous machines
- Armature windings
- Permanent magnets and DC field winding
- Explain that rotor can be cylindrical or salient pole
- In motor mode, explain that stator windings are connected to AC supply and the field winding mmf interacts with armature mmf to produce electromagnetic torque between rotor and stator
- In generator mode, explain that stator windings are connected to load and rotating magnetic flux produced by rotor field current induces voltages in stator winding
- Explain the principle of air gap flux
- Analyse methods of field current excitation: separate DC current source with brushes, slip rings or generator mounted on same shaft with solid-state rectifiers
- Calculation of rpm from frequency and number of poles
- Use phasor diagrams to illustrate power flow to machine (E lags V_t), or from machine (E leads V_t)

2. Analyse the operating characteristics of a synchronous generator (16 hours)

- The role of the synchronous generator in the power generation industry
- Use equivalent circuit and phasor diagrams to evaluate the performance of synchronous generator, open/short circuit tests
- Analysis of internal emf and terminal voltage
- Voltage regulation
- Analysis of torque angle
- Variation of power factor against excitation current
- Calculation of generator power output
- Active and reactive power-angle characteristics
- Analyse rotor and stator losses
- Synchronous machine connected to infinite bus
- Parallel operation and importance of correct synchronisation procedures
- Synchronising torque
- Loading capability diagram

3. Analyse the operating characteristics of a synchronous motor (10 hours)

- Use equivalent circuit and phasor diagrams to evaluate the performance of a synchronous machine in motor mode, comparison with generation mode.
- Real and reactive power flow control, overexcited/underexcited.
- Torque and power relations in cylindrical motor and salient pole motors.
- Motor power factor improvement.
- Variation of power factor against excitation current.
- Starting methods for synchronous motors.
- Role of synchronous condenser in pf correction.
- Applications of synchronous motors.

Unit assessment
One written paper lasting 2 hours

This unit may be taught as a freestanding unit, however it also could be combined with appropriate unit(s) to allow integration of related topics.

Guidance on the delivery and assessment of this unit

The unit is designed to introduce the candidate to synchronous machines and to develop an understanding of their operating characteristics.

Details on approaches to assessment are given under evidence requirements and assessment guidelines under each outcome in the SQA Advanced Unit Specification: statement of standards section. It is recommended that these sections be read carefully before proceeding with assessment of candidates.

While not mandatory, it would be advantages if the delivery of this unit were supported by practical laboratory work. Formal lectures should be kept to a minimum and extensive use should be made of tutorials, reference handouts, and visual aids including the use of any relevant simulation software available.

Open learning

This unit could be delivered by distance learning, which may incorporate some degree of on-line support. However, with regard to assessment, planning would be required by the centre concerned to ensure the sufficiency and authenticity of candidate evidence. Arrangements would be required to be put in place to ensure that the assessment was conducted under controlled, supervised conditions.

For information on open learning arrangements, please refer to the SQA guide *Assessment and Quality Assurance of Open and Distance learning (SQA 2000).*

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.

General information for candidates

Unit title: Synchronous Machines

This unit has been designed to provide you with knowledge and understanding of synchronous machines and their uses. These skills are especially relevant for those pursuing a career in the field of power generation and related industries.

In Outcome 1 you will study the constructional features and basic principle of operation of synchronous machines, including typical methods of supplying field current excitation. In Outcomes 2 and 3 you will mathematically analyse the operating characteristics of a synchronous machine operating both as a generator and as a motor. You will be introduced to practical applications of synchronous machines, such as the role of the synchronous condenser in power factor improvement.

Tutorials, reference handouts and visual aids will be employed to help you to properly understand how these machines work, in addition to covering the theory behind them. Material is also available via the Internet such as illustrations, photographs and current information relating to synchronous machines and their uses. Some of the unit may involve practical laboratory work. Additionally the unit will allow you to further develop skills and knowledge in the field of rotating machines, electromagnetism, ac circuit analysis and three-phase supply.

Formal assessment of this unit will consist of one assessment paper lasting two hours. The assessment will be conducted under closed-book conditions in which you will not be allowed to take notes, textbooks etc. into the assessment venue. However you will be allowed to use an approved scientific calculator.