Higher National Unit Specification

General information for centres

Unit title: Three Phase Induction Motors

Unit code: DN45 35

Unit purpose: This Unit has been developed to provide candidates' with an opportunity to develop knowledge and understanding about the performance characteristics of three phase induction motors. Candidates will also learn about normal starting and braking methods used with induction motor. They will also be provided with the opportunity to select a suitable three phase induction motor and ancillary equipment to match a given industrial load.

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

1. Analyse the performance characteristics of three-phase induction motors.
2. Analyse three phase induction motor starting methods.
3. Analyse three-phase induction motor braking methods.
4. Select a three-phase squirrel cage induction motor and ancillary equipment to match a given industrial load.

Credit points and level: 1 HN Credits 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 Access 1 to Doctorates.*

Recommended prior knowledge and skills: Candidates should have a broad knowledge and understanding of electrical principles and machines. This may be evidence by possession of the following HN units: DG54 34 Single Phase AC Circuits, DG3G 34 Electrical Networks and Resonance, DN47 34 Three Phase Systems, DN4J 34 Electrical Machine Principles and DN4K 35 Electrical Motor Drive Systems.

Core Skills: There may be opportunities to gather evidence towards the following 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 Higher
- Written Communication (writing) at Higher
- Numeracy at Higher
- Problem Solving at Higher

Context for delivery: This Unit has been developed for the HNC and HND Electrical Engineering awards. If the Unit is delivered as part of 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.

General information for centres (cont)

Assessment: The Unit has two assessments. The first assessment, which covers Outcomes 1 to 3, should be a written test, lasting two hours which should be conducted under supervised, controlled conditions. The second assessment, which covers Outcome 4, should comprise of an assignment involving the selection of a three phase induction motor and ancillary equipment to match a given industrial load. Candidates should submit a report of between 750 -1000 words in length plus diagrams and appendices.

Higher National Unit specification: statement of standards

Unit title: Three Phase Induction Motors

Unit code: DN45 35

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

Analyse the performance characteristics of three-phase induction motors.

Knowledge and/or skills

- Review constructional features and principle of operation of a three-phase induction motor
- Single-phase equivalent circuit
- Induction motor tests (no-load, lock rotor and d.c. resistance)
- Calculations involving the equivalent circuit
- Power flow diagram
- Relationships between torque and slip
- Effect of rotor resistance on torque-slip

Outcome 2

Analyse three phase induction motor starting methods.

Knowledge and/or skills

- Direct-on-Line
- Star-Delta
- Auto-Transformer
- Rotor Resistance (wound rotor motors only)
- Soft-starting
- Comparison of starting methods

Outcome 3

Analyse three-phase induction motor braking methods.

Knowledge and/or skills

- D.C. Injection
- Plugging
- Regenerative
- Comparison of braking methods

Higher National Unit specification: statement of standards (cont)

Unit title: Three Phase Induction Motors

Evidence Requirements

Evidence for the knowledge and /or skills in Outcomes 1 to 3 will be provided on a sample basis. The evidence may be presented in responses 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 **four out of seven** knowledge and/or skills items should be sampled from Outcome 1, **four out of six** knowledge and skills items from Outcome 2 and **three out of four** knowledge and skills items for 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 four out of seven knowledge and/or skills items from Outcome 1, four out of six knowledge and/or skills items from Outcome 2 and three out of four knowledge and skills items from Outcome 3 are required each time the Unit is assessed. Candidates must provide a satisfactory response to all items.

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 item by showing that the candidate is able to:

Outcome 1

- explain the constructional features and operation of a three-phase induction motor
- identify the components in the single-phase equivalent circuit of a three-phase induction motor
- use motor test results (from no-load, lock-rotor and d.c. resistance tests) to determine the component values in the single-phase equivalent circuit
- perform calculations using the equivalent circuit
- draw the power flow diagram for a three-phase induction motor
- explain, using toque-slip curves, the relationship between torque and slip (other factors remaining constant)
- explain the effect of rotor resistance on torque-slip

Outcome 2

- explain, with the aid of a circuit diagram, the principle of operation of Direct-on-Line starting
- explain, with the aid of a circuit diagram, the principle of operation of Star-Delta starting
- explain, with the aid of a circuit diagram, the principle of operation of Auto-Transformer starting
- explain, with the aid of a circuit diagram, the principle of operation of Rotor Resistance starting
- explain, with the aid of a circuit diagram, the principle of operation of soft starting

- compare, in table format, the above starting methods in terms of performance and relative cost

Outcome 3

- explain, with the aid of a circuit diagram, the principle of operation of d.c. injection braking
- explain, with the aid of a circuit diagram, the principle of operation of plug braking
- explain, with the aid of a circuit diagram, the principle of operation of regenerative braking
- compare, in table format, the above braking methods in terms of performance and relative cost

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 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 textbooks, handouts or notes to the assessment. Candidates should be permitted to use scientific calculators during the assessment.

Assessment guidelines

The assessment paper should be composed of an appropriate balance of short answer, restricted response and structured questions.

Outcome 4

Select a three-phase squirrel cage induction motor and ancillary equipment to match a given industrial load.

Knowledge and/or skills

- Classes of cage induction motors (National Electrical Manufacturers Association)
- Selection criteria are applied (load characteristics, power supply, KVA rating, starting, braking, reversing, normal running, duty cycle, protection, safety, environment)
- Choice of motor and ancillary equipment is justified

Evidence Requirements

All knowledge and /or skills items in Outcome 4 should be assessed. The evidence should be presented in response to an assignment in which the candidate is set the task of selecting a three phase induction motor and ancillary equipment (i.e. starting, braking and protection equipment) to match a given load.

A candidate's response can be judged to be satisfactory where the evidence provided is sufficient to meet the requirements for each item by the candidate showing that he/she has:

- taken into account different cage classes
- taken account of all the selection criteria in the second bullet point
- justified the selection of the motor and ancillary equipment

Higher National Unit specification: statement of standards (cont)

Unit title: Three Phase Induction Motors

The assignment should be based on a real industrial situation in which a three-phase squirrel cage induction motor is required to drive a load.

Evidence for this Outcome should be gathered by the candidate preparing a report which covers the three knowledge and skills items for this Outcome. The report should be between 750 -1000 words long plus diagrams and appendices.

Candidates should have access to course notes, relevant textbooks and suppliers' catalogues whilst doing the assignment.

Assessment Guidelines

Centres may wish to issue candidates with suitable guidance notes giving advice on the best way to structure their reports.

Centres should make every reasonable effort to ensure the assignment solution is the candidate's own work. Where copying or plagiarism is suspected candidates may be interviewed to check their knowledge and understanding of the subject matter. A checklist should be used to record oral evidence of the candidate's knowledge and understanding.

Administrative Information

Unit code: DN45 35

Unit title: Three Phase Induction Motors

Superclass category: XJ

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SQA acknowledges the valuable contribution that Scotland's colleges have made to the development of Higher National qualifications.

Additional copies of this Unit specification can be purchased from the Scottish Qualifications Authority. Please contact the Customer Contact Centre for further details, telephone 0845 279 1000.

Higher National Unit specification: support notes

Unit title: Three Phase Induction Motors

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. Analysis of the performance characteristics of three-phase induction motors
2. Analysis of three phase induction motor starting methods.
3. Analysis of three-phase induction motor braking methods
4. Selection of a three-phase squirrel cage induction motor and ancillary equipment to match a given industrial load

This Unit has been developed to provide HNC and HND Electrical Engineering candidates with a sound knowledge and understanding of the performance characteristics of three phase induction motors and common methods of starting and braking used with this type of motor. In addition, candidates will be provided with an opportunity to select an appropriate three phase induction motor and ancillary equipment to match a given industrial load. The Three Phase Induction Motors Unit is a 1 credit unit at SCQF Level 8(8 SCQF credit points at SCQF Level 8). It is included within the optional section of the HNC and HND Electrical Engineering frameworks. The Unit can be offered on a free standing basis, but can also be combined with other specialist electrical machines Units such as Applications of Power Electronics in Electrical Motor Drive Systems, Synchronous Machines and Transformers to form a detailed study in electrical motors and transformers.

It is recommended that candidates have studied the Units Electrical Machine Principles and Rotating Plant before taking this Unit.

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 to 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. The list of topics is as follows.

Outcome 1 (16 hours)

Analyse the performance characteristics of three-phase induction motors

- Review of the constructional features of three phase induction motors to include stator and stator winding design, wound and squirrel cage rotor design (e.g. single and double bar cage rotors), cooling arrangements and enclosures, and other salient features
- Advantages and disadvantages of squirrel cage rotor over wound rotor
- Development of single phase equivalent circuit (including comparison to power transformer equivalent circuit)
- No-load, lock rotor and dc resistance tests (use results to determine equivalent circuit parameters

Higher National Unit specification: support notes (cont)

Unit title: Three Phase Induction Motors

- Calculations involving the single phase equivalent circuit
- Development of power flow block diagram
- Development of torque slip relationship from power flow diagram and equivalent circuit
- Variation of torque with slip all other variables remaining constant (diagrammatic representation of torque-slip relationship)
- Analysis of the effect of rotor resistance on torque-slip relationship
- Slip at which maximum torque occurs

Outcome 2 (8 hours)

Analyse three phase induction motor starting methods.

- Discussion of normal and adverse starting conditions (e.g. high inertia loads, high starting currents, potential serious volt-drops)
- Duty cycle
- Description, principle of operation, circuit and wiring diagrams for the following starting methods: Direct-on-Line, Star-Delta, Auto-Transformer and Rotor Resistance (wound rotor motors only)
- Brief discussion of starting problems (e.g. motor taking too long to reach full speed, motor not reaching full speed, cogging)
- Practical issues relating to starting (e.g. six stator winding ends required in the case of Star-Delta Starting)
- Principles of Soft-starting and typical soft-starting arrangements
- Comparison of starting methods in terms of overall performance and relative cost

Outcome 3 (5 hours)

Analyse three phase induction motor braking methods

- Operational constraints of braking different motor and load combinations
- Description, principle of operation, circuit and wiring diagrams of the following braking methods; D.C. Injection, Plugging and Regenerative
- Practical issues relating to braking methods
- Comparison of braking methods in terms of performance and cost

Assessment: Written Test – 2 hours

Outcome 4 (9 hours)

Select a three phase squirrel cage induction motor and ancillary equipment to match a given industrial load

- The content for this Outcome is fully specified under Outcome 4 in the Higher National Unit specification: statement of standards section.

Higher National Unit specification: support notes (cont)

Unit title: Three Phase Induction Motors

Guidance on the delivery and assessment of this Unit

This Unit has been designed to incorporate sufficient time to allow lecturers to teach all of the three phase induction motor content contained in the Unit. There is also sufficient time for candidates to practice what they have learnt through appropriate formative assessment exercises and practical laboratory work. In regard to practical work, it is recommended that candidates are allowed to study disassembled three phase induction motors so that they can examine the various component parts of this type of motor. Good charts and other visual aids showing the disassembled parts of three phase induction motors will also assist candidates to learn. Visual inspection of different types of starting and baking systems will also aid learning. Centres are strongly recommended to allow candidates to perform a range of practical test on three phase induction motors to determine essential performance characteristics. Such tests might include no-load and lock rotor tests and test to determine the operation of three phase induction motors under various load conditions. This will help candidates to relate theory to practice.

Information on Evidence requirements and Assessment guidelines is given after Outcomes 3 and 4 in the Higher National Unit specification: statement of standards section. The written assessment should take place after Outcomes 1 to 3 have been completed and the Assignment would normally be undertaken following the written test.

Open learning

This Unit could be delivered by distance learning, which may incorporate some degree of on-line support. However, with regards 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 assessment, whether done at a single or multiple events, was conducted under controlled, supervised conditions.

To keep administrative arrangements to a minimum, it is recommended that for distance learning candidates the assessment paper is taken at a single assessment event.

Candidates with additional support needs

This Unit specification is intended to ensure that there are no artificial barriers to learning or assessment. The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments or considering alternative Outcomes for Units. For information on these, please refer to the SQA document *Guidance Assessment Arrangements for Candidates with Disabilities and/or Additional Support Needs,* which is available on the SQA website www.sqa.org.uk.

General information for candidates

Unit title: Three Phase Induction Motors

Three phase induction motors are the most commonly used type of motor in industry principally because they are easy and cheap to manufacture, robust, reliable and lend themselves to good speed control performance via appropriate power electronic equipment. Given that this is the case it is important that you understand the performance characteristics of the motor especially as you will almost certainly come across it in your working life and you may be required to select an induction motor to meet an industrial load application. It is also useful that you know about starting and braking methods for this type of motor as you may also have to select appropriate starting and braking arrangements for a given three phase induction motor application.

The centre where you study this Unit will probably provide you with opportunities to study the component parts of different types of three phase induction motors closely using disassembled motors, charts and other visual aids. You will also probably perform various tests on induction motors to determine their key performance parameters and characteristics.

Assessment for this Unit will comprise of a two hour, closed book test which you will take after you have completed the first three Outcomes. You will also have to do an assignment in which you will have to select an appropriate three phase induction motor and ancillary equipment for a given industrial load. You will be required to submit a report of between 750 -1000 words long plus diagrams and appendices, relating to the selection of the motor and ancillary equipment.