SQA Advanced Unit specification

General information for centres

Unit title: Three Phase Systems

Unit code: HT7K 47

Unit purpose: This Unit is designed to enable candidates to know and understand the principles of three phase systems. It provides candidates with the opportunity to develop the knowledge and skills to enable them to describe the production and characteristics of a three phase supply. It also provides candidates with the opportunity to develop the necessary knowledge and skills to determine voltages and currents in both balanced and unbalanced three phase loads. The Unit also allows candidates the opportunity to develop the knowledge and skills to calculate different types of power in three phase loads and also to describe the techniques used to measure active power in three phase systems.

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

1. Describe the production and characteristics of a three phase supply.
2. Analyse the response of balanced star and delta connected loads supplied by symmetrical three phase supplies.
3. Analyse the response of unbalanced star and delta connected loads supplied by 3- and 4-wire symmetrical three phase supplies.
4. Analyse power in three phase loads.

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.*

Recommended prior knowledge and skills: Candidates should possess a broad knowledge and understanding of single phase a.c. circuit theory. They should be able to solve single phase problems using network theorems and complex numbers. This may be evidenced by the possession of SQA Advanced Units HP46 47 DC and AC Principles, HP3J 47 Electrical Networks and Resonance and HP48 46 Engineering Mathematics 1. However, entry requirements are at the discretion of the centre.

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:

- Using Number at SCQF level 6
- Using Graphical Information at SCQF level 6
- Critical Thinking at SCQF level 6

Context for delivery: This Unit has been developed for the SQA Advanced Certificate and SQA Advanced Diploma in Electrical Engineering. If the Unit is to be used in another Group Award, it is recommended that it be taught and assessed in the content of that particular Group Award.

Assessment: The assessment for all four Outcomes in this Unit should be combined together into one written assessment paper. This paper should be taken by candidates at one single assessment event that should last two hours. The assessment paper should be composed of a suitable balance of short answer, restricted response and structured questions. This assessment should be conducted under controlled, supervised conditions. At the assessment, candidates should be provided with the formula to calculate the potential difference between the load star point and the supply star point for an unbalanced 3-wire star connected load (Outcome 3). This formula could be incorporated in the assessment paper, or it could be issued on a separate sheet. It should be noted that candidates must achieve all the minimum evidence specified for each Outcome in order to pass the Unit.

SQA Advanced Unit specification: statement of standards

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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

Describe the production and characteristics of a three phase supply.

Knowledge and/or skills

- construction and operation of a three phase a.c. generator
- star and delta winding configurations
- phase and line voltage and current relationships for star connected supplies
- phase and line voltage and current relationships for delta connected supplies
- mathematical expressions for three phase voltages
- phasor diagram for voltages in a three phase supply
- advantages of three phase supply systems over single phase systems

Outcome 2

Analyse the response of balanced star and delta connected loads supplied by symmetrical three phase supplies.

Knowledge and/or skills

- phase and line voltage and current relationships for balanced star connected loads
- phase and line voltage and current relationships for balanced delta connected loads
- calculation of phase and line voltages and currents for complex star connected loads
- calculation of phase and line voltages and currents for complex delta connected loads
- phasor diagrams for balanced three phase loads

Outcome 3

Analyse the response of unbalanced star and delta connected loads supplied by 3- and 4-wire symmetrical three phase supplies.

Knowledge and/or skills

- calculation of voltages and currents in an unbalanced star connected load supplied by a three phase 4-wire supply
- calculation of the current in the neutral wire of an unbalanced load supplied by three phase 4-wire supply

- calculation of the potential difference between the load star point and the supply star point for an unbalanced star connected load supplied by a three phase 3-wire supply
- calculation of voltages and currents in an unbalanced star connected load supplied by a three phase 3-wire supply
- calculation of voltages and currents in an unbalanced delta connected load supplied by a three phase supply

Outcome 4

Analyse power in three phase loads.

Knowledge and/or skills

- power in balanced three phase loads
- power in unbalanced three phase loads
- measurement of active power in three phase loads
- effect of load power factor on wattmeter readings

Evidence Requirements

Evidence for the knowledge and/or skills in Outcomes 1 to 4 will be provided on a sample basis. The evidence may be provided in response to specific questions. Each candidate will need to demonstrate that he/she can answer correctly questions based on a sample of the items shown under the knowledge and/or skills in all four Outcomes. In any assessment of the Outcomes **four out of seven** knowledge and/or skills items should be sampled from Outcome 1, **three out of five** knowledge and/or skills items from Outcome 2, **three out of five** knowledge and/or skills items from Outcome 3, and **two out of four** knowledge and/or skills items from Outcome 4.

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, three out of five knowledge and/or skills items from Outcome 2, three out of five knowledge and/or skills items from Outcome 3, and two out of four knowledge and/or skills items from Outcome 4 is 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

- describe the construction and operation of a simple-three phase a.c. generator
- draw and describe star and delta winding configurations
- state the relationships between phase and line voltages, and phase and line currents in a star connected supply (Magnitude and phase)
- state the relationships between phase and line voltages, and phase and line currents for a delta connected supply (Magnitude and phase)
- state mathematical expressions for the voltages of a symmetrical three phase supply
- draw a phasor diagram showing voltages in a symmetrical three phase supply
- state three advantages that three phase supply systems have over single phase systems

Outcome 2

- state the relationships between phase and line voltages, and phase and line currents for a balanced star connected load (Magnitude and phase)
- state the relationships between phase and line voltages, and phase and line currents for a balanced delta connected load (Magnitude and phase)
- calculate phase and line voltages and currents for a balanced star connected load consisting R&L **or** R&C
- calculate phase and line voltages and currents for a balanced delta connected load consisting R&L **or** R&C
- draw a phasor diagram showing all voltages and currents associated with one balanced three phase load

Outcome 3

- calculate the phase voltages and the line currents for an unbalanced star connected load connected to a three phase 4-wire supply; the load comprising reactive components on at least two phases
- calculate the current in the neutral wire of an unbalanced load supplied by a three phase 4-wire supply
- calculate the voltage between the load star point and the supply star point for an unbalanced star connected load connected to a three phase 3-wire supply; the load comprising reactive components on at least two of the phases
- calculate one phase voltage and one line current for an unbalanced star connected load connected to a three phase 3-wire supply; the load comprising reactive components on at least two phases
- calculate the phase voltages, two of the phase currents, and one line current for an unbalanced delta connected load connected to a three phase supply; the load comprising reactive components on at least two of the phases

Outcome 4

- calculate at least **two** of the following quantities for a balanced three phase load: total active, reactive and apparent power, and overall power factor
- calculate at least **two** of the following quantities for an unbalanced three phase load: total active, reactive and apparent power, and overall power factor
- with the aid of diagrams, show how wattmeters could be connected to measure total active power in a three phase load (one, two or three wattmeters may be used)
- describe how the load power factor affects the wattmeter readings in the two-wattmeter method of measurement

Evidence should be generated through assessment undertaken in controlled, supervised conditions. Assessment should be conducted under closed-book conditions and as such candidates must not be allowed to bring any textbooks, handouts, or notes to the assessment. At the assessment, candidates should be provided with the formula to calculate the potential difference between the load star point and the supply star point for an unbalanced 3-wire star connected load (Outcome 3). This formula could be incorporated in the assessment paper, or it could be issued on a separate sheet. Candidates will be permitted to use scientific calculators during the assessment however the use of programmable calculators is forbidden.

Assessment guidelines

The assessment for Outcomes 1 to 4 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 be carried out under supervised, controlled conditions. Candidates must not bring any text books, handouts or notes to the assessment. Such a paper should be composed of an appropriate balance of short answer, restricted response and structured questions. If knowledge and/or skills items 3 and/or 4 in Outcome 3 are assessed then candidates should be provided with the formula to calculate the potential difference between the load star point and the supply star point for an unbalanced 3-wire star connected load. This formula could be incorporated in the assessment paper, or it could be issued on a separate sheet. Candidates will be permitted to use a scientific calculator during the assessment however the use of a programmable calculator is forbidden.

Administrative information

Unit code: HT7K 47

Unit title: Three Phase Systems

Superclass category: XK

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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.

SQA Advanced Unit specification: support notes

Unit title: Three Phase Systems

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:

- production and characteristics of a three phase supply
- the use of relevant laws and theorems to analyse the response of balanced star and delta connected loads supplied by symmetrical three phase supplies
- the use of relevant laws and theorems to analyse the response of unbalanced star and delta connected loads supplied by symmetrical three phase supplies
- power calculation and measurement in three phase loads

This Unit is at SCQF level 7 and has been devised as a mandatory Unit within the SQA Advanced Certificate and SQA Advanced Diploma in Electrical Engineering. However, this does not preclude the use of this Unit in other awards where award designers feel this to be appropriate.

In designing this Unit, the 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 recommended that they do so since the assessment exemplar pack for this Unit is based on the knowledge and/or skills and list of topics in each of the Outcomes.

A list of topics for each Outcome is given below. Lecturers are advised to study this list in conjunction with the assessment exemplar pack so that they can get a clear indication of the standard of achievement expected of candidates in this Unit.

1. Describe the production and characteristics of a three phase supply (7 hours)

Construction and operation of a simple 3-phase generator
120^o displacement of coils
Relationship between speed, number of poles and frequency
$f=np/60$
U.K. supply system voltage and frequency values and limits
Star and delta winding configurations
voltage and current relationships (magnitude and phase) associated with three phase star and delta winding configurations
Plots of voltage against time/degrees for the output phases of a generator
Mathematical representation of voltages: $e_a=E_{max}\sin\omega t$, $e_b= E_{max}\sin(\omega t-120^o)$,
$e_c= E_{max}\sin(\omega t+120^o)$
Phasor diagram for voltages in three phase system
Advantages of three phase system as compared to single phase systems

2. Analyse the response of balanced star and delta connected loads supplied by symmetrical three phase supplies (10 hours)

Derivation of voltage and current relationships (magnitude and phase) associated with balanced three phase star and delta loads. Graphical methods using phasors could be used
Calculation of voltages and currents in balanced star and delta loads. The loads to consist of resistance and reactance
Show that the current in the neutral wire is zero for balanced 4-wire star load
Show that the circulating current in balanced delta load equals zero
Phasor diagrams for balanced star and delta loads

Areas for practical work may include, but not be limited to, the following:

Measurement of phase and line voltages and currents in balanced star and delta loads. Measured values should be recorded and compared with calculated values. Laboratory exercises are preferred, but simulation software could also be used.

3. Analyse the response of unbalanced star and delta connected loads supplied by three and 4-wire symmetrical three phase supplies (13 hours)

Calculation of voltages and currents in the following unbalanced load types: 4-wire, 3-wire star and delta
Calculation of current in the neutral wire for a 4-wire supply
Calculation of the potential difference between supply and load star points in 3-wire star connected load using:

$$V_{nN} = \frac{V_{AN}\ Y_{an} + V_{BN}\ Y_{bn} + V_{CN}\ Y_{cn}}{Y_{an} + Y_{bn} + Y_{cn}}$$

(Candidates should be provided with the above formula at assessment events)

Phasor diagrams for unbalanced star and delta loads
Consequences of unbalanced loads (with reference to overloading conductors and volt drop)

Areas for practical work may include, but not be limited to, the following:

Measurement of phase and line voltages and currents in unbalanced star and delta loads. Measured values should be recorded and compared with calculated values. Laboratory exercises are preferred, but simulation software could also be used.

4. Analyse power in three phase loads (8 hours)

Derivation of $\sqrt{3}V_L I_L \cos\phi$ from $3V_{PH}I_{PH}\cos\phi$
Calculation of total active, reactive and apparent power, and overall power factor in balanced and unbalanced three phase loads
Diagrams showing active power measurement methods. Methods should include the use of one wattmeter, two wattmeter method and use of three wattmeters
Effect of load power factor on the wattmeter readings in the two wattmeter method
Calculation of load power factor using readings from two wattmeters

Areas for practical work may include, but not be limited to, the following:

Measurement of active power per phase and total active power in balanced and unbalanced loads. Single wattmeter, two wattmeter and three wattmeter methods should be used. Measured values should be recorded and compared with calculated values.

Unit Assessment: Written assessment paper (2 hours)

It is recommended that as much practical work as is possible is carried out so that candidates have the opportunity to measure electrical quantities in three phase systems and compare their recorded values with those obtained by application of laws and theorems.

Guidance on the delivery and assessment of this unit

It is recommended that this Unit be delivered after the candidate has gained experience in the use of complex numbers and single phase a.c. circuit theory. In the SQA Advanced Certificate and SQA Advanced Diploma in Electrical Engineering awards these topics are covered in various other Units: HP46 47 DC and AC Principles, HP3J 47 Electrical Networks and Resonance and HP48 46 Engineering Mathematics 1. It is recommended that, if possible, the delivery of these other Units be carried out in advance of this Three Phase Systems Unit.

During the delivery of this Unit students should be given the opportunity to participate in tutorial sessions to enable them to practice and apply the theorems and laws that are crucial to this Unit.

This Unit has been designed to incorporate some time for practical work. Note, this aspect of the Unit is not formally assessed. However it is a valuable part of the candidate's learning experience and allows them to confirm values obtained from the application of laws and theorems. It is recommended that the practical exercises be conducted in a laboratory. However if resources do not permit this, then computer simulation may be used.

This Unit has been developed as part of the SQA Advanced Certificate and SQA Advanced Diploma in Electrical Engineering. Where this Unit is incorporated into other Group Awards it is recommended that it be delivered in the context of the specific occupational area(s) that the award is designed to cover.

Details on approaches to assessment are given under Evidence Requirements and assessment guidelines 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.

Assessment should take place after delivery of the Unit is complete.

Open learning

This Unit could be delivered by distance learning, which may incorporate some degree of online 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: Three Phase Systems

Three phase supply systems are used throughout the world to produce, transmit and distribute electrical power to industrial, commercial and domestic premises. This Unit has been designed to enable you to develop the knowledge and skills that will allow you to understand the theory and principles of three phase systems.

In this Unit you will begin by learning how three phase supplies are produced by generators. You will then progress to study the characteristics and responses of various types of loads that can be connected to three phase systems. Complex notation will be extensively used to calculate voltages and currents in a variety of three phase loads. You will also learn how to calculate the different types of power consumed by three phase loads. Methods of measuring active power in three phase systems will be studied in detail.

In summary, by the end of this Unit you should be able to: describe the production and characteristics of a three phase supply; use laws and theorems to analyse the response of various loads connected to a three phase supply system and describe techniques for measuring active power in such loads.

It is likely during the Unit that you will be provided with the opportunity to relate theory to practice by doing practical laboratory exercises and/or computer simulations.

The formal assessment for this Unit will consist of a single assessment paper lasting two hours. The assessment will be conducted under closed-book conditions and you will *not* be allowed to take notes, textbooks, etc, into the assessment. However you will be allowed to use a scientific calculator. You will sit this assessment paper at the end of the delivery of the Unit.