Unit 32: Building Services Control Systems

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

The need for and complexity of automatic control systems for use in building services installations have increased significantly in recent years. The ongoing need to reduce energy consumption, coupled with progress in technology, has resulted in the development of sophisticated systems which can monitor and optimise plant performance to meet building needs.

Although current legislation makes it impossible to avoid the use of control systems, these are often not given sufficient consideration by the designer, and are not understood by the user.

A sound understanding of control systems, what they do and how they work, is therefore fundamental to all those involved with building services engineering, whether as designers, installers, controls engineers, or commissioning engineers, or as owners/facilities managers.

The unit explores control systems from fundamental control principles, the features of the equipment and components used, and the design and specification of control strategies for specific applications. It covers the more standard forms of control application, and does not deal in detail with the more specialised technology associated with Building Management Systems, or with electronic control theory.

Learning outcomes

On completion of this unit a learner should:

1 Understand the purpose of building services control systems and the functions they perform

2 Understand the terminology and fundamental principles associated with building services control systems

3 Know how the operational features and characteristics of control components, devices and types contribute to their application and use

4 Be able to develop appropriate control strategies, schemes and schematic drawings for specific building services plant, systems and sub-systems.

Unit content

1 **Understand the purpose of building services control systems and the functions they perform**

Reasons for having control systems: what building services controls are for; purpose of controls; consequences of poor control eg for owner and environment; legislative requirements for control in building services

What building services control systems do: generic functions (functions commonly performed by building services controls and control systems, eg temperature, humidity, air quality, level, flow, lighting level, time, contamination/pollution, pressure, fire and smoke); specific functions (adaptations of the generic function commonly performed by building services control systems, eg weather compensation, night set-back, zone control, optimum start/stop, system frost protection, fabric protection, pump exercising, plant sequencing); safety controls (functions performed by safety controls and control systems, eg flame failure, combustion, pressure relief, leak detection, high and low level warning)

2 **Understand the terminology and fundamental principles associated with building services control systems**

Control terminology: definition, explanation and illustration of control terminology in common use, eg controlled condition, set point, controlled process, controlled variable, manipulated variable, deviation, disturbances, offset, controller, sensor, actuator, controlled device, lag, hunting, dead-band

Control loops: components of a control system; features, illustration and typical applications for control loops, eg open and closed, single and multi

Control modes: features; operational characteristics; typical application of modes of control commonly used in building services control applications, eg two position, proportional, integral, derivative, PI, PID

Control loop features: lag; transport and transfer lag (causes, effects, methods of reduction); stability and accuracy; definition; causes and effects

3 **Know how the operational features and characteristics of control components, devices and types contribute to their application and use**

Sensors: types; operating principles; features; characteristics of the various types of sensors commonly used in building services, eg temperature, humidity, flow, velocity, pressure, level, air quality, rotational speed, gas detection, flame, smoke, light, presence, thermal radiation

Controlled devices: control valves (two port and three port valves; construction, types and operation; problems associated with throttling effect of two-port valves; configuration of three port valves to obtain mixing and diverting application); control valve characteristics; valve authority; reasons for and application of characterised valves; control dampers (types; blade action; construction and operation); inherent and installed characteristics; reasons for and application of characterised dampers; damper authority; use of dampers to achieve mixing; other controlled devices (types; operating principles); features and characteristics of the various other types of controlled device, eg light dimmers, variable speed drives for fans, pumps and compressors

Actuators: types; operating principles, features and characteristics of various types of linear and rotary actuators; types of power; drive and positional feedback

Controllers: purpose and types of controller; control signal media (mechanical; pneumatic; electrical; electronic); control data (analogue and digital; examples of each); conversion from analogue to digital; the role of microprocessors and software in control systems; types of control (characteristics, features and application of the various categories of control commonly used in building services, eg manual, simple automatic, direct digital control, building management system and integrated control systems)

Direct acting controls: construction, operating principles, features, characteristics, applications and limitations of the various direct acting (self-acting) controls commonly used in building services installations and plant, eg thermostatic radiator valves, float valves, thermostatic expansion valves, pressure relief valves, flame failure valves, thermostatic shower mixing valves, thermostatic hot water valves

4 **Be able to develop appropriate control strategies, schemes and schematic drawings for specific building services plant, systems and sub-systems**

What functions are needed: identifying and specifying required control functions for various installations, systems or items of plant; legislative requirements; guidance and good practice recommendations; desirable and essential functions

Developing control strategies: identification of key features required before a successful control strategy can be developed; key factors considered in selecting an appropriate control strategy

Selecting and designing control strategies and schemes: selection and recommendation of appropriate simple automatic or direct digital control strategies for various specific building services installations and plant, eg low pressure hot water heating systems and boiler plant, central ventilation/warm air heating/air-conditioning systems and air handling units, domestic hot water installations, calorifiers and hot water generators, chilled water installations and refrigeration plant, packaged air conditioning systems, refrigeration plant for commercial applications; location of sensors to achieve required control functions; explanation of sequence of events and scenarios; functions of the various sensors; selection of appropriate sensor set points, dead bands (differential)

Graphical detailing: production of appropriate schematic control drawings and sketches as required to communicate control system detailed designs; use of drawing symbols and annotation

Grading grid

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all of the learning outcomes for the unit. The criteria for a pass grade describes the level of achievement required to pass this unit.

Grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 identify the purpose of controls and control systems for building services systems and the functions they commonly perform	M1 compare alternative types of sensors, actuators, controlled devices and controllers for given specific building services installations and recommend the most suitable	D1 analyse and justify the rationale used in the production of control strategies and demonstrate how proposed control systems satisfy operational needs
P2 explain, using correct terminology, the fundamental principles of control loops and the operational features, properties and characteristics of the modes of control performed by such loops	M2 make clear recommendations for control strategies and produce comprehensive control schemes for specific building services installations	D2 evaluate the energy, environmental, financial and operational benefits of a variety of specific control systems within building services installations.
P3 describe how the features and characteristics of the various types of sensors, actuators, controlled devices and controllers contribute to their selection for specific applications	M3 analyse control schematic drawings and control function proposals for specific installations to produce detailed and comprehensive explanations of the control system operational sequence and settings.	

Continued

Grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P4 describe the construction, operating principles, functions and limitations of direct acting controls for a range of specific applications P5 identify control functions required for specific applications in order to satisfy the requirements of legislation, good practice and client needs P6 produce basic functional and workable automatic or direct digital control scheme designs appropriate to specific building services installations.		

Essential guidance for tutors

Delivery

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, supervised practicals, research using the internet and/or library resources and the use of personal and/or industrial experience are all suitable. Delivery should stimulate, motivate, educate and enthuse learners. Visiting expert speakers could add to the relevance of the subject.

The learning outcomes are linked and form a logical and progressive structure. Teaching and learning strategies should reinforce this integrated learner-centred approach. Learning outcomes 1 to 3 provide the underpinning knowledge of what building services control systems do and how they work. This should prepare learners for learning outcome 4 in which they are required to apply the knowledge by specifying control systems for real applications.

The method of delivery should be, as far as possible, activity based. Learning activities could include the use of case studies, product investigations, laboratory work and design exercises. The unit should not be perceived as an academic exercise and should at all times be based on real-life applications, and reflect industry best practice.

Learners are not required to cover every possible control hardware and schemes for every the mechanical and electrical building services installations. The Unit content should be interpreted so that they meet the vocational needs of learners. It is recommended that as far as possible the unit be integrated rather than be delivered in isolation, with other specialist vocational technology units in the programme.

Given that this unit is inherently about a form of technology that is specifically applied to various mechanical and electrical building engineering services, there is an assumption that learners has a basic understanding or are studying concurrently one or more of these other building services.

Group activities are permissible, but tutors will need to ensure that individual learners are provided with equal experiential and assessment opportunities.

Health, safety and welfare issues are paramount and should be strictly reinforced through close supervision of all workshops and activity areas, and risk assessments must be undertaken prior to practical activities. Centres are advised to read the *Delivery approach* section on page 24, and *Annexe G: Provision and Use of Work Equipment Regulations 1998 (PUWER)*.

Assessment

Evidence for this unit may be gathered from a variety of sources, including well-planned investigative assignments, case studies or reports of practical assignments.

There are many suitable forms of assessment that could be employed and tutors are encouraged to consider and adopt these where appropriate. Some examples of

possible assessment approaches are suggested below. However, these are not intended to be prescriptive or restrictive, and are provided as an illustration of the alternative forms of assessment evidence that would be acceptable. General guidance on the design of suitable assignments is available on page 19 of this specification.

Some criteria can be assessed directly by the tutor during practical activities. If this approach is used suitable evidence would be observation records or witness statements. Guidance on the use of these is provided on the Edexcel website.

The structure of the unit suggests that the grading criteria may be fully addressed by using integrative assignments.

Although this unit can be stand-alone, it is strongly recommended that, where learners are concurrently studying other units, centres consider integrative assignments. For example, the assessment evidence for the learning outcomes of this unit could be integrated with assessments associated with heating, ventilation and air-conditioning, refrigeration, lighting, hot water.

This approach provides added realism to the assessment instrument and avoids unnecessary duplication. As a general principle, the assessments should be contextualised to reflect the learners' vocational background or aspirations. Assessment should include the control requirements associated with a range of two or more types of building services installations within the specialist group. For example heating, ventilation and air-conditioning, or refrigeration, ventilation and air-conditioning or, heating and hot water, or lighting. As services control installations often fall within the remit of electrical installation engineers, learners with an electrical installations bias are expected to include controls associated with mechanical building services installations as well as electrical.

To achieve a pass grade learners must meet the six pass criteria listed in the grading grid.

For P1, learners must identify the purpose of controls and control systems for building services systems and the functions they commonly perform. They could contextualise the functions to include the generic, specific and safety functions expected for a variety of vocationally relevant applications. Evidence could take the form of a presentation or a report, supported by appropriate diagrams and other images.

For P2, learners must explain, using correct terminology, the fundamental principles of control loops and the operational features, properties and characteristics of the modes of control performed by such loops. It is important that control terminology is used correctly and appropriately throughout the explanation and that all the features and characteristics are explained and illustrated with vocationally relevant applications. Examples of suitable evidence approaches are as for P1.

P3 requires learners to describe how the features and characteristics of the various types of sensors, actuators, controlled devices and controllers contribute to their selection for specific applications. They should include all categories of component (sensors, actuators, controlled device and controller) but not necessarily every type of each category.

For P3, learners should cover fully the range of components that are typically associated with the building services that most accurately reflect their vocational background or aspirations. This must include the range of control components for two or more different types of vocationally relevant building services installations.

Evidence could take the form of a presentation or a report, supported by appropriate diagrams and other images. Manufacturers' brochures and specifications are not sufficient on their own but could be used to support the required evidence.

For P4, learners must describe the construction, operating principles, functions and limitations of direct acting controls for a range of specific applications. Having identified the locations where controls might be used, learners are expected to describe the construction, operating principles, functions and limitations of those controls within the context of that installation.

The installations used should be those that most accurately reflect the learners' vocational background or aspirations but must contain a range of different buildings services installations and their associated plant. The tutor could identify the installations in the form of services installation layout and/or schematic drawings or they could be learners' own designs if used as part of an integrated assignment. Examples of suitable evidencing approaches could be as for P1.

For P5, learners must identify control functions required for specific applications in order to satisfy the requirements of legislation, good practice and client needs. The installations used should be those that most accurately reflect learners' vocational background or aspirations but must contain a range of different buildings services installations and their associated plant.

The tutor could identify the installations in the form of services installation layout and/or schematic drawings or could be the learner's own designs if used as part of an integrated assignment. Learners must make reference to why a particular function is required, whether it satisfies legislative requirements, good practice recommendations or a particular client need. Examples of suitable evidence approaches could be as for P1.

For P6, learners must produce basic functional and workable automatic or direct digital control scheme designs appropriate to specific building services installations. Designs should include a controls schematic drawing(s) indicating the locations of all the necessary sensors and control components together with the controller requirements.

The installations used should be those that most accurately reflect learners' vocational background or aspirations but must contain a range of different buildings services installations and their associated plant. The tutor could identify the installations in the form of services installation layout drawings or could be learners' own designs if used as part of an integrated assignment. Examples of suitable evidence approaches could be as for P1.

To achieve a merit grade learners must meet all of the pass grade criteria **and** the three merit grade criteria.

For M1, learners are expected to compare alternative types of sensors, actuators, controlled devices and controllers for given specific building services installations and recommend the most suitable. They must make informed and appropriate recommendations as to the most appropriate for specific vocationally relevant installations. Learners should relate their decisions to the needs and characteristics of the particular installation and comment on the compatibility of the various components to each other including details of the type of control signal. In making the recommendations, learners could make use of manufacturers' literature and data. This must be to support their recommendations and must not be a mechanistic use with little demonstration of understanding. This could be a natural extension of the work carried out for P3.

For M2, learners must make clear recommendations for control strategies and produce comprehensive control schemes for specific building services installations. The control schemes should include the more complex installations including control of multiple plant and multi-circuit distribution networks etc. The designs should include details of all control components and their locations. There should be clear evidence that learners have carefully considered the proposed design including features of the installations, legislative constraints and the clients requirements. Controls, schematic drawings and reports should be well produced, detailed and unambiguous. This could be a natural qualitative extension of the work carried out for P2, P5 and P6.

For M3, learners must analyse control schematic drawings and control function proposals for specific installations to produce detailed and comprehensive explanations of the control system operational sequence and settings. They are expected to use this information to write a comprehensive explanation of the sequence of events as an installations control system goes through its sequence from initial start through the operational phase to eventual shut down. This should include the roles of each control component, together with typical set points and dead bands, sensed and controlled condition values. This could be a natural extension of the work carried out for P2, P3, P5 and P6.

To achieve a distinction grade learners must meet all of the pass and merit grade criteria **and** the two distinction grade criteria.

For D1, learners must analyse and justify the rationale used in the production of control strategies and demonstrate how proposed control systems satisfy operational needs. In justifying the rationale the learner must clearly demonstrate how a proposed strategy meets the needs of the building, client and end users. As part of the justification learner are expected to be able to link the features of the strategy with appropriate underpinning fundamental principles. This could be a natural extension of the work carried out for P1, P2, P3, P4, P5, M2 and M3.

For D2, learners must evaluate the energy, environmental, financial and operational benefits of a variety of specific control systems within building services installations. The evaluation must include both factual evidence as well as engineering opinion. This could be a natural extension of the work carried out for P3, P5, P6, M1 and M2.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

The learning outcomes in this unit are closely linked with, for example, *Unit 8: Graphical Detailing in Construction and the Built Environment*, *Unit 34: Heating in Building Services Engineering*, *Unit 35: Ventilation and Air Conditioning in Building Services Engineering*, *Unit 37: Refrigeration Technology in Building Services Engineering*, *Unit 38: Plumbing Technology in Building Services Engineering*, *Unit 39: Electrical Principles in Building Services Engineering* and *Unit 41: Electrical Installations Design in Building Services Engineering* together with similar units at Higher National and degree level.

This unit may have links to the Edexcel Level 3 Technical and Professional NVQs for Construction and the Built Environment. Updated information on this, and a summary mapping of the unit to the CIC Occupational Standards, is available from Edexcel. See *Annexe D: National Occupational Standards/mapping with NVQs*.

The content of this unit also covers some of the knowledge and understanding associated with SummitSkills National Occupational Standards, particularly Unit 008: Design RAC systems — small commercial refrigeration and air conditioning systems and Unit 015: Design heating and ventilating systems.

The contents of this unit covers some of the knowledge and understanding associated with Summit Skills N-SVQ Level 3 Building Services Engineering Technology and Project Management, particularly Unit SST/NOS 3: Apply Design Principles to Building Services Engineering Projects and Unit SST/NOS 7: Provide Technical and Functional Information to Relevant People.

The content of this unit will also provide a developmental stage in acquiring some of the knowledge and understanding associated with Summit Skills N-SVQ Level 4 Building Services Engineering Technology and Project Management, particularly NOS 7: Prepare and Advise on Building Services Engineering Project Design Recommendations and SSTE/NOS 8: Prepare and Agree Detailed Building Services Engineering Project Designs.

This unit presents opportunities to demonstrate key skills in communication and problem solving. Opportunities for satisfying requirements for Wider Curriculum Mapping are summarised in *Annexe F: Wider curriculum mapping*.

Essential resources

There are no specific resources necessary other than access to a wide range of technical and manufacturers' literature, some of which are listed below.

The availability of visual aids such as the range of the components indicated in learning outcome 3 is considered to be highly advantageous. These can be in either the form of individual items or preferably as part of live installations.

Centres should have access to sets of building services installation drawings and schematic drawings to support the learning process and to facilitate assessments. Where these drawings are used as part of the assessment process it is recommended that repeated use of the same installation be avoided to maintain the freshness of the assessment process.

Indicative reading for learners

Textbooks

Chartered Institute of Building Services Engineer — *Building Control Systems* (Elsevier Science and Technology, 2000) ISBN 0750650478

Day A, Ratcliffe M and Shepherd K — *Heating Systems, Plant and Control* (Blackwell Science, 2003) ISBN 0632059370

Dicks M and Brown R — *Heating Controls in Large Spaces* (BSRIA, 1997) ISBN 0860224767

Martin A and Banyard C — *Library of System Control Strategies* (BSRIA, 1998) ISBN 086022497X

Roper M — *Energy Efficient Chiller Control* (BSRIA, 2000) ISBN 0860225658

Other publications

Approved Document L1A and B Conservation of Fuel and Power — (ODPM, 2006) ISBN 9781859462171 and ISBN 9781859462188

Approved Document L2A and B Conservation of Fuel and Power — (ODPM, 2006) ISBN 9781859462195 and ISBN 9781859462201

DoE General Information Report 40 — *Heating Systems and Their Control* (BRECSU, 1996)

Energy Efficiency Programme Good Practice Guide 132 — *Controls For Wet Heating Systems*

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Tutors should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Communication Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• identifying the purpose of controls and control systems for building services systems and the functions they commonly perform; or, • explaining the fundamental principles of control loops and the operational features, properties and characteristics of the modes of control performed by such loops; or, • describing how the features and characteristics of the various types of sensors, actuators, controlled devices and controllers contribute to their selection for specific applications; or, • analysing control schematic drawings and control function proposals for specific installations to produce detailed and comprehensive explanations of the control system operational sequence and settings; for example.	C3.2 Read and synthesise information from at least **two** documents about the same subject. Each document must be a minimum of 1000 words long. C3.3 Write **two** different types of documents each one giving different information about complex subjects. One document must be at least 1000 words long.

Problem solving Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• identifying control functions required for specific applications in order to satisfy the requirements of legislation, good practice and client needs; or, • producing basic functional and workable automatic or direct digital control scheme designs appropriate to specific building services installations; or, • evaluating the energy, environmental, financial and operational benefits of a variety of specific control system within building services installations; for example.	PS3.1 Identify a problem and identify different ways of tackling it. PS3.2 Plan and implement at least one way of solving the problem. PS3.3 Check if the problem has been solved and review your approach to problem solving.