Unit 47: Industrial Plant and Process Control

Unit code: D/600/0326

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

The aim of this unit is to introduce learners to the principles and techniques involved in the control of industrial process plants. The methods of process control are investigated, along with the industrial techniques that are employed to ensure that plant is controlled to meet given specifications.

Unit introduction

Modern industrial plant would fail to operate effectively without appropriate process control systems and methods. Engineers play a vital role in designing, installing and operating such systems.

The aim of this unit is to introduce learners to the principles and techniques involved in the control of industrial process plants. The methods of process control are investigated, along with the industrial techniques that are employed to ensure that plant is controlled to meet given specifications.

The unit starts by considering the basic principles of control in terms of open and closed loop systems and the elements that are required as part of the loop. Further areas of closed loop control are discussed and simple analysis techniques are considered.

Having identified a control system the unit then considers the main controller types that are available. Emphasis is placed on the widely used two step and three term controllers. These controllers are examined in some depth with opportunities to extend knowledge of controllers through standard tuning methods.

Modern large industrial process plants are controlled using hierarchical control systems. This unit allows learners to consider hierarchical control strategies such as supervisory control and distributed control systems. The philosophies of these systems are discussed and reference to the physical structure is covered.

Learning outcomes

On completion of this unit a learner should:

1 Understand the characteristics of process control systems

2 Know about common modes of control and their effect on control system performance

3 Be able to apply tuning methods to three-term controllers to improve control system performance

4 Understand hierarchical and advanced process control systems.

Unit content

1 Understand basic process control concepts

System components: block diagrams; control loops eg open, closed; accuracy and stability; elements eg detecting, measuring, comparing, controlling, correcting

Transfer functions: block diagrams; transfer functions for simple closed loop systems derived; closed loop gain determined using derived transfer function; block diagram reduction techniques

System characteristics: inherent regulation; time constant; initial reaction rate; exponential growth and decay eg equations (simple first order) for process systems, curves; lags eg transfer, distance velocity, dead time; measurement of process dead time

2 Know about common modes of control and their effect on control system performance

Two-step control and terminology: applications of two-step control eg temperature control, level control; definition of two-step control; functional attributes eg effect of process lag, overlap, effect of the degree of overlap on process response

Three-term control and terminology: applications of three-term control eg flow rate control, positional control; types of control (proportional (P), integral (I), derivative (D), proportional-integral-derivative (PID))

Three-term control parameters and system response: responses eg under P control, under PI control, under PID control; parameters eg proportional band, proportional gain, integral gain, integral action time, derivative gain, derivative action time

3 Be able to apply tuning methods to three-term controllers to improve control system performance

Tuning methods: methods (process reaction curve, ultimate cycle, frequency response); plant under three-term control eg flow rate control, positional control

4 Understand hierarchical and advanced process control systems

Hierarchical control: pyramid of control, process instrumentation layer, supervisory layer, management layer

Types of hierarchical control systems: applications of distributed control systems (DCS) eg petrochemical, nuclear, paper mill; architecture of DCS; multi-loop structure eg plant interfaces, process managers, operator stations, history modules, control networks, management networks; applications of supervisory control and data acquisition (SCADA) eg machine control, assembly line production, sequential manufacture; architecture of SCADA eg remote terminal units, programmable logic controllers, control networks, remote input/output, supervisor stations

Advanced control: cascade control; feed-forward control (applications and improvement of response time)

Assessment and grading criteria

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

Assessment and 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 describe the main system components of a given process control system	**M1** design a block diagram of a single closed-loop process control system to meet a given specification in terms of transfer function and system characteristics	**D1** evaluate the performance of a given process control system.
P2 explain the operation of a given process control system using block diagrams and transfer functions	**M2** design and explain a structure for a hierarchical control system to meet a given requirement.	
P3 explain process control system characteristics		
P4 for a given application, describe the functional attributes of a two-step controller, using controller terminology		
P5 describe an application of a three-term controller and the meaning of the four types of control		
P6 record control system output responses relating to various values of three-term parameters [IE1, IE4]		
P7 use three tuning methods to improve the performance of plant under three-term control		
P8 explain the pyramid of control for hierarchical control systems		
P9 describe two types of hierarchical control system		

Assessment and 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:**
P10 explain how two types of advanced control can improve plant performance.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

This unit may be delivered as a stand-alone unit or integrated with others in the qualification. Wherever possible, a practical approach should be adopted in which the underpinning knowledge is consolidated using a structured programme of workshop practical investigations and demonstrations.

Industrial visits could be used to provide learners with opportunities to experience industrial standard process control rigs and controllers.

Case study material can be used to support the lectures and provide an opportunity to lead onto structured practical activities.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole class teaching: • introduction to unit, scheme of work and methods of assessment • explain the operation of the main process control system components • explain the main transfer functions for closed loop systems and the use of block diagrams • explain process control system characteristics – inherent regulation, time constant, initial reaction rate, exponential growth and decay, lags and measurement of process dead time.
Preparation for and carrying out **Assignment 1: Characteristics of Process Control** (P1, P2, P3, M1)
Whole class teaching: • define two-step control and describe its applications. Describe its functional attributes • explain the applications of three-term control and describe the different types of control • describe the responses and parameters of three-term control. *Industrial visit:* • view use of real control systems in industrial applications.
Whole class teaching: • explain and demonstrate the use of tuning methods to improve control system performance. *Practical activities:* • practise process reaction curve, ultimate cycle and frequency response methods for plant under three-term control.
Preparation for and carrying out **Assignment 2: Modes of Control** (P4, P5, P6, P7)

Topic and suggested assignments/activities and/assessment
Whole class teaching: • explain the hierarchical control system and its different layers • explain the function and operation of the different types of hierarchical control system • explain the use of advanced process control systems.
Preparation for and carrying out **Assignment 3: Hierarchical and Advanced Process Control** (P8, P9, P10, M2 and D1)
Feedback on assessment, unit evaluation and close.

Assessment

Assessment evidence for pass criteria P1, P2 and P3 could be produced through a written assignment. After describing the main components (P1) learners would then need to consider a single closed-loop process control system and explain its operation. Block diagrams and transfer function calculations should be used to aid the explanation (P2). The use of simulation software within the assignment should also be encouraged to identify the system characteristics of the single control loop. Hard copy printouts using the simulation software could form part of the evidence for P3 within the assignment.

Assessment evidence for pass criteria P4, P5 and P6 could be produced through a combination of a practical assignment and written tasks that will enable learners to describe the functional attributes of a two-step controller (P4) through a practical application (eg the control of liquid level within a tank). The assessment could then require learners to control liquid flow or shaft position (P5) and record the responses of the system under three term control.

Various three-term controller parameters should be used within the practical activity and context given, and a report produced concluding on the various response results (P6). The practical activity could be extended to include the tuning of a three-term controller to improve the performance of the plant (P7). All three tuning methods should be used and conclusions clearly stated identifying the most suitable technique in terms of final system improvement.

Assessment evidence for pass criteria P8 and P9 could be produced through a written assignment relating to case studies of hierarchical control systems. The assignment could require learners to explain and describe the operation of given schematics of an industrial SCADA and a DCS. Evidence for pass criteria P10 could also be considered within the same assignment. Learners could be asked to consider a single loop within one of the given hierarchical systems and provide a written explanation of how both feed forward and cascade control can improve the performance of the loop.

Assessment evidence for M1 is likely to be an extension to the assignment that covers P1, P2 and P3. Learners could be asked to design a new control loop in block diagram form to meet a given control specification. This specification can be addressed through the design and identification of control system elements whose transfer functions will contribute to an overall system transfer function. This type of activity could be supported through the use of simulation software to confirm that the specification has been met.

Assessment evidence for criterion M2 could be achieved through the assignment covering P8, P9 and P10. Learners could be asked to design a hierarchical control structure to meet a given specification, in terms of plant size and plant operation. This design may be in the form of a block diagram supported by an explanation for the choice of system and constituent elements.

Assessment evidence for criteria D1 is likely to be achieved through an extension of the assignment covering criteria P8, P9, P10 and M2. Learners could be asked to evaluate the performance of a system that is controlling a given industrial process plant. This evaluation will consider the operation and performance of the system and learners could be requested to suggest improvements to both the structure and the selection of control method.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1	Characteristics of Process Control	Learners need to describe the operation of a control system.	Written report.
P4, P5, P6, P7	Modes of Control	Learners describe the use of controllers and use tuning methods.	Written report and logbook from practical activities supported by witness statements.
P8, P9, P10, M2 and D1	Hierarchical and Advanced Process Control	Learners explain process control systems.	Written report.

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

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with:

Level 1	Level 2	Level 3
		Industrial Process Measurement
		Principles and Applications of Engineering Measurement Systems

The unit can contribute skills, knowledge and understanding towards the evidence requirements of several units in the Level 3 NVQ in Engineering Maintenance, particularly:

- Unit 27: Maintaining Process Controller Equipment within Engineered Systems
- Unit 39: Maintaining Process Control Systems
- Unit 40: Maintaining Instrumentation and Control Systems
- Unit 42: Maintaining Environmental Control Equipment.

The unit also contributes towards the knowledge and understanding of Unit 24: Commissioning Instrumentation and Control Equipment and Systems within the Level 3 NVQ in Installation and Commissioning.

Essential resources

Learners should have access to a relevant workshop or laboratory facilities including:

- industrial plant, rigs or system simulators
- control system simulation software
- data books and manufacturers' specifications
- process rig schematics
- appropriate tools.

Employer engagement and vocational contexts

Much of the work for this unit can be set in the context of learners' work placements or be based on case studies of local employers. Further information on employer engagement is available from the organisations listed below:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI, University of Warwick) – www.warwick.ac.uk/wie/cei
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbook

Bolton W – *Instrumentation and Control Systems* (Newnes, 2004) ISBN 0750664320

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	identifying questions to answer and problems to resolve and analysing information when recording control system output responses relating to various values of three-term parameters.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Creative thinkers	asking questions about industrial process control to extend their thinking
Reflective learners	reviewing progress and acting on the outcomes.

Functional Skills – Level 2

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	explaining the operation and use of industrial control systems
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating industrial process control systems
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining the operation and use of industrial control systems.