Unit 50: Industrial Process Controllers

Unit code: Y/600/0339

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit provides learners with an opportunity to gain knowledge and experience of the industrial process controllers that are the main elements within a controlled system.

Unit introduction

Control engineering plays an important role in ensuring that process plant and machine controlled systems function correctly and with optimum performance. This unit provides learners with an opportunity to gain knowledge and experience of the industrial process controllers that are the main elements within a controlled system.

The unit starts with basic control and the comparison of common control technologies and applications. It then proceeds to examine the traditional three-term controllers that are still widely used in industry and the principles required to tune and set up these controllers.

The unit then develops the knowledge and practical skills that are essential to configure and program a programmable logic controller (PLC). Various instruction types are described and learners will be required to write programs to perform a range of control applications.

Learners will also gain a knowledge of fault-finding techniques and tools and will be able to write and fault-find programmable logic controllers.

Learning outcomes

On completion of this unit a learner should:

1 Know about control system types and their applications

2 Know about the operating principles and tuning of three-term controllers

3 Know about the types and operation of programmable logic controllers

4 Be able to write and fault-find programmable logic controller programs.

Unit content

1 Know about control system types and their applications

Control loops: open loop systems; elements of closed loop control (controller, error, correction, process, measurement, comparator); signal flow diagrams (transfer function, calculation of steady state error)

Control system types and applications: sequential control eg component sorting, product assembly; continuous control eg flow, level, temperature, displacement, velocity; batch control eg chemical mixing, bottling plant, brewery

2 Know about the operating principles and tuning of three-term controllers

Operating principles: proportional controller (proportional band, gain, steady state error, rise time, overshoot); proportional-integral (PI) controller (Kp, integral action time, integral gain, responses); proportional-integral-derivative (PID) controller (kp, Ki, derivative action time, responses)

Controller tuning methods: process reaction curve eg level, velocity; ultimate cycle eg flow, displacement; lambda eg paper mill, large holding tanks; adaptive; auto tuning

3 Know about the types and operation of programmable logic controllers (PLCs)

Programmable controller types: unitary; modular; rack-mounted; selection to meet specification eg application, cost, versatility

Operational characteristics: central processing unit (CPU); (Arithmetic Logic Unit (ALU), flags, registers); input/output (I/O); memory organization; scanning

System hardware and software: specification of I/O units eg digital, analogue; power supply; operating system; configuration of I/O; number systems eg binary, octal, hexadecimal, binary-coded decimal (BCD)

External input and output devices: mechanical switches; relays eg electromechanical, solid state; input transducers eg temperature, pressure, flow, smart sensors; output devices eg motors, pumps, valves

4 Be able to write and fault-find programmable logic controller programs

PLC programs: program applications eg on-off process control, washing machine, traffic lights, conveyor control with component sorting

PLC instructions: ladder relay instructions; bit instructions; branches; timers; counters; logical instructions; arithmetic instructions

Test and debug programs: software debug instructions; diagnostic indicators; data monitors; search and force facilities

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 control loops in terms of their individual elements	**M1** apply an alternative to a given tuning method so as to improve the performance of a given process controller in terms of its system response	**D1** analyse a given PLC control program and identify improvements that can be made to improve control system performance.
P2 determine transfer functions and values for steady state error from closed loop signal flow diagrams [IE1]	**M2** produce a structured design that will minimise the code of an existing control system whist maintaining existing capability.	
P3 describe the three different control system types and identify an application for each type		
P4 describe the operating principles of a three-term controller in terms of its three constituent parts		
P5 describe an appropriate tuning method for three different applications		
P6 describe three types of PLC and select an appropriate type to meet a given specification		
P7 describe the four main components that identify the operating characteristics of a PLC		
P8 select system hardware and software elements that will be required to meet a given specification		

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:**
P9 describe the four different types of external input and output devices that can be connected to a PLC for plant control or monitoring		
P10 write and document a PLC program using the seven different instruction types that will control a given application [IE1, IE4, SM2, SM4]		
P11 use common debugging tools to fault-find a PLC program. [IE1]		

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

Wherever possible, a practical approach should be adopted when delivering this unit. Ideally the underpinning knowledge would be consolidated using a structured programme of laboratory and workshop practical investigations and demonstrations. It is expected that learners will be exposed to industrial controllers or educational equivalents.

The learning outcomes should be delivered in sequential order. Learning outcome 1 will provide learners with an introduction to control system types and applications, providing the underpinning knowledge needed for the other learning outcomes. Learning outcome 2 will enable learners to apply the knowledge gained in learning outcome 1 through the use of three term controllers. Learning outcome 3 will give learners an understanding of PLC architecture and operating characteristics essential for writing PLC programs.

The range of equipment used should expose learners to both three term and programmable logic controllers. Software simulators should be used where appropriate, particularly to cover the breadth of controller application.

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 • describe open loop systems, elements of closed control and the use of signal flow diagrams • describe sequential, continuous and batch control systems and their applications.
Prepare for and carry out **Assignment 1: Control System Types and Applications** (P1, P2, P3)
Whole class teaching: • describe the operating principles of proportional controllers, proportional-integral controllers and proportional-integral-derivative controllers. *Whole class teaching/practical demonstration:* • describe and demonstrate controller tuning methods. *Practical workshop activities:* • learners practise the selection and use of controller tuning methods.
Prepare for and carry out **Assignment 2: Three-term Controllers** (P4, P5, M1)

Topic and suggested assignments/activities and/assessment
Whole class teaching: • introduce and describe the operational characteristics of unitary, modular and rack-mounted programmable controllers • describe the specification and configuration of I/O units. Describe power supply and operating systems. Explain the use of number systems • explain the different external input and output devices that can be connected to a PLC for plant control. *Practical workshop investigation:* • learners investigate the operation and application of different types of PLC
Prepare for and carry out **Assignment 3: Programmable Logic Controllers** (P6, P7, P8, P9)
Whole class teaching/practical demonstration: • describe different typical applications of PLC programs • explain and demonstrate the use of the seven types of PLC instructions • explain and demonstrate how to test and debug PLC programs. *Practical workshop activities:* • learners investigate and practise writing, testing and debugging PLC programs using all seven instruction types.
Prepare for and carry out **Assignment 4: PLC Programs** (P10, P11, M2, D1)
Feedback on assessment, unit evaluation and close.

Assessment

Assessment evidence for pass criteria P1-P3 could be produced through a written assignment. The first part of the assessment could ask learners to describe, with the aid of signal flow diagrams, the difference between an open loop and a closed loop system (P1). The second part of this assessment could ask learners to calculate the overall system transfer function of a given closed loop system (eg velocity control) and then calculate the steady error using the transfer function result (P2). The final part of the assessment could look at types of control systems in terms of application (P3). For example a computer controlled washing machine could be given and learners asked to identify and describe the type of control system and the control processes that will occur.

Pass criteria P4 and P5 could be assessed through a written assignment, supported by practical formative tasks. This could ask learners to consider a given control system and determine and describe the operating principles of the controller using practical investigations (P4). As a second part of the assessment learners could be provided with three different control systems. They could then be asked to select a tuning method for each system (P5).

Evidence for pass criteria P6-P9 could be produced through a short research project. Learners could be asked to research the types of PLC (P6), PLC operating characteristics (P7) and PLC hardware/software (P8) that would be required to meet a given specification. This specification could include information regarding system type, I/O requirement, interface, software requirements and communication system. The project report should include a description of the three types of PLC (unitary, modular and rack mounted) and identify the most appropriate for the given specification (P6).

The response for P7 should include a description of the four component parts listed in the unit content of the operational characteristics (CPU, I/O, memory organisation and scanning). The last part of the report should include the hardware and software requirements to meet the given specification (P8).

A final task within the research project could ask learners to describe a mechanical switch, a relay, an input transducer and an output device (P9) that could be part of the selected solution for the given specification. The given specification needs to be carefully thought through before it is given to learners to ensure that all pass criteria can be evidenced.

A final assignment covering pass criteria P10 and P11 could be in the form of a practical PLC workshop. Learners could be given access to a process rig and be asked to identify the input and output devices found on the rig (eg sensors and motors) and connect the PLC to these devices. It is important that these devices include a mechanical switch, a relay, an input transducer and an output device as listed in the unit content. Once the PLC is connected to the rig, learners could be asked to write, document, debug and fault-find a PLC program that will provide rig control (P10 and P11). A witness statement/observation record may be the best way to record the evidence for criteria P10 and P11 supported by annotated photographs and the documented PLC program.

Assessment evidence for M1 is likely to collected as an extension to the assignment covering criteria P4 and P5. Having selected a tuning method for three different systems, learners could be provided with a given tuned system with an identified tuning method. They could then be asked to select and apply an alternative tuning method that will improve the original system response.

Criterion M2 could be achieved through an extension to the assignment covering criteria P10 and P11. Having written a PLC program to meet a specification, learners could be asked to redesign the program to meet a new specification that identifies the maximum number of lines of code. This will require learners to produce an elegant program structure. The program would still be required to meet specification.

Assessment of D1 could be achieved through an extension of the assignment covering criteria P10, P11 and M2. Learners could be asked to analyse the performance of a given short PLC control program and identify improvements to the program operation in terms of operating speed and memory use. Learners could then be asked to alter the program and measure its performance against the original.

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	Control System Types and Applications	Learners produce an information leaflet detailing control systems and their applications.	A written assignment.
P4, P5, M1	Three-term Controllers	Learners produce a report describing three-term controllers and identifying the most appropriate tuning method for different applications.	A written assignment.
P6, P7, P8, P9	Programmable Logic Controllers	Learners have been asked to research and produce a report on the different types of PLC.	A written assignment.
P10, P11, M2, D1	PLC Programs	Learners need to write and fault-find a PLC program.	A practical assignment supported by observation records and annotated photos.

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 the following unit titles in the Engineering suite:

Level 1	Level 2	Level 3
		Selecting and Using Programmable Controllers

This unit covers some of the knowledge and understanding associated with the SEMTA Level 3 NVQ in Engineering Maintenance, Unit 40: Maintaining Instrumentation and Control Systems.

It also supports the SEMTA Level 3 NVQ in Installation and Commissioning, Unit 24: Commissioning Instrumentation and Control Equipment and Systems.

Essential resources

Centres will need to provide access to process controllers, process rigs, data books and manufacturers' specifications.

Employer engagement and vocational contexts

This unit should be delivered and assessed in a vocational context. Much of the work can be based on learners' work placements or case studies of local industry. There are a range of organisations that may be able help centres engage and involve local employers in the delivery of this unit, for example:

- 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

Textbooks

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

Bolton W – *Programmable Logic Controllers* (Newnes, 2006) ISBN 0750681128

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 while calculating transfer functions and values and writing a PLC program analysing and evaluating information when writing a PLC program to control a given application
Self-managers	working towards goals, showing initiative commitment and perseverance, when writing and documenting a PLC program organising time and resources and prioritising actions when writing a PLC program.

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 process controllers to extend their thinking
Reflective learners	setting goals with success criteria for their development and work
Team workers	collaborating with others when working in small groups on practical activities.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	selecting system hardware and software elements to meet a specification writing and documenting a PLC program
Troubleshoot	testing and debugging a PLC program
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating control systems and PLCs
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing control loops, control systems and PLCs.