Unit 25: Selection and Applications of Programmable Logic Controllers

NQF Level 3: **BTEC National**

Guided learning hours: 60

Unit abstract

The automation of machines, process control and conveyor lines has resulted in the ever-increasing consistency of quality, speed and cost savings within complex processes. Consumers have come to expect high standards of quality in the manufactured goods they use, but to an engineer these are the challenges that make the profession interesting.

This unit will consider programmable logic controllers (PLCs), control devices which aid the automation of these processes. The capabilities of PLCs have developed over the years, with performance, reliability and operational resilience being key attributes to their continued success. In order to achieve automated monitoring and control, these devices can be used on their own or in conjunction with others through communication systems/links, which are themselves becoming more versatile.

The unit will introduce learners to the use and applications of PLCs, the hardware and software that makes up a PLC and the interaction needed between the component parts. Learners will develop their ability to use programming techniques to produce programs for modern PLCs. They will also gain an understanding of the different types of communication media used to link larger numbers of PLCs together, the networking architecture used and the associated standards and protocols.

Learning outcomes

On completion of this unit a learner should:

1 Understand the selection, hardware and software requirements of a programmable controller

2 Be able to use programming techniques to produce a program for a modern programmable controller

3 Understand complex programmable controller applications

4 Understand data communications media and networks used with modern programmable controllers.

Unit content

1 **Understand the selection, hardware and software requirements of a programmable controller**

Programmable controller selection: criteria eg cost, versatility and scanning time; internal architecture eg central processing unit (CPU), arithmetic and logic unit (ALU), flags, registers, memory and types (volatile, non-volatile); scan cycle (self-test, input/logic/output scans)

System hardware and software requirements: manufacturers' specification of input/output (I/O) units (digital and analogue); power supply; use of operating system; configuration of inputs and outputs; number systems eg binary, octal, hexadecimal, binary-coded decimal (BCD); input/output devices; mechanical switch relays (electromechanical and solid state); transducers eg temperature, pressure, flow, smart sensors, simple motors and drives

2 **Be able to use programming techniques to produce a program for a modern programmable controller**

Programming method: eg ladder and logic diagrams, statement listing, functional diagrams, graphical programming languages, mimic diagrams, sequential function charts (SFCs)

Produce, store and present program: human computer interface (HCI) eg handheld input pad, personal computer, text, graphical touch screens; use of system software to write, edit, delete, save, restore, create reports, load/unload, search; use of fault diagnostic indicators; print copies of program; storage eg scanning, memory organisation, continuous updating, back-up copies, supervisor control and data acquisition (SCADA)

Instruction types: production of program using relay, bit, branch, timer/counter, comparison, logical, arithmetic instructions; proportional integral derivative (PID) controller loops

3 **Understand complex programmable controller applications**

Program documentation: hardware considerations (environmental, operational, maintainability); instruction types; documentation for testing eg software debug instructions, diagnostic indicators, data monitors, search, force facilities; complex engineering applications eg machine, process control, conveyor

Health and safety with programmable controller: safe working practices for personnel and with equipment eg tools and equipment risk assessment, job safety analysis (JSA), housekeeping practices for work areas, personal protective equipment (PPE), restriction of non-participants from areas; health and safety standards (local, national, international) eg local safety agreements between employees and employers, Health and Safety Executive (HSE), Health and Safety at Work Act 1974, regulations for the use of display screens; avoiding haphazard operations eg risk management, planning considerations, testing (usability, unit, component, acceptance), 'what If' scenarios, commissioning

4 **Understand data communications media and networks used with modern programmable controllers**

Communication media: selection criteria, description of features, frequency ranges, technology eg analogue, digital, wireless; media types (cable eg twisted pairs, coaxial, fibre-optic, shielded/unshielded, categories, operational lengths; connector eg Bayone-Neill-Concelman (BNC), registered jack (RJ-45), straight tip (ST), universal serial bus (USB) type A and type B; opto-isolator eg photodiode, phototransistor, thyristors, triacs)

Network: network architecture (fieldbus, distributed intelligence, 'open' communications networks); network standards/protocols eg International Organisation for Standardisation (ISO), Institute of Electrical and Electronic Engineers (IEEE), Manufacturing Automation Protocol (MAP), Electronics Industry Association (EIA - 485), Factory Instrumentation Protocol (FIP)

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 describe 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 the learner is able to:**	**To achieve a distinction grade the evidence must show that the learner is able to:**
P1 describe the selection criteria and a practical application for a unitary, a modular and a rack-mounted programmable controller P2 explain the system hardware and software requirements for a programmable controller application P3 use a programming method to produce, store and present a program that demonstrates the full range of instruction types P4 explain the program documentation that has been used for a complex engineering application P5 describe the importance of health and safety when working with programmable controlled equipment	M1 select and describe the benefits and limitations of a programmable controller for a specific application M2 justify the choice of a specific programming method and the methods used to produce, store and present the program M3 compare two different networks used for a modern programmable controller system.	D1 evaluate program documentation used to control an automated machine/process and make recommendations for improvement D2 compare the current capabilities and limitations of a programmable controller and identify possible areas of future development.

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 the learner is able to:**	**To achieve a distinction grade the evidence must show that the learner is able to:**
P6 explain how one example of each of the three types of communication media would be selected for a specific programmable controller application P7 describe a network and relevant standards and protocols used for a modern programmable controller system.		

Essential guidance for tutors

Delivery

This unit could be delivered as a stand-alone unit or be integrated with other units such as *Unit 61: Construction and Application of Digital Systems* and *Unit 68: Principles and Applications of Microcontrollers*. An integrated approach to delivery will give learners an opportunity to consider the wider aspects of hardware and software development within modern integrated applications. Delivery and learning will be maximised through a strong, practically based learning programme.

PLC capabilities and their range of uses within the control industry has grown considerably over recent years, meaning that there is a wide variety of PLCs available. However, it is important that learners recognise the limitations of earlier models (in terms of hardware and software) and the potential of newer models for longer life cycles and advanced characteristics and features.

In order to ensure breadth of learning, centres should ideally work with employers to introduce real work-based applications of PLC technology. Educational visits to appropriate events such as exhibits, trade fairs and system manufacturers are an important method to inspire learning.

Practical work should ensure that learners can recognise a range of PLC units, interfaces and connections, programming techniques and large system integration, for both existing and future demands. This will enable them to appreciate how the various aspects fit together to produce an efficient, reliable and safe control method that is capable of fitting within a range of operational environments. In some cases, this will include the need for portability and an operationally sustainable energy source.

Appropriate attention must be given to health, safety and welfare arrangements throughout the delivery of this unit.

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.

Assessment

PLCs involve a complex mixture of computer technology, communication interfaces and software programming techniques.

The assessment strategy for this unit should consist of a mix of written technical reports and hands-on practical work. Annotated photographic evidence could also be a valuable tool to capture ‘on-site’ information and support learners’ written work.

Where the grading criteria refer to an ‘application’ this is intended to mean a real-world situation wherever possible. Although a different application could be used for different criteria it would be reasonable to use the same or closely related applications throughout.

P1 and P2 are closely linked. P1 requires learners to describe the selection criteria and a practical application for a unitary, a modular and a rack-mounted programmable controller. In doing so, learners need to demonstrate their ability to recognise the different approaches to PLC operational activities. In describing the selection criteria learners should consider things such as cost, versatility and scanning time, together with relevant descriptions of the internal architecture (eg central processing unit (CPU), arithmetic and logic unit (ALU) etc) and a practical application of each.

For P2, a comprehensive range of hardware and software requirements should be considered. For example, the power supply available may have quite different consequences for an application involving a field monitoring system as opposed to an installation in a factory. The amount of coverage of content for this criterion will be determined by the actual programmable controller application considered but it is expected that the learner should have at least four or five system hardware and software requirements indicated and explained.

P3 requires learners to use a programming method to produce, store and present a program that demonstrates the full range of instruction types. Learners are not expected to be fully competent programmers but their programs should be printed out, annotated where appropriate and stored.

The explanation required for P4 needs to cover all the related unit content including hardware considerations, instruction types and documentation for testing. A 'complex engineering application' in this context is intended to mean some form of machine, a manufacturing process control operation or a conveyor system based on a real-life situation. Learners will need to provide some details of the complex application and go on to explain the documentation, for example the program instructions, testing documentation and forced facilities etc associated with it. Ideally this would be a work-based application, although learners could be provided with a case study of a complex application.

P5 requires learners to describe the importance of health and safety when working with programmable controlled equipment. A range of 'what if' scenarios for various applications could be used to cover the full requirements of the unit content.

P6 requires learners to explain how one example of each of the three types of communication media (cable, connector, opto-isolator) would be selected for a specific programmable controller application. The key point here is for learners to recognise the media, understand how each one is selected, describe the main features and consider aspects such as frequency ranges and the technology to which they are being applied.

For P7, there is a possibility that the description of a network and relevant standards and protocols could become overly complex and involve a wide range of issues. Therefore, learners need to be restricted to describing just the general network architecture of perhaps an Ethernet, and provide details of the associated standards and what they generally imply.

M1 builds on the work carried out for pass criteria P1 and P2, as learners need to consider a specific application and apply their understanding of the selection criteria already used. The important point is that they can demonstrate ability in selecting an appropriate PLC type and have knowledge as to why it is an appropriate choice.

M2 can be clearly linked to pass criteria P3 and P4. To achieve M2, learners need to reflect on their choice of programming methods. In their justification learners should identify why one programming method has been chosen and make it clear why the others have been rejected.

M3 builds on the work undertaken to achieve P7 and P8. It requires learners to compare two different networks used for a modern programmable controller system. This should include details of the networks, standards and key differences. Learners need to demonstrate that they realise the important differences between networks and how they may influence the associated PLC systems.

To achieve D1, learners must consider the wider implications of the work carried out for P4 and M2. Learners need to be able to appraise the material and suggest improvements. These improvements should not simply be related to the amount of material documentation. Learners should also consider the documentation in light of their ability to recognise the hardware considerations, work with the range of

instruction types and use the documentation for testing. As with the related pass criterion, this must be set within a complex engineering application.

Finally, D2 requires learners to reflect on the unit as a whole. The comparison could include aspects such as memory capacity, the types of PLC available, the growing development in networking technologies (eg wireless implications), the use of smart sensors and how this may impair the programme and feedback loops, how processor power may influence the programming method etc. Satisfactory achievement of this criterion will require learners to have considered the range of issues covered by the unit content and undertaken some independent research of trends and potential benefits.

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

This unit can be linked with *Unit 61: Construction and Application of Digital Systems* and *Unit 68: Principles and Applications of Microcontrollers*.

The unit also links with the SEMTA Level 3 National Occupational Standards in Engineering Technical Support, particularly:

Unit 30: Loading and Proving Computer Control Programs

Unit No 32: Producing Off-line Programs for Programmable Logic Controller Equipment.

Essential resources

Centres will need access to a range of PLCs, communication media and interface devices. Software packages and tools should also be available to permit programming and implementation of device/applications for circuit performance and debugging. Learners will require access to a range of relevant manuals, reference data and manufacturers' information.

Indicative reading for learners

Bolton W — P*rogrammable Logic Controllers* (Newnes, 2006) ISBN 0750681128

Hooper J — *Introduction to PLCs* (Carolina Academic Press, 2004) ISBN 0890893896

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. Staff 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:**
• carrying out research into system hardware and software, programming methods and applications of programmable controllers • preparing technical reports on programmable controllers' features, characteristics and applications.	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.
Information and communication technology Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• carrying out research into system hardware and software, programming methods and applications of programmable controllers • using ICT to prepare and present technical reports and to program.	ICT3.1 Search for information, using different sources, and multiple search criteria in at least one case. ICT3.2 Enter and develop the information and derive new information. ICT3.3 Present combined information such as text with image, text with number, image with number.

Problem solving Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• using a programming method to produce, store and present a program that demonstrates the full range of instruction types.	PS3.1 Explore 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.