OUTCOME 3

CONTENT

Understand complex programmable controller applications

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

**Health and safety with programmable controller:** safe working practices for personnel and with equipment e.g. 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) e.g. 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 e.g. risk management, planning considerations, testing (usability, unit, component, acceptance), ‘what If’ scenarios, commissioning

The content of this outcome does not seem to fit the title and it is difficult to understand what the student is required to do. Most of it is about health and safety which could equally well apply to any module connected with work.

There are many PLC manufacturers each producing their own software for programming, testing and debugging. For this reason it is impossible to cover the first part of this outcome in a tutorial without being specific to a given software programme. The accompanying tutorials and assignments will cover much of this area.

There are no self assessment exercises with this tutorial but students should complete the accompanying assignments on the web site.
HEALTH AND SAFETY EXECUTIVE

Health and safety is broadly covered by the Health and Safety Commission (HSC). Their web site (www.hse.gov.uk) states the following.

The Health and Safety Commission is responsible for health and safety regulation in Great Britain. The Health and Safety Executive and local government are the enforcing authorities who work in support of the Commission.

Our mission is to protect people's health and safety by ensuring risks in the changing workplace are properly controlled.

We look after health and safety in nuclear installations and mines, factories, farms, hospitals and schools, offshore gas and oil installations, the safety of the gas grid and the movement of dangerous goods and substances, and many other aspects of the protection both of workers and the public.

Local authorities are responsible to HSC for enforcement in offices, shops and other parts of the services sector.

The work of the HSC is carried out by the Health and Safety Executive (HSE). Their part on their web site states the following.

HSE's job is to help the Health and Safety Commission ensure that risks to people's health and safety from work activities are properly controlled.

In order that any organisation complies with the HSE requirements they should carry out a process of risk assessment or JOB SAFETY ANALYSIS (JSA).

HEALTH AND SAFETY LAWS

A fuller explanation of the following may be found by downloading the document at this address http://www.hse.gov.uk/pubns/hsc13.pdf

The basis of British health and safety law is the Health and Safety at Work Act 1974.

The Act sets out the general duties which employers have towards employees and members of the public, and employees have to themselves and to each other.

These duties are qualified in the Act by the principle of 'so far as is reasonably practicable'. In other words, an employer does not have to take measures to avoid or reduce the risk if they are technically impossible or if the time, trouble or cost of the measures would be grossly disproportionate to the risk.

What the law requires here is what good management and common sense would lead employers to do anyway: that is, to look at what the risks are and take sensible measures to tackle them.
The Management of Health and Safety at Work Regulations 1999 (the Management Regulations) generally make more explicit what employers are required to do to manage health and safety under the Health and Safety at Work Act. Like the Act, they apply to every work activity. The main requirement on employers is to carry out a risk assessment. Employers with five or more employees need to record the significant findings of the risk assessment. Risk assessment should be straightforward in a simple workplace such as a typical office. It should only be complicated if it deals with serious hazards such as those on a nuclear power station, a chemical plant, laboratory and so on.

The HSE leaflet 'Five steps to risk assessment' will give you more information. Besides carrying out a risk assessment, employers also need to:

- make arrangements for implementing the health and safety measures identified as necessary by the risk assessment;
- appoint competent people (often themselves or company colleagues) to help them to implement the arrangements;
- set up emergency procedures;
- provide clear information and training to employees;
- work together with other employers sharing the same workplace.

Hazards that may be more applicable to operators of PLC controlled systems might include the risk to health from the viewing screens and from sitting at a work station. The regulations regarding viewing screens may be seen at this web address http://www.hse.gov.uk/lau/lacs/16-1.htm where it states the following.

### The objective in enforcing the Regulations is to minimise the risk of occupational ill-health, by ensuring that operators or users have:

- adequate training and information;
- proper breaks or changes of activity;
- work stations suitable for them which meet, where necessary, the standards in the schedule; and eye tests if they request them.

**PERSONAL PROTECTIVE EQUIPMENT (PPE)**

The HSE have produced a guide to the Personal Protective Equipment at Work Regulations 1992 (as amended). This may be viewed at http://www.hse.gov.uk/pubns/indg174.pdf. The document explains the basic duties of employers concerning the provision and use of personal protective equipment (PPE) at work and what needs to be done to meet the requirements of the regulations.

PPE is defined in the Regulations as ‘all equipment (including clothing affording protection against the weather) which is intended to be worn or held by a person at work and which protects him against one or more risks to his health or safety’. Hearing protection and respiratory protective equipment provided for most work situations are not covered by these Regulations because other regulations apply to them. However, these items need to be compatible with any other PPE provided.

Examples are:

- safety helmets
- gloves
- eye protection
- high-visibility clothing
- safety footwear
- safety harnesses

The Regulations also require that PPE:

- is properly assessed before use to ensure it is suitable;
- is maintained and stored properly;
- is provided with instructions on how to use it safely; and
- is used correctly by employees.
JOB SAFETY ANALYSIS (JSA)

JSA is the systematic identification of potential hazards and risks in the workplace as a step to ensuring that adequate precautions and actions are taken to reduce such risks to an acceptable level (reasonably practical). An expert must produce an assessment of the risks that might occur in the workplace. He/she must take an organised look at what could cause harm to people and recommend what should be done to avoid harm. This applies to long term health also such as injury due to repetitive strain or bad body posture at a work station. Extra assessment is required if any of the personnel have special needs (e.g. unable to hear an audible warning).

- A hazard is anything that has the potential to cause harm.
- A risk is the likelihood of someone being exposed to that hazard and harmed as a result.

Here are just a few of the many possibilities.

HAZARDS TO THE EYES - chemical or metal splash, dust, projectiles, gas and vapour, radiation.
PPE Options: safety spectacles, goggles, face shields, visors.

HAZARDS TO THE HEAD - impact from falling or flying objects, risk of head bumping, hair entanglement.
PPE Options: a range of helmets and bump caps.

HAZARDS TO BREATHING - dust, vapour, gas, oxygen-deficient atmospheres.
PPE Options: disposable filtering face piece or respirator, half or full face respirators, air-fed helmets, and breathing apparatus.

HAZARDS TO THE BODY - temperature extremes, adverse weather, chemical or metal splash, spray from pressure leaks or spray guns, impact or penetration, contaminated dust, excessive wear or entanglement of own clothing.
PPE Options: conventional or disposable overalls, boiler suits, specialist protective clothing, e.g. chain-mail aprons, high-visibility clothing.

HAZARDS TO THE HANDS AND ARMS - abrasion, temperature extremes, cuts and punctures, impact, chemicals, electric shock, skin infection, disease or contamination.
PPE Options: gloves, gauntlets, mitts, wrist cuffs, armlets.

HAZARDS TO THE FEET AND LEGS - wet, electrostatic build-up, slipping, cuts and punctures, falling objects, metal and chemical splash, abrasion.
PPE Options: safety boots and shoes with protective toe caps and penetration-resistant mid-sole, gaiters, leggings and spats.

The competent person carrying out the assessment would produce a report and these would go to the management for their attention. Computer software is available to assist in generating reports and identifying hazards. See http://www.jsareporter.com/ for examples.
Example of a report sheet

<table>
<thead>
<tr>
<th>HAZARD</th>
<th>CONTROL</th>
<th>RISK LEVEL</th>
<th>ACTION TAKEN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All chemicals are to be assessed before initial use.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All chemicals to be handled must be on an approved list resulting from their assessment and no unapproved chemicals must be brought into the establishment with out prior approval by the operations manager.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All persons handling chemicals must refer to the material assessment before the product is used for the first time.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Personal protective clothing as detailed in the material assessment must be provided and worn at all times when handling the chemical.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All staff handling chemicals must be trained and understand the meaning of the hazards.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All chemicals must be kept in their original containers and kept sealed when not in use.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date of assessment</th>
<th>Assessors signature</th>
<th>RISK LEVEL MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st ??????</td>
<td>??????</td>
<td>1 - 5 Small and acceptable</td>
</tr>
<tr>
<td>2nd ??????</td>
<td>??????</td>
<td>6 - 10 Medium and requires monitoring</td>
</tr>
<tr>
<td>3rd ??????</td>
<td>??????</td>
<td>10 - 15 Severe and requires immediate attention</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 + Emergency and activity must be stopped immediately.</td>
</tr>
</tbody>
</table>
TRAINING

Make sure anyone using PPE is aware of why it is needed, when it is to be used, repaired or replaced and its limitations.
Train and instruct people how to use it properly and make sure they are doing this.
Because PPE is the last resort after other methods of protection have been considered, it is important that users wear it all the time they are exposed to the risk. Never allow exemptions for those jobs which take ‘just a few minutes’.
Check regularly that PPE is being used and investigate fully any reasons why it is not. Safety signs can be useful reminders to wear PPE.

MAINTENANCE

Make sure equipment is:
- well looked after and properly stored when it is not being used, for example in a dry, clean cupboard, or in the case of smaller items, such as eye protection, in a box or case;
- kept clean and in good repair - follow the manufacturer’s maintenance schedule (including recommended replacement periods and shelf lives). Simple maintenance can be carried out by the trained wearer, but more intricate repairs should only be done by specialists. Make sure suitable replacement PPE is always readily available.

CE MARKING

Ensure any PPE you buy is ‘CE’ marked and complies with the requirements of the Personal Protective Equipment Regulations 2002. The CE marking signifies that the PPE satisfies certain basic safety requirements and in some cases will have been tested and certified by an independent body.

SAFE WORKING PRACTICE

This involves such things as:
- correct tools for carrying out the tasks required
- notices of possible hazards e.g. identification of pipe contents by colour code
- permits to work on plant e.g. permit to shut down a system for maintenance
- notices of work being done e.g. isolation of electrical power
- provision of protective clothing e.g. ear muffs in noisy environment

HOUSE KEEPING PRACTICE

This is important to ensure a safe workplace. It is a good indication of the attitude of workers to safety in their workplace. Good practice is the responsibility of everyone in the work place. Things that should be done might include the following.
- Clean work areas and aisles help eliminate tripping hazards.
- Safe storage of all materials, tools and equipment.
- Clear signs identifying materials, tools and equipment.
- Respecting “wet floor” signs and immediately cleaning up spills prevents slipping injuries.
- Keeping storage areas uncluttered reduces the chances of disease and fire as well as slips, trips, and falls.
- Accumulated debris can cause fires, and clutter slows movement of personnel and equipment during fires.
- Keeping tools and equipment clean and in good shape.
- Keeping hoses and cables or wires bundled when not in use.
• Broken glass should be picked up immediately with a broom and dustpan, never with bare hands.
• Be aware of open cabinet drawers, electric wires, sharp corners or protruding nails.

Besides preventing accidents and injuries, good housekeeping saves space, time, and materials. When a workplace is clean, orderly, and free of obstruction; work can get done safely and properly. Workers feel better, think better, do better work, and increase the quantity and quality of their work.

GUARDS AND INTERLOCKS and FAIL SAFE

Machinery that produces a danger to humans in close proximity must be enclosed to prevent the human from entering the dangerous area. Guards, fences and perimeters should be used for this purpose. These should be fitted with interlocks so that any human entering the danger area will cause the machinery to stop. For example a robot could cause harm by striking or crushing a human near to it.

When a process is stopped during normal operation, such as interruption to the power supply or someone pressing the emergency stop button, they should always be designed stop so that the system is safe. For example actuators including robots should park themselves in a safe position.

The PLC programme must contain the elements that enable the above to take place.

INSTALLATION AND COMMISSIONING

The installation and commissioning or de-commissioning of systems controlled by a PLC must only be done by competent persons. When this is completed the system is handed over to the operators. Clearly the operators must be trained and qualified to operate the plant. It is a legal requirement for persons working on or around a plant to be trained and competent. For example, on commissioning, the competent persons would complete a certificate to the effect that the system is working satisfactorily and that the operators have demonstrated their ability to do their job.

In complex applications of PLC control the consequences of errors in the programme must be seriously considered. It would be unacceptable for an error to produce an affect that would be harmful to people or plant. The following are things that should ideally be done.

The programme should be thoroughly tested on a simulator to ensure it produces the expected results.

The affects of all possible changes to the settings that can be made by the operator must also be thoroughly tested with 'what if' scenarios where the changes are put in at the simulator and the affects observed.

Modern programming software should come with tools for debugging the programme as well as for testing and simulating the programme.
TESTING AND DEBUGGING

The diagram illustrates a basic system for testing a PLC programme. The Light Emitting Diodes are a useful feature to help monitor and debug the programme. The input terminals have a bank of switches attached to it to enable each to be set high or low. These are normally available as standard for simulation, testing and debugging. The programme is run and the output status observed. The inputs switches are closed and opened to simulate the feedback status and so each step in the programme can be followed to ensure that the appropriate output action occurs as required.

This system of monitoring is all very well for basic installations but more modern programming software should enable the programme to be tested and debugged on screen. For example, the on screen graphics would show where the programme has stopped and the status of all the inputs and outputs.

The main monitoring and debugging tools are in the software used to programme the PLC. If the PLC is connected to the computer with a suitable interface, the programmes may be moved either way between the PC and the PLC. The software may highlight the parts of the programme (e.g. ladder diagram) that are active and display the status of timers, counters and registers.

The most advanced software enables the controlled system to be produced graphically on screen and linked to the program. The system can be simulated and seen working. The simulation may well be the same graphics that will be seen at the operator's station on the human machine interface or mimic screen.
BYTRONIC LADSIM

This is a very useful commercially available programme for students to construct ladder diagrams, test them and debug them. You will find a full description at this web address.
http://www.edusoft.co.za/ladsim.htm

The full version of this software includes some standard problems such as traffic lights and car park control and these have a great simulation to enable you to see it working. It is highly recommended that colleges use this software for training.

You can download a free evaluation version of this at this address.
http://www.bytronic.net/html/downloads.html

The picture below shows the screen you get when you run this free software. It has many of the best features of programming software. You can drag and drop symbols to form the ladder diagram. When you run the programme the inputs may be activated by clicking on the box (IP0 to IP15). In this example IP0 has been closed making the timer T1 run for 5 seconds. The timer has closed as indicated by the completion of 5 seconds and a '1' appearing under DN (for down). The second rung shows that the timer has closed and operated output OP0 as indicated by the red spot. The ladder diagram turns red as it is activated making it easy to see the effect of operating the various switches.

**WARNING**
In many real applications, the software may be actually controlling the machine and operating a switch on the screen can override the real switch on the machine thus forcing something to happen. Such a system must be used with great care as the result can produce unwanted actions that might damage the machine or make the process do something unintended with danger to persons working on it.

The assignments on the web site www.freestudy.co.uk include some Ladsim exercises.
AUTOMATION STUDIO

This is an advanced suite of computer programmes available from this web address.
http://www.automationstudio.com/EDUC/index.htm

You may also download movie demonstrations and this is recommended.

It has many features for constructing PLC programmes and mimic diagrams in various forms for hydraulic, pneumatic and electric systems. Interfaces are available to link the computer to real systems. Again, great care must be taken when forcing an output from the screen as the action can cause harm. A typical screen for use with Grafct programming is shown below. When PB1 is closed by clicking on it, the Grafct programme is activated after step 1 and each step progresses in parallel with the simulation on the right. If it sticks at any point then the problem is easily identified as the point in the diagram is highlighted and enables debugging to be used.

The company also markets interfaces that enable the computer to be turned into a real PLC and operate real equipment that can be monitored in real time. Again, great care must be taken when forcing any action as unforeseen consequences can arise.

The assignments on the web site www.freestudy.co.uk include some exercises with this software.