THE DESIGN OF A PORTABLE PROGRAMMABLE LOGIC CONTROLLER (PLC) TRAINING SYSTEM FOR USE OUTSIDE OF THE AUTOMATION LABORATORY

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ABSTRACT

Programmable Controllers are predominately laboratory based subjects as they require “hands on” electrical wiring, interface to industrial electrical components, to Human Machine Interfaces (HMI) and may be networked. As PLC courses evolve to incorporate the IEC 6-1131 defined programming languages with the resultant extra software theory learning requirement and an increasing demand for in-company courses a requirement arises for a PLC system which is portable and can be accommodated in a training or class room. This paper seeks to address this issue.

INTRODUCTION

The PLC is a robust industrial computer which accepts input data, both digital and analogue, from switches and sensors and controls outputs to drive devices such as motors, pneumatic devices and status indicators. At its most basic the PLC replaces relay logic circuits, at its most advanced it can implement Proportional Integral and Derivative (PID) control algorithms over networks. While the Programmable Controller is by far the most common process control mechanism in the manufacturing spectrum of large to small business it has also found a niche in environment control, food processing, mining and in automated test equipment [1] [2]. Programmable controllers were developed in the U.S. for the motor manufacturing industry in the 1960s. By the late 1970s they appeared in the Irish industrial scene. Today due to their increasing sophistication and falling costs they are to be found in the smallest production environment. The PLC programming environment may be dedicated terminal or a Personal Computer (PC). Latterly, with the event of the range of programming languages defined by IEC 6-1131 the PC is the favoured programming environment. Ladder Logic (LL) is currently the most popular language [3]. There is however, anecdotal evidence that the other defined languages are slowly gaining acceptance.

TRAINING AND EDUCATION

As the PLC is part of an automated system there are several modules that should be included, or be a prerequisite, in any course. Those modules are software engineering, electrical design and in some cases, mechanical design. Software engineering includes applying a Software Development Life Cycle (SLDC) approach to the system being designed and the ability to write the control program. Electrical design encompasses electrical panel design (and construction) to the relevant standard. The PLC apart from being run as a “stand alone” course is now an integral part of courses ranging from agricultural engineering to mechatronics and industrial automation. PLC courses, as for all control engineering courses, must deliver "a balance of practical skills and theoretical knowledge" and as such are laboratory based [4]. Increasingly, in response to demands from industry PLC courses are being run in-house, in training rooms, away from the traditional venue of the automation laboratory using hardwired "kits" and PC based simulators.

THE PLC TRAINING SYSTEM DESIGN BRIEF

The aims of the new proposed training system are that it must support the sub-disciplines of software engineering, computer programming and panel wiring. While the basic system must support digital I/O it should be expandable to support analogue handling and non proprietary networking. The system should have components from multiple users – it should not be seen as favouring a particular manufacturer.

The detailed objectives being that it must:

1Be safe;
2Be portable;
3Fit comfortably on a desk;
4Incorporate an industrial standard PLC ;
5Interfaces to a PC;
6Support Ladder Logic and at least two of the other IEC 6-1131 defined Languages;
7Interface with common industrial electrical components;
8Be low cost as continuing transportation will likely result in the need for frequent component replacement ;
9Be expandable to facilitate analogue handling;
10Be expandable to facilitate Ethernet networking.

A REVIEW OF AVAILABLE PORTABLE TRAINING SYSTEMS

There are two sources for training systems, commercially available ones and those proposed by education. A review of both is useful.

1 Commercially Available System

Commercially available portable training systems fall generally into two categories:

- Hard wired "kits";
- Simulators.

- **Hard wired "kits";**

A kit generally consists of a PLC incorporating banks of switches to simulate input devices and lamps to simulate output devices [5]. They do not facilitate interfacing industrial electrical components to the PLC. They are useful for teaching programming only, for experienced programmers to explore new programming techniques and for black box software testing. They do not however, for entry level programming students, provide the experience of selecting and connecting actual components to the PLC and generating the Input / Output (I/O) List to document those connections. The I/O List is a vital part of the documentation required for effective program design and maintenance [6].

- **Simulators**

Simulators may be sub-divided further in to two categories:

PC based using an actual PLC. Simulators generally have a range of industrial processes ("virtual machines") such as "pick and place" and "tank level control systems" [7]. The programmer selects a "virtual machine" from a menu, writes the program to control it and downloads it to the PLC. The PC based simulator communicates serially with the PLC simulating the "virtual machine".

In the second type the PLC and the machine or process are both "virtual", that is no physical PLC exists. Again, as with the previous system the programmer selects a "virtual machine" from a menu, writes the control program on the PC based "virtual PLC". The "virtual machine" is then controlled by the "virtual" PLC [8].

Simulators can be used effectively for engineering training generally [9]. However, for PLC training, as with the hard wired kits the simulators are best exploited by students who have the applied skills required to interface the PLC to peripheral devices, have some programming skills and want to develop those programming skills. The simulators in common with the hardwired kits do not provide the practical experience of wiring up the PLC, interfacing it to peripheral devices and generating the electrical drawings and the I/O List to document the system.

2 Training Systems Proposed by Education

A literature review of existing systems identified two that approached the criteria required for this project. Dickinson and Johnson describe a low cost PLC Trainer for use in a university level agriculture electricity course. The trainer is programmed with a PC, supports Ladder Logic programming and costs less than $500.

The trainer however, is mains powered and interfaces to a software simulator [10]. A PLC workbench was developed for use in the faculty of engineering at the University of Blue Nile based on a Siemens STEP7 PLC [11]. In this case, however the physical size was at issue, the workbenches being desk size required a dedicated room. None of those systems meet the current requirements.

DISCUSSION AND CONCLUSIONS

The new system consists of a simple timber structure in the form of an "A" frame rotated through 45° , see Figure1 (a), onto which is fitted an length of "DIN" rail onto which the components such as the PLC, Miniature Circuit Breaker (MCB) and electrical contactors are mounted, see Figure 1 (b). The PLC selected in the Mitsubishi Fx1n, 10 I/O capabilities, 24 Volt Direct Current (DC) operations. This PLC is selected because:

- It is powered by a low voltage supply for safety reasons;
- It support Ladder Logic (LL), Instruction List (IL) and Sequential Function Chart (SFC) languages;
- It supports, with the addition of an add –on module, Analogue Handling;
- It supports, with the addition of an add –on module, Ethernet networking.
- The electrical contactors are 24 Volt Alternating Current (AC) operations. A central power supply provides two supplies to each training system i.e. 24 Volts DC to power PLCs and sensors and 24Volts AC to supply the electrical contactors. The students have no access to the mains supply thus ensuring electrical safety. The system fits comfortably on a standard desk, see Figure 3

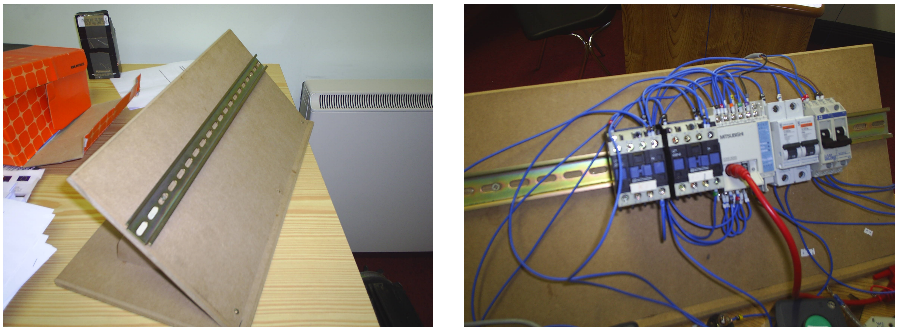

Figure 1 (a) System platform and (b) with PLC and peripherals.

Figure 2 Training system and PC.

CONCLUSION

The system has been used in a classroom situation three times over the last year. The students were a combination of technicians, engineers and electricians all with industrial manufacturing experience. All had encountered PLCs in their work and were aware of their uses but only one had experience of programming or faultfinding. The training courses were problem based where students were asked to design a PLC controlled system to control two electrical contactors as drivers for three phase motors to run two conveyors. This involved analysing a requirements statement, producing an electrical drawing, producing SDLC documentation and connecting the PLC to the power supplies and peripheral equipment. For testing purposes test cases to test the requirements were generated. Black box and white box testing was carried out.

Feedback from participating students was positive, the “hands on” aspect being especially well received. While the system cannot substitute for the laboratory for advanced courses it has found a niche for the purpose for which it was intended, delivering introductory courses in situations where access to the automation laboratory is not feasible.

FUTURE DEVELOPMENTS

While the courses currently being run are confined to Ladder Logic programming and digital I/O it is proposed to extend the syllabus to include analogue I/O and the Sequential Function Chart (SFC) programming language. An increasing demand is emerging for training in data capture and Overall Equipment Effectiveness (OEE) measurement. By the addition of an Ethernet module OEE data collected by the PLC may be networked and presented on remote PCs as part of a Management Information System (MIS).

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