Using Programmable Logic Controllers for an interdisciplinary oriented Instrumentation Laboratory

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Abstract --- **This project describes the efforts towards developing an interdisciplinary laboratory to reinforce hands-on experience of engineering students. The laboratory is based on the Allen-Bradley's® (AB) SLC-500 family; combining them with resources that are typically found at an Electronic Engineering (EE) laboratory. Such devices are used on programmed practical assignments and applied for teaching Instrumentation Engineering concepts. The project is implemented on a junior Bachelors course for Biomedical and Electronic Engineering students, having a good acceptance level.**

I. INTRODUCTION

The Electronic Engineering BSc. program at Universidad Iberoamericana, Mexico has a population of 330 students and is focused on Networks, Telecommunications and Instrumentation and Control Engineering. It is a traditional five year program oriented toward a systems approach. For this reason, Instrumentation plays an important role at the EE curricula. One of the main concerns is to educate students on solving real problems; however cost and space problems are found when dealing with an industrial approach such as the required by industrial instrumentation. Nevertheless a special effort has been done towards developing an Instrumentation and Control laboratory based on Programmable Logic Controllers (PLCs). This kind of controllers have an important part on automation, that may result on solving productivity and quality issues at a particular industry.

II. PROJECT DESCRIPTION

Previous efforts have been documented in the past proving the feasibility of the project[1,2]. In this case it is an objective to achieve the involvement of different engineering disciplines in order to obtain a broader experience of students and faculty[3] as well as a cost-effective approach. The objective is to teach industrial instrumentation concepts to Electronic and Biomedical Engineering students on the first stage. Later to incorporate Mechanical, Industrial and Chemical Engineering students. The main concepts to emphasize are Instrumentation parameters, system design techniques, modeling, emulation, PLCs control architecture, data acquisition systems, sensors and man-machine interfaces (MMIs). This is done through practicals that have been designed for this purpose[4] and that will be commented later.

One of the main concerns is cost and space, for this reason and in order to involve Mechanical, Industrial and Chemical Engineering students. The second stage of the project is focused toward developing simulators and emulators to be controlled by using PLCs, tend to develop a virtual laboratory such as Mosterman et al[5].

The SLC-500 Allen-Bradley's® PLCs family was chosen for the project. These are low cost controllers that include all of the basic ladder language functions together with special instruction for data management and PID control, among others. They are small and can be part of an EIA-485 Industrial Network. They can be programmed by a PC using a serial interface. They have other features available as handling PC communication using a Basic Module at the SLC rack, counting on operator interface products and support by MMI software tools. It was also considered important to use a product that is representative of some industrial needs in Mexico.

III. LABORATORY DESCRIPTION

The laboratory is implemented at the Manufacturing Pilot Plant Area. Ten PCs are used together with RS485 interfaces (PIC) to communicate with 10 Programmable Logic Controllers. The controllers are configured with different input/output (I/O) modules, mainly 24 VDC, 120/240 VAC and four analog I/O devices. A theoretical introductory four hour course and nine practicals were developed. The following figure shows two different workstation layout.

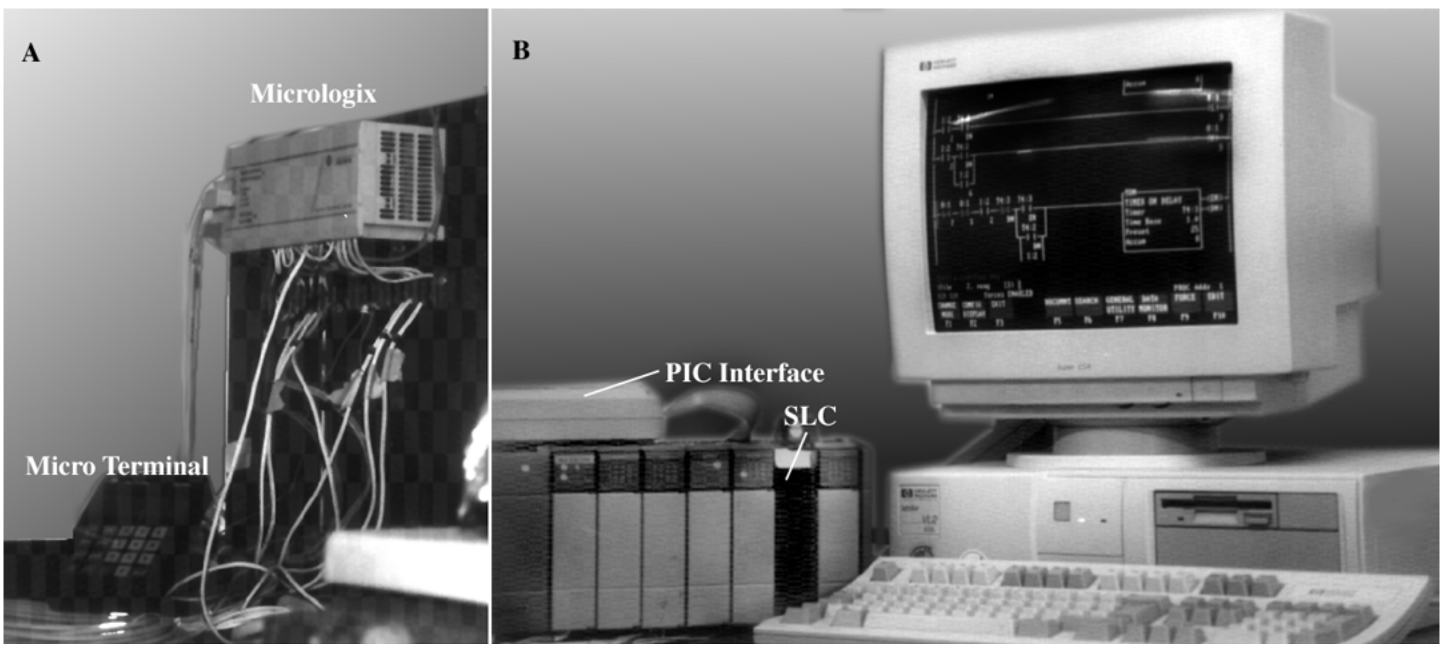

Figure 1. Workstation layout. (A) shows an arrangement with a Micrologix and the microterminal for programming, (B) shows a PC computer with a SLC interfaced through RS-485 (PIC).

Practicals are to be implemented by teams of two students on one or two four hour lab. sessions. The proposed practicals were implemented by keeping in mind simplicity and progressive learning by the student. The basic equipment used for each practical is an SLC-500 fixed controller or SLC 5-02 or 5-03, one PIC a PC and I/O modules as requested for the practical needs. The practicals are briefly commented below:

1) Ladder Language Programming . Introduction to the Advanced Programming Software® (ABs APS). Using discrete I/O modules and applying latch and unlatch instructions to solve simulated problems and to control a forward and reverse operation of a DC motor.

2) Timers. A bacteria production cycle is simulated. Timers and I/O modules are use to control this batch process, based on the actual behavior of a Chemical Engineering water treatment experiment controlled by an SLC-500. A secondary objective of this practical is understanding the scan time concept and its consequences on input-output signal. This control program is later compared with the results obtained by using Sequencers. See figure 2 A.

3) Counters . A small production line is controlled. Counters, timers and I/O modules are used to control a production line formed by two conveyors and a robot, aided with position detectors and a LabView monitoring application. Due to equipment limitation the process is first simulated and later on, each team must interface his controller with the production line. See figure 2 B.

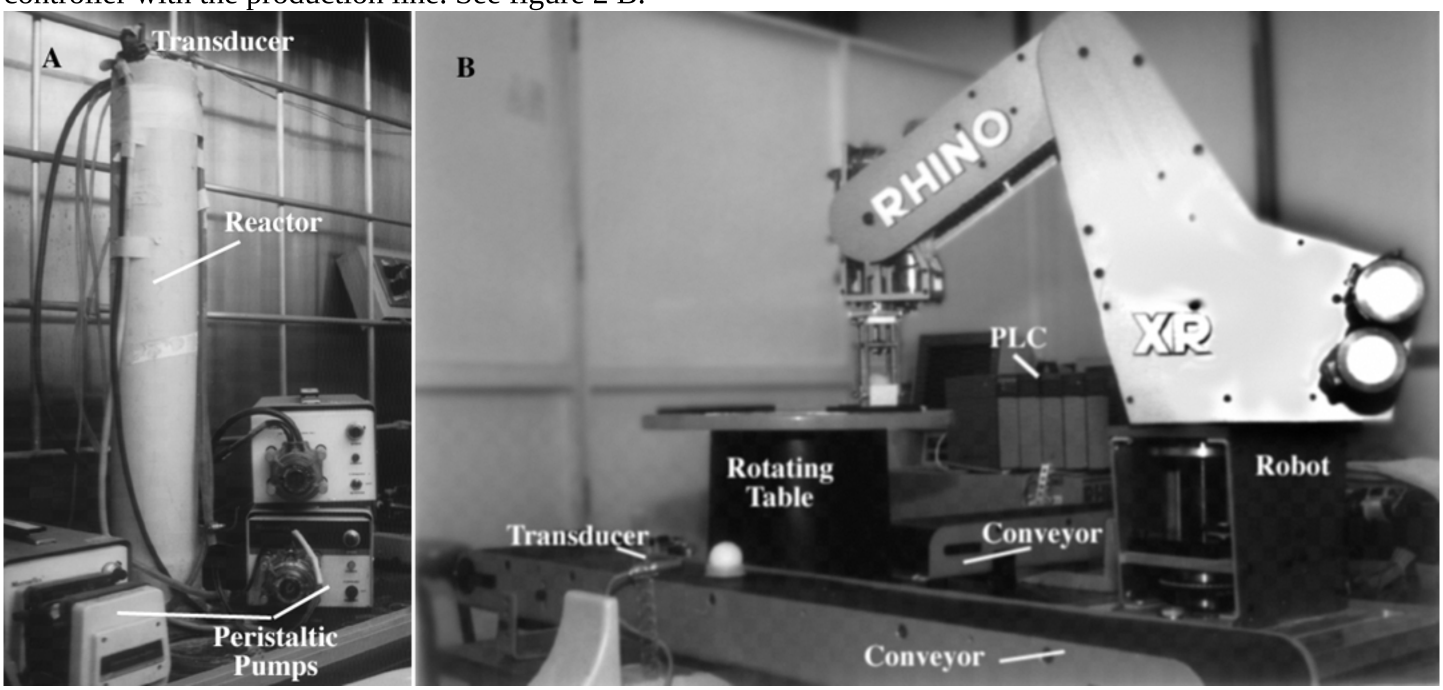

Figure 2. Experimental layout. Left (A), bacteria production cycle practical for PLC timers applications and right (B), a small production line for PLC counter applications learning.

4) Speed measurement . The purpose of this practical is to measure the speed of a DC motor by using photodetectors, signal conditioning circuits, a TTL to 24 VDC interface, counters, timers, mathematical and comparison instructions and a 24 VDC module. The system is calibrated by using a digital oscilloscope
(HP 54501A) due to the low frequency nature of the signals. Emphasis is put on calibration, accuracy, precision and resolution concepts, as well as in the proper display of the measurement using an RPM format.

5) Sequencers. An elaborated product transport process is simulated and control is implemented by means of sequencers. SLC memory zones are managed together with discrete I/O modules. A comparison is done with practical 2 to observe the advantages of using sequencers.

6) Temperature measurement. The purpose is to implement a temperature transducer signal acquisition circuit, as well as using a signal acquisition module to obtain the temperature signal and handle this information on the SLC's memory. Different temperature transducers are used for this purpose (RTD, thermocouple or thermistor), each acquisition circuit must be calibrated depending on the sensor in order to obtain a 100 mV/_C sensitivity. This practical is divided in two parts: The first one is implemented by using the SLC-500 input analog module as well as it's instructions; the second one is building a signal acquisition module by using an free-running external 8 bit analog to digital converter and interfacing it to a 24 VDC SLC module. On every case some sort of internal SLC memory management must be done depending on the processor. If a 5-02 or 5-03 is used, the FIFO and LIFO instructions are used to build a historic register. If a fixed SLC-500 is to be used, the FIFO and LIFO instructions are not available and so a special procedure is implemented for memory management by using the MOVE instructions.

7) Speed control. A PID feedback control is implemented using a conveyor controlled by a DC motor a PID feedback control is implemented. The PID instruction is explained, however a knowledge of control concepts is expected for this practical. The Ziegler-Nichols method is applied for obtaining the proper values for the PID parameters. The practical is implemented on 5-02 or 5-03 processors, the fixed controllers do not handle this instruction. Due to the length of the practical, it is handle as a final project for a control or instrumentation course

8) Networking. This practical is an implementation of a SLC network using the AIC AB modules. Usage of messaging and information exchange is the base of this practical. A protocol analyzer is connected to PIC interface in order to observe the behavior of the token-bus protocol used by this network,.

9) Man-Machine interfaces (MMIs). The main purpose of this practical is establishing the basis for developing GUIs for industrial purposes. Three approaches are suggested: the first one is based on FIX, an Intellution® program for developing MMIs. The proper use of this package and implementing a GUI on one of the previous practicals is done. The second approach is using ABs C language libraries and a PCB interface to obtain data from SLCs. For this practical, knowledge of C is expected. The third approach is the implementation of an interface between the PC and the SLC producing an interface based on Visual Basic or Visual C. Due to the length of the practical, it is handle as a final project for an instrumentation course

Another practical has been implemented to reinforce data acquisition concepts. However such work is oriented toward those disciplines that deal directly with hardware issues. This practical is focused toward signal acquisition by using instrumentation amplifiers, implementing a positioning system by using a rotary potentiometer and noise and interference reduction techniques. Emphasis is on calibration, accuracy, precision, resolution and reproducibility concepts.
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IV. RESULTS

The project is implemented on a junior Bachelors course for Biomedical and Electronic Engineering students. This is an elective course involving 64 hours of practical work and 64 hours of lectures. Laboratory work was usually focused on developing microcontroller based systems for electronic instrumentation applications. However, since microprocessors knowledge is not a prerequisite for the course, different learning levels were accomplished and most of the effort was on learning microcontrollers and not on instrumentation. For this reason a systems approach is proposed for the course and learning PLCs became the main component of the laboratory.

Most of the practicals, previously described, were implemented. It was not possible to pursue the PID and MMI practicals due to lack of knowledge from the group. Nevertheless, final three week open projects were implemented using PLCs. One of the projects was on MMIs and developing an interface with the PC, others were concerned with emulation of industrial plants as well as implementing single loop controls such as a mixer to obtain a chemical product.

The course has had good acceptance level, ever since the students are glad to get in touch with practical knowledge on industrial devices that they will later use on professional work. It is considered that better learning results on instrumentation are obtained ever since less time was invested on learning hardware and software issues.

V. DISCUSSION

Practicals for learning instrumentation concepts by means of an industrial device (PLC) were implemented on an Instrumentation course taught to Electronic and Biomedical Engineering students. Based on comments from the students, it is needed to put more emphasis on previous sessions to explain the concepts to be applied at each practical. This is specially important during the first theoretical sessions, emphasizing paper exercises for ladder language programming. This could be done by using part of the available lecture time. One of the factors that has been useful for the implementation of the project is that the teacher for the lecture and the laboratory are the same.

A second stage of the project is to be implemented by means of developing emulators that may simplify the learning process for other disciplines whose strength is not on hardware or software issues. Such devices are at a development stage, aiming to put together a microprocessor architecture with SLC modules in order to simulate signals obtained by computer models.

One of the interests that have emerged as result of this work is networking, mainly based on protocols such as Token Bus and the Controller Area Network protocol, CAN. Experimental work is actually done on this area, mainly at the microcontroller and PICs level.

Other courses related to the one described here, are part of the pilot project, these are on Instrumentation and Control Engineering regarding Mechanical, Industrial and Chemical Engineering students.

Further development is to be done to establish a stronger relation with Allen-Bradley® and other automation companies in order to reinforce knowledge of our faculty, maintain a good level on the hardware and software requirements of this laboratory, and providing a profitable working environment for our students

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BIOGRAPHICAL INFORMATION

L. F. Borjón was born in 1962. He received an MSc. degree from Brunel University (UK) and the BSc. degree from Universidad Iberoamericana . On 1994 he was awarded the Best Masters Thesis on 1991 from the United Kingdom Institute of Measurement and Control Mr. Borjón is Assistant to the Dean of Science and Engineering and lecturer at the Electronic Engineering program at Universidad Iberoamericana. He works on the development of Instrumentation projects . These are related with sensors, data acquisition and programmable logic controllers. As an assistant to the Dean, Mr. Borjón works on accreditation issues, establishing relations with Industry and supporting technological applications at the Division.

L. M. Martínez was born in 1965. He received an MSc. degree from Brunel University (UK) and the BSc. degree from Universidad Iberoamericana . Mr. Martínez is lecturer at the Electronic Engineering program He works on the development of Instrumentation projects . These are related with sensors, data acquisition and programmable logic controllers.

K. A. Córdova , J. L. Hernández, A. Lozano were born on 1972. They received the BSc. on Electronic Engineering with honors from Universidad Iberoamericana (Mexico). They receive their degree by supporting the development of the project presented on this paper and are currently working at Mexico city.