Programmable Logic Controller Teaching Method

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Abstract:

Programmable Logic Controllers (PLC's) have been found in industry since the early 1970's. The application of PLC's has long been considered a required course for majors in Electrical Engineering Technology. Course content has traditionally centered on hardware with labs giving some programming experience. It is proposed that the education process for teaching PLCs should concentrate on programming from the beginning with the object of training good PLC programmers.

The course content of two courses will be described with the first course usually placed in the sophomore year and the the second course in the senior year. Course content of both courses will be discussed as well as the philosophy of placement of various topics in the two-course sequence.

Introduction:

The two-course sequence is designed to challenge PLC students and provide more well-prepared students for the manufacturing environment. The challenge requires more programming than may be presently taught in a more traditional PLC course.[1-9]

The first course concentrates on programming the PLC. A choice must be made for the PLC manufacturer and Allen-Bradley (A-B) was chosen. Any course should look at the PLC generically with programming techniques taught that are common between different vendors. Allen-Bradley is a good choice for teaching the PLC but other vendors should be considered as the industry changes. Allen-Bradley has made it easy for the educator to teach using A-B's hardware and software with the many choices of hardware available. A-B also incorporates good pricing structures, especially with their software pricing discounts.

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First Course Description:

The first course begins by discussing the history of PLCs. A lab using low-voltage relays to build simple boolean logic circuits and a memory or seal circuit follows. This lab is included in the historical section to require a student to employ relays to wire combinational and memory circuits. This lab bridges the gap between the student's digital background and the PLC. The student may use relays for the first time in this lab and be exposed to the ladder diagram for the first time as well.

A second lab introducing the motor starter as a control circuit is performed. Only the 120 VAC circuit of the motor starter is wired. With this experience, however, the student begins to think beyond the low voltage dc circuits seen in other electrical courses. This may especially be the case for the student who has not experienced an industrial electrical course.

It is believed after this second lab that the student is adequately experienced in the devices that PLCs replaced and that it is time to move on to PLC programming. A philosophical approach to labs requires that labs or projects should be visually easy to see. Machines from industry are not available and most students have not seen a typical machine. It is believed that a better approach is to select labs from experiences common to the student.

A first PLC project is given with the program already written. The student must master the programming of the circuit using the programming language of the PLC. In A-B, the choices are RS-Logix, RS-Logix 500 or RS-Logix 5000 [11, 13, 14]. The student must learn the programming methods of PLC ladder logic before being expected to create a new program.

The program is entered and the push buttons, lights and other I/O are wired. The project is then demonstrated to the instructor for grading. A listing is acceptable evidence for a report along with the demonstration that the project is completed successfully. Programs are accepted even though they may vary somewhat from the original premise or if programmed using methods other than the techniques used when explaining the project. Care must be taken when designing a project since several interpretations may occur. It has been found that projects or labs should be designed for students to have a visual image of the project in mind prior to programming. Partial programs are given for early lab experiences in order for the student to not start with a blank page. Early success of these programming experiences is an encouragement to continue the task to completion.

These projects require that I/O remain simple. It is believed that an advantage of the course is that a student may use any instruction or programming approach to accomplish the task. Students are encouraged to pursue the solution without knowing a best approach. Students should be encouraged to try any approach and not be bound by what is normal or comfortable to the instructor. Numbers of rungs to accomplish the task should not be counted. Students quickly find that bigger is not necessarily better since larger programs require proportionally longer time to debug.

List of Projects in First Course:

Early projects prepare the student for later projects. Starting with the fourth project, students are required to read a statement of the project and design the I/O layout and program to perform the task. These projects include:

Combinational Logic:

The project uses the coin changer to allow some coin entries but not other entries. Outputs turn on with certain combinations of inputs. Several outputs may be used including “Accept”, “Change”, and “Reject”.

Traffic Intersection:

The inputs to this project include a series of timers. The timer chain is established and outputs to traffic lights are programmed to turn on during the various timing periods. This lab uses combination logic as well as the timer circuits to build a simple traffic light sequence. Options are introduced to allow for blinking lights at night, addition of a pedestrian cross-walk, or addition of a turn lane if a car is present. Options may require a memory circuit be turned on and off with events.

Cash Register:

This project introduces the combination of use of numbers with logic. Counters are used as well to count entries of each item requested. The cash register is to be designed to resemble the typical McDonalds cash register.

Binary Add/Subtract in Ladder Logic:

It was noticed that students were not making a connection between the 16-bit integer word and the storage of 16 separate control bits. Writing a number as 16 bits that could be useful in control as individual bits had not been stressed. The project to build a binary adder uses the fact that the PLC can use 16 individual bits as an integer number and give the student the means to program a simple binary adder using control bits. The exercise serves as a means for the student to make a connection between the digital course’s binary adder and the PLC’s similar binary logic structure.

Multiplexer:

Multiplexer technology for entering large numbers of analog or numeric data may be old technology. However, to require the multiplexing of data into the PLC requires the student to use timing diagrams. The student must not rely on the screen for up-to-date feedback of the state of the program. The use of multiplexers introduces the student to timing diagrams used in the PLC as well as a possible need for scan dependent logic.

Difficult Logic Lab:

A difficult logic lab is included in the course to encourage the student to accept difficult projects. This lab at present is a floating master pump project. Usually one pump is turned on. If the process calls for more water, a second pump is turned on. If still more water is needed, a third pump turns on. The first pump on is then the first to turn off when less water is needed. The master pump continues to move to the next pump in the sequence as that pump turns on. To complicate the lab further, a condition is added that a pump may be taken out of automatic service and turned on or off manually. This type of lab should convince most students that a difficult lab is capable of being solved (in a week or two). As students encounter this type of lab, they are encouraged to use state diagrams to aid in solving the program. Drawing a state diagram is helpful when development of a solution of labs such as this.

Sequential Logic:

Sequencers form a powerful instruction set when used in the PLC. Whether the sequencer instruction or a sequential counter is used, the concept of sequential states using a counter is a necessary concept for the PLC programmer to understand.

Part Tracking/Control:

Part tracking using shift registers is also an important concept for the PLC student to master. Tracking the movement of boxes or parts on a conveyor is necessary for many control programs. Instructions such as the shift right or shift left are useful for programs involving tracking.

Recipe Storage and Retrieval:

Two different games are used to teach the concept of numeric storage and retrieval of data from tables. The game Simon Says is a simple game that can be programmed on the PLC to mimic this old 1980’s game (without the sound). A second game is Whack-a-Mole taken from the arcade game. Each game requires a file of time delay and discrete outputs to determine a particular light or button. The game is not programmed as a random game but repeats the same sequence if the same table of values is used.

A major concept emphasized in these programs is addressing. Direct addressing as well as indirect or indexed addressing must be explained. One-shots are discussed as well as other scan-dependent concepts. One-shots are included under the topic of scan-dependent code.

Second Course Description:

The second course is more involved with integration of products than with programming. While the course is not intended to prepare the student for every aspect of life after the classroom, it is intended to build an attitude that the very difficult systems can be broken down into more manageable parts and then solved. The second course assumes a basic programming background of the instruction set learned in the first course.

This course tends to be more intense. It involves the process of product integration. Students are being prepared for the interview process and later success with a first job. One of the less appealing side effects of this course is that the intensity of the course coupled with (for lack of a better term) senioritis tends to make a very difficult grading experience for the instructor. The student is either motivated to perform well in order to find a good job or not very motivated at all.

The course has evolved from a grant for a core of equipment purchased to begin an advanced course in PLC training. Equipment was purchased for one-of-a-kind lab experiences and students are forced to program these labs at various times throughout the week. More than one group cannot work on the same project at the same time. Labs from the second course include:

Communications Interfaces:

The student usually finds it difficult to log onto the PLC incorporated into a network after only having to log onto stand-alone PLC processors in the first course. The process of logging onto a particular processor in a local network takes time and some persistence.

Messaging Commands:

Students are asked to communicate between multiple PLC processors using messaging commands. The messaging commands must be successfully configured and the process understood before data can be successfully written or read between processors. Having multiple applications of RSLogix 500 active at the same time is encouraged while troubleshooting the MSG command to help the student verify data flow between both processors.

PID Algorithm:

The PID algorithm may be programmed and used to control devices using the PLC. Tuning and implementation of the basic PID block is a first exercise. Control of a water valve for flow was the PID block programmed.

Interface of PID with Human-Machine-Interface (HMI):[10]

The HMI is added to the PID block to give a machine operator control of the PID block. The face-plate is discussed and the various modes of the PID block are programmed.

ASCII Read/Write:

Many devices such as bar code readers, weigh scales and RFID readers may use the ASCII read/write command blocks. To test the read/write block, a computer is set up as simple terminal for text transmission instead of a typical bar code reader.

Handling Faults and Interrupts:

To recover from a fault or handle an interrupt requires the same type of command from the PLC. A lab experience to cause a fault and then recover from the fault is required.

Stepper Motor Configuration:

The excitement of actually moving a device to an exact location is the object of this lab. Stepper motors may be configured manually using the data table of the stepper controller card to manually enter configuration and control information and move the stepper. The lab is enhanced when the HMI is programmed to enter the same information.

Servo Motor Configuration:

After the stepper motor is configured successfully, the servo-motor may be assumed to be as easy to configure and run as the stepper motor. However, its configuration and control prove to not be as simple. With devices such as the servo, the student is pointed to the sample program of the appendix of the servo control user manual as a starting point to successfully control the device.

DeviceNet Configuration:

Data highways for sharing of data are a part of the modern PLC. DeviceNet is a simple I/O network that works well with most processors. Configuration of the network and using the network to control a simple PLC program is required. [12]

Introduction to ControLogix and CompactLogix Processors:

Most schools standardize on the Allen-Bradley processors and the processors most often chosen are the MicroLogix series. These processors require RSLogix 500 to program the PLC. The latest processors introduced from A-B are the ControLogix and CompactLogix processors. These processors require RSLogix 5000. The main difference between the two is the use of a database of tags for addresses in the ControLogix and CompactLogix series. Programming data points are created on an individual basis by the user. With RSLogix 500 and the SLC or MicroLogix processors, data points were pre-defined by the PLC manufacturer. While the difference may appear at first to be simple to understand, the experience of setting up a program using the newer RSLogix 5000 database is of value and should be included.

RSLogix 5000 supports other programming languages as well as ladder logic. These different languages may be imbedded in the same program with ladder logic to provide an overall best solution.

Introduction to Advanced HMI:

RSView32 was selected as an advanced HMI. The newer PanelView products were purchased to provide an interface with the operator. It was learned that the same software could reside on the desktop computer and provide the same functionality as the PanelView. If budgetary constraints make hardware choices difficult, the newer PanelView products may be replaced by the stand-alone computer and the RSView32 software. The RSView32 software may be used on the desktop computer in a similar manner to the PanelView. Graphics are more complete on RSView32 than on other HMI products. Graphic detail plus capabilities to write control statements in VBA allow the control engineer much flexibility in this product.

With this product is also supplied the KEP drivers that may be used to communicate directly between the PLC and desktop computer. Applications written in Visual Basic 6.0 (or VB.NET perhaps later) are capable of communicating with the KEP driver and providing a direct link between the desktop computer program and the PLC.

RSView32 is Allen-Bradley's advanced HMI product for use with a wide number of dedicated touch-screen panels as well as on a standard Windows-based computer. Applications may be networked together sharing a common data-base between computers.

Safety:

Safety and safety-related products are addressed. Several types of products are discussed.

Other Programmable Logic Control Manufacturers:

While Allen-Bradley is a popular brand especially in the United States, other brands of PLC's must be studied to familiarize the student with the differences between major brands. Brands may be roughly divided into those from the U. S., from the European community, and those from Pacific Rim. Each area has several distinguishing features that are unique to the particular area.

Networks and Protocols:

It has become increasingly necessary for the PLC student to have a working knowledge of networks and network protocols. Setting up a network of PLCs and accompanying HMI computers should be the responsibility of the electrical engineer or engineering technologist. The establishment of a stable network is critical to the success of a project and should be addressed in a course such as this. Network security, while not necessarily a part of this course, should be addressed in the curriculum at some point.

AutoCad and other Electrical Design Packages:

The development of a drawing package for construction of the electrical system is the responsibility of the engineer or technologist in the workplace. Successful implementation of each step of building a drawing set is important and should be understood. Packages such as AutoCad are designed to automate the process. Whether the student interfaces directly with such a package or incorporate some of the drawing processes in other ways is usually defined by a manager at the work-place. However, students should be aware of today's automated processes for generating electrical packages.

Future Directions of Courses:

The first course is a more stable course with only minor changes taken in each year's development. A lab may be added or changed but no major changes occur annually. On the other hand, with the equipment changes occurring in the PLC market, changes in the second course may be wide ranging.

A move to incorporate more course work to include more experiences pertinent to the newer ControLogix platform may be necessary. More work with networking PLC's, computers, and use of process networking across the Web may be needed. Use of a programming class to include either Visual C or Visual Basic to teach principles of addressing the PLC and providing an automated HMI screens is also a subject to be explored.

Conclusion:

Whether planning a new curriculum or additions to a present course, programming of the PLC should be considered a fundamental part of course development. Care should be taken to keep the course pertinent to students for today's needs while requiring a strong programming experience for the student. While the approach outlined may be difficult to implement or maintain, the results are worth the effort with a well trained student entering the work force.

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Biography:

Wm. Ted Evans is a professor of Engineering Technology at the University of Toledo. His educational background includes a BSEE in 1971 and MSEE in 1975. He will receive the PhD in Industrial Engineering this spring. Mr. Evans was also a practicing Controls Electrical Engineer in industry for 15 years.