PLC Systems - University Course Material or Industrial Training Material ?

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Introduction

In the late 1960's, a new electronic device made its debut, at the request of the automotive industry. It was called a programmable logic controller (PLC) and its function was to replace an existing system of machine control logic. The existing system was based on an electro-mechanical device called a *relay* and the machine control logic was implemented by wiring the *coils* and *contacts* of these *relays.* This existing machine control logic system had served industry well for many decades. However, the two main aspects of this existing system—"mechanical" and "wired logic"---made maintenance and design changes costly to manufacturers, especially the automotive industry, where yearly model changes required machine control logic changes and mass production required around the clock production operations. With the growth of integrated circuits and the advent of the microprocessor, it was possible to implement machine control logic in solid state memory and to make design changes by simple computer programming entries.

Over the next 20 years, PLCs found their way into *all* industries: automotive, metals, rubber, plastics, chemical, food, beverage, pharmaceutical, etc. *The market for PLCs grew from a volume of $80 million in 1978 to $1 billion per year in 1990. ……PLCs are also used extensively in building energy and security control systems.*[1] Along the way, more and more capabilities were added to PLC's and they soon appeared in all shapes and forms, large and small, controlling any and all machine and process operations. PLCs have been the "workhorse" of industrial control systems for the past 25 years and continue to be an integral part of all new, state of the art, evolving control schemes.

Question

However, since the PLC could be considered as simply another piece of electronic equipment, a question arises. Where should the teaching (and learning) about how the PLC works and how to apply the PLC be conducted? Should it be accomplished through customer training by the PLC system supplier and/or systems integrator or through the end user's own training department—as is usually the case with new system installations? Or should this teaching and learning be implemented through a formal course as part of a university or college curriculum in engineering or engineering technology?

Answer
This question can be answered by addressing it from two different viewpoints--from the manufacturing industry in general where PLC control systems are installed and from the engineering (technology) students' view, who will be entering the manufacturing industry workforce.

From the manufacturing industry view, there are two main factors supporting a formal course in PLC systems as part of a university or college curriculum in engineering or engineering technology: economics and the rapidity of changes in industrial factory automation control systems. *In the 1970s and the 1980s companies were able to hire both an electrician and an electronics technician to install, interface, program…PLCs. Since the late 1980s the number of PLCs has grown………better to hire one individual with both electronic and electrical experience.*[2] Also, in today's competitive market, most manufacturers no longer have the luxury of maintaining a formal training department or implementing a long term development program for incoming maintenance, production, or engineering personnel. Many manufacturers require new hires to "hit the ground running."

Adds Krones' Oldenburg: "As [technology] curve goes up, fewer and fewer people are qualified to deal with [troubleshooting………systems]. Several years ago, customers got left in the dust………And in the last couple of years,………engineering community got left in the dust." [3] *Programmable control has transformed manufacturing. There is a huge need for trained personnel who can program and integrate industrial controllers and devices.*[4]

The new industrial control systems, PLC based included, are "user friendly' with built in diagnostics and monitoring features, pop up menus, etc. Also, the new generation of workforce, both skilled and degreed, were brought up on video games and move through screen windows with the "fastest mouse in the West" syndrome. However, just as the user of a video game cannot create nor change the video game logic and screens, so also the control system *operators (users)* cannot be expected to change the control system logic or operator interfaces. However, in industry, it is *always* the case that these control changes will occur—as new control devices (sensors, actuators) are added, as sequence timing is changed, as new models and products must be produced by the machine or process, as new recipes are added, and *as system failures and faults occur*. This function will require technical personnel familiar with programming language skills, control concepts, system components specifications, and strategies for converting process operations into logic. This will require engineering (technology) graduates with PLC experience. That is why the advertisements for technical personnel in the Classified section of every newspaper mention PLC experience as a requirement or desired qualification.

From the students' view, including a formal course in PLC systems as part of a university or college curriculum in engineering or engineering technology wins hands down. First, the majority of an engineering (technology) student's course work is theory: differential equations, Laplace Transforms, boundary value equations, theorems, formulas, x and y as input and output. Engineering students have been "chalk boarded, overheaded, powerpointed to death" with little "hands on" education. The students have studied the classic RLC circuit and the mass, spring, damper system in many courses, but they wouldn't know where to find a real world industrial

R(dynamic braking/accelerating), or L(coil), or C(power factor correction), or mass(work roll), or spring(actuator return), or damper(hydraulic fluid). Many of the laboratories, by necessity, are bench top setups with decade boxes, patch panels, and plug in connections—very unrealistic. For example, students may learn how to design a regulated power supply but some of them don't know how to "wire" a real world power supply. In the author's PLC systems course, one of the first assignments is to install the PLC system, including input/output wiring and incoming power connections. Occasionally, there is a student who wires the 115 VAC power cord to the +/- 24 VDC terminals.

However, only fifteen per cent of engineering (technology) graduates enter the research and development workforce. Eighty five per cent of the graduates enter the manufacturing industry workforce where they are required to *apply and maintain* designed and developed pieces of equipment and devices for production processes. As such, in order to prepare these eighty five per cent, it is important to present a course which is more real world and application orientated, such as a course in PLC systems. The author's own experience is a perfect example of better preparing engineering (technology) students for an engineering career in one of the manufacturing industries. One of his first assignments after graduation was working with an electrical schematic with many **-| |-** symbols in it. He kept asking, "What are all those capacitors doing in this circuit?" The "capacitors" were, in fact, normally open relay contacts!

A PLC systems course benefits students in two ways. It exposes them to real world devices and equipment, and also it teaches them the basics of controlling all processes and machines—namely: timing, sequencing, I/O (input/output), if/then, on/off, triggering, events, PID, recipe selection, communications. These two learning components of a PLC systems course make it beneficial to all engineering students. The author's PLC systems course is cross listed in all engineering departments at Cleveland State University. Also, many former engineering students from the Industrial & Manufacturing Engineering Department and the Electrical & Computer Engineering Department return to take the PLC systems course at the request of their employer or because their work experience involves PLCs in one form or another.

Knowledge Gained

Ok, what's a relay? What's a solenoid? Better yet, what's a wire? This is where the author's PLC systems course starts. Why-because the majority of engineering students have *no* practical experience coming into the course-other than possibly summer employment or co-operative education assignments. And, as stated above, the majority of courses in engineering are conducted in a classroom or laboratory environment. The first treatments (lectures and assignments) in a PLC systems course, are designed to give the students hands on experience with real world devices used in industrial control systems. The students physically wire simple control circuits connecting selector switches, control relays, proximity switches, limit switches, motor starters, pilot lights and solenoids. In the process, they learn to equate schematic symbols to physical devices.

Another assignment in a PLC course has the students selecting devices (3 position selector switches, plunger actuated limit switches, push to test pilot lights, etc.) from electrical equipment vendor catalogs. (Now this is done by accessing vendors' websites.) Again, the students gain knowledge of physical devices (pictures) but also the students gain understanding of the variety of devices that must be specified. In these first assignments, the students also learn the “pilot” nature of motor starters and solenoids. That is, the electrical symbol in the control diagram for turning on a motor or operating an actuator is only the *pilot part* of the operation. There must be a source of power for the motor (usually 3 phase power) and for the actuator (a control valve plus either fluid (hydraulic) or compressed air (pneumatic)). This is invaluable for the students to learn, as attested to by the author’s own rude awakening early in his career.

The next step in a PLC systems course is designed to familiarize the students with the hardware portion of a PLC system. The students configure the PLC hardware and *interface the PLC system to the process or machine to be controlled*. That is, the students wire the inputs (sensors, transmitters, operator devices) and outputs (motor starters, transducers, controllers, pilot lights, solenoids) to the PLC. In doing so the students must use the vendor manuals to install and wire. Also, the students use the vendor manuals to troubleshoot indicator lights which are part of the PLC system. The students observe the input and output status lights which verify the wiring and/or the control logic. The students also observe the PLC processor lights: OK, RUN, BATTERY, COMMS, etc. All industrial factory automation control systems, whether PLC based or computer based, have these status indicators which are necessary for troubleshooting and maintaining the control system operation. Therefore, this learning experience is universal.

Next, control strategies are implemented by programming the PLC. Until recently, the programming language for PLC logic has been *ladder logic*. This language format was selected for PLCs to make the program look similar to existing relay control diagrams. When PLCs were introduced into industry, the existing engineering and maintenance workforce was familiar with this format. A PLC course should stress that 90% of all industrial control is simply Boolean logic—if/then, and/or, on/off, goto/return. As such, ladder logic is simply a tool for implementing this Boolean logic. Also, the new standard for control programming, IEC 61131-3, defines 5 languages. It appears one of the 5 standards, the ST (Structured Text) language, will become the “open” standard for all PLCs, regardless of manufacturer. The ST language is English text for Boolean logic—if/then, and/or, for/next, goto, etc. and should be presented in a PLC course in parallel with ladder logic or as an option.

Regardless of the programming format, ladder or ST, a PLC course should teach general control concepts such as sequential scan, I/O updates, trigger pulses, initializing data, latches, timing, machine sequencing, events, subroutines, BCD and Hexadecimal numbers, digital vs. analog values. The microprocessor-based PLC system operates on combinations of 0’s and 1’s, which is compatible with the operations of most machines and processes: in/out, up/down, on/off, open/close, high/low, etc. The students work with “bits,” PLC memory locations, shifting, setting, masking, and forcing these bits to turn real world process control equipment on and off. Again, this learning experience is universal and can be applied to any controller or any process.

The PLC course assignments should be related to real industry applications, such as temperature sampling, finding maximum and minimum and average values of pressure and flow, machine control as a repetitive sequencer of events, alarm logic strategies with bit set, good part/bad part tracking schemes with bit shifting, recipe retrieval and selection using FIFO stacks, indirect addressing, table moves, control algorithms, such as PID and FOR/NEXT using function blocks. If the PLC course is presented in the form described above, all students taking the course will be prepared to work with industrial factory automation control systems, regardless of the control system equipment or vendor and regardless of the industry. They will "hit the ground running."

Conclusion

The face of industrial factory automation control systems is rapidly changing, largely due to Ethernet serial I/O, PC-based real time control, control via the Internet, enterprise level communications, etc. These phenomena dictate that engineering students be qualified and prepared to contribute in this evolving environment immediately upon graduation. Therefore, it is important to include a treatment of PLC systems in an engineering or engineering technology curriculum. It provides students with a "hands on" familiarity with real world devices and equipment which are integral components of all control systems. Also, working with PLC systems provides engineering graduates with fundamental concepts applicable to any control strategy.

Added to this statement is the following strong argument for presenting a treatment of PLC systems in an engineering or engineering technology curriculum. At Cleveland State University, *two* sessions of Applications of PLC Systems, one based on Allen Bradley equipment and the other based on General Electric equipment, are presented *each* semester. The average enrollment is 15 students per session and each session has students from the Engineering Technology Department as well as Electrical & Computer Engineering Department, the Industrial & Manufacturing Engineering Department, and the Chemical Engineering Department. Every semester these sessions receive the highest student approval rating, based on standardized evaluation forms.

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