PLC's in the Control System Laboratory

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Abstract

This paper describes how ladder logic, Programmable Logic Controllers, and operator interfaces have been integrated into the analog/digital control systems laboratory at the University of Arkansas. This material is typically not taught to electrical engineering students during their undergraduate education, but has been incorporated here due to demands from the manufacturing industry today. A detailed course outline is presented and discussed. In addition, an experiment will be presented to illustrate the use of this material.

I. Introduction

Sequential control using ladder logic, Programmable Logic Controllers (PLC's), and operator interfaces is used very heavily in the manufacturing industry today. Typically, electrical engineering students are not taught this material or exposed to this equipment in their undergraduate education. There has been a stigma for years that this topic belongs in technology programs. This stigma comes primarily from the fact that most sequential control systems are maintained and modified by technicians. However, it has been the experience of the author that most sequential control systems using PLC's, ladder logic, and operator interfaces are initially developed and installed by electrical engineers. Therefore, the author feels that electrical engineering students should have the opportunity to study this topic in their education. It is not being suggested that this material be required for all electrical engineering students, but be available in the curriculum as an elective.

II. Overview of the Laboratory

The prerequisite for the laboratory is the classical controls systems course ELEG 4463 – Control Systems. The description of the course is as follows:

> Experimental study of various control systems and components. The use of Programmable Logic Controllers (PLCs) in the measurement of system parameters, ladder-logic applications, process-control applications, and electromechanical systems.

The class schedule is given below in Figure 1. During Week 1 through Week 4, the structure and operation of a PLC is presented in a class/laboratory setting. The students are setting at a PLC workstation and the instructor is presenting material via overhead projection. As each instruction is presented, the students are able to do small exercises at that time utilizing the instruction to better understand the instruction. Also, during these weeks the students are working on several small homework types of problems outside of the scheduled laboratory time.

Class Schedule	
Week 1	PLC Structure & Operation
Week 2	PLC Structure & Operation
Week 3	PLC Structure & Operation
Week 4	PLC Structure & Operation
Week 5	PLC Project
Week 6	PLC Project
Week 7	PLC Project Demonstration
Week 8	Servo System Operation
Week 9	Servo System Identification
Week 10	Servo System Controller Design
Week 11	Operator Interface Structure & Operation
Week 12	Operator Interface Structure & Operation
Week 13	Operator Interface Project
Week 14	Operator Interface Project
Week 15	Operator Interface Project Demonstration

Figure 1 – Class Schedule

After the students have developed a basic understanding of the PLC and its operation, they are assigned a PLC project that takes approximately three weeks to complete.

Weeks 8 through 10 the class takes a break from the PLC and devotes time to classical control system topics. However, during this time the students are cleaning up their PLC projects that did not correctly work during the demonstration in Week 7.

Weeks 11 and 12 are very similar to Weeks 1 through 4. The students are at the computers and the instructor is guiding them through the basics of operator interfaces. Weeks 13 through 15 are devoted to the development of an operator interface for the PLC project that was developed earlier in the semester.

The textbook for the class is the PLC Software and Processor References that are published by the PLC manufacturer. The students use laboratory copies of these textbooks that have been supplied by the manufacturer.

III. PLC Project and Operator Interface

For the PLC project to be successful, it must be one where the student understands the machine and its operation. The washing machine makes a good PLC project because most college students have developed an understanding of this machine by their senior year. Figure 2 below gives the details of what students are expected to do for their project.

Automatic Control of Laundry Washing Machine

Objective
The objective of this experiment is to completely control the operation of a washing machine using a Programmable Logic Controller (PLC) with ladder logic.

Description
This washing machine has feed lines of hot water, cold water, bleach, fabric softener, and detergent and one exit line for draining the water. Through the combinations of these variables the operation can be completely automated using a PLC.

Operation
The operator will select between the following modes of operation prior to pressing the START pushbutton.

Wash, Rinse, or Spin
Hot, Warm, or Cold Wash
Warm or Cold Rinse
Bleach or No Bleach
Fabric Softener or No Fabric Softener

The operation can be stopped at any time by pressing a STOP pushbutton. Pressing the START pushbutton after the STOP will resume operation at the point prior to pressing the STOP pushbutton. Pressing the RESET pushbutton after the STOP will reset the operation back to the initial state. If there is water in the machine when RESET operation is initiated, then the machine must be drained.

Wash Cycle

a) Fill with water - Allow 20 seconds for the machine to fill with water.
b) Add detergent - Allow 5 seconds to add detergent 5 seconds after the machine has started to fill with water.
c) Agitate - Allow 60 seconds for agitation.
d) Add Bleach - Allow 5 seconds to add bleach 15 seconds after the machine has stared to agitate.
e) Drain water - Allow 10 seconds to drain most of the water from the machine.
f) Spin and drain water - Allow 10 seconds to spin and drain the remaining water from the machine.
g) Fill with water -Allow 20 seconds for the machine to fill with water.
h) Add Fabric Softener - Allow 5 seconds to add fabric softener 5 seconds after the machine has started to fill with water.
i) Agitate - Allow 30 seconds to agitate.
j) Drain water - Allow 10 seconds to drain most of the water from the machine.
k) Spin and drain water - Allow 10 seconds to spin and drain the remaining water from the machine.

Rinse Cycle

a) Fill with water - Allow 20 seconds for the machine to fill with water.
b) Agitate - Allow 30 seconds to agitate.
c) Drain water -Allow 10 seconds to drain most of the water from the machine.
d) Spin and drain water - Allow 10 seconds to spin and drain the remaining water from the machine.

Spin Cycle

a) Drain water -Allow 10 seconds to drain most of the water from the machine.
b) Spin and drain water - Allow 10 seconds to spin and drain the remaining water from the machine.

Inputs and Outputs

Inputs to the PLC are below		Outputs from the PLC are below	
0	Hot Wash	0	Hot Water Feed
1	Warm Wash	1	Cold Water Feed
2	Cold Wash	2	Detergent Feed
3	Warm Rinse	3	Bleach Feed
4	Cold Rinse	4	Fabric Softener Feed
5	Wash Cycle	5	Drain
6	Rinse Cycle	6	Agitate
7	Spin Only	7	Spin
8	Add Bleach		
9	Add Fabric Softener		
10	START		
12	RESET		
15	STOP		

Figure 2 – PLC Project

Figure 3 below give details of what students are expected to do for the operator interface project. There are various software packages for creating operator interfaces. This laboratory uses Rockwell’s WinView package.

Operator Interface
For
Automatic Control of Laundry Washing Machine

The objective of this project is to develop an operator interface using Rockwell's WinView for the Automatic Control of a Laundry Washing Machine. The operator interface is to assist the operator in monitoring and controlling the operation of the laundry washing machine. The interface is a visual picture on the computer monitor rather than a control panel with pushbuttons and indicator lights. The operator interface will have as a minimum the components listed below. Any additional components that you feel would enhance the operators ability to understand and operate the machine can also be included.

1) Allow the machine to be controlled either from the original panel pushbuttons or from the operator interface.
2) Complete status of the operation. This includes such things as operator selections, errors, time remaining in cycles, etc.
3) Feed lines to the machine should be black when no feed is occurring and colors as follows when feed is occurring.
   - Hot Water - Red
   - Cold Water - Blue
   - Detergent - Yellow
   - Bleach - White
   - Fabric Softener - Pink
4) Water in the machine should be as follows:
   - Hot Water - Red
   - Warm Water - Orange
   - Cold Water - Blue
5) Additives to the water should appear as follows:
   - Detergent - Yellow spots in the water
   - Bleach - White spots in the water
   - Fabric Softener - Pink spots in the water.
6) Some type of animation should be developed to distinguish between agitation and spinning action of the machine.
7) Drain line should be black when not in use and the color of the water when in use. It is not necessary to have additive spots in the drain line.

Be creative!

Figure 3 – Operator Interface

IV. Reaction from Students

Student feedback from this course has been very positive. This positive feedback comes from several aspects of this course. One reason is that students have a hunger and desire for exposure to equipment and software that is currently being used in industry. Also, this laboratory is taught from a "hands on" approach, which will almost always bring positive feedback. At the senior level, students typically also like team/project oriented classes. In the six years that this course has been taught, the author has not received one negative comment from the students about this laboratory.

V. Reaction from Faculty

Faculty feedback has been mixed. Initially, some faculty were very supportive of this class and others somewhat negative. The negative feedback has typically come from faculty that has never worked in industry at a bachelor's engineering level. Their experience in industry has typically been at the research or doctoral level. One faculty commented that ladder logic is to simple to be teaching at the engineering level. However, the initial negative reaction from the faculty has grown into a positive support over the past several years. The author feels that this change is largely due to educating the faculty of existing industrial manufacturing practices.

VI. Reaction from Industry

One source of feedback from industry has been in the are of jobs for the graduating students. Several students have obtained jobs as a direct result from taking this laboratory. Industry recruiters many times would like to have an experienced PLC programmer, but will consider a new graduate with some exposure to PLC programming. This laboratory does not make the students "expert" PLC programmers, it only provides an exposure to the material and topic. Several former graduates (prior to PLC material being in the controls laboratory) have commented that this material is definitely needed in the electrical engineering curriculum.

VII. Conclusion

The inclusion of the ladder logic, PLC's, and operator interface material into the laboratory has been a success. The students, faculty, and industry all agree that this material has a place in the undergraduate engineering curriculum. In the future, the PLC and the classical control topics may be separated into separate laboratories to allow additional coverage of both topics.

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Terry Martin received the B.S., M.S., and Ph.D. degrees in electrical engineering from the University of Arkansas, Fayetteville in 1977, 1983, and 1989, respectively. From 1977 to 1983, he worked as a Process Control Engineer for Reynolds Aluminum Company in Arkansas and Alabama. Since 1983, he has held various positions with the Department of Electrical Engineering at the University of Arkansas. Currently, he is an Associate Professor of Electrical Engineering teaching and conducting research primarily in the control systems area. His research interests are disturbance reduction in control systems, digital signal processing applications in control systems, motor control, and the application of new control techniques in industrial environments. He currently has funded research with Baldor Electric, U.S. Navy, and U.S. Army.