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MAKER: Programmable Logic Control (PLC)-Based Automated System for Water-Level Control for Teaching Pneumatics and Hydraulics

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Abstract

This paper describes the design, construction, and evaluation of a learning module on pneumatics, hydraulics, and actuators that incorporate a PLC controlled automated system for water level control. The module was developed to address a knowledge gap between two courses—one on pneumatics/hydraulics and another on automated control—and employs cost-effective hardware and software tools to provide interesting hands-on experiences for college students. The automated control system consists of level sensors, relays, water tank, and a submersible pump along with a motor, DC power supply and programmable logic controller (PLC) to automate the pumping of water. The system is used to show students how to interface I/O devices with a programmable logic controller (PLC) in the context of designing and building a system to control the water level in an overhead storage tank. The system also controls the pump motor on/off switch, thus saving energy. The system is portable and can also be used for K-12 outreach activities. Evaluation results suggest that students learned the subjects well and that the hands on experience helped them to better understand how pneumatic and hydraulic components are used within industrial automated systems.

Motivation

The introduction of PLC has revolutionized the manufacturing industry and automation as a whole. For complex manufacturing PLCs are used widely. Our educators are reluctant to introduce PLC related Courses in the industry because of lack of teachers, not enough Lab equipment or not having enough funds for this emerging technology. There are different ways of introducing this Course (PLC) one way is to make it web based teaching which can be accessible from anywhere. A Model building of PLC in an existing Course, Also it can be done in hybrid Course and Labs can be done in person at schools. To make our students to succeed we have to use intelligent tutoring system technology and games to teach about programmable language for PLC. Research has established Hands on education approach is most effective there fore PLC lab oriented activities will be more exciting to Automation students.

Integration of PLC Project

A PLC project to develop a system for water level control was added to an existing two-year college course on hydraulics and pneumatics systems in the manufacturing and energy sectors. The system will automate the process by placing two sensors (lower level and upper level) into a tank and integrate them with a PLC so that measurements of the water levels and be periodically taken and feedback will be provided to the system, which will control the motor automatically and eventually control the pump. This system eliminates the need for people to fill the water tanks and check for overflow daily. Problems such as water overflow, empty tank, and motor overheating due to continuous usage can be avoided.

The syllabus with the added project is shown below.

Week Number	Activities and Assignments	Objectives and Details
1	Class introduction	Meet and greet students. Introduction of students and instructor
	Introduction to Hydraulics and Pneumatics. (Lab)	Define the terms fluid power, hydraulic System and Pneumatics..
	Different types of fluid power systems. (Lab)	Explain the functions of fluid power systems. Identify the basic structure of fluid power systems.
2	Basic physical principles. (Lab)	Identify and explain the design and operation of the six basic machines. Explain and apply different basic electrical circuits.
	Fluid power standards and symbols. (Lab) Test1	Importance of standards and symbols in the fluid industry. Identify groups that regulate fluid power industry.
3	Safety and health (Lab).	Importance of safety and health, define safety rules and regulations. How good and bad working environment can influence the safety and health.
	Study of hydraulic fluid	To introduce different properties of hydraulic fluid.
	Sources of hydraulic power. (Lab)	Introduce pumps and compressors and its application in providing Kinetic energy to the fluid.
4	Fluid storage and distribution (Lab) Test 2	Explain the factors that must be considered when establishing the size of a reservoir. Contamination and its effects.
	Application of Actuators. lab	Importance and application of actuators in fluid power.
	Lecture on how to control the system with the help of different valves. (Lab)	Explain the effect of temperature, pressure variations have on the operation of different valves.
5	Introduction to accumulators (Lab) Mid Term	Explain the four basic functions of accumulators.

Week Number	Activities and Assignments	Objectives and Details
	How to perform conditioning. (Lab)	Study different types of heat exchangers.
	Study of different circuits and systems. (Lab)	Learn about advanced hydraulic circuits.
	Introduction to Pneumatics. (Lab)	Describe the characteristics of compressed air.
6	Sources of pneumatic Power. (Lab)	Study of different types of compressors
	Conditioning of Air. (Lab)	To introduce different methods used in conditioning of Air
	Introduction of pneumatic motors and cylinders	How to apply linear and rotary motion in pneumatic systems.
7	Controlling a pneumatic. Lab system	Introduce different types of valves.
	Introduction of pneumatic circuits. (Lab)	Explain the design and operation of motion control circuits.
8	Practical application of different circuits	Hydraulics and Pneumatics working circuits
9	**PLC PROJECT:** **Develop a PLC based program to control the pump Flow rate to keep a fixed upper level and fixed lower level in a water tank all the time, and hence controlling the pump motor.**	**To elevate and solidify learning process of students in the field of Hydraulics and Pneumatic systems by incorporating PLC controlled System**
	Final test	Comprehensive test

PLC Project Scope

The PLC project covered the following topics:

1. Introduction to PLC
2. Relays
3. Contactors
4. Starters
5. Programmable logic controllers and programming
6. Ladder and Line diagrams
7. Industrial interfacing
8. Motor control
9. Pumps
10. Level sensors

Discussion of PLC benefits

Smaller physical size than hard-wired solutions.

- Easier and faster to make changes.
- PLC has integrated diagnostics and override functions.
- Diagnostics are centrally available.
- Applications can be immediately documented.
- Applications can be duplicated faster and less expensively.
- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly.
- Computational abilities allow more sophisticated control.
- Trouble shooting aids make programming easier and reduce downtime.

Component Used

The Water Level Controller has the following main components, which can be acquired from LabVolt:.

- Two sensors
- DC Power Source
- Full-wave rectifier
- PLC
- Centrifugal Submersible Pump
- Relay
- Motor
- Water tank

Project System platform

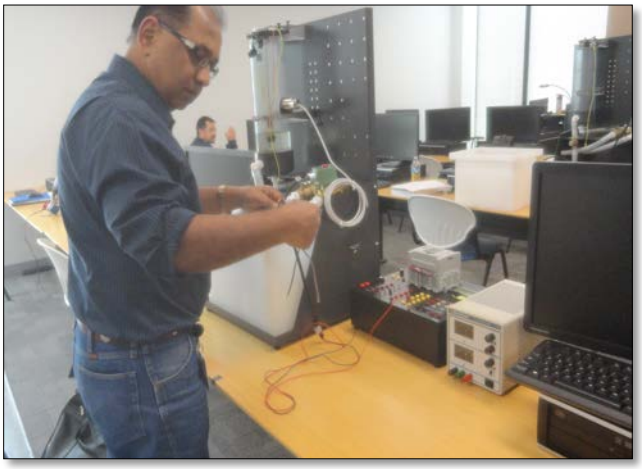
For students this system is multi-purpose, flexible, and allows them to do different lab- job sheets with the same components. Several groups of students can integrate these platforms to form larger PLC controlled systems.

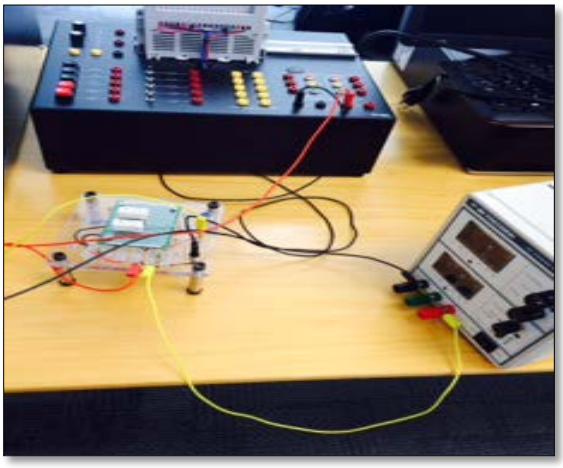
The information in Table 1 will assist financial decision makers to purchase this system.

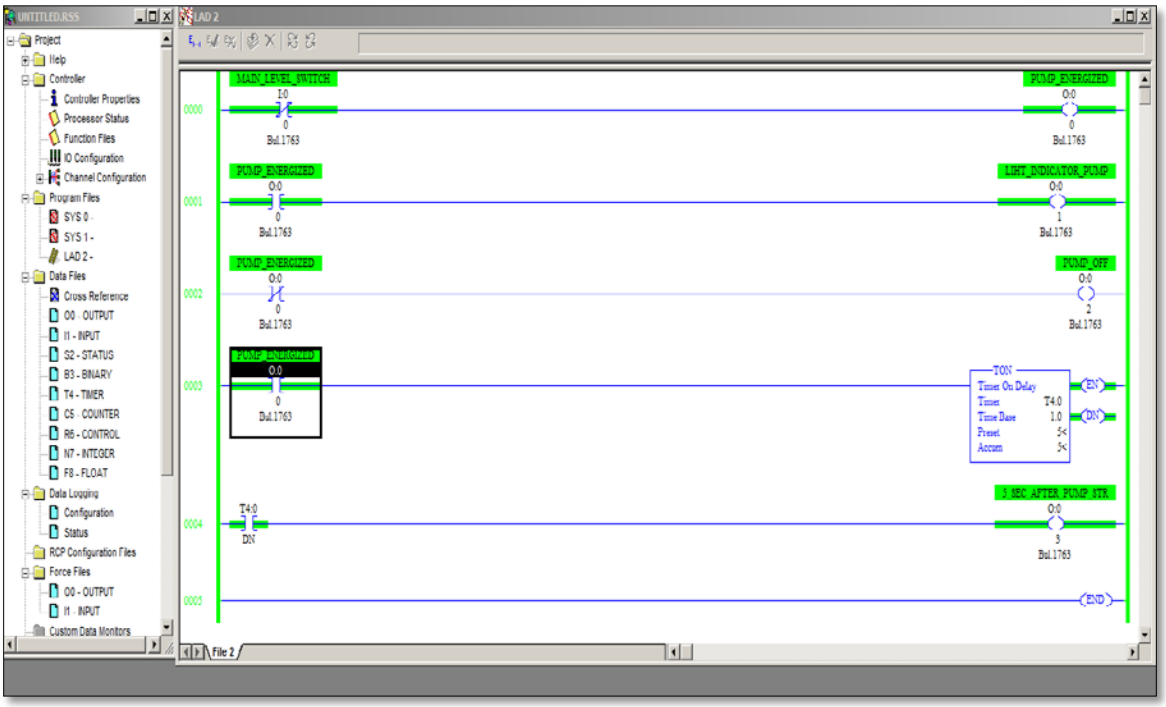
Table 1. Items for project system platform.

	Item	**Price**
1	Allen Bradley Micrologix 10000 plc	$ 1000
2	PLC software	$0
3	DC power supply	$250
4	Relays	$20
5	Set of sensors	$40
6	Set of water pump and motor with tank	$550
	Total	$1860

The system platform can also be used with K-12 students. A group of middle and high school students from underserved areas were invited to interact with hands - on learning experience “Water level Control By PLC”. The student learning outcomes were 80 percent positive and program learning outcomes were assessed and forecasted to buy more trainers so that smaller groups can be formed, allowing individual students to experience this activity and write program and run the systems.







The ladder diagram above includes the following steps:

1- Input 0 energizes the pump when activated
2- Output 2 is ON when motor energized

3- A 5 sec delay is timing 5 second delay after motor energized to indicate required time motor has been on
4- Output 3 indicates the end of 5 second delay

The most common applied control systems today are PLC which will precisely control fluid level in a tanks. PLC or programmable controller is a digital computer used for automation in electromechanical processes, such as control of machinery on factory assembly lines, or lighting fixtures. PLCs are used in many industries and machines. Unlike general-purpose the subject invention pertains to facilitating communication between industrial computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, Pressure, flow rate, level control immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed or non-volatile memory. A PLC is an example of a real time system since output results must be produced in response to input conditions within a bounded time.

Evaluation

The student evaluation is based on building and implementing a ladder diagram to control the water level. The students were assigned this project in the beginning of the hydraulic and pneumatic course. Pre- and post-tests suggested that they improved their knowledge by 90 percent.

Pretest Programmable Logic Controllers
Water level control
Unit 1, Task 1

1. What is a PLC?
   (Digital electronic apparatus with a programmable memory.)
2. What are the four main components of a PLC?
   (Input section, CPU section, Programming Device, Output section)
3. What is a discrete device?
   (Two states, On and Off)
4. What is a pulse-generating device?
   (Shaft Encoder)
5. What term is used to describe the CPU in a PLC?
   (Brain)
6. What is the difference between a communication port and a programming port on a PLC?
   (Programming Device-Programming Port, Other PLC-Communication Port)
7. What is an Uninterruptible Power Supply?
   (UPS) (Clean AC Power source)

Post-Test Programmable Logic Controllers
Water level control
Unit 1, Task 1

1. What are the components required for water level control system.
   (Pump, hoses, motor PLC, and a tank)
2. What is the typical maximum amperage for switching with the output section of a PLC?
   (Typically 10A max)

3. What are the three main categories of loads controlled by a PLC?
   (Discrete, Analog, Pulse)
4. What are the two main parts of a PLC programming device?
   (Display and Keyboard)
5. What are the four functions of a PLC programming device?
   (Program Entry, Documentation, Run, Monitoring)
6. What are two main classifications of Pumps?
   (Positive displacement and Non-Positive displacement
7. How can we increase the flow rate of a pump

The work presented in this research paper highlights the level control of water in the tank. With this implemented system pump motor is switched on and off with the feedback system from the level sensors. By doing so the water wastage is eliminated and more energy efficient system is designed. All control signals pass through and processed by the microcontroller. Tests were conducted to ensure the functionality of water level control.

Future Activities

The future recommendations are, application of PLC in the control of Pneumatic Actuators (Cylinder speed control for variable loads) and then studying the Hydraulic and Pneumatic Systems simultaneously controlled by PLC.

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