A Remote Control Project to Enhance Undergraduate Students' Interest and Knowledge in Industrial Automation

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Abstract

The objective of this project is to develop and establish a user-friendly online operation of a remotely controlled Programmable Logic Controller (PLC) unit, utilizing the Internet and the World Wide Web. This effort provides students with valuable hands–on experience in computer-assisted control systems. Also, based on this concept, courses with lab modules within many disciplines of engineering and technology can be offered to local and distance learning students, eliminating a major obstacle to establishing a complete remote education engineering curriculum. The concept is of particular interest to countries with large distances between major educational centers with limited resources and budgets. The described technology can also be applied to general remote instrument control in many areas of research and engineering.

The project includes constructing and controlling a system remotely. The system operates by loading parts onto a conveyor belt which then transports parts to a labeling station. The station uses a photoelectric sensor to detect the part, a pneumatic actuator to manipulate the part, and a labeling mechanism to label the part. The process is controlled by programming running on an Allen Bradley PLC. When the photoelectric sensor detects the arrival of the part, the PLC program stops the conveyor and uses a time delay to allow labeling to take place. The actuator then moves the labeled part into a storage area and the process is repeated.

Introduction

The U.S. manufacturing industries are turning to cost-saving technologies to improve their competitiveness and productivity. Clearly, knowledge of how to automate and

control the system including applying PLC in production lines is essential in most engineering, design, and manufacturing curricula. As a result, education and training in the area of control and PLC are on the rise across most colleges and universities in the U.S.

As the use of automation increases in the manufacturing industry, as well as the distribution and shipment industry, understanding this technology is critical for technology and engineering technology students who want to be prepared for their first job. The PLC is widely used in industry to control manufacturing process, to increase reliability and flexibility, reduce cost, and increase maintainability. References [1-4] provide some applications of PLC and sensors in dredging, GPS, research laboratories, pharmaceutical and other sectors of industry.

The advance of internet technology tools developed in the1990's made it possible to access a facility or laboratory at distance. Many companies have facilities spread out across the country or around the world and they need a way to remotely monitor and control the utilization of equipment and facilities with a reliable communication system. This project is designed to establish a remote control PLC unit not only to increase technical skills and knowledge of a large number of diverse undergraduate students in area of PLC, but also to promote remote control laboratory concepts and to maximize utilization of equipment and facilities and sharing of equipment at different locations. In addition, the tendency in higher education programs is to move from traditional teaching in the classroom to new ways of teaching, such as offering more online courses. For example, many colleges and universities offer a full range of online courses that make education accessible to those who do not fit the model of traditional full-time students and/or have budget limitations. Nearly 3.5 million college and graduate students, one of every five, took at least one online course during fall 2006, double the figure of five years earlier [5]. The increase has occurred mostly among community colleges and specialized online schools. Also, another study [6] showed that a large percentage of middle and high school students are interested in taking courses online that aren't offered at their schools.

New technology gives a great promise to deliver meaningful laboratory instruction over the web. Several universities including John Hopkins University, Old Dominion University, and University of Iowa have developed a Virtual Laboratory with fully interactive experiments via web for engineering courses [7-8]. Another example of an online laboratory course, developed by the Technical University of Catalonia, is the Microcontroller Remote Lab for online teaching and interaction with microcontroller systems via the internet [9]. The faculty members of the Department of Technology at the University of North Dakota have set up a Robot that can be controlled either by manually pressing buttons on the webpage or by sending a program [10]. However, despite the exponential increase of education delivered via web pages in recent years, the full potential of the remote control laboratory for PLC equipment was not attained for engineering courses. While Web-based instruction works well for lecture courses, educational programs that rely heavily on a "hands-on" learning approach must develop novel, more meaningful *laboratory-level* processes that can be delivered over the

Internet. Today, this is an active focus area for many universities and various distance learning/education setups are being evolved towards a "remote lab" model [11-13].

The project can be used either in a manufacturing laboratory or in a Capstone Project for assessing student learning. It is also a useful method to measure educational outcomes through an effective assessment program to improve program curriculum, course content, and instructional delivery.

Methodology

The objective of this project was to design and construct a remotely programmed and monitored automated labeling system for educational purposes. The process began with loading parts onto the conveyor belt. The conveyor belt transported parts to the labeling station that was equipped with a photoelectric sensor, actuator, and labeling machine. When the part arrived at the station, the photoelectric sensor detected the part and sent a signal to the PLC to stop the conveyor. The time delay at this station allowed the labeling machine to label the part. After the part was labeled, the pneumatic actuator extended and pushed the part into the storage area for packaging. The actuator retracted before the conveyor motor restarted to carry another part to the labeling station. This is a repetitive process in which, after storing a part, the system will reset itself to label and store another part.

Several steps were necessary to accomplish the project.

Step one: Identify necessary components with appropriate specifications to design, construct, and simulate the system.

The system consists of an Allan Bradley PLC [14], conveyor belt that runs by a 120V ac electric motor [15], labeling machine, 24V dc double solenoid valve, double acting pneumatic actuator, 24V dc photoelectric sensor [16], relays, two dc power supplies to power the solenoid valve and the photoelectric sensor, and a storage area for packaging the parts. The chassis of PLC houses a 120V ac power supply, a CPU 5/2, 120V ac four and eight-terminal input modules with 120V ac com terminal connections, and a 120V ac eight-terminal output module with 120V ac terminal connection. The initial design of the project and ways to integrate them were discussed and depicted.

Step two: Design a main ladder logic diagram to integrate all the components to work together as a system.

Figure 1 illustrates a ladder logic diagram using RSLogix 500 [17] software. The program uses both the counter and the timer functions that require the precise coordination of tasks. As depicted in the figure, the process starts with energizing the conveyor's motor contactor that is latched and stays energized until the photoelectric sensor detects the presence of a part. The conveyor belt stops when a part cuts the light beam of sensor. The photoelectric sensor sends an input pulse to timer on delay T4:0 that provides 5 seconds of time elapsed for the labeling machine to mark the part. The other two timers provide

enough times for the actuator to push the part to the storage area and to retract prior to reset of the conveyor. Meanwhile, the photoelectric sensor provides an input pulse to the counter C5:1 each time a part cuts the light beam.
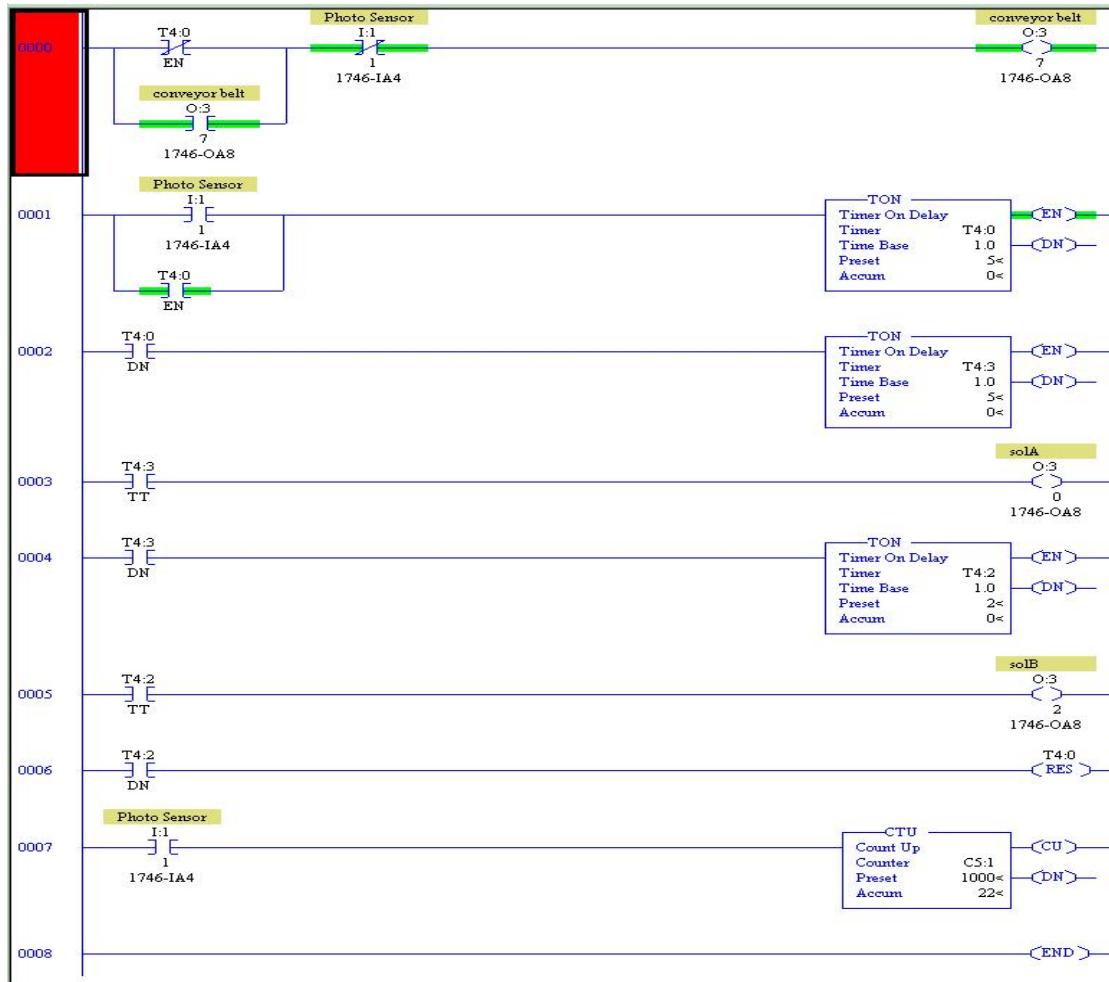

Figure 1: Ladder Logic Diagram

Step three: Wiring the components and simulating the system.

This step was a major challenge in the process to integrate the components correctly. Figure 2 shows the components that are connected by wiring to each other and figure 3 illustrates the wiring diagram. As depicted in figure 3, the solenoid valve and conveyor's motor are connected to the PLC output module and the photoelectric sensor is connected to the input module of the PLC. The solenoid valve and photoelectric sensor operate with 24V dc voltages. However, the input and output modules of the PLC operate with 120V ac voltages. The two relays with coil of 120V ac and contact of 24V dc are utilized for

providing isolation between these two circuits. A 24V dc power generator and the solenoid valve are wired to the contacts of the relays. The coils of relays are wired to the ac com terminal, on input module #2, and to the terminals 0 and 2 on the output module of the PLC. This allows the PLC to energize the solenoid valve; the actuator arm then moves forward and backward to push the part into the storage area. A relay with coil of 24V dc and contact of 120V ac is utilized to connect the photoelectric sensor to the input module of the PLC.

**Figure 2: Components of Automated Labeling System**
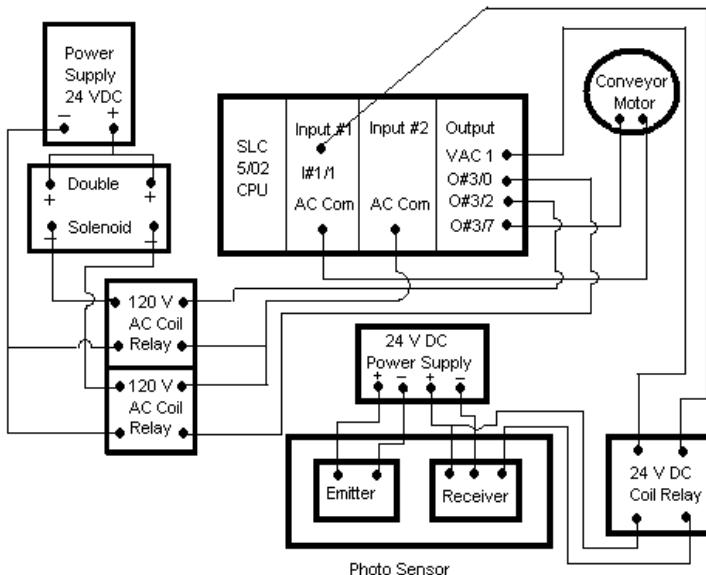
Figure 3: Wiring Diagram of Components of Automated Labeling System

The photoelectric sensor and a 24V power supply are wired to the coil of relay and one of the terminal contacts is wired to the terminal 1, on the input module, and the other terminal contact is wired to the120V ac1 terminal on the output module of the PLC. The automated labeling system was simulated successfully after finishing the wiring and troubleshooting.

Step 4: Access the system remotely.

The major effort focuses on implementing the Web-based access application software for remote users, allowing them access to remotely control the PLC unit from any computer connected to the Internet using a common web browser. The planned setup is shown in figure 4 and consists of a remote-host type setup in which users access the PLC across the Internet via a Web-based interface. A key design objective of this project is to use the ubiquity of the Internet to enable a wide range of users to use the PLC unit.

As depicted in figure 5, a web camera and an Allen Bradley PLC unit are connected to the host computer. The RSLogix 500 software is installed on the host computer. Here, the remote Web-based access application will play a key role and main functionalities will include:

* Install appropriate software on client (remote) computer including Remote Desktop, and Virtual Private Network (VPN)
* Provide user id and password to log on to the host computer connected to the PLC
* View software (RSLogix 500) on host computer to control the PLC unit.
* Write PLC program/verification/corrections and download it to the PLC unit
* View the PLC unit by web camera installed on the host computer to view process
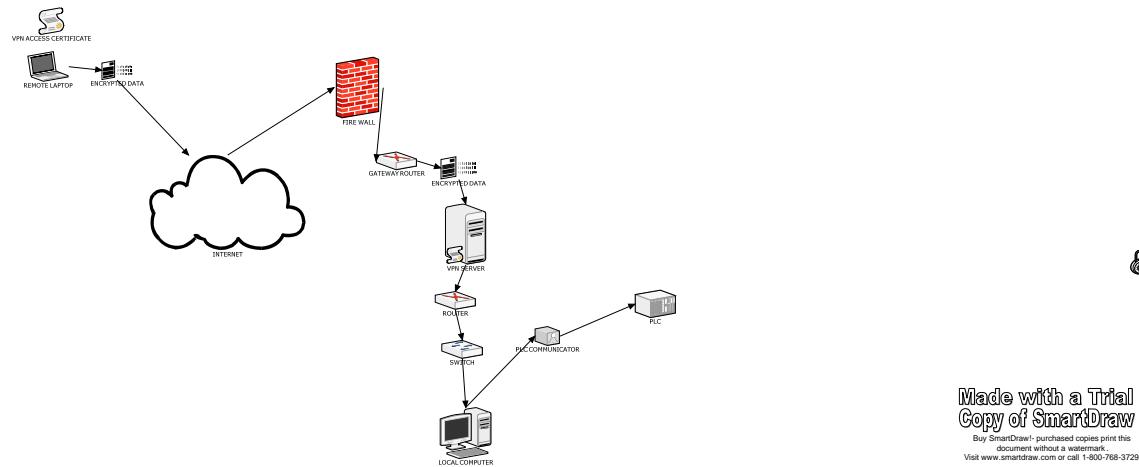
Figure 4: Remote Access Components

Figure 5: PLC Remotely Accessed System

For example, the remote user uses a client (remote) computer to log into the host computer from a remote location over the Internet, and has access to RSLogix 500 software installed on the host computer and essentially downloads the program to a PLC unit located in the host location. Figure 6 shows the login and the view of the PLC unit through the web camera on the remote computer.
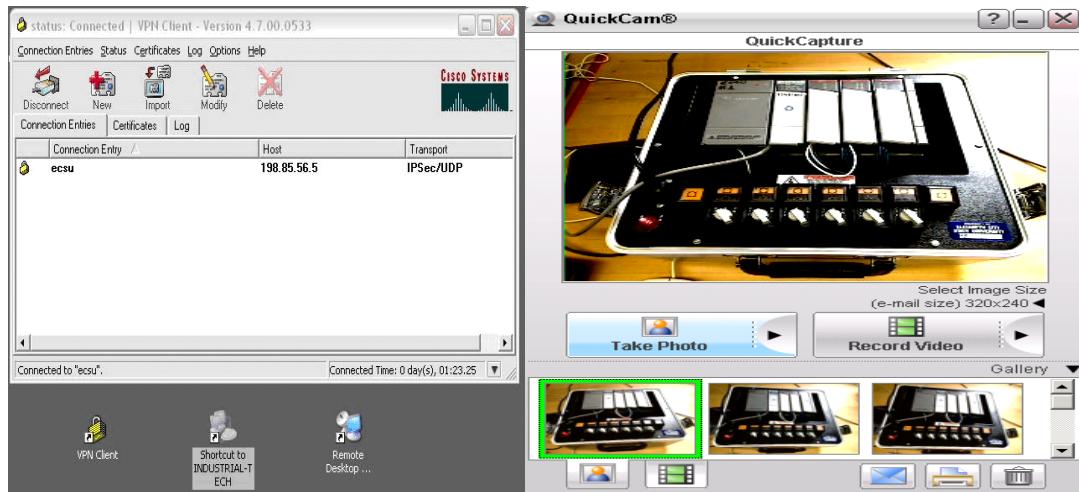
Figure 6: Login and Web Camera View of PLC Unit

Assessment of Students

In this performance assessment project, students were observed working with complex tasks associated with a real world project. The project afforded students an opportunity

to put into practice many of the competencies learned in their field of study including design, software simulation, wiring, and system construction. The Department has established program outcomes/student competencies to improve the quality of the Technology Programs and meet accountability demands. A team of faculty members utilized a capstone project matrix instrument to validate students' competencies in the areas of scientific, technical knowledge, problem solving skills, writing, oral presentation, ethical practice and team work. The matrix includes the following outcomes.

- Scientific knowledge skill: Students are able to demonstrate mathematical and scientific principles to solve technical problems.

- Technical knowledge skill: Students are able to gather, analyze and interpret scientific data to solve technical problems. Students are able to design, construct and test basic technological systems.

- Communication skill: Students are able to demonstrate effective written, oral, and presentation skills.

- Computer application skill: Students are able to demonstrate computer application skills to solve technical problems.

- Professional and ethical practice: Students are able to demonstrate policies for everyday ethical conduct, policies for research and development responsibility.

- Team work practice: Each student plays a vital role in the project and team members work and communicate effectively.

Many universities use direct assessment instruments such as written exams, oral exams, embedded questions in exams, certification exams, and other instruments. Traditional teacher-constructed tests and standardized tests yield information about student knowledge and performance. Alternative forms of assessment, such as this constructive project, may also be expanded to examine student development and progress in creativity, design, problem solving, trouble shooting, and approaches in handling real world projects.

Conclusion

The objective of this project was to illustrate the design and implementation of a PLC controlled system that could be programmed and monitored/controlled remotely. Collaboration between local and remote team members in troubleshooting and testing as well as design and system integration is an important feature of this project. This is an example of how a practical application can be used to allow a student or other team participant to work with an industrial system remotely from the actual system using the Internet and standard software. This project develops essential skills and knowledge for a

process control system, here a PLC controlled one, but this technique could be applied to almost any industrial setting including robotics and CNC.

The project is an example of a practical application which can be performed in an industrial setting as well as in a control laboratory. This experience develops skills in designing an advanced motion and process control system with practical applications in an industrial setting. Through numerous experiments on the automated labeling process, it was verified that the proposed project is an effective module for an undergraduate capstone project course.

For further investigation, expanding and developing of the protocols for remote and local user collaboration, multiple users and security of the remote access should be considered.

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