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Design and Implementation of PLC Based Industrial Application Prototypes

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Abstract

Objectives: The objective of this work is to use the PLC techniques for atomization of industrial product manufacturing to achieve high throughput and improved quality and consistency. Software validation and hardware implementation used for demonstrating the ease of operation with this control along with tuning of the entire system for the three applications are presented. The results from programming and experimental setup are presented with system hardware and software details along with the agreement between count of total time taken for each operation and the time set in program. The agreement between the parameters set in the programs and experimental results are reported. **Methods/Statistical Analysis:** This paper presents a study by simulation and experimental models for three types of applications of PLCs. The applications reported are automatic mixing and bottle filling, automatic counting and packing and automatic sorting. A specific industrial PLC IndraLogic PLC and associated software, has been employed for the work presented. The verification of the logic is carried out using Ladder diagram and based on this logic hardware has been implemented. **Findings:** The results from programming and experimental setup are presented with system hardware and software details along with the agreement between count of total time taken for each operation and the time set in program. The agreement between the parameters set in the programs and the experimental results are verified. The time parameter for mixing of liquids and filling of bottles have been set up for 35 seconds, with other two applications timing working on sensing delay. The timing parameters setup for simulations closely agree with the hardware results. The counting of packaging and sorting has been also applied for varieties of Integrated circuits and can be easily extended to PCBs. **Application/Improvements:** Apart from the above mentioned industrial applications this technique can be extended to for packing of PCBs and ICS.

Keywords: Automatic Control, Industrial Automation, Ladder Logic, Prototypes, PLC

1. Introduction to Controllers

1.1 Automatic Controllers

Automation is making the processes automatic. It is the method of using control systems to operate and control the working of industrial processing technology. Automation can be found in industries like steel factories, food and beverage industries scientific automation and so on. One of the control systems is Programmable Logic Controller, PLC, or programmable controller, using digital computer for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures.

1.2 Programmable Logic Controllers

Nowadays, PLC is widely used in applications of digital world which is applied at the industrial sector. Normally, the PLCs have been used in the industrial field, to control a mechanical movement, either of the machine or heavy machines for efficient production. The sequential operations and repeated operations in industries is normally carried out using PLC. In Food and beverage industries, bottle filling task is carried out by a machines as manual filling process has many shortcomings for example spilling of water while filling it in bottle, equal quantity of water may not be filled, delay due to natural activities of human and hygiene conditions. The automatic

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process can be smooth and the process of refilling can reduce worker cost and operation cost. An investigation into the problem using simulation has been attempted here.

Automatic segregation and directing of materials is controlled using PLCs[1]. It makes use of limiting sensor, colour sensor, proximity sensors for segregation and directing of the materials is controlled by using motor and the conveyer belt depending on the instructions specified in the ladder logic in PLC. In food packaging industry PLC is mainly used for automation purpose which helps in reducing packaging time and increases the production rate as compared with manual system. The accurate weight of an object is measured through vibrator cell and load cell and has been explained in[2,3]. The obtained electrical signal is passed to PLC machine which contains the ladder diagram of the circuit which holds the specified instructions of the system in internal storage. Hence the system is totally automated without manual intervention. Another application of PLC can be found in automatic liquid mixing and bottle filling industry and has been discussed in[4,5]. A comparative study has been made to analyse the advantages of PLC and SCADA when compared to microcontrollers like ARM and PIC. Here the automation is controlled by PLC, error indication is done through alert signal which is generated by data acquisition system has called for advancements in PLC which has taken automation industry for wider application. The sorting of the manufactured boxes considers varying parameters, such as varying height, colour, weight. This method can eliminate human error with better and sorting can be achieved faster[6]. It makes use of sensor to sense the presence and sort the object depending on the height of the box (SCADA). Entire memory accessing can be done using PLC.

The validation of the results in a PLC based application is carried out using ladder diagrams which are logic based. PLC can be programmed using ladder logic, Boolean language and functional chart. Ladder logic makes use of symbolic set of instructions to create a controller program. Ladder logic reduces the complexity of programming and it's easy to design large modules in short span of time[7,8].

This paper is divided in to four sections. Section 1 gives introduction to the controllers used in industry for various applications. In Section 2 gives the basic architecture of PLC and IndraLogic module used for the work. The implementation of three application prototypes has been discussed in Section 3. The results have been discussed in Section 4.

2. Architecture of Programmable Logic Controller

The programmable logic controller is universally used for industrial applications. The programmable logic controller architecture is mainly dependent on three functional areas which consists of processing, memory and input/output. Depending upon the input instruction, the programming of PLC has been done. The output conditions are generated to drive the associated devices, and the input/output actions are dependent on the program which is stored in the memory. The Figure 1 depicts the basic architecture of PLC which consist of input/output, communication modules and memory unit.

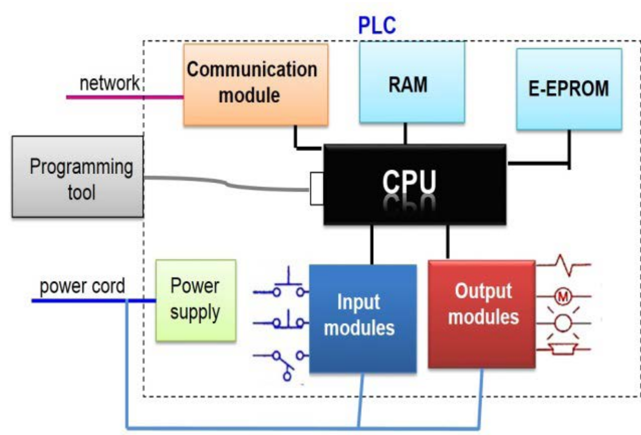

Figure 1. Architecture of PLC[9].

The input devices may be analog or digital devices which comprises of sensors, limit switches, push buttons. Outputs can be analog or digital devices like relays, motors, and LED lights. Memory consists of ROM, RAM and EEPROM. Communication module has Ethernet, PROFIBUS and RS232[10].

2.1 IndraLogic

The IndraLogic PLC and its associated software IndraWorks is the heart of the work presented here. A range of function modules (fieldbus interfaces and technology modules) are available to integrate the IndraControl into several heterogeneous control topologies. The modules use the high-speed system bus for communicating with the control processor ensuring high requirements of performance and functionality. Partial implementation of functions by the modules reduce the load on the controller CPU. Figure 2 depicts the IndraLogic L20 PLC module along with its connectivity and interfaces.

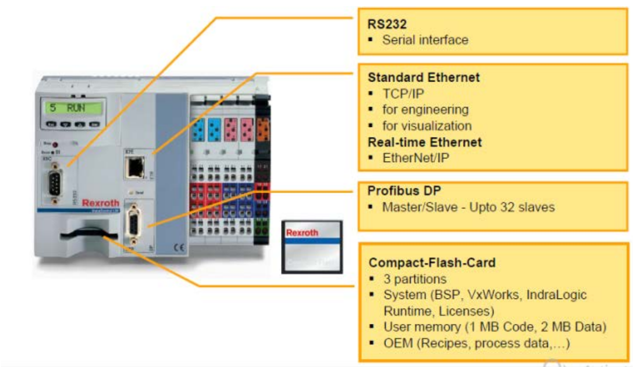

Figure 2. Indracontrol L20 connectivity and interfaces[9].

3. Design and Implementation of Various Prototypes

This section gives the implementation details of three prototypes which are used for industrial applications. The prototypes discussed are automatic mixing and bottle filling system, automatic counting system and automatic sorting of objects from the bulk manufactured products based on size and height.

3.1 Automatic Mixing and Bottle Filling System using PLC Prototype

Automatic mixing and bottle filling system using PLC has been presented. There are two objectives to be achieved in this project.

- To develop a program using PLC for automatic mixing and bottle filling.
- To develop and design an automatic mixing and bottle filling system, the prototype must reduce the human intervention in the processes.

Figure 3 shows the prototype of the proposed work for mixing of water and proteins used in beverages and juice industry. Here the sensor output is input to the PLC and outputs of PLC controls the valves, mixer and conveyor belt. In automatic mixing and bottle filling system, initially two liquids namely water and protein liquid from two different containers are to be mixed in a mixing container. The mixed solution is to be filled in the bottles one by one. The whole system has to be started by 'S1' start button. The first liquid (water) has to flow in to the mixing container for 10 seconds. Similarly second one (Protein liquid) has to flow into the mixing container for 15 seconds. The mixing operation has to take place for 20 seconds. When mixing operation completes, filling of each bottle has to take place for 15 seconds. The whole system has to be stopped by 'S2' stop button. The required components are as given below:

- Programmable logic controller for developing the software/Logic to automatic whole system.
- Containers to store liquids.
- Conveyor belt system for bottle filling process.
- DC motor for mixing operation.
- Sensors and relays to detect the bottle.

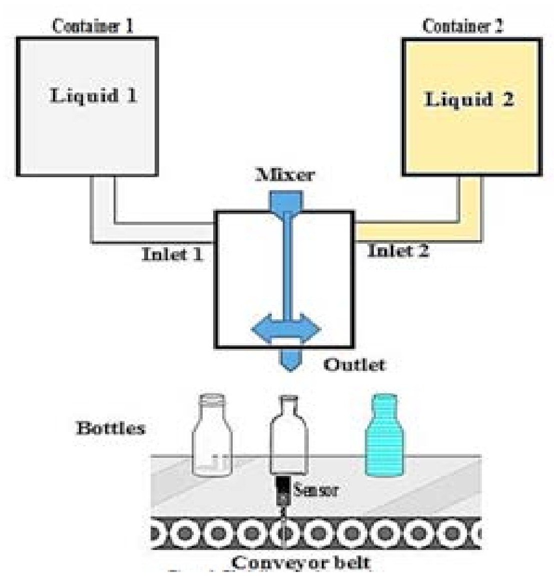

Figure 3. Automatic mixing of different liquids and filling.

3.2 Automatic Counting and Packing Prototype

The basic working of automatic counting system is, it should count the number of boxes which are sent into the carton via conveyer belt. It can be used in industries for packaging purpose. Here maximum number of boxes in each carton must be 4, so we have made use of 3 LED lights to indicate the status of the boxes present in carton. The components used are conveyer belt, object detecting sensor, LED's power supply and programmable logic controller. Figure 5 depicts the hardware connectivity of automatic counting system prototype, where the inputs are sensor, conveyer belt and outputs are LED lights.

The system gets started when the start button is ON, thus the conveyer belt is moving, when the box is placed on the belt the object detecting sensor detects the object and then the counter counts the object. We make use of three LED's that is red, yellow and green to indicate the number of boxes present in the carton. These LED lights are connected to the PLC output, when the count is less than four, yellow light is blinked, thus indicating need to pass still more boxes into the carton to reach it to maximum level. When the count reaches four that is when the number of boxes are equal to four then green light blinks indicating the maximum capacity of the cartoon. When the 5th box is on the conveyer belt, then red light is blinked and further the conveyer belt is stopped automatically indicating that the maximum capacity of the carton exceeded.

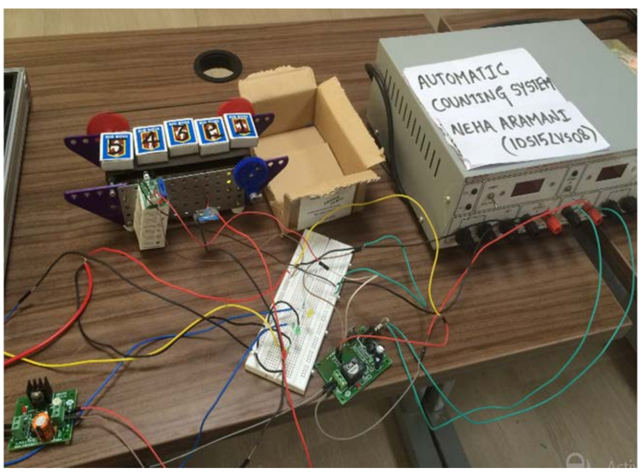

Figure 4. Experimental setup for PLC based automatic counting and packaging prototype.

3.3 Automatic Sorting Machine

Automatic object sorting is used in industries for sorting the object based on its height and further sending it to the carton for packaging purpose. Here we have used two object detecting sensors, conveyer belt, relays and programmable logic controller. In this project the sorting of work piece is done depending upon long and short work piece.

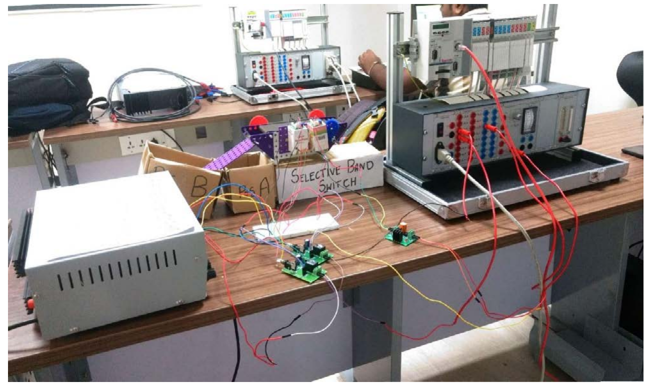

Figure 5. Experimental setup for prototype of automatic sorting system.

Figure 5 shows the prototype for automatic sorting system, here the system gets started when the start button is on. Once the system gets ON, the conveyer belt starts moving and there are two object detecting sensors placed on the belt if a long work piece is sent on the belt. Both the sensors sense the object at the same time and the work piece is sent to carton B and if the work piece is short then the sensors get ON after a short delay and the work piece is sent in carton A so this can be further taken for packaging.

4. Software Validation and Results of the Prototypes

PLC programming can be done by making use of ladder logic. Ladder logic is the symbolic instruction set which is used to create a PLC program the instruction set comprises of relay-type, timer/counter, data manipulation, arithmetic, data transfer, and program control. Programming in PLC is carried out by making use of this instruction set[11]. The ladder logic is the simplest way of coding and it reduces the complexity as compared to other programming languages.

Ladder logic validation is done for automatic counting system, the ladder logic consists of a counter to count the boxes, input S1 to start the system, three outputs to indicate the status of objects placed in the carton. Figure 6 depicts the ladder logic for automatic counting system the logic consists of counter and input/output commands.

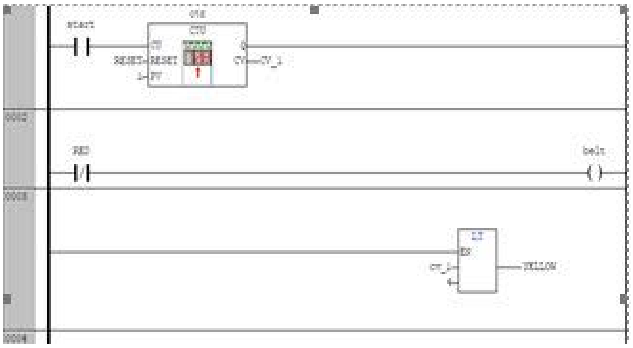

Figure 6. ladder logic for automatic counting system.

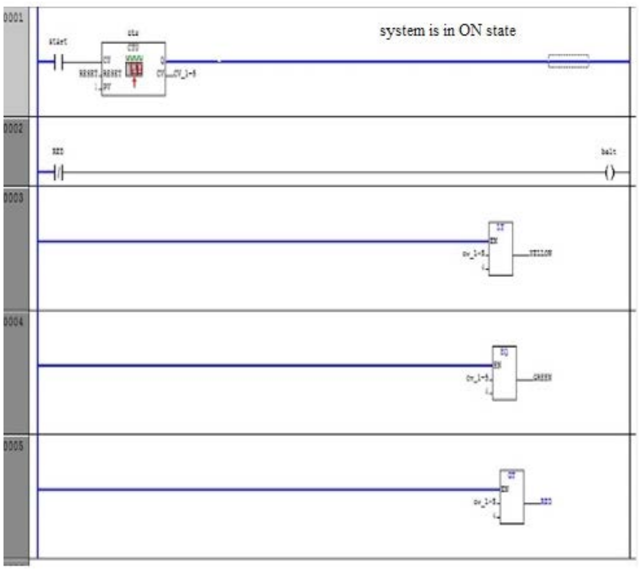

Figure 7. Output status when count is greater than 4.

Figure 7 depicts the status of the ladder logic when the system is in ON state and also it gives the status of ladder logic when the count is greater than 4. When blue line from the Figure 7 indicates that the system is in ON state. The software code for automatic counting system is shown below.

```
PROGRAM PLC_PRG
  VAR
  YELLOW AT %QX0.0: BOOL;       //  output assigned to QX0.0
 GREEN AT %QX0.1: BOOL;         // output assigned to QX0.1
  RED AT %QX0.2: BOOL;          // output assigned to QX0.2
 reset AT %IX0.0: BOOL;         // resets the system
 cv_1: INT;                     // integer value to start the count
  PV:INT;                       // integer value of maximum count
 start AT %IX0.1: BOOL;         // system gets ON with input IX0.1
 ctr: CTU;                      // counter block
 belt AT %QX0.3: BOOL;          // assigning conveyer belt at output QX0.3
 RED1: BOOL;
 END_VAR
```

Similarly, three types of prototypes have been designed and implemented. The hardware prototype is found working successfully. The logic has been verified using ladder logic as given in the previous section. Figure 8 shows the prototype of mixing of two liquids automatically.

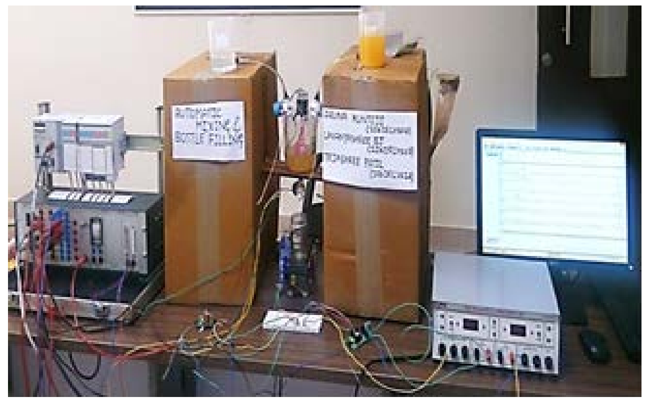

Figure 8. Hardware setup for the PLC control.

The timings recorded for the bottle filling and mixing operations have been tabulated as given below:

Table 1.

Operation	Time constraints
Liquid 1 (water)	10s
Liquid 2 (protein mix)	15s
Mixing	20s
Bottle filling	15s

5. Acknowledgment

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