A PLC CONTROLLED MODEL OF A DRINKING WATER PACKAGER ASSEMBLY LINE

Sheik Khairul Anwar B. Sheik Ihsanuddin
B.Eng. (Hons) Electrical
Faculty of Electrical Engineering
Universiti Teknologi MARA
40450 Shah Alam
SeIangor Darul Ehsan

Abstract- *A model of a packaging assembly line is constructed and is to be controlled by a Programmable Logic Controller (PLC). The assembly line mainly consists of a conveyor system with four stations to execute specific tasks. These stations are equipped with sensors, actuators, and indicators to help students visualize the role of PLC in the production industry. It is hoped that students will understand better the operations and applications of ladder programming and the PLC.*

Keywords: Programmable Logic Controller (PLC), CX-Programmer, Ladder Diagram, Conveyor, Sensor, Actuator, Valve, Pneumatic.

1.0 INTRODUCTION

A conveyor is usually referred to as a mechanical apparatus that transports materials, packages, or items being assembled from one place to another. It is very widely used in the production industry and helped boost productivity miraculously. Among other areas of conveyor applications are in the mining industry, solid waste compacting systems and in the ordinary supermarket counters.

In this project, a plastic chain conveyor, which is driven by a motor, is used to transport plastic cups, from the beginning, up to the end of an assembly line. The cup will be transported through four stations, for specific tasks and will undergo several process until is ready to be packed. All the process of water filling until packaging will be simulated with pilot lights. These pilot lights will indicate the operation of various actuators such as pneumatic valves, and pistons. The cups will be transported on a specially designed base. At every station, an inductive proximity sensor will detect the arrival of the cups on their bases while pneumatic valves are used to actuate clamps to hold the base while specific process is conducted. This method will enable the conveyor to move constantly without stopping, hence improving the productivity.

All these devices are connected to the input and output modules of a PLC hence enabling the PLC to control every operation of the system, according to the ladder program downloaded.

1.1 PROGRAMMABLE LOGIC CONTROLLER

A programmable logic controller is a user friendly electronic computer that carries out control functions of many types and levels of complexity. To achieve proper control, the programmable logic controller essentially uses a controller logic called ladder diagram. The resulting ladder diagram takes the place of the relays system and much of the external wiring required for control of a process. [1]

A programmable controller is basically a CPU (Central Processing Unit) containing a program and connected to input and output (I/O) devices. These connect the PLC to sensors and actuators. [1]. PLC read limit switches, temperature indicators and the positions of complex positioning systems. Some even use machine vision. On the actuator side, PLCs drive any kind of electric motor, pneumatic or hydraulic cylinders or diaphragms, magnetic relays or solenoids. The input/output arrangements may be built into a simple PLC, or the PLC may have external I/O modules attached to a proprietary computer network that plugs into the PLC. The input devices in this project are inductive proximity sensors toggle switches and push buttons that produce signals that can be input into the controller. The output devices of the system are relays, pilot lamps, and pneumatic valves. [3]

1.2 OMRON C200HS CPU21

The PLC model used to control this system is the C200HS CPU21. It is of the rack-style PLCs, which have processor modules with separate I/O modules, which may occupy many racks. These often have thousands of discrete and analog inputs and outputs. Often a special high speed serial I/O link is used so that racks can be remotely mounted from the processor, reducing the wiring costs for large plants. The C200HS CPUs come equipped with 16 KW of RAM in the PC itself, so a very large memory capacity is available without purchasing a separate Memory Unit. [1]

Figure 1: Omron PLC (C200HS)

A C200HS CPU Rack consists of three components: (1) The CPU Backplane, to which the CPU and other Units are mounted. (2) The CPU, which executes the program and controls the PC. (3) Other Units, such as I/O Units, Special I/O Units, and Link Units, which provide the physical I/O terminals corresponding to I/O points. A C200HS CPU Rack can be used alone or it can be connected to other Racks to provide additional I/O points. The CPU Rack provides three, five, eight, or ten slots to which these other Units can be mounted depending on the backplane used. [1]

2.0 METHODOLOGY

The sequence of task executed in order to realize this model must be planned carefully. This should be practised always as automation involves the safety and health of human beings more often than not. Most of these steps can only be taken after the preceding step has been performed. Basically, the processes involved are:

i. Develop the operation and flowchart of the assembly line
ii. List down the input and output devices, and assigned addresses to them
iii. Design and develop ladder diagram of the control system
iv. Wire the hardware to PLC
v. Test the system, evaluate, and make the necessary modifications.

2.1 PLANNING STEP

- ✓ Define the process to be controlled
- ✓ Make a sketch of the process operation
- ✓ Create a written steps sequence listing for the process
- ✓ Create the ladder logic diagram that will be used as a basis for the PLC program
- ✓ Consider the safety of the operation and make additions and adjustment as needed

2.2 PROCESS DISCRIPTION

This project is a model of an automation system that actually fills seals, stamps information and sort cups of drinking water. It consists of a conveyor and four stations, which is the Filling station, sealing station, stamping station, and sorting station

The conveyor used is a specially constructed conveyor for educational purposes. It has four stations or stops. Each stop is equipped with an inductive proximity sensor. The cups will not be conveyed directly on the conveyor, but is placed on a specially designed base, with metal plates attached to the bottom part. When the base reaches a stop, the sensor will detect the metal attached to it and the PLC will be programmed to activate a pneumatic solenoid to clamp the base. This allows the necessary process to be completed at each stop.

The Filling Station

The filling station consists of a main tank (or a supply of produce), and a pre-fill tank with the same volume as the cup. The pre-fill tank will be equipped with two inductive sensors. One to detect if it is empty (Empty sensor) and the other one for full (Full sensor). There are also valves fitted in this station. One is at the outlet of the pre-fill tank (PV) and the other at the outlet of the main tank (or supply of produce) (TV). All these actuators and sensors are simulated with indicators and switches. The sequences of events are as below:

1. When cup arrives at the first station, the base will be clamped.
2. Pre-fill valve will open and start filling cup.
3. When pre-fill tank is empty, valve will shut.
4. Main tank valve will open to fill pre-tank.
5. When full, clamp will release base, and cup starts moving again.

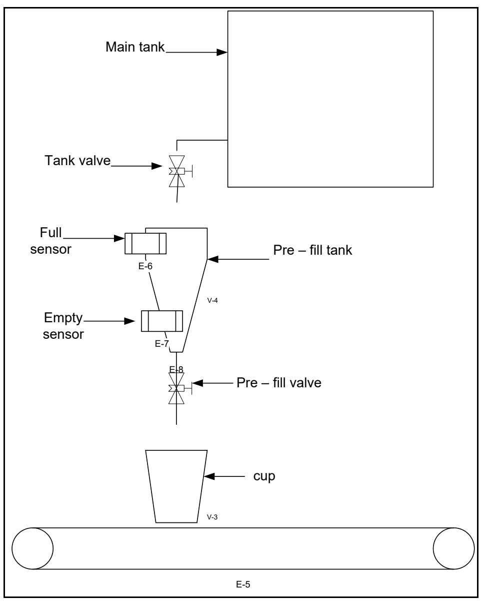

Figure 2: The filling process

Sealing Station

The sealing station consists of two pneumatic pistons, a plastic cover holder, and a heating element. The heating element is mounted at the end of one of the pistons and it is round with a diameter as same as the cup. It will be in 'off and on' mode, according to the programmed timer. This is to ensure that the heating element is not overheated. The first piston is to place the plastic cover into place, and when the second piston extends (heating element); it will lightly press the mouth of the cup, enabling the plastic cover to melt a little hence sealing the cup. The sequences of events are as stated:

1. When the cup reaches this station, the base will be clamped
2. First piston will be extended for 6 seconds, and than automatically retracted.
3. After 2 seconds the first piston is extended, the second piston extends for 4 seconds and then automatically retracted.
4. After 6 seconds, both pistons are retracted and clamp will release the base.

Stamping Station

The stamping station is equipped with only one piston with a stamp at the end. It will extend to stamp the necessary information on top of the cup. It will extend 2 seconds and then automatically retracted. The sequences of events are as below:

1. When cup reaches this station, the base will be clamped
2. Stamping piston will extend hence stamping information on the cup.
3. After 2 seconds, the piston will be automatically retracted and the base is released.

Sorting station

The sorting station consists of only one piston and a count indicator. Once the system counts up to ten cups, the count indicator will turn on.

3.0 SOFTWARE AND HARDWARE DEVELOPMENT

The development of this project is broken down into two major parts which are the software and the hardware. When both parts are ready, they are interfaced.

3.1 SOFTWARE DEVELOPMENT

The software or otherwise called ladder programming of this system is developed using the CX-Programmer produced by Omron.

Figure 4: CX-Programmer Version 4.0

Among functions used in this ladder program are timers and counters. This software enables online programming and editing, which means, one could modify the program straight away when an error is detected while troubleshooting the program. [2]

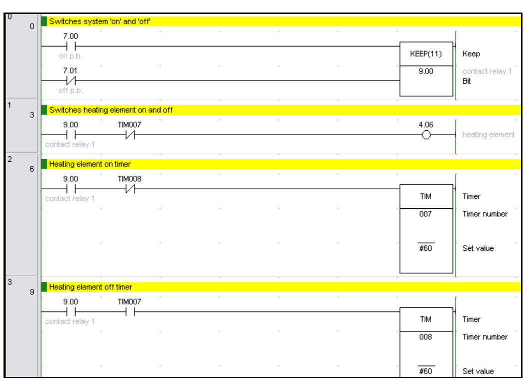

Figure 5: A part of the ladder program

Once a program is developed, it could be downloaded the PLC CPU from any computer with an I/O port via an RS-232 cable. Downloading a program is very convenient and would only take a few seconds depending on the size of the program.

3.2 FLOWCHART OF THE SYSTEM

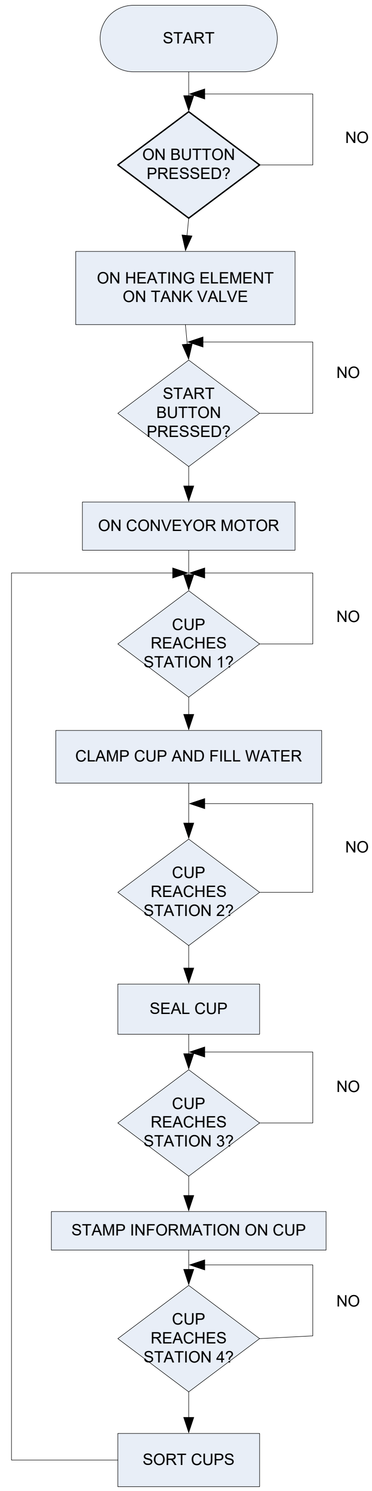

Figure 3: Flowchart of the conveyor operation

The assembly line model system starts when the 'on' button is pressed. When the system is switched on, the heating element and tank valve will be switched on. The tank valve will stay on until the pre-fill tank is full and the heating element will be switched on and off continuously to avoid overheating. The system will stay in that condition as long as the 'off' button is not pressed. When the 'start' button is pushed, the conveyor motor will start to run. The system will stay in this condition, until one of the stations detects the arrival of a cup. If one of the stations detects the presence of a cup, the cup's base will be clamped and appropriate process will be executed according to the predetermined process of the station.

3.3 INTERFACING OF HARDWARE AND THE SOFTWARE

The figure below shows the wiring of the hardware to the PLC. The wiring connection from hardware to PLC must be properly wired according to the address of the input and output assignments. Other points to be considered are the common or ground connections and the voltage supply of the actuators.

The indicators used in this model is light up using AC current, meanwhile, a PLC output only acts as a contact point. To solve this problem, a relay circuit board has to be constructed. Once an output port is closed, a current loop is established hence activating these relays, enabling the AC current to flow through the indicators.

The plunger and clamps used in this project are pneumatically activated, via a pneumatic valve. These valves operate on 24V direct current. Hence, it can communicate directly to the C200HS, and receives voltage supply from the CPU itself.

Other components connected to the C200HS PLC are, inductive proximity sensors, toggle switches and push buttons. All these components run on direct current.

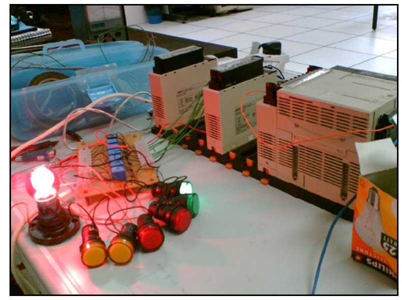

Figure 6: Wiring for the AC indicators and relay circuit.

4.0 RESULTS

The model of a drinking water packager assembly is tested stage by stage. Testing started with devices standing alone, without the PLC. Pneumatic valves, actuators, sensors, switches, and indicators were tested with their respective level of voltage supply and appropriate input signal. The next stage of testing was the execution of ladder programming. The program was downloaded into the PLC and input signal in form of voltages were given, to observe the output signal implicated. The program was corrected online where error was detected. After all this was done, every component and device wiring was made to the input and output module of the PLC, and the system was tested once again. This time with all the components working accordingly, the program was altered once more taking into consideration the timing of execution. Timer values were modified so that the system is well integrated and runs smoothly.

It takes approximately 50 seconds, for the cup to go through all four stations, assuming that the flow rate of water from pre-fill tank is fixed and takes about 3 seconds to fill the cup. These time test, is done by, measuring time, using a stopwatch, from the moment cup reaches the first station until it is sorted by the sorting piston.

Final testing, involves the acquiring of timing diagrams. Timing diagrams for various parts were collected and shown below.

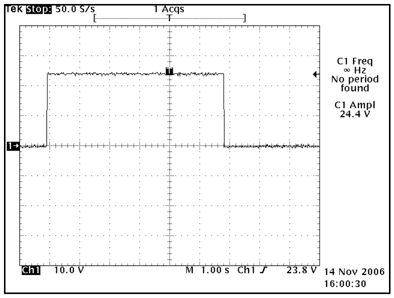

Figure 7: Switching Element Timing Diagram

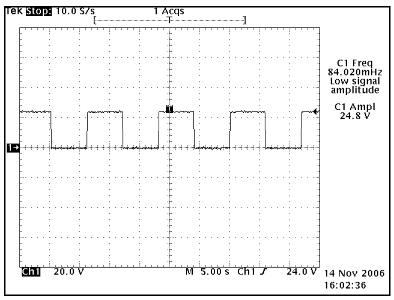

Figure 8: Switching Element Timing Diagram

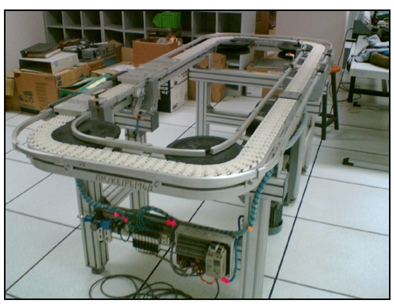

Figure 9: Testing of conveyor motor without PLC

5.0 DISCUSSION

The construction of this assembly line model is basically divided into two major parts; the software and the hardware. Both parts require proper attention and systematic approach to ensure the model work according to the design.

Developing the software starts with identifying the exact step by step operation. Operation of the system is listed in sentences so that the whole task is visibly clear. From the description of operation, a table listing all the inputs and outputs are tabulated. The next step is to assign addresses to all the inputs and outputs.

output	add	input	add	contact relay	add
t.v	0400	on	0700	contact relay 1	0900
c.v.	0401	off	0701	contact relay 2	0901
coverpiston	0402	start	0702		
sealingpiston	0403	full	0703		
stampingpiston	0404	empty	0704		
sorting piston	0405	station1	0705		
heating element	0406	station2	0706		
count light	0407	station3	0707		
clamp1	0000	station4	0708		
clamp2	0001				
clamp3	0002				
clamp4	0003				
conv motor	0004				
stopper 1	0005				
stopper 2	0006				
stopper 3	0007				
stopper 4	0008				

Figure 10: Tabulation of input and output addresses

After the all the input and output devices were assigned an address each, the ladder program is constructed. Special attention was given to critical process especially regarding safety. When the programming was done, the PLC was connected to the computer using an RS-232 cable to enable simulation via CX-Programmer. When the program is completed, it is downloaded into the PLC and is ready to be tested with the hardware.

The hardware is constructed stage by stage, by firstly, designing the relay circuit for switching of the AC indictors. The relays used are of the 5 pin 12V DC relays. Once the circuit is ready, it is tested with the indicators and AC supply.

The next stage was the pneumatic components. The pneumatic plungers were given a pressure supply from a pneumatic compressor, and the supply is controlled with a 24V DC 5/2 way piloted pneumatic valves. Tests were conducted by giving the valves 24V DC voltage supply and observing the operation of the plungers. If a problem arises, the system was troubleshooted and the proper modifications were made.

The last stage was to test the switches and sensors. This stage was an easy stage to test and construct. At last all the components and devices were integrated and tested with the program in the PLC.

Constructing this model was quite a challenge as the wiring requires very detail concentration. Among problems faced were certain parts of the system does not work. Most of the time, the problems are because of imperfectly connected wires and improper grounding. All the devices must be grounded to the same point depending weather they are defined as an input of an output. Problems also arise from design of the ladder program, where counters were not properly reset, and contacts were not interlocked.

6.0 CONCLUSION

Programmable Logic Controller (PLC) is proven to be a more simple and effective way to do automation. It replaces the relay functions and eliminates the needs for hardwired installations. Furthermore, the ability of the controller to be reprogrammed has contributed to less set up time and easier troubleshooting in production floors. The control operation of the PLC has been successfully implemented and demonstrated in this project, hence it is hoped that this model could help students understand PLCs better, and realize the importance of a programmable controller in the production industry.

7.0 FUTURE DEVELOPMENT

This model of assembly line has a lot of improvements to be done, be it neither the software nor the hardware.

Among areas which could be developed in the future are; replacement of the indicators with a proper pneumatic pistons and water control valves to create a more realistic experience for students. Replacement of the switches used to simulate water level in the pre-fill tank with actual sensors, so that the operations of the inductive sensors could contribute to the effectiveness of this project as a educational device. And lastly, but not least, software could be upgraded to a more simplified ladder programming using more complex functions.

8.0 ACKNOWLEDGEMENT

I would like to express sincere appreciation and gratitude to Puan Rosidah Sam for her guidance, comments, encouragement and support to complete my final year project up to this stage. Special thanks also go to Dr Ahmad Maliki Omar for his patience and willingness to share his expertise in the area of automation. This model would never be a reality without their advice, guidance and technical supervision from the early stage of designing until the process of construction and troubleshooting.

The author also would like to thank his parents and all friends who have given encouragement and support in making this project a success.

9.0 REFERENCES

[1] OMRON C200HS Operation Manual

[2] CX-Programmer User Manual

[3] Omron “A Beginner Guide to PLC” Omron Singapore, 2001

[4] Introduction To PLC (from Dr. Maliki’s class)