PLC-Controlled of a Conveyor System I

(Supervisor: Dr Nordin B Saad)

By

LIM CHIN YONG

(Student ID: 12358)

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Electrical & Electronics Engineering Department

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

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1.0 Abstract

PLC-Controlled of a Conveyor System I project is an experimental based project which aims to help the author understands the basic operation of a Flexible Manufacturing System and to operate the Flexible Manufacturing system using a structured method of programming routines via PLC. From Universiti Teknologi PETRONAS's point of view, the target is to study and operate the upgraded Conveyor system in Automation Laboratory. Hence, in Final Year Project I, the author runs simulation by using Automation Studios 5.0 with a given case study to familiarize with the real system. The study is done because system upgraded from custom setting to programmable setting, hence in Final Year Project II, author are required to operate the visual inspection system of the conveyor system in the lab. By having the basic knowledge of structured way of PLC programming, the author is expected to operate the real system in Final Year Project II. From industry point of view, the main purpose of doing this project is to develop a programming routine for Flexible Manufacturing System-controlled PLC via structured method. Hence, engineers can easily understand the operation of the complicated system and have better control on industrial automation system. By practicing this, highly dependent on vendor for operating the system can be eliminated. In Final Year Project I, the research process is divided into three main phases, which are Research Process Phase I, Phase II and Phase III. In Research Process Phase I, feasibilities studies, collection of sources, generation of proposal and literature review has been conducted. For Research Process Phase II, the author focuses on Studies on automation studio software and application of ladder logic diagram programming language. Simulation of cases study and result and discussion on sample case study simulation are the points of focus for Research Process Phase III. As a conclusion, the project of PLC-Controlled of a Conveyor System I is introduced because it has a better control on the behavior of the system and help the industry to produce better quality products with less defect.

2.0 Project Background

2.1 Introduction/ Background of Study

PLC-Controlled of a conveyor system is one of the projects based on the ideas of Flexible Manufacturing System. In 1960s, the ideas of an FMS was proposed in England under the name "System 24", a flexible machining system that could operate without human operators 24 hours a day under computer control[5]. In the early years, Flexible Manufacturing Systems were large in size and complex in design. It consists of dozens of Computer Numerical Controlled machines (CNC) and sophisticate material handling systems. In recent years, it has evolved into a small version of Flexible Manufacturing System, called Flexible Manufacturing Cells which have three level of manufacturing flexibility, which are basic flexibility, system flexibility and aggregate flexibility. In general, a flexible manufacturing system (FMS) can be defined as an automated manufacturing system consisting of multifunctional machines that are interconnected by a material handling system, all controlled by a computer system [3]. Nowadays, Flexible Manufacturing System receives growing popularity in manufacturing industry due to improvement on company capital utilization by lower cost and faster changes from one part to another of FMS. Other than that, automated system has reduced the number of workers needed for operating the system and reduced error, repair, rework and rejects. Hence, it experiences lower direct labor cost and indirect labor cost. Reduction in inventory also happens due to the planning and programming precision of Flexible Manufacturing System. Due to the automated control on the system, Flexible Manufacturing System has better control on the behavior of the system and produce better quality products. However, Flexible Manufacturing System has some drawbacks at the same time. The initial cost of installing the automated system is very costly and expensive because of the high technology and sophisticated manufacturing system. Other than that, Flexible Manufacturing System is a substantial pre planning activity where the actions are programmed into the systems before running the systems. As a result, pre-planning activities is essential and fewer errors are expected. In the future, Flexible Manufacturing System is expected to grow rapidly and the task for designing and process planning are going to be fully automated. In this project, the purpose is to develop a structured way of programming by using Programmable Logic Controller (PLC) for a conveyor system. Conveyor systems are often modular in nature and can be built up from basic units (or primitives) such as linear conveyor modules, either belt or roller type, and connecting devices such as lift stations and conveyor junction modules [1]. By applying control program like Ladder Logic Diagrams (LLDs), the coded program can be easily executed by Programmable Logic Controllers.

2.2 Problems Statements

Figure 1- Flexible Manafacturing System Laboratory

In Universiti Teknologi PETRONAS, there is a Flexible Manufacturing System lab equipped with a conveyor system, a Kuka Robotic Arm, a programmable controller (computer) and a Programmable Logic Controller in Electrical and Electronics Engineering academic building. However, for the past years, this lab is only function as a demonstration lab, where no programming changes are allowed to implement into the system. By executing the fixed control application program that is stored within the PLC memory, the PLC is constantly monitoring the state of the system through the input devices' feedback signal. The feedback signal is then used to decide and implement course of actions that should be carried out by the output devices by using the program. Hence, in this project, studies on Flexible Manufacturing System and Programmable Logic Controller are conducted to progress with the works on the upgraded flexible manufacturing system, where the controller system is programmable.

The main challenge faced for the project of PLC-controlled of a conveyor system is to understand the system or layout of the conveyor system in the lab. Moreover, the suitable programming language that is needed to program the upgraded Flexible Manufacturing System is also equally important. Another challenge for this project is to understand the behavior of the conveyor system so that appropriate actions can be implemented by writing suitable programming language.

By understanding the system and layout well, the used sensors and actuators are known. Hence, suitable course of actions can be performed by activating the sensors and actuators. When the ladder logic diagrams are developed, the system will operate as programmed by performing certain tasks. Basically, the conveyor system can be divided into three main sections, which are the image processing section, package movements sections and pick and place operations.

In-charge section: Visual Inspection Section

The basic description of sequences for visual inspection section

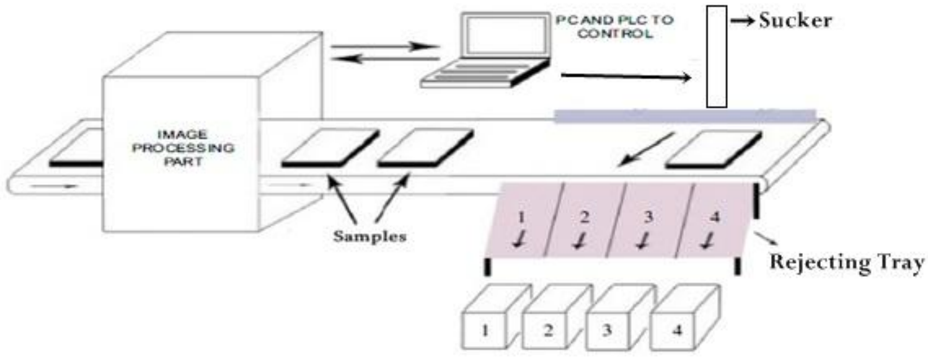


Figure 2- Visual Inspection Section

1. Start.
2. The conveyor's motor works.
3. Wait for a sample.
4. If Yes, Stop the motor of the conveyor. If NO, return to Step 3.
5. Capture the sample.
6. Determine whether it is the desired one as programmed.
7. Start the conveyor.
8. Stop the conveyor when the sample reaches a platform for select and deselect, called reject inspection station.
9. If it is rejected, the sample is being sucked and placed on the rejecting tray. If it is accepted, the conveyor continues moving load back to Component Station for storing purposes.
10. Repeat the procedures until Power off.

2.3 Objective

This report studies the application of PLC controlled of a conveyor system in the Flexible Manufacturing System Laboratory. The objectives are as followed:

- To study Flexible Manufacturing System and its application in the manufacturing industry.
- To investigate the capability of a PLC as a controller.
- To understand the basic operation of a conveyor system.
- To operate 3 different sections of a conveyor system, which are visual inspection system, conveyor belt system and pick and place system.

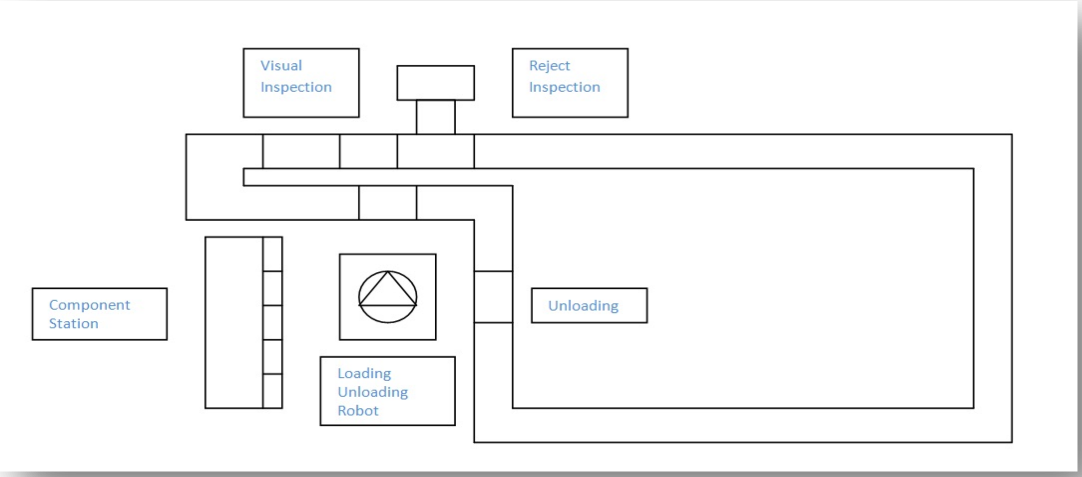


Figure 3- Engineering drawing of a conveyor system

2.4 Scope of Study

The scope of the research works is summarized as follows in order to achieve the objectives within the time frame and funds allocated:

- To familiarize with the FMS that to be upgraded to allow modification of routines via PLC programming language where the current arrangement does allow only demonstration.
- To develop routines for controlling FMS via PLC and to perform experiments to verify the correctness of the developed routines.

3.0 Literature Review

3.1 Programmable Logic Controller education

Erdal Yilmaz and Seven Katrancioglu [1] showed that with the advance of control system nowadays, programmable logic controller equipment has been growing in popularity every day. As a result, programmable logic controller is chosen as a medium of education because the price of PLC is getting cheaper in the advanced stage and complex control systems. In PLC education, it helps students to master in this subject by practicing in the laboratories. *Hany Bassily, Rajat Sekhon, David E.Butts and John Wagner* [2] supported the statement by saying that programmable logic controllers and material handling experiments in the educational laboratory is playing an important role for encouraging multi-disciplinary hands-on engineering discovery within team setting among students. A well rounded engineering curriculum should be provided in the classroom and laboratory because engineering graduates have generally required practicing material handling and other multi-disciplinary concepts in the field. Hence, this project is mainly to learn the basic way to operate and program the upgraded Flexible Manufacturing System which will be developed as a research and development laboratory in the future.

3.2 Programmable Logic Controller overview

W. Huet, A.G.Starr and A.Y.T. Leung [7] mentioned that Programmable Logic Controllers (PLC's) are used by most Flexible Manufacturing Systems (FMS's) as control process controllers because they are adaptable, user-friendly, modular, and can be obtained at low price. *Erdal Yilmaz and Seven Katrancioglu* [1] described PLC as a system which can produce for use which is suitable in industrial environment.PLC integrates different control processes many input and output ports. Basically, PLC is the heart of the control system in an automated system. By executing the control application program that is stored within the PLC memory, the PLC is constantly monitoring the state of the system through the input devices' feedback signal. The feedback signal will then used to determine the course of actions that should be carried out by the output devices by using the program logic.

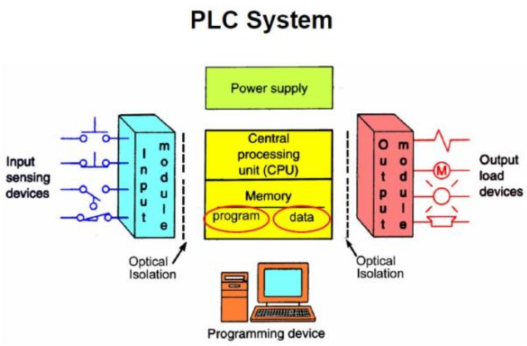


Figure 4- PLC System overview

3.3 Flexible Manufacturing System

Norachai Nampring and Sakol Punglae [5] focused on the point that Flexible Manufacturing System consists of several machine equipments along with part and tool handling devices such as robots, arranged so that can handle any family of parts for which it has been designed and developed. In today industry, people are seeking for benefits from flexibility. Hence, this is only feasible when a production system is under complete control of FMS technology.

3.4 Conveyor System

W.H.R Yeung and P.R.Moore [6] stressed that in an automated assembly system, Flexible Conveyor System indicates a number of distinct features can be identified as important in a system. Firstly, it should be able to support different parts of product mix simultaneously. Other than that, it has a relatively large number of workplaces distributed around the conveyor system. Besides, the entire system should be able to reconfigure to allow it to service new product mixes. Robotic systems and other intelligent devices are usually employed which require to work in a cooperative manner.

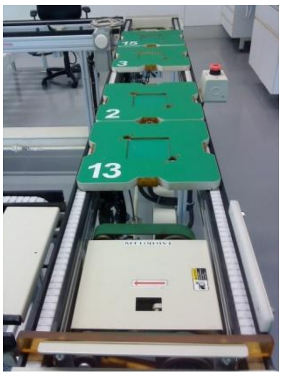
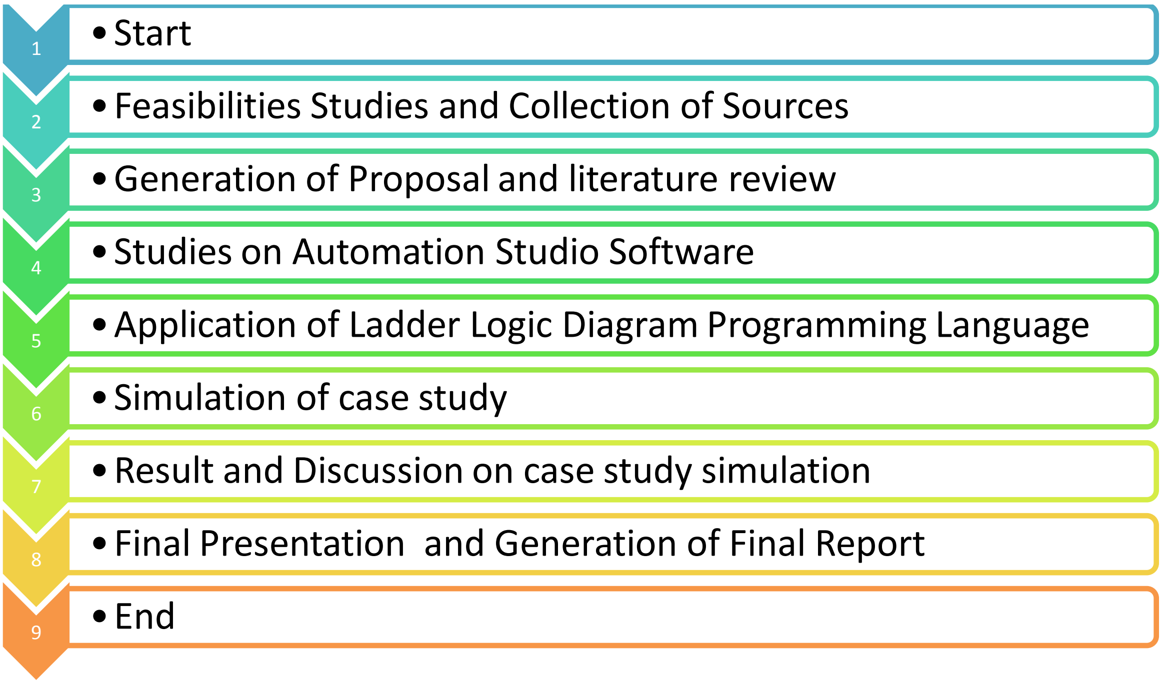


Figure 5- Conveyor Belt

Hany Bassily, Rajat Sekhon, David E. Butts and John Wagner [2] mentioned that for modern conveyor system, engineers are partitioning and dividing conveyor system into smaller focused segments that can be controlled independently depending on the factors such as localized product flow rate, need for product buffering and process inconsistencies. *M.Alper Selver at el* [4] stated that in a conveyor system, it should consists of a conveyor belt, a serial port communication system, pneumatic pistons, a programmable logics controller (PLC) and its control circuit.

4.0 Methodology

4.1 Research Methodology



4.2 Project Activities/ Research Process

Research Process Phase I includes:

i. Feasibilities studies and Collection of sources
ii. Generation of proposal and Literature review

PLC-Controlled of a Conveyor System I final year project is experiment based and it is a study of Programmable Logic Controller of a conveyor system in the Flexible Manufacturing System laboratory. For Final Year Project I, feasibilities studies on the topic and collection of useful and relevant sources are practiced. Then the extended proposal and the literature review are done based on the useful sources. In literature review, the author includes the theory and the feasible studies on Programmable Logic Controller experiments, Programmable Logic Controller overview, Flexible Manufacturing System and Conveyor System.

Research Process Phase II includes:

i. Studies on Automation Studio Software
ii. Application of Ladder Logic Diagram Programming Language

<u>Automation Studio Software</u>

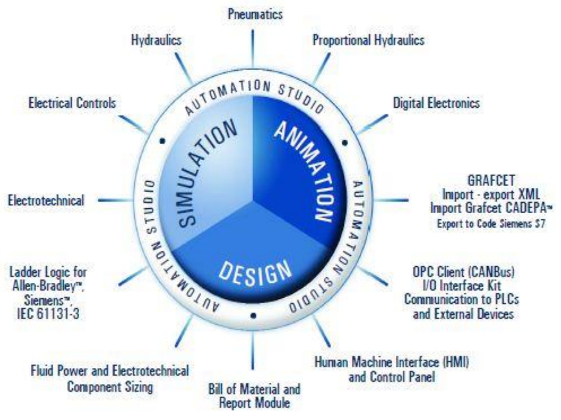


Figure 6- Automation Studio overview

Automation Studio software is software that offers its users to design, run animation, simulation and system analysis functionalities in a user-friendly work space. It is the tool of choice for learning hydraulic, pneumatic, electrical, and automation technology. Furthermore, it is an ultimate software solution to expose its users to the basic concepts and ideas on the industrial technology nowadays.

By using Automation Studio software, PLC-Controlled of a Conveyor System is basically the combination pneumatics system and electrical control (IEC, JIC) system. From Automation Studio software, the configuration of pneumatics system shows the realistic behaviour of the conveyor system. For example, 5/2 ways normally closed (NC), electronics actuated, spring-returned solenoid valves and so forth. The Electrical (IEC, JIC) control is used to interact the component from the pneumatic system to create electrically controlled systems. It includes push buttons, limit switches, contact normally on, contact normally off, timers, counters and so forth.

As a result, Automation studio 5.0 is suitable software for Final Year project I of PLC-Controlled of a Conveyor System. It represents the accurate system behaviour in a dynamic and visual way. All the generated components are animated and the lines and wires are colour-coded according to their state during the simulation. Through the simulation, it can help to explain the real systems operation.

Application of Ladder Logic Diagram Programming Language

Ladder logic diagram is simply a symbolic representation of electrical circuit which is used to programme the Programmable controller. Ladder diagram is the most popular languages designed for user communication with PLC. Since the symbols of the components in the ladder logic diagram looked similar to schematic symbol of electrical devices, engineers who work on PLC can easily understand a ladder logic diagram languages without any guidelines. It is named as Ladder logic diagram because the program is drawn pictorially and looks like a ladder as shown from the diagram below. Unlike another type of programming such as C++ or Java, it does not use alpha numeric characters. The components available in the ladder logic diagram are the field devices such as push buttons, limit switches, lights, and controlled variables such as motor starters, solenoid operated valves.

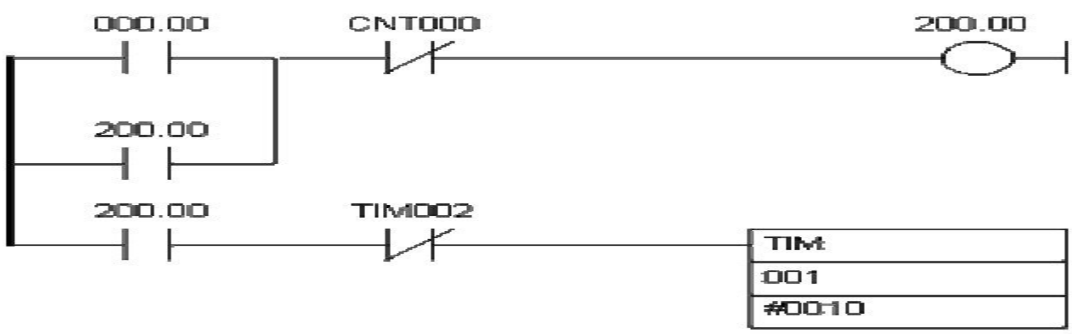


Figure 7- Ladder logic diagram

Research Process Phase III includes:

i. Simulation of cases study
ii. Result and Discussion on sample case study simulation

Research process Phase III is the simulation of case study by using Automation Studio software. Automation Studio allows the author to virtually test the specific type of systems and reinforce the understanding of systems interactions. The main purpose of case study simulation is to expose the author to the real systems by practicing the proper way of developing programming routine via structured method. A structured way of programming routines consists of description of sequence, timing diagram and ladder logic diagram. Each and every part is essential in developing proper system behaviour.

4.3 Required Tool:

(1) PLC software: Automation Studio

4.4 Gantt Chart and Key Milestone

No	Details	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic: PLC controlled of a Conveyor System														
2	Preliminary Research Work: Research on literatures review														
3	Submission of Preliminary Report														
4	Studies on Automation Studios Software														
5	Application of Ladder Logic Diagram in simulation														
6	Simulation of Sample Projects														
7	Oral Presentation														
8	Preparation Draft of Inter-rim report														
9	Submission of Inter-rim final report														

Figure 8- Gantt Chart and Key Milestone for FYP 1

= Milestone

= Gantt Chart

	Activities	Week														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Work Continue from FYP 1															
2	Progress Report															
3	Final Research															
4	Pre-SEDEX															
5	Draft Report															
6	Final Report															
7	VIVA															

Figure 9- Gantt Chart and Key Milestone for FYP2

= Milestone

= Gantt Chart

5.0 Results and Discussion

Case Study Simulation

Title

Simulation of a Robot Manipulator system

Objective

To analyse and develop a ladder diagram for a robotic system and implement on Automation Studio software

Introduction

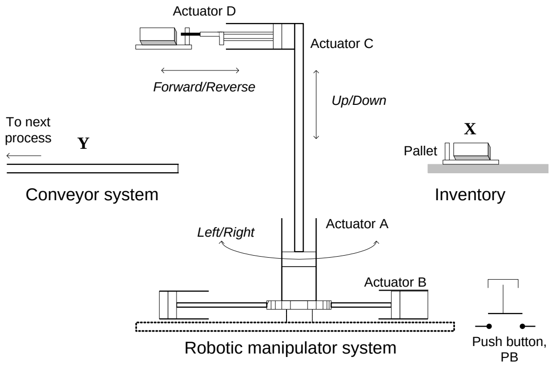


Figure 10- Robotic Manipulator system

Figure above shows the initial position of actuators that forms part of a robotic manipulator system used for moving components from point X to point Y. The double-acting-cylinder actuators A, B, C and D are to be energized individually by four different 5/2 normally closed (NC), electronic-actuated, spring-returned solenoid valves. The sequence is to be initiated by a manual push button (PB) switch. The optimum working actuator sequence has been established as follows:

{(A+B-A-D-D+A+B+C+|delay 2.5s|A-D-D+C-)} x3

Approach Recommended- Structured Way of Programming

The optimum working actuator sequence is solved by using a structured way of programming routines. A structured way of programming routines is developed for better understanding of engineers. Hence, engineers can understand the system well and provide maintenance task for any minor defects. By having a structured way of programming routines, it may help the company for cutting the costs of outsourcing the maintenance tasks to the vendors. Other than that, it can help to maximize the production because the problems can be solved immediately after the problems occurred.

For modern conveyor system, engineers are partitioning and dividing conveyor system into smaller focused segments that can be controlled independently depending on the factors such as localized product flow rate, need for product buffering and process inconsistencies. [6] Hence, S-Method is proposed to solve the modern manufacturing system operation. S-Method of programming consists of four main elements, which are description of the system, timing sequence diagram, Boolean logic equation and ladder logic diagram. By integrating all the elements above, engineers can solve the programming problems of the flexible manufacturing system and maintain the condition of the system.

i. Description of sequence (By referring the Figure 8)

Description of sequence is the first step in the S-Method. It is the process of giving an explanation of the series of actions of the system. By reading on it, engineers will have basic understanding of the function and operation of the system. Hence, it is easy for them to further investigate on the programming of the system.

Actuator A allows the manufacturing robot to go up and down. The axis extends the robot's horizontal reach.

Actuator B located at the robot base. It allows the robot to rotate from left to right. The sweeping motion extends the work area to include the area on either side of the system.

Actuator C allows the robot to extend forward or backward. This extends the robot's vertical reach.

Actuator D is responsible for gripping the pallet. When it moves forward, it grips the pallet. When it moves backward, it releases the gripping.

<u>Given working actuators sequence, (A+B-A-D-D+A+B+C+|delay 2.5s|A-D-D+C-) x3</u>

1. Start Switch (PB) is pressed and released to start the system.

2. Turn on the robotic manipulator system. Make sure the robot at the initial condition where the robot is at lower position(A-), left position (B+), reverse position (C-) and grip position (D+).

3. Move the manufacturing robot to the upper position and turn right after that.

4. Lower down the position of the manufacturing robot to the inventory position for getting the pallet.

5. Open the grip and wait for the pallet.

6. Grip the pallet and rinse the robot to the upper position.

7. Turn left and extends the robot’s vertical reach to the position of the conveyor belt.

8. Pause at that position for 2.5seconds.

9. Lower down the position of the robot to the conveyor position to release the pallet.

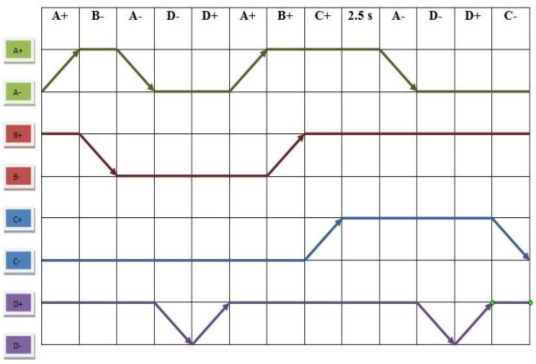
10. Open the grip and wait for the conveyor belt to transfer the pallet.

11. Close the grip after the pallet is transferred and move the robot extend backward.

12. Repeat the whole process for 3 times and power off.

ii. Timing Sequence Diagram

Timing sequence diagram is the second step in the Structured Method. Timing sequence plays its role in showing the sequence of the event. The input and output are listed down in this sequence diagram.



Set and Reset for variables

Holding Relay	Set	Reset
I	PB and C-	B-
II	I and B-	D-
III	II and D-	C+
IV	III and C+	Tim001
V	IV and Tim001	D-
VI	V and D-	C-

Set and Reset for actuators

Actuator	Set	Reset
A	I or III and D+	I and B- or IV
B	III and A+	I and A+
C	III and B+	VI and D+
D	II and D- or V and D-	II and A-or V and A-

Based on the timing sequence diagram, the number of holding relay are determined. Other than that, the set and reset for both holding relays and actuators are determined. By applying the structured method, the number of holding relays can be minimized. As a result, unnecessary time delay is eliminated and speeds up the time response of the system.

iii. Boolean Logic Expression

From the sequence diagram, we can generate the particular Boolean logic Expression. The general form of the Boolean equation is given as follow =, OUT= (SET + OUT). $\overline{(RESET)}$

Where,

Out= Logic output Set= Signal to ON the sequence Reset= Signal to OFF the sequence

Line 1: HR100 = (((PB1 + HR1600) . LSC- . LSA-) + HR100) . (LSC+. $\overline{HR1800}$)
Line 2: HR200 = $\overline{HR500}$
Line 3: YB = HR200 + HR1000
Line 4: HR300 = $\overline{HR700}$
Line 5: YD = (HR300 + HR800) . ($\overline{HR1400}$ + $\overline{HR1500}$)
Line 6: HR400 = HR100 . (LSA- + HR400) . $\overline{HR600}$ + $\overline{HR1800}$
Line 7: YA = (HR400 + HR900) . $\overline{TIM1}$
Line 8: HR500 = (HR100 . HR400 . LSA+) + ($\overline{HR1300}$.$HR500$)
Line 9: HR600 = (HR100 . HR400 . HR500 . LSB-) + ($\overline{HR1600}$.$HR600$)
Line 10: HR700 = (HR100 . HR600. LSA-) + ($\overline{HR1100}$.$HR700$)
Line 11: HR800 = (HR100 . HR700 . LSD-) + ($\overline{HR1600}$.$HR800$)
Line 12: HR900 = (HR100 . HR800 . LSD+) + ($\overline{HR1600}$.$HR900$)
Line 13: HR1000 = (HR100 . HR900. LSA+) + ($\overline{HR1600}$.$HR1000$)
Line 14: HR1100 = (HR100 . HR1000. LSB+) + ($\overline{HR1600}$.$HR1100$)
Line 15: HR1200 = ((HR100 . HR1100) + (HR1200). $\overline{HR1600}$)
Line 16: YC = HR1200
Line 17: HR1300 = (HR1200 . LSC+) + (HR1600 . HR1300)
Line 18: TIM1= HR1300
Line 19: HR1400 = (TIM1. LSA-) + ($\overline{HR1600}$.$HR1400$)
Line 20: HR1500 = (HR1400. LSD-) + ($\overline{LSB -}$. HR1500)
Line 21: HR1600 = (HR1500 . LSD+) + ($\overline{LSA +}$. $HR1600$)
Line 22: HR1800 = HR1600. CTU1. LSC-

Figure 11- Boolean Logic Diagram

iv. Ladder Logic Diagram

Ladder logic diagram is simply a symbolic representation of electrical circuit which is used to programme the Programmable controller. Ladder diagram is the most popular languages designed for user communication with PLC. Since the symbols of the components in the ladder logic diagram looked similar to schematic symbol of electrical devices, engineers who work on PLC can easily understand a ladder logic diagram languages without any guidelines.

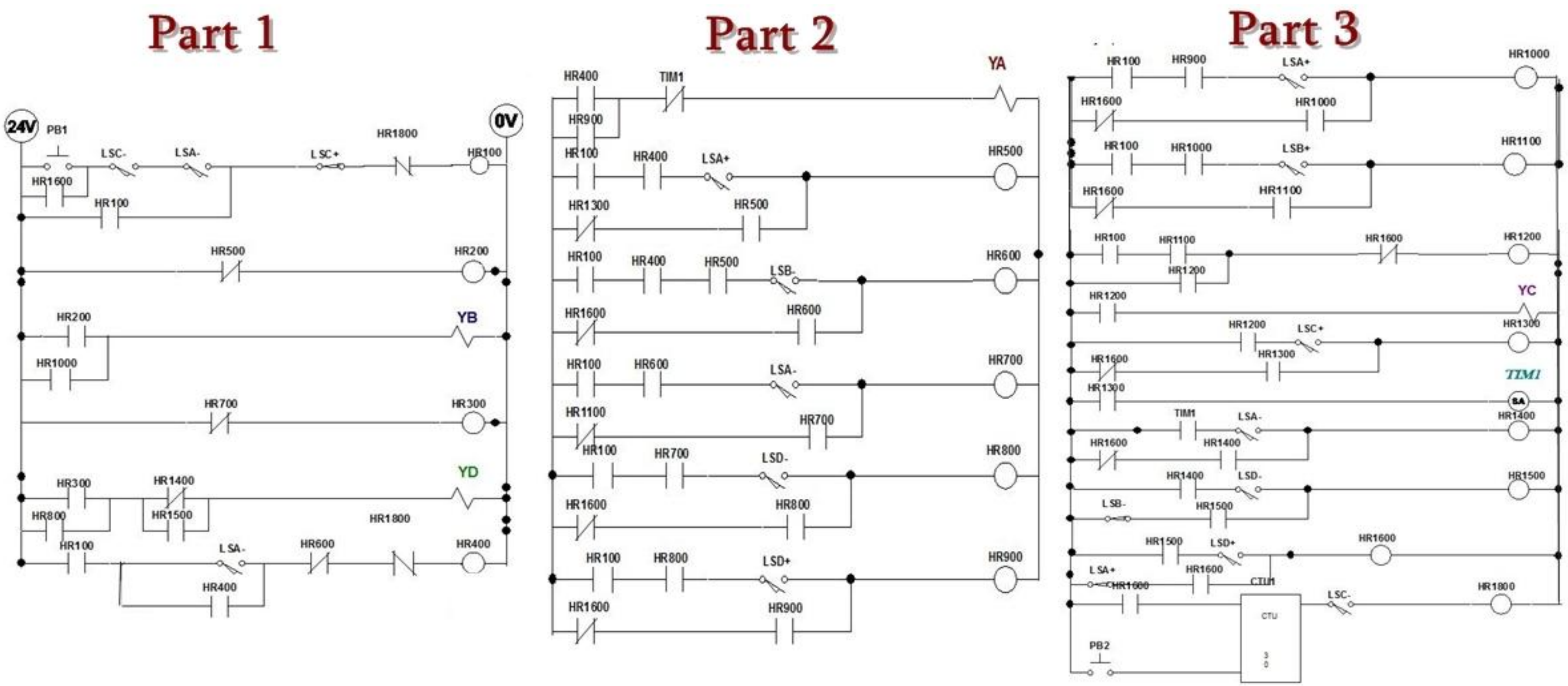


Figure 12- Ladder Logic Diagram

v. Result observed from the simulation of the ladder diagram in Automation Studio software and the operation of the system is evaluated.

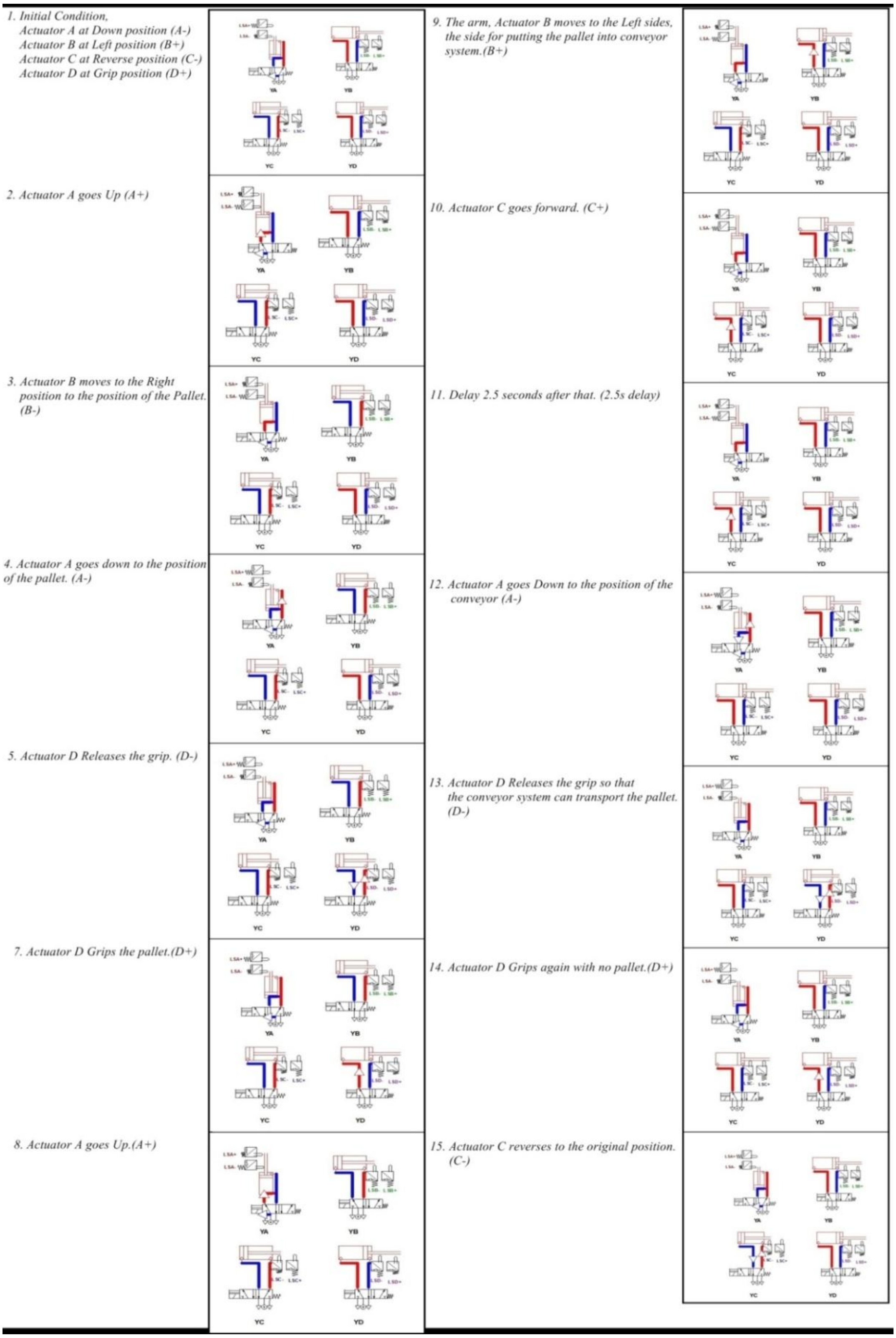


Figure 13- Results

5. Conclusion

Knowledge based on programming a Flexible Manufacturing System (Conveyor System) by using Programmable Logic Controller is acquired. The basic operation of a conveyor system is studied. There are three different sub-systems in a conveyor system, which are visual inspection system, conveyor belt system and pick and place system. Programming routines for a given case study is developed via structured methods, which consists of description of sequences, timing diagram, Boolean logic equation and ladder logic diagram. Further work to be included in this page will be to extend the programming of vision inspection and conveyor belt operation.

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