# PLC-CONTROLLED CONVEYOR SYSTEM II

By

AHMAD HAZWAN SYAHMI BIN WAGINOH

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

## CERTIFICATION OF APPROVAL

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Approved:

______________________________

Assoc Prof Dr Nordin Saad
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2012

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Ahmad Hazwan Syahmi Bin Waginoh

# ABSTRACT

Automation Controller in Flexible Manufacturing System (FMS) plays a significant role to increase productivity and flexibility in an industry. Programmable Logic Controller (PLC) is an industrial computer, controlled by a program having input and output unit, memory, arithmetic logic unit and control unit, that is superior to past relay logic in terms of robustness and flexibility. The objective of this project is to operate FMS using a structured method of programming routine via PLC. The project is to provide appropriate programming routine for the integration of Automation Laboratory in Block 22, Universiti Teknologi PETRONAS which is combination of 3 systems; vision system, conveyor system and robotic system. Currently, the laboratory is not in use and its function is limited only for demonstration purposes. This makes it difficult for Research & Development (R&D) work to be conducted. Scope of study for this project is more on the familiarization of the FMS using the software and hardware approach. The Automation Studio is used to create, design and simulate the conveyor systems. The sequence of the whole process need to be understood prior to work on the programming routine. For the hardware, the FMS system in the laboratory is divided into 3 sub-categories which are Omron Vision Sensor, Conveyor Systems and KUKA (Robotic Arm KR-15 System). Methodology used in this project is on study to get overview of FMS system, learning on the software Automation studio and training by the vendor on the PLC Siemens S7-200 before interfacing the designed programming routine to the PLC. Besides that, understanding the configuration of the hardware in the laboratories such as I/O of PLC, timer, sensor at the conveyor can help designing the programming routine. The objective of this project to develop new programming routine has been achieved. Besides that, planning to integrate with all the systems which are vision system, conveyor system and also robotic system has been achieved.

# ACKNOWLEDGEMENTS

Name of Allah, Most Gracious, Most Merciful

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| CIM | Computer Integrated Manufacturing |
| FMS | Flexible Manufacturing System |
| FBD | Function Block Diagram |
| PLC | Programmable Logic controller |
| R&D | Research & Development |
| ST | Structured Text |
| UTP | Universiti Teknologi PETRONAS |

# CHAPTER 1

## INTRODUCTION

### 1.1 Background Study

Automation is a technology concerned with the application of mechanical, electronic, and computer based systems used to operate and control production systems. One of the most important types of automation is flexible automation. Productivity, cost, quality, and utilization are concepts of concern in most industries. Flexible Manufacturing Systems (FMS) can promote the integration of these concepts and many more which are important to the manufacturer [1]. "FMS consists of a group of processing work stations interconnected by means of an automated material handling and storage system and controlled by integrated computer control system."[2]

A study has shown that, FMS is used in industries increase from year to year and because of that, Universiti Teknologi PETRONAS (Figure 1) setup one laboratory special to give students exposure to study on FMS system same with industrial robotic systems which is used in factories.


**Figure 1: Automation Laboratory, Universiti Teknologi PETRONAS**

The laboratory consists of material handlings which are OMRON Vision Sensor System, Conveyor System and KUKA robot. The integration of these three systems is essential for the whole systems to be successfully run. The FMS system in the laboratory is based on SIEMENS S7-200 PLC.

First system in the laboratory is OMRON Vision Sensor System (Figure 2). The function of this system is to check the orientation of the product and coding that programmed decide to reject or accept the product based on similarities of image processing in early stage. If the object is rejected, it will be lifted by pneumatic handling system and moved to separate section. (Figure 3)

**Figure 3:OMRON Vision Sensor**

**Figure 2: Reject Side**

Meanwhile, second system is the Conveyor Belt System (Figure 4) which also named as Conveyor System II. The conveyor system is function to transfer object from one sub location to another location in the lab such as from vision system to Kuka robot. Along the conveyor system, it have 21 different sensors (Figure 5) such as lifting sensor, limit switch sensor and solenoid-operated air valve.

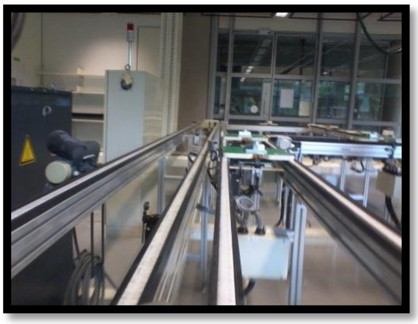


**Figure 5: Conveyor Belt System**

**Figure 4: Lifting Valve and Limit Switch**

Lastly, third system is KUKA, Robotic Arm KR-15.The KUKA system is independent system which function to load/unload product depends on programming that has been set.

## 1.2 Problem Statement

A current facility in Flexible Manufacturing System (FMS) laboratory in Universiti Teknologi PETRONAS usage is only limited for demonstration purpose only. FMS laboratory does not allow any programming routines conducted except using the vendor-made routine. So, in order to allow making this laboratory can be operate and demonstrate this project of a PLC controlled conveyor system has been initiated. The study of capability of PLC has to be made to ensure it is working well. The laboratory will be upgraded to enable PLC used as a controller in this laboratory so that the development of PLC conveyor system installed has better training, learning and teaching approach.

## 1.3 Objectives and Scope of Study

The objectives for this project are:

- To do a study of Flexible Manufacturing System (FMS).
- To establish communication link between PLC and conveyor system
- To integrate the capability of PLC as a controller in the FMS laboratory in Universiti Teknologi PETRONAS (UTP) by developing programming routine via ladder diagram using structure method.

The scope of study start by familiarize with the Flexible Manufacturing System (FMS) that to be upgraded in the laboratory to allow modification using PLC program language. The current arrangement of the FMS does not allow any demonstration in the laboratory. Second is to develop routine for controlling FMS via PLC and to perform the experiments to verify the correctness of the developed routines.

### 1.4 Significant and Feasibility of the Project

The notion of the project is to design and developed programming routines for the FMS system in Automation Laboratory in Block 22. The lab will be used for student for study, research and development for the FMS system in the future. Nowadays, fact has been shown that FMS system is widely used using PLC as the main controller. So it is good point of view to expose student with the real technology used in industries. As we know, PLC is widely used in industry to control manufacturing process, to increase, reliability and flexibility, reduce cost, and increase maintainability [3-6].

This project can be done within the given two semesters. In the end of the project, the programming routine will be successfully implemented PLC in the laboratory using the structure method such as have the description of the process, timing diagram, Boolean logic expression and ladder diagram. The planning of doing this project will be explained in the methodology and milestone that has been planned, in chapter 3.

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 Flexible Manufacturing Systems

Increasing global competition has made many business leaders and policy makes turn their attention to such critical issues as productivity and quality. Businesses seek new approaches to production process and manufacturing techniques and explore new boundaries of technology. Buzacott [7] present some important features of today's manufacturing environment and speculates on their implications for organizational changes. More specifically, technologies such as computer integrated manufacturing (CIM), robotics and flexible manufacturing systems (FMSs) are the focal point of much research and exploration. Flexible manufacturing technologies are a relatively recent addition to the portfolio of automated manufacturing technologies. To achieve strategic competitive benefits of FMSs which are to improve quality, greater flexibility and cost reduction, firms must carefully manage the implementation of these technologies [8]

#### 2.1.1 The Definition of FMS

Despite all of the interest in Flexible Manufacturing Systems (FMSs) there is no uniformly agreed upon definition of the term FMS. The main distinguishing feature of FMS from traditional manufacturing system is the term "flexibility" [9] still does not have specific meaning. One of the most cited definition of FMS is by Ranky [10], who defines an FMS as a system dealing with high level of distributed data processing and automated material flow using computer controlled machines, assembly cells, industrial robot, inspection machine and so on, together with computer integrated material handling and storage systems.

## 2.2 Programmable Logic Controller

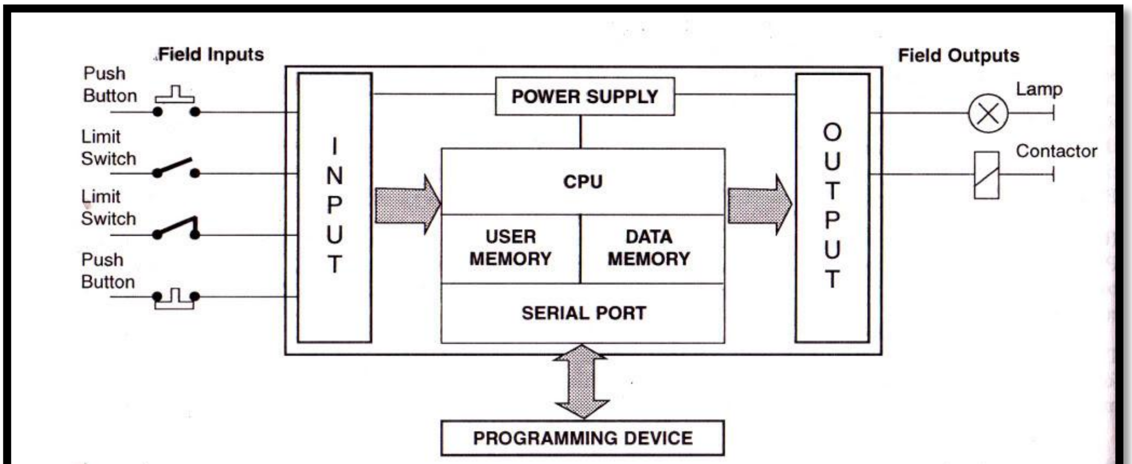
Back to 20 years back, humans was the main method for controlling a system. More recently electricity has been used for control and early electrical control was based on relays. Without a mechanical switch these relays allow power to be switched on and off. It is common to use relays to make simple logical control decisions. Now, many industries have changed their controlling system by using PLC controller [11]. In the modern manufacturing, PLC (programmable logic controller) device is well adapted to a range of automation tasks. These are typically industrial processor, where changes to the system would be expected during its operational life and production systems that feature cost of maintaining is relatively higher than cost of automation [12]. PLC is a special purpose computer, which is designed for multiple input and output arrangement, extended temperature ranges, immunity to electrical noises, and resistance to vibration and impact. PLC program such as ladder diagram, structured text programming, functional block programming and instruction list determines automation level of a manufacturing industry. In other words, the whole process structure of production line can be modeled and controlled through the set of instruction to PLC is the PLC program.

The PLC is widely used in industry to control manufacturing process, to increase reliability and flexibility, reduce cost, and increase maintainability. References [3-6]

provide some applications of PLC and sensors in dredging, GPS, research laboratories, pharmaceutical and other sectors of industry.

A Programmable Logic Controller (PLC) consists of four main units:

I. Central Processing Unit (CPU)
II. Memory
III. Input Module
IV. Output Module




*Source:http://i932.photobucket.com/albums/ad167/selectautomation1/PLC.jpg*

**Figure 6: Programmable Logic Controller (PLC)**

### *2.2.1* Central Processing Unit CPU

Like other computerized device, there is a Central Processing Unit (CPU) in a PLC. The CPU, which is the "brain" of a PLC, does the following operation:

- Updating input and output. The function allows a PLC to read the status of its input terminal and energize or de-energize its output terminals.
- Performing logic and arithmetic operation. A CPU conducts all the mathematic and logic operation involved in PLC.
- Communicating with memory. The PLC's program and data are stored in memory. When PLC is operating, its CPU may read or change the content of memory locations.
- Scanning application programs. An application program, which is called ladder logic program, is a set of instruction written by a PLC programmer. The scanning function allows the PLC to execute the application program as specified by the programmer.
- Communicating with a programming terminal. The CPU transfers program and data between itself and the programming terminal.

A PLC's CPU usually is controlled by operating system software. The operating system software is a group of supervisory programs that are loaded and stored permanently in the PLC's memory by manufacturer.

### 2.2.2 Memory

Memory is the component that stored information, programs, and data in a PLC. The process of putting new information into a memory location is called writing. The process of retrieving information from memory location is called reading.

The memory capacities of PLC vary. Memory capacities are often expressed in term of Kilobyte (Kb). One byte is a group of 8 bits. One bit is a memory location that may store one binary number that has the value either 1 or 0.

### 2.2.3 Input Modules

A PLC is a control device. It takes information from input and makes decision to energize or de-energize the output. The input device is used with a PLC included:

- Push button
- Limit Switched
- Relay contacts
- Photo Sensors
- Proximity Switches
- Temperature sensors
- Interlock Setting
- Etc

The input voltages can be high or low, digital or analog. Different input required different input modules. Input modules provide an interface between input devices and PLC's CPU.

### 2.2.4 Output Modules

The function of PLC is not limited to the controlled input only. It also can control the output included:

- Relay
- Alarm
- Solenoid
- Fan
- Light
- Motor starter
- Actuator
- Etc

## 2.3 Programming Language

PLC program are the software counterpart of the machine, according to IEC 6113-3, as Ladder Diagram (LD), Sequence Function Chart (SFC), Function Block Diagram (FBD), Instruction List (IL), and Structured Text (ST) are set among them and LD programming language is the most common industry accepted for PLC programming [13].

Ladder Diagram is a set of programming language that represent a program by using graphical diagram based on electrical circuit diagram of relay logic hardware in order to achieve efficiency in data-processing program. It is constructed by unit called “rung” (Figure 7) which is defined as one network connected together.

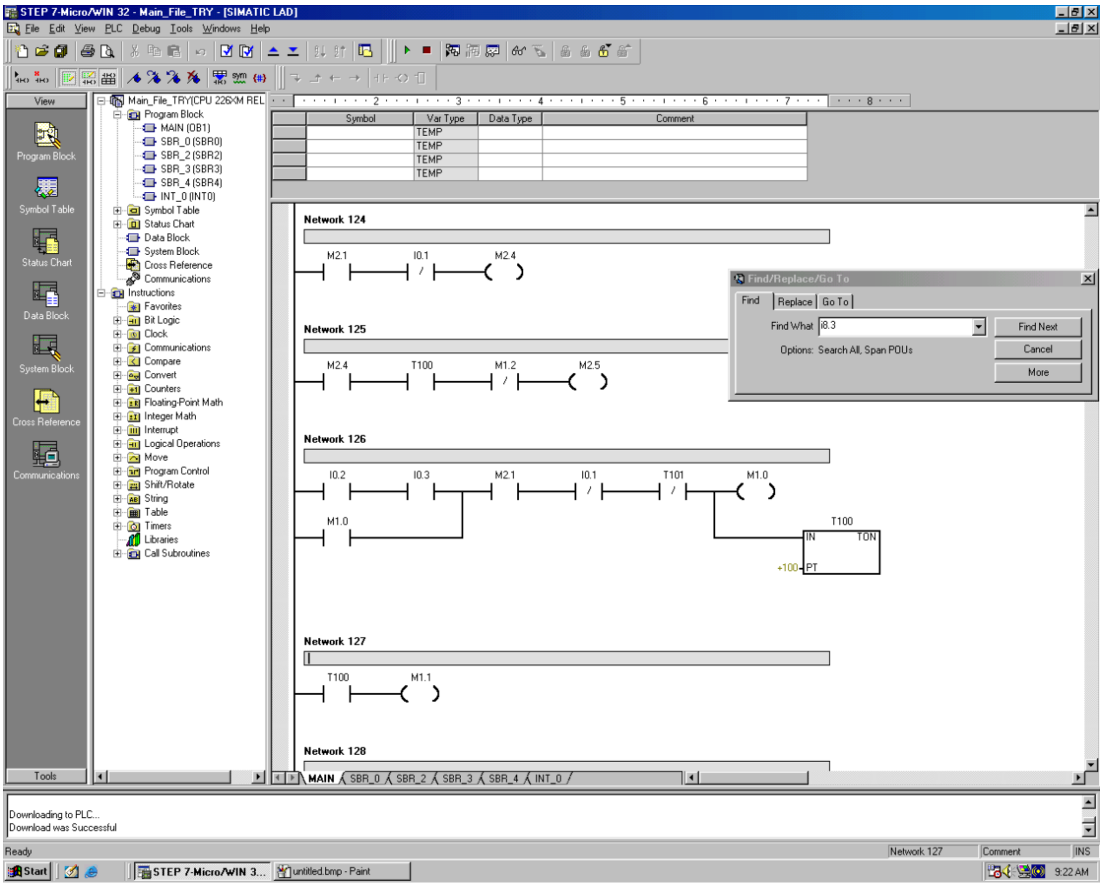



**Figure 7: Rung of the ladder diagram**

Based on IEC 1131 Sequential Function Chart (SFC) is same like ladder diagram which it is used graphical method but it have three main components which are steps, action and transition. Steps are like a unit of programming logic that accomplishes a control task like a chunk of logic. Furthermore, action is a individual aspects of that task and transition is the mechanism used to act from task to task .

Function Block Diagram (FBD) is a block diagram that describes the function between input and output in one picture. In the programming, it is include all the input and output, clearly identify all the input power data and structural interfaces between subsystem and etc.

Structured Text (ST) is a high level language that is using Pascal and C#. Programmer need to know all the basic of coding before can code using Structured Text (ST). It needs to include all the variables, operators, expression and control flow in order to complete the programming routine.

**2.4 Description of the System**

The system is mainly function on the manufacturing and product systems to moving, checking, testing, loading and storing. In the lab, there are three different sub-systems in a conveyor system which are visual inspection system, conveyor belt system and pick and place system. All the system is controlled by the PLC. In the project, PLC is function like a heart of the conveyor system as it is used to control all the input and output.

The PLC used in this project is SIEMENS S7-200 CPU 226XM where the modules can caries up to 24 inputs and 16 outputs which can have maximum 7 expansion modules. In the lab, there are consists of 6 modules of SIEMEN S7-200 to control the conveyor systems.

Besides that, PLC SIEMENS S7-200 is controlled by the programming software which can be used to do the programming for this PLC. The software for this PLC is SIMATIC S7-200.It is used RS 485 interface between the system with PC with the maximum transmission rate up to 187.5 Kbit/s. This software is used to create and design the ladder diagram for the conveyor system.

The area of researched for this project is at conveyor system which is system number two after the inspection system. The purpose of this conveyor belt system is to drive the object or products from place to another place. Besides that, it also functions to capture the result of the inspection station and update the components availability on the component station. The system will be describes at chapter 4 on result and discussion part.

# CHAPTER 3

## METHODOLOGY

### 3.1 Introduction

This chapter will cover the details explanation of methodology that is being used to make this project complete and working well. The method is use to achieve the objective of the project that will accomplish a perfect result.

In order to achieve the objectives of this project, some researches had been done on some resources from books and technical papers. Firstly, the project will begin with literature review by obtaining all the information about the Flexible Manufacturing System (FMS), how FMS system works, the definition and structure of PLC, Programming language used to program system and description of system in FMS laboratories located at block 22-00-12. The study provides the information that need to be implemented in this project. After that, the literature review will be done continuously by referring to books, reference and some are from the previous papers, manual and journal which are related to the PLC and programming language using ladder logic diagram.

For FYP I and II, author is using different set of software which are Automation Studio 5.0 and SIEMENS SIMATIC S7-200. Both of the software is important through this project because Automation Studio will give early simulation of the programming routine that is being developed and SIEMENS SIMATIC S7-200 is used in order to write program to the PLC. To familiarize with both of the software, author need to read the manual book, explore the function and do the example and tutorial given in the manual.

After getting the overview and familiarize with the project. Several set of flow of sequence of the sample project are designed and developed to make sure it can by simulate by Automation Studio. If the language becomes unstable; the process will be will need to edit or applying another method of programming ladder diagram.

A process to familiarize with all the software and hardware in the lab will start in week 2 of FYP II. Vendor wills comes conducts training to author to give overview and introduce all the equipment used in lab such as vision sensor and conveyor belt system. The laboratories used SIEMENS PLC and SIEMENS SIMATIC S7-200 software to do programming routine. After that, author need to list out all the input and output needed for the system to work. Planning stage of sequence diagram will takes place after all the I/O list has been figured to make sure the system will work well when the testing is obtained. Sequence diagram will show step by step how the process operates and in what order. After that, timing diagram will be made to represent the system in time domain. Timing diagram help to find digital logic for go to Boolean diagram. After sequence diagram, timing diagram and Boolean expression are developed, designing stage of ladder diagram takes place. The designing ladder diagram will be edited and conducted again if the result cannot be simulate and run by the system.

Lastly, result and discussion will be compiled in final report, the result will be interpreted and then the operational and safety requirements can be developed from the study.

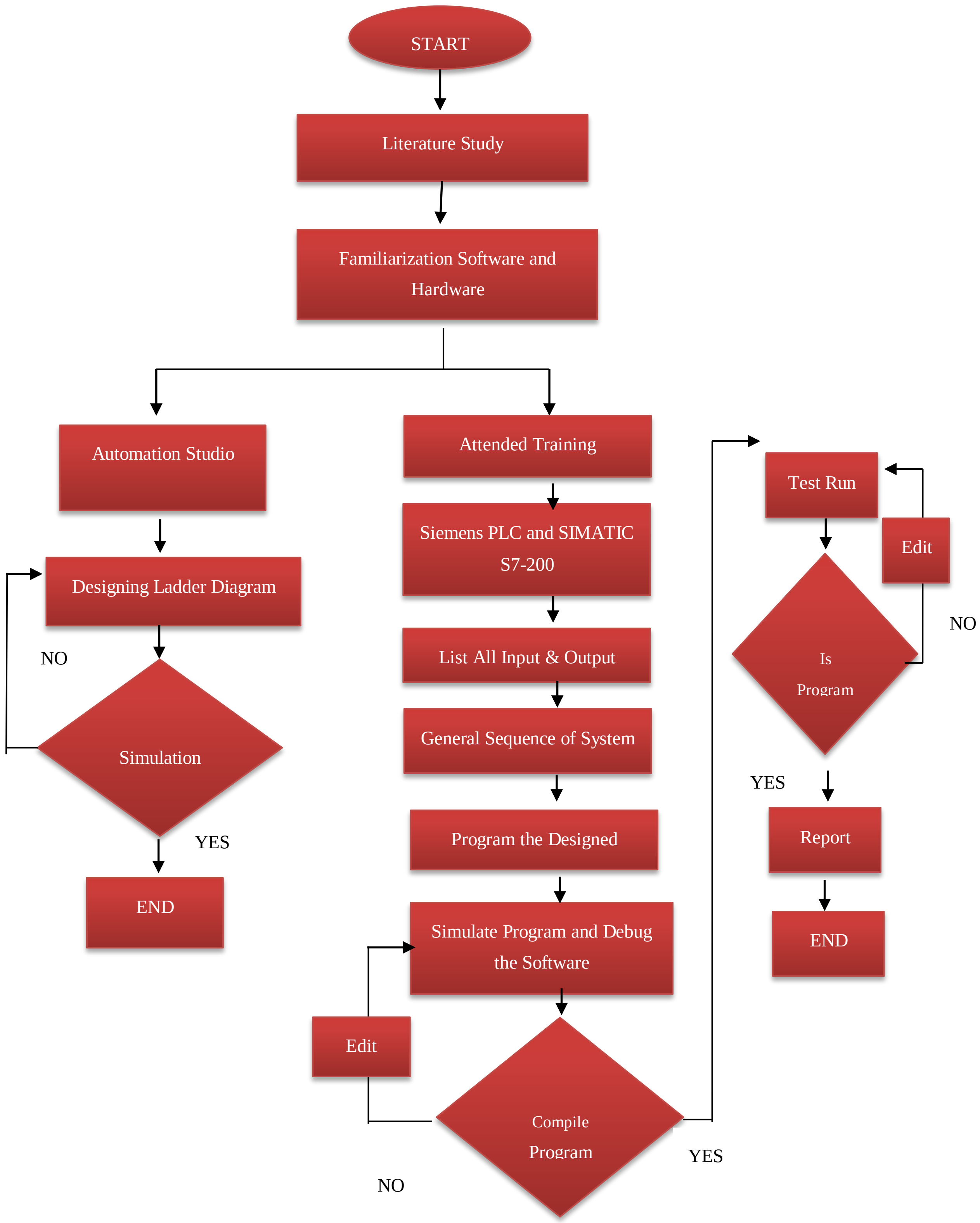



**Figure 8: The methodology of the project**

### 3.2 Project Activities

#### 3.2.1 Project Activities FYP I

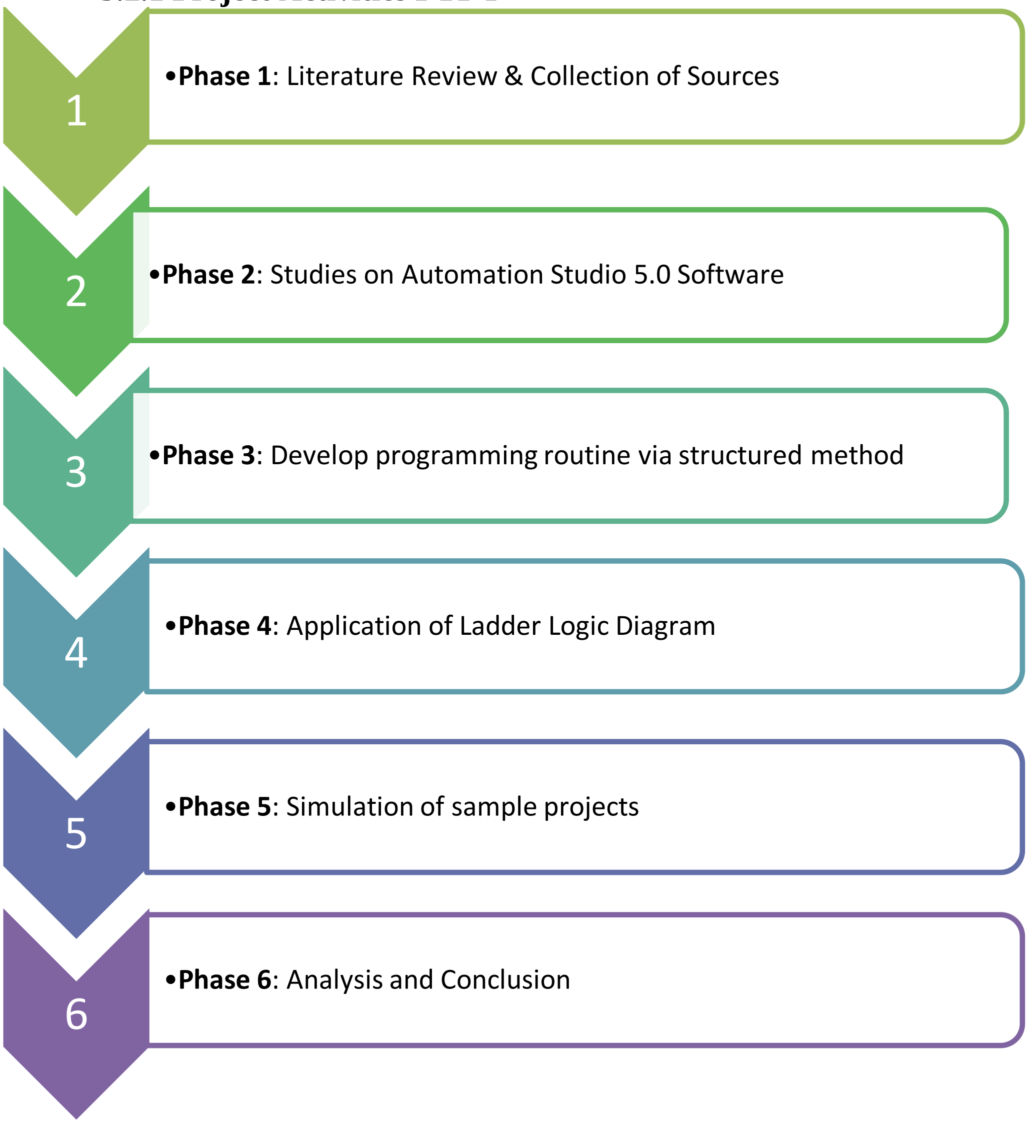



**Figure 9: Project Activities for FYP I**

The project for FYP is focusing in familiarization of FMS system by using software simulation. It is generally divided into six main phase:

- **Phase 1:** Literature Review & Collection of Sources
  Study on the Flexible Manufacturing System (FMS) and Programmable Logic Controller. Other required studies which are related to the project were done.

- **Phase 2:** Studies on Automation Studio 5.0 Software

  Automation Studio is software to simulate the ladder diagram. Before the designing phase, study on Automation Studio is important to familiarize with the software. All the related items in library setting is analyse its function and its principle of work.

- **Phase 3:** Develop programming routine via structured method

  Build ladder diagram via structured method by using sequence diagram, timing diagram, Boolean expression and then developed routine through ladder diagram.

- **Phase 4:** Application of Ladder Logic Diagram

  Programming ladder diagram is made in this stage. part of valve, pnematic actuator, sensor need to be added at the software in order to link the ladder diagram. After finish developing ladder diagram, the programming routine needs to be applied at Automation Studio.

- **Phase 5**: Simulation of sample projects

  Apply simulation using Automation Studio from the sample and task given. If th eproject cannot be run, editted the programming routine will takes place until it fulfill the step by step sequence diagram.

- **Phase 6**: Analysis and Conclusion

  From the sample project, analysis and conclusion will be done whether project is significant to be continued or not.

### 3.2.2 Project Activities of FYP II

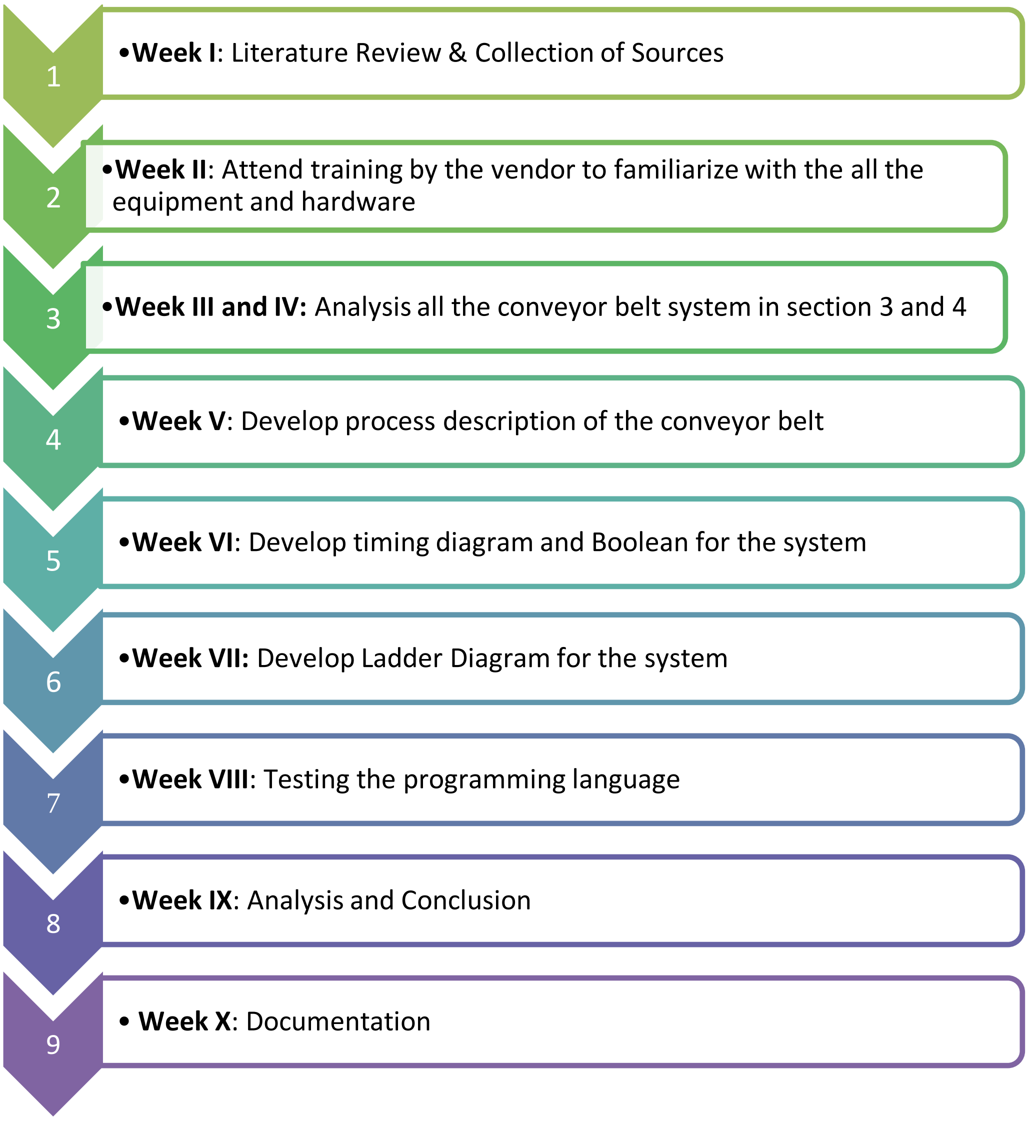



**Figure 10: Weekly Activities for FYP II**

The project is generally divided week by week:

- **Week 1:** Literature Review & Collection of Sources

  Do the final study on the programming language for SIEMENS's PLC. Other required studies which are related to the project were done too.

- **Week 2:** Attend training by the vendor to familiarize with the all the equipment and hardware

  After familiarization of the Automation Studio 5.0 software in FYP I, student need to undergo training by vendor to familiarize the hardware used and also SIMATIC S7-200.

.

- **Week 3 and 4:** Analysis all the conveyor belt system in section 2 and 3
  In week 3 and 4, author need to list out all input and output of the system involved. Author also needs to do analysis and consider all the factors to avoid collision among object/product when it moves through conveyor belt. All the sensor and valve also need to analysis and know the function of each. Speed of the conveyor also needs to consider in order to synchronise with other section and to avoid collision

- **Week 5:** Develop process description of the conveyor belt
  After done with the analysis of conveyor, then process description can be done to describe each action done by system. Process description will show step by step how the process operates and in what order to give clear view of the system.

- **Week 6:** Develop timing diagram and Boolean for the system
  Timing diagram will be developed to represent the system in time domain. Timing diagram help to find digital logic for go to Boolean diagram.

- **Week 7**: Develop Ladder Diagram for the system
  From all the description, timing diagram and Booleen expression provided, it is easier to develop ladder diagram for the system. All the holding relay need to be considered in order to built the routine. Besides that, author need to consider future expansion of the programming routine to easier to modified.

- **Week 8 until 11**: Testing, Analysis and Conclusion
  Using SIMATIC S7-200 PLC programming software, author needs to run and test before doing fault analysis. If the test is fail author needs to modify programming routine. Integration of all the system I, II and III will take place in this stage.

- **Week 12- 14**: Documentation

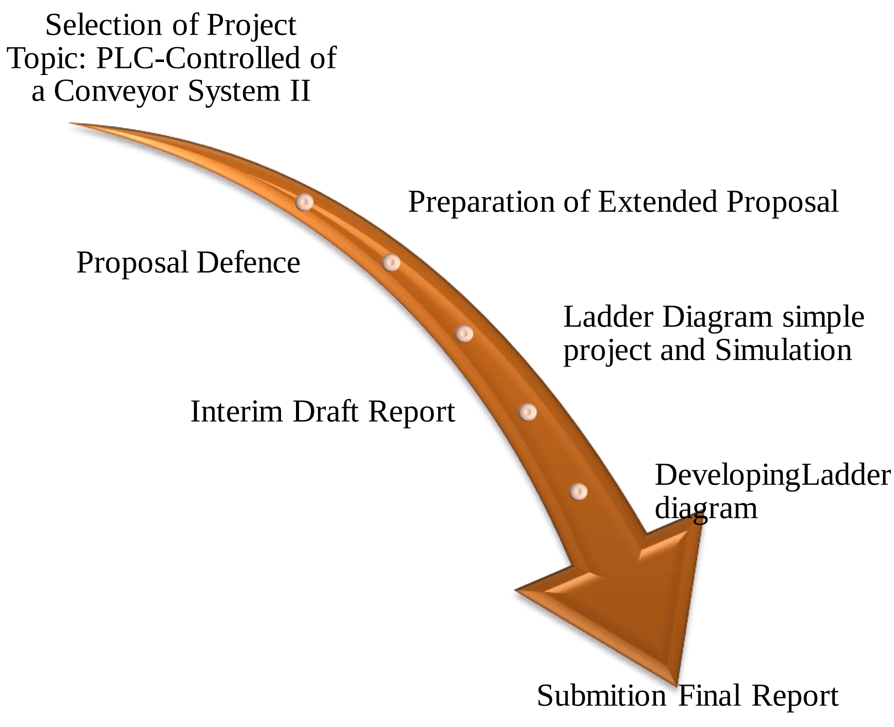
  After the programming routine has been developed, all the step and task are arranged in order to make sure it is properly documentate

### 3.3 Gantt Chart and Milestone

Gantt chart attached in Appendixes.

### 3.4 Key Milestone

The projects planned can be seen from the Gantt chart previously and there are a few milestones that have been set in order to ensure that the project will be completed within time and scope.



### 3.5 Tools Required

1) SIEMENS S7-200 PLC

SIEMENS S7-200 PLC is a basic PLC to do the automation task. It is compact and powerful PLC that fast in communication-capable and has a highly productive in real-time mode (Figure 11). The modules can caries up to 24 inputs and 16 outputs which can have maximum 7 expansion modules. In the lab, there are consists of 6 modules of SIEMENS S7-200 to control the conveyor systems.

**Figure 11: Stopper valve**

2) Conveyor Belt system

Conveyor Belt System is used to move object from one place to another place. There have 5 part of conveyor belt system with length of 23.62m. Each conveyor has different handling system attached to it.

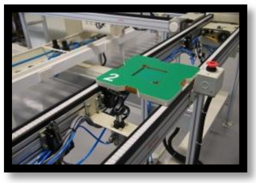


**Figure 12: Conveyor Belt system**

3) SIEMENS SIMATIC S7-200 Software

SIEMENS SIMATIC S7-200 is a programming tool in order to communicate with SIEMENS PLC in the system. Ladder Diagram is used to make programming routine.

4) Automation Studio 5.0 Software

Automation Studio is software that is used to design, simulate and do documentation for a project. It also used to troubleshoot hydraulic, pneumatics, synoptic and electrical control system (Figure 12)

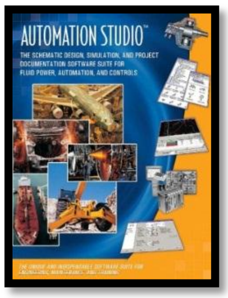



**Figure 13: Automation Studio 5.0 software**

5) OMRON Limit Switch

OMRON limit switch using OMRON D4D-2121N. This limit switch is using AC 15 2A/400V power. It is used as an input sensor to give signal to the output like valve or motor.

**Figure 14: OMRON Limit Switch**

6) Stopper Valve and Solenoid Valve

Stopper Valve and Solenoid Valve using Chelic 5V-5201 model. Stopper valve get the signal from the sensor whether want to open or closed the valve. It has 135psi maximum pressure rating using 24 V DC.

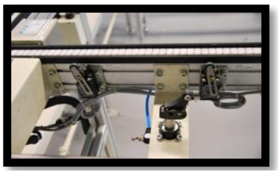


**Figure 15: Stopper valve**

# CHAPTER 4

## RESULT AND DISCUSSION

### 4.1 Simulation in Automation Studio 5.0

In the middle phase of FYP 1, developing of ladder diagram has taken placed. The work was begun with searching a simple model robotic arm pick and place. The example of development of research on picks and place section has been chosen to familiarize with automation studio.

Figure 14 shows the actuators start position that forms part of an industrial assembly process used for moving components from point **X** to point **Y**.

Double-acting-cylinder actuators A, B and C are to be energized individually by three different 5/2 normally closed (NC), electronic-actuated, electronic-returned solenoid valves. The sequence is to be initiated by a manual push button (PB) switch.

{(c+ b+ | delay 1.5s | a- b- a+ | delay 2.0s | b+ c+ | delay 3.0s | b- a- c- )}x3

The optimum working actuator sequence is solved by using structured way of programming. This structured way of programming is developed for better understanding to engineers and students. If this targeted people can understand the system well, they can provide troubleshooting and maintenance for any minor defect towards the system. Besides that by having this structured way of programming, company can cut the cost of outsourcing service of maintenance to vendors. The time can be save in order to get the system online if anything happened to the system.

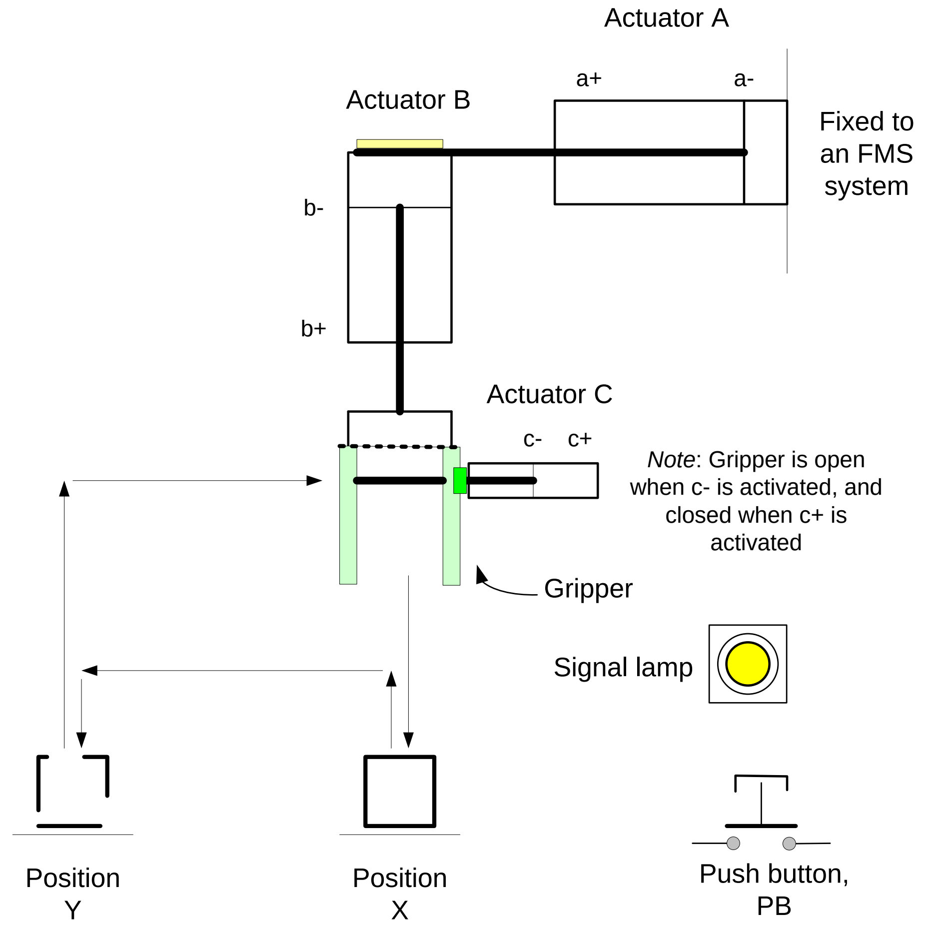



**Figure 16: Robotic Arm System**

There are four main elements that is involve in this programming routine which are description of the sequence, timing diagram , Boolean logic equation and ladder logic diagram.

### 4.1.1 Description of Sequence

Description of sequence is the first step using structured method. This process is the process to explain series of action taken to operate the system. By reading this sequence, engineers will have basic understanding of the function and operation of the system.

Given {(c+ b+ | delay 1.5s | a- b- a+ | delay 2.0s | b+ c+ | delay 3.0s | b- a- c- )}x3

i. Start switch (PB) is pressed and released to activate the system.
ii. Turn on the robotic manipulator system. Make sure the robot at initial condition where the robot is at right position (a-), upper position (b-), and open grip (c-).
iii. Move the grip closed position by change the direction to c+ position.
iv. Actuator B will be activating. Sensor b+ will be triggered to lower down the actuator to position X for gripping the pallet.
v. Pause at that position for 1.5 seconds
vi. Actuator C open to c- position to hold the object at position X
vii. Actuator B activated to lift the object
viii. Actuator A activate to retract the valve to position Y by activating sensor a+
ix. Pause at that position for 2.0 seconds
x. Actuator B activate to expand the valve to position b+ which is in position Y
xi. Actuator C will be activate and it will closed the gripper
xii. Pause at that position for 3 seconds
xiii. Actuator B retract back to original position
xiv. Actuator A retract to original position at a-
xv. Actuator C will be open at c-
xvi. Repeat the same process three times

### 4.1.2 Timing Sequence

This is second step sequence to show the sequence of the event. Timing diagram help to find digital logic for go to Boolean diagram.

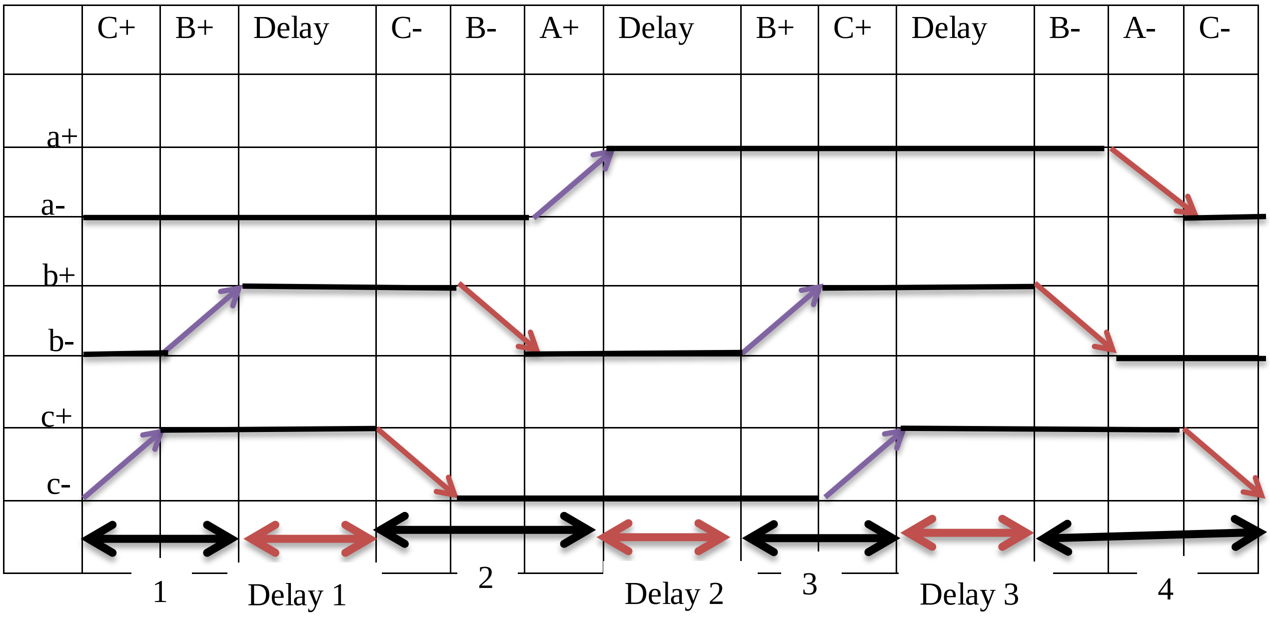



**Figure 17: Timing Sequence for Robotic System**

Timing sequence is representation of a set of signals in the time domain. This sequence diagram is made to see each sensor based on description of the sequences. There are 6 sensors involved in this actuator which are sensor a+, a-, b+, b-, c+, and c-. Figure 17 show timing sequences for this sample before it converted to the ladder diagram.

Set/ Reset for secondary Level

| Variable | Set | Reset |
|---|---|---|
| **1** | PB and c- | b+ |
| **Delay 1** | 1 and b+ | Tim01 |
| **2** | Delay 1 | a+ |
| **Delay 2** | 2 and a+ | Tim02 |
| **3** | Delay 2 | c+ |
| **Delay 3** | 3 and c+ | Tim03 |
| **4** | Delay 3 | c- |

Set/ Reset for Actuator

| **Variable** | **Set** | **Reset** |
|---|---|---|
| **A** | 2 and b- | b- and 4 |
| **B** | 1 and c+<br>or<br>3 | 1 and c-<br>or<br>4 |
| **C** | 1<br>Or<br>3 and b+ | 2<br>Or<br>a- and 4 |

### 4.1.3 Boolean Logic Expression

Boolean logic expression can be generating from the sequence. The given form of Boolean equation is given as follow = OUT = (SET + OUT). RESET where OUT= Logic output set = signal to ON the signal RESET= signal to OFF sequence

Line 1

$HR1 = (PB1 + HR1) . \overline{PB2} . \overline{HR11}$

Line 2

$C = ( HR1 . \overline{HR2} ) + ( HR6 . \overline{HR9} )$

Line 3

$B = ( HR1. C+ . \overline{HR3} ) + (HR5 . \overline{HR7})$

Line 4

TIM 01 = b+

Line 5

$HR2 = (TIM01 + HR2 ) . \overline{HR10}$

Line 6

$HR3 = (HR2 . c-) + HR3 . \overline{HR10}$

Line 7

$HR4 = (HR3 . b-) + HR4 . \overline{HR10}$

Line 8

A = HR4 . $\overline{\text{HR8}}$

Line 9

TIM 02 = HR4 . a+ . c- . b-

Line 10

HR5 = (TIM 02 . a+ . b- ) + HR5 . $\overline{\text{HR10}}$

Line 11

HR6 = (HR5 . b+ ) + HR6 . $\overline{\text{a-}}$

Line 12

TIM03 = HR6 . b+ + c +

Line 13

HR7 = (TIM 03 . b+ ) + HR7 . $\overline{\text{HR10}}$

Line 14

HR8 = (HR7 . a+ . b-) + HR8 . HR10

Line 15

HR9 = (HR8 . a- . c+) + HR9 . HR10

Line 16

HR10 = (HR9 . c-) + HR10 . $\overline{\text{b+}}$

Line 17

HR11 = (HR10 . CNT 01) + PB3

### 4.1.4 Ladder Diagram

Ladder diagram is symbolic of electric circuit which is used to programme PLC.

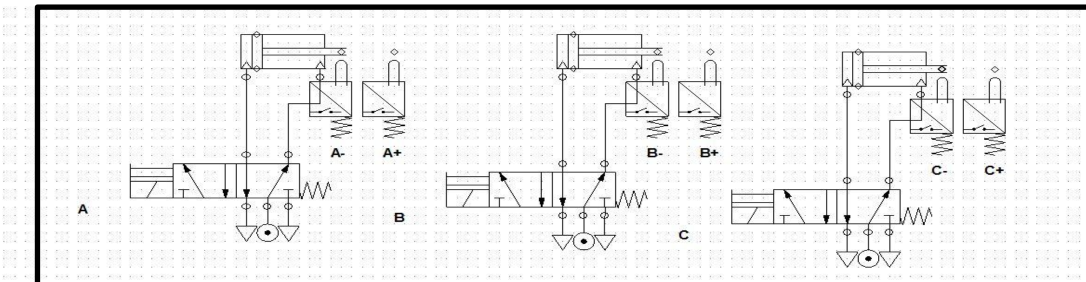
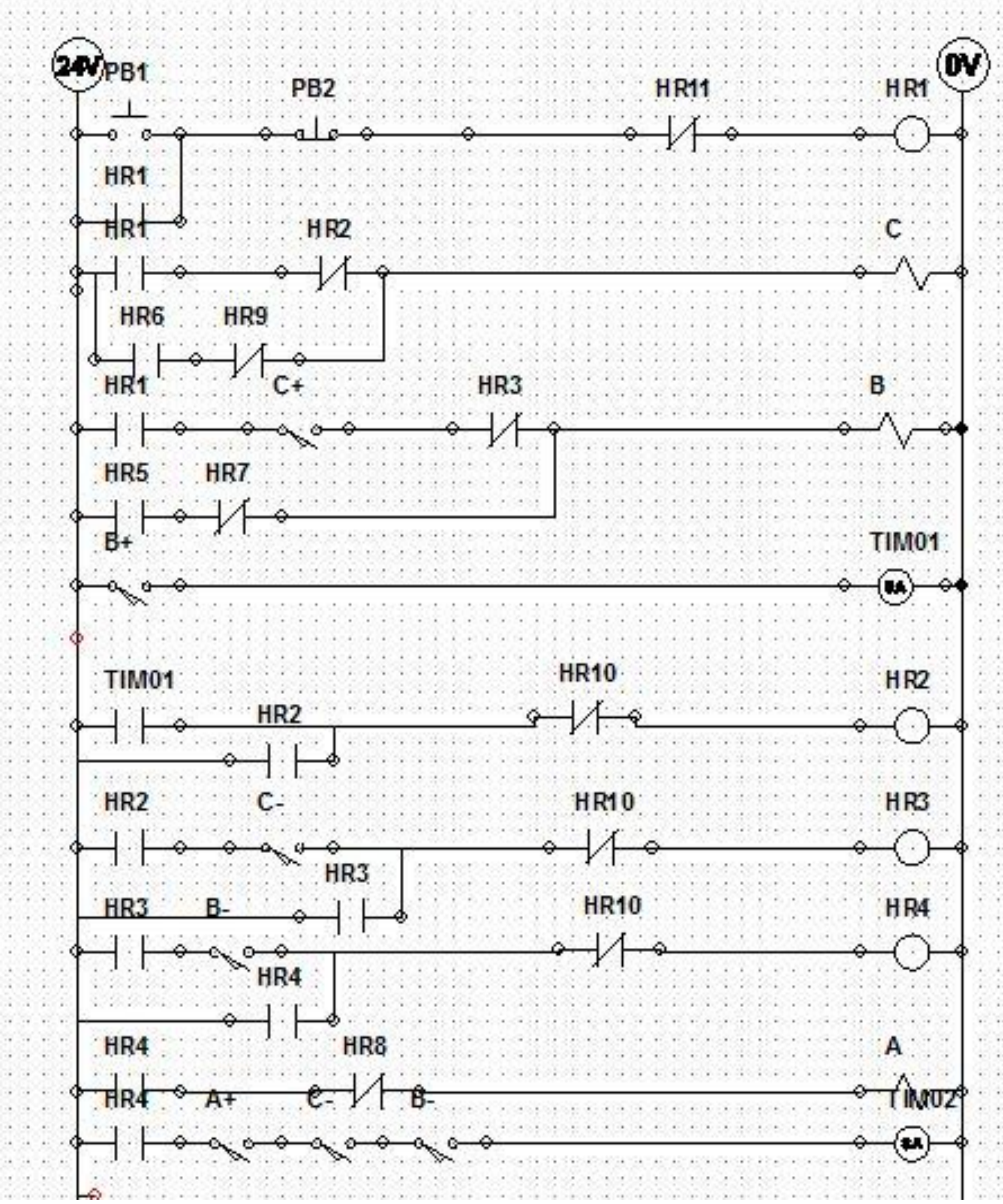



**Figure 18: shows all valves A, B and C in Automation Studio**



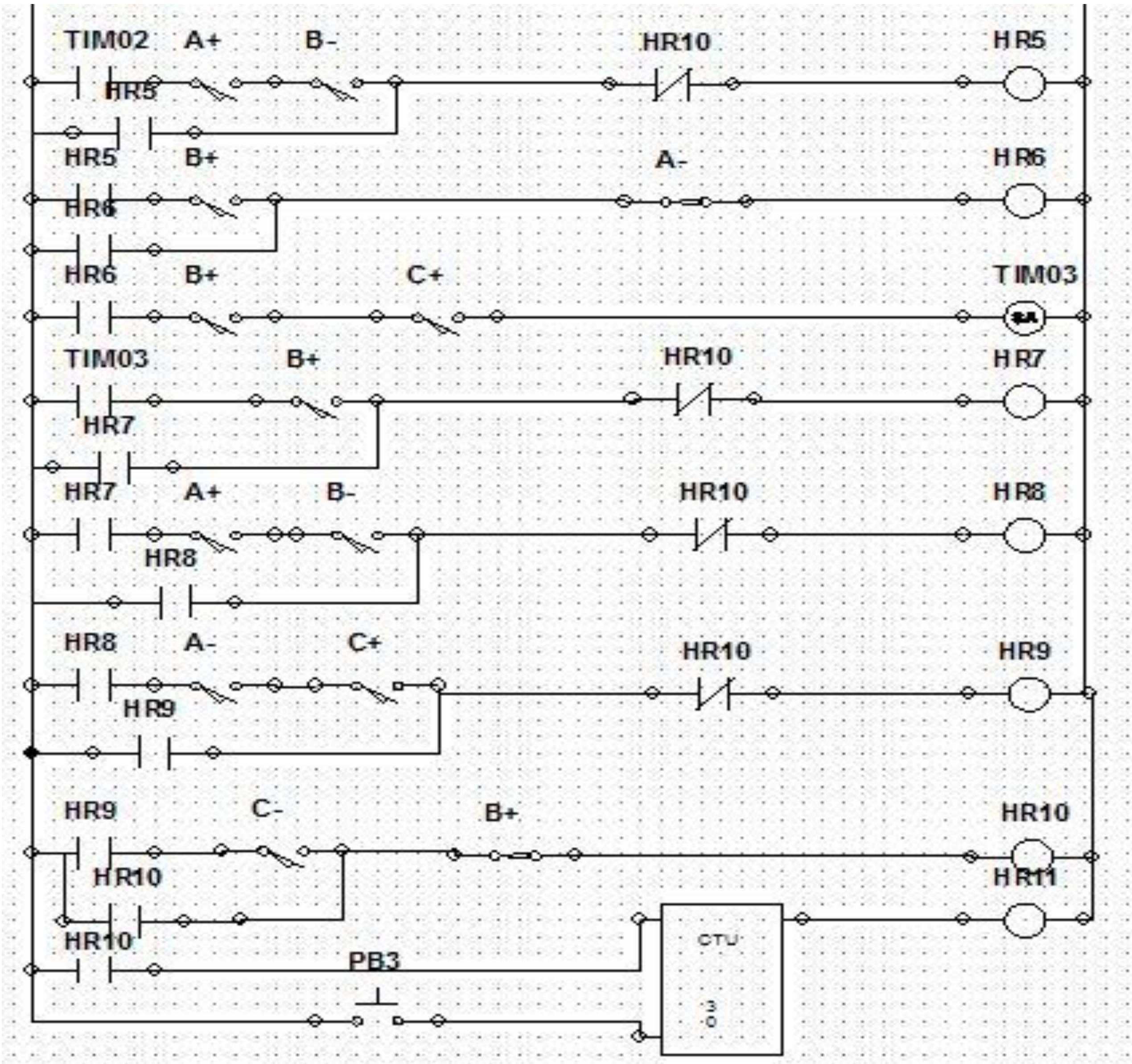



**Figure 19: Ladder Diagram for Robotic Arm**

From the studies case above is concept how to programme and operate pick and place robotic arm robot using pneumatic. Programming is successfully implement by using structured method which are start by define the step of sequence, and then continued by timing diagram to show input and output status in every sample of time. After that, develop Boolean expression to give clearer view of input and output in the system. Last but not least is developing ladder diagram to ensure the program can run smoothly. Advantage to use Automation Studio 5.0 is the software capable to simulate the programming routine like actual event before engineers build program at actual side. For example, when engineers want to build programme at offshore, they must at least try their programming routine first at software and from there they can do some modification depends on their needs.

### 4.2 Designing FMS System for Conveyor System II

For FYP II, the work is started at Flexible Manufacturing laboratory (FMS) located at block 22-00-12. This project involves software and hardware of the system. All the system in the lab is controlled by SIEMENS S7-200 PLC which is situated in the junction box. First, it is start with understanding layout of conveyor section 3 and 4. Then, after understand with the layout of the system, developing description of the sequence of the conveyor to plan what is the step in order to ensure that the system is working well.

To help engineer understand status of input and output in each segment of event, timing diagram is developed. After that, Boolean expression is developed before ladder diagram is done. Last part of this section is by doing analysis for the conveyor system II on the speed, operability of the system and improvement to the system.

### 4.2.1 Layout of Section 3 and 4

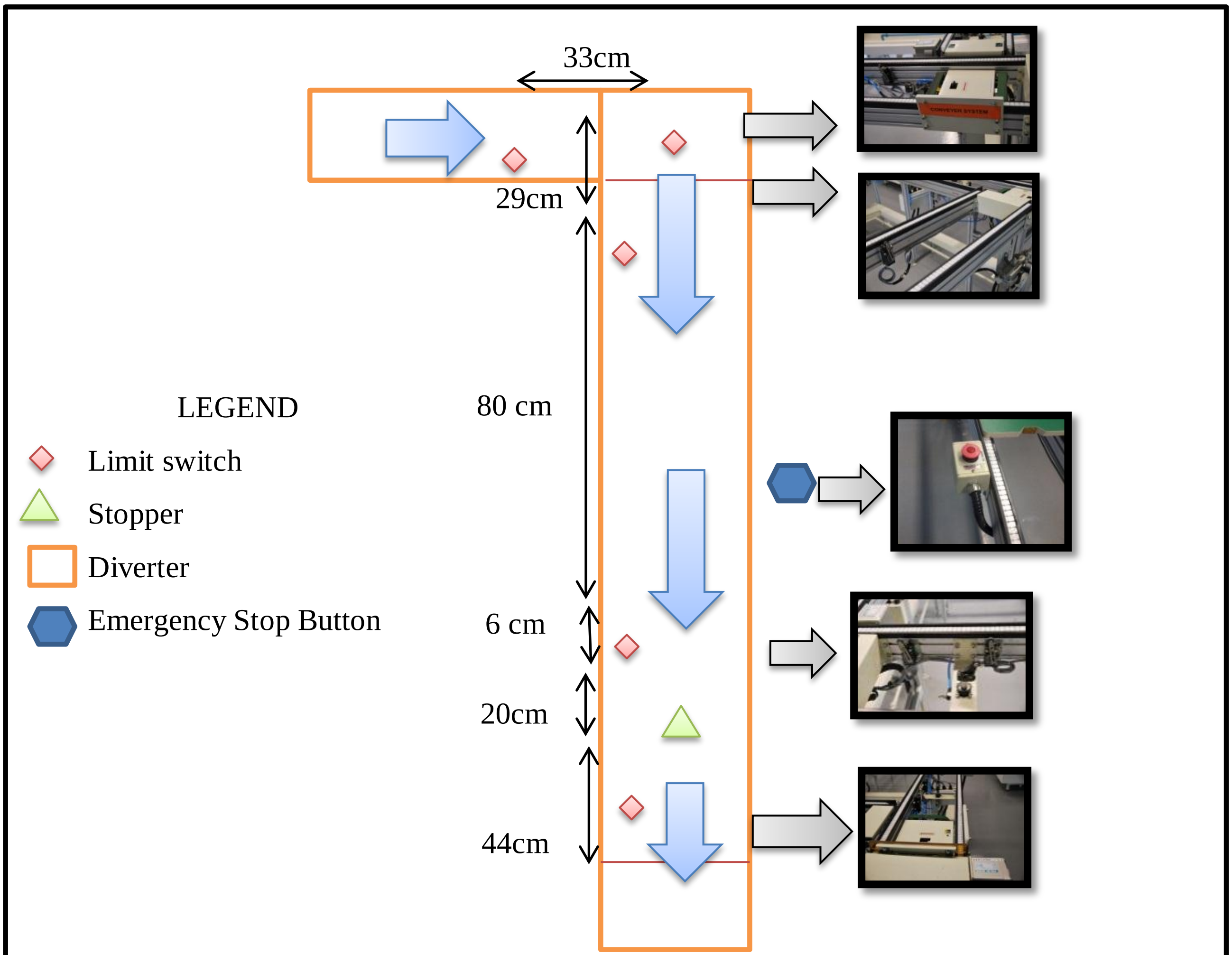



**Figure 20: Conveyor in Section 3**

Input: T08 ARRIVE

T08 Div UP Position

T08 Div DOWN Position

Output: MOTOR DIVERTER 08

T08 Diverter UP Vslve

T08 Diverter DOWN Valve

Input: T09 ST ARRIVE

T09 ST RESET

Output: T09 Stopper

Input: T09 Full / Pass

Input: Emergency Stop Relay

Input: T10 Div UP Position

T10 Div DOWN Position

Output: T10Diverter UP Vslve

T10 Diverter DOWN Valve

T09 Conveyor

I/O List for Conveyor 3

**INPUT**

| CH | ADDRESS | DESCRIPTION |
|---|---|---|
| **X 01 04** | **I1.4** | T08 Diverter Overload Trip |
| **X 01 05** | **I1.5** | T09 Conveyor Overload Trip |
| **X 01 06** | **I1.6** | T10 Diverter Overload Trip |
| **X 04 01** | **I4.1** | T08 Diverter UP Position |
| **X 04 02** | **I4.2** | T08 Diverter DOWN Position |
| **X 04 03** | **I4.3** | T10 Diverter UP Position |
| **X 04 04** | **I4.4** | T10 Diverter DOWN Position |
| **X 08 03** | **I8.3** | T09 Stopper Valve |
| **X 08 04** | **I8.4** | T09 Line Full/Pass |
| **X 08 05** | **I8.5** | T09 Stopper Arrive |
| **X 08 06** | **I8.6** | T09 Stopper Reset |

**Table 3: Table of input of conveyor 3**

**OUTPUT**

| CH | ADDRESS | DESCRIPTION |
|---|---|---|
| **Y 01 04** | **I1.4** | T08 Diverter |
| **Y 01 05** | **I1.5** | T09 Conveyor |
| **Y 01 06** | **I1.6** | T10 Diverter |
| **Y 03 04** | **I3.4** | T09 Stopper Valve |
| **Y 06 00** | **I6.0** | T08 Diverter UP Valve |
| **Y 06 01** | **I6.1** | T08 Diverter DOWN Valve |
| **Y 06 02** | **I6.2** | T10 Diverter UP Valve |
| **Y 06 03** | **I6.3** | T10 Diverter DOWN Valve |

**Table 4: Table of Output of conveyor 3**

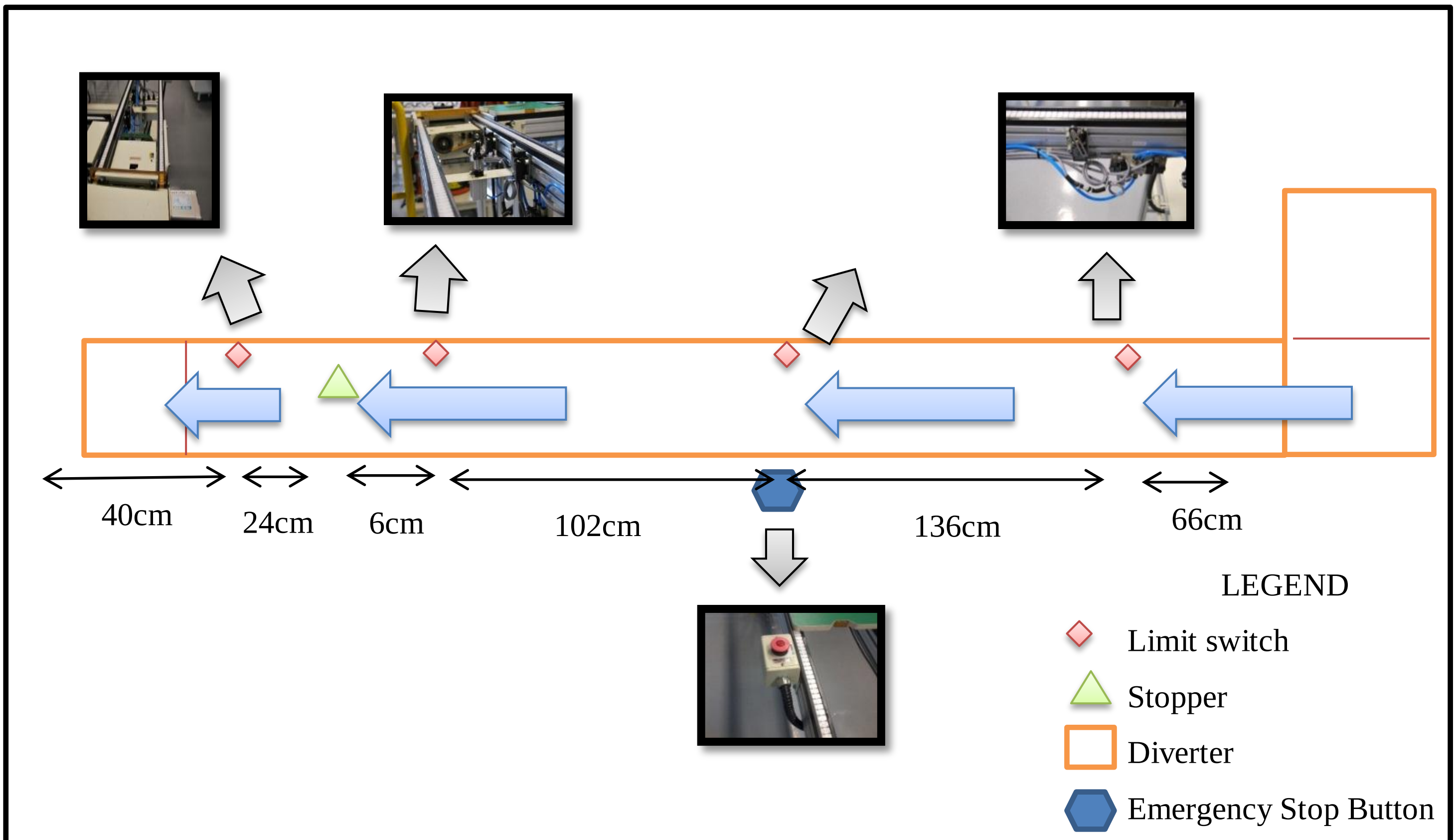



**Figure 21: Conveyor in Section 4**

Input: T11 Pass

T11 Full

Output: T11 Conveyor

Input: T11 ST ARRIVE

T11 ST RESET

Output: T11 Stopper

Input: T12 Div UP Position

T12 Div DOWN Position

Output: MOTOR DIVERTER 12

T12 Diverter UP Vslve

T12 Diverter DOWN Valve

**INPUT**

| CH | ADDRESS | DESCRIPTION |
|---|---|---|
| **X 04 05** | **I4.5** | T12 Diverter UP Position |
| **X 04 06** | **I4.6** | T12 Diverter DOWN Position |
| **X 09 00** | **I9.0** | T11 Pass |
| **X 09 01** | **I9.1** | T11 Line Full |
| **X 09 02** | **I9.2** | T11 Stopper Arrive |
| **X 09 03** | **I9.3** | T11 Stopper Reset |

**Table 5: Table of input of conveyor 4**

**OUTPUT**

| CH | ADDRESS | DESCRIPTION |
|---|---|---|
| **Y 01 07** | **I1.7** | T11 Conveyor |
| **Y 02 00** | **I2.0** | T12 Diverter |
| **Y 03 05** | **I3.5** | T11 Stopper Valve |
| **Y 06 04** | **I6.4** | T12 Diverter UP Valve |
| **Y 06 05** | **I6.5** | T12 Diverter DOWN Valve |

**Table 6: Table of Output of conveyor 4**

### 4.2.2 Description sequence of the system

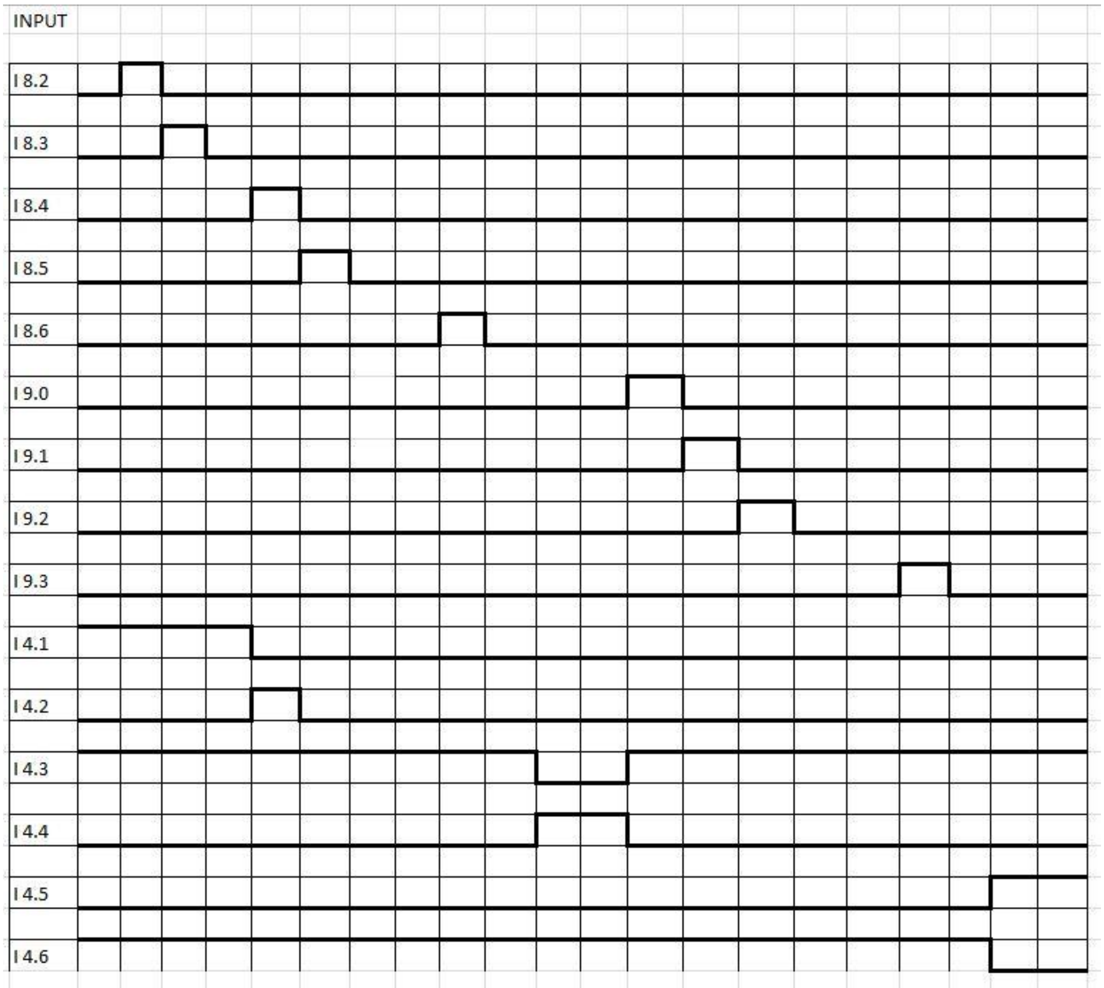
Description of Conveyor Belt Section 3 and 4

1. Open pneumatic supply and PB button is released
2. Turn ON the motor for Conveyor 9 and 10
3. When T07 S1 trigger, MT08 DIV go to avoid pallet from fall down.
4. When T07 S2 touched, MT 08 motor will turn ON
5. Then pallet will divert from section 2 to section 3. When the pallet touches T08 Arrive, it will trigger MT DIV to release pneumatic air as a result it will going down.
6. Conveyor 9' belt move the pallet until it trigger the switch T08 FULL PASS, MT08 MOTOR STOP and MT 08 DIV return to early condition (going up).
7. T09 Arrive trigger, Delay start for 10 seconds before STOPPER 9 released pneumatic air to go down OR when T07 STOPPER going down then T09 STOPPER will go down.
8. T09 ST RESET trigger, HOLD for 1 second.
9. After DELAY 1 second, MT 10 DIV go up and motor turn ON. Pallet change direction to the section 4 until MT 12.
10. T11 PASS trigger, MT10 DIV at end of section 3 will go down.
11. T11 FULL trigger it will clear anything at T11 STOPPER as a result T11 STOPPER go down.
12. Then, when T11 ST ARRIVE triggered, Hold 1 second.
13. After delay, T11 STOPPER goes up.
14. After pallet pass through T11 STOPPER, It will touch T11 ST RESET and HOLD 1 second.

15. After DELAY, MT 12 DIV go up and motor turn to let pallet go through next section.

### 4.2.3 Timing Diagram

This is timing diagram for the entire input and output system conveyor 3 and 4. There are 15 input and 14 output involved extracted from sequence.



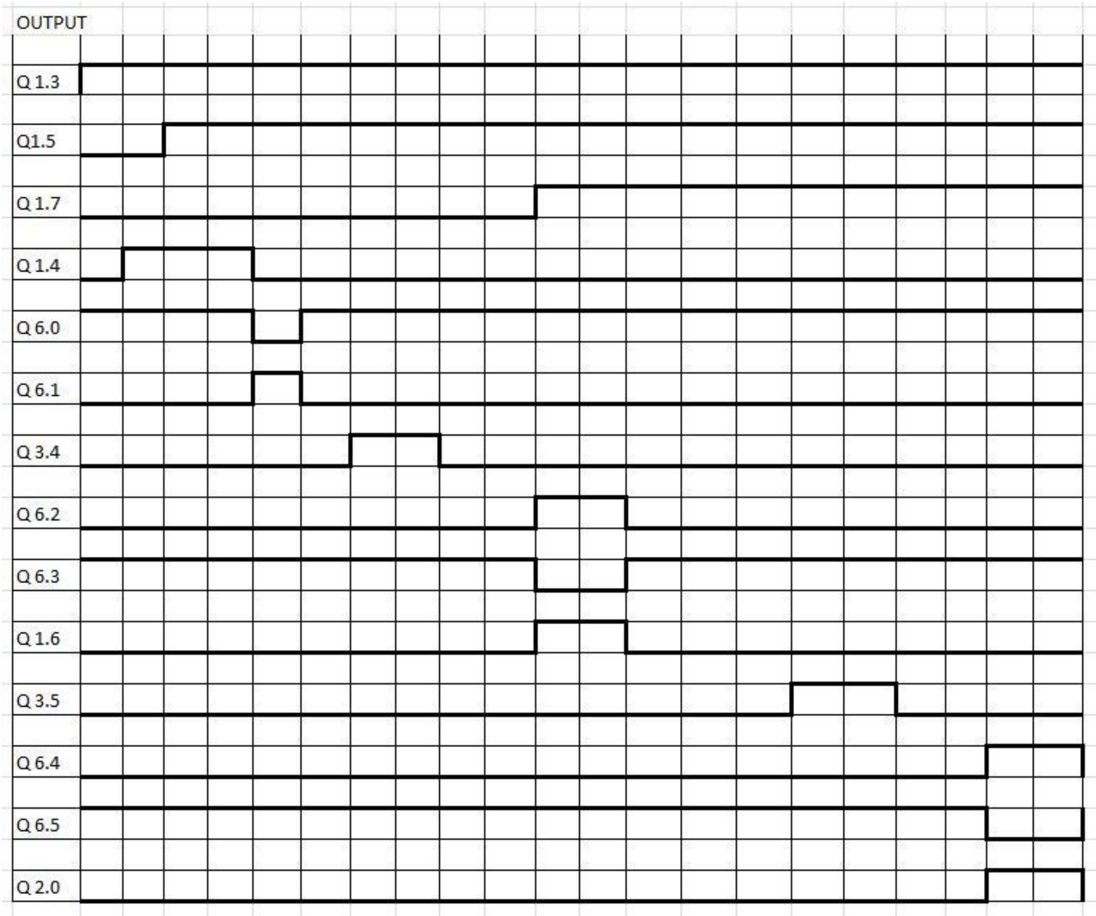



**Figure 22 : Timing Diagram for Both Sections input and output**

From the input and output's table above shown clearly status of input or output in specific frame of time in the system. This timing diagram has been set to help engineers to find solution when comes to troubleshooting part. First they need to find at what event or time frame the system is conflict, then they can refer to timing diagram to compare all the status input and output from timing diagram.

### 4.2.4 Boolean Sequence

**GENERAL FORM**

**OUT = (SET + OUT) .** $\overline{\textbf{RESET}}$

**Line 1**

**V0.1** = (I0.2 + V0.1) . $\overline{\text{I0.4}}$

**Line 2**

**Q1.5** = (V0.1+ Q1.5)

**Line 3**

Q1.3 = (V0.1 + Q1.3)

**Line 4**

**Q1.7** = (V0.1 + Q1.7)

**Line 5**

**V0.2** = (V0.1.I8.2) +V0.2

**Line 6**

**Q6.0** = V0.2 . $\overline{\text{I8.3}}$

**Line 7**

**T37** = I8.3

**Line 8**

**V0.3** = T37 . I4.1

**Line 9**

**Q6.1** = V0.3 + (Q6.1 + I8.4)

**Line 10**

**Q1.4** = (T37 + Q1.4) . $\overline{\text{I8.4}}$

**Line 11**

**V0.4** = (V0.1 . I8.4) + V0.4

**Line 12**

**T38** = V0.4 . I8.5

**Line 13**

**Q3.4** = V0.4 . T38 . $\overline{\text{I8.6}}$

**Line 14**

**T39** = I8.6

**Line 14**

**Q6.3** = I8.6

**Line 16**

**Q1.6** = (T39 + Q1.6) . $\overline{\text{I9.0}}$

**Line 17**

**T40** = I9.2

**Line 18**

**Q3.5** = T40 . I9.2 . $\overline{\text{I9.3}}$

**Line 19**

**T41** = I9.3

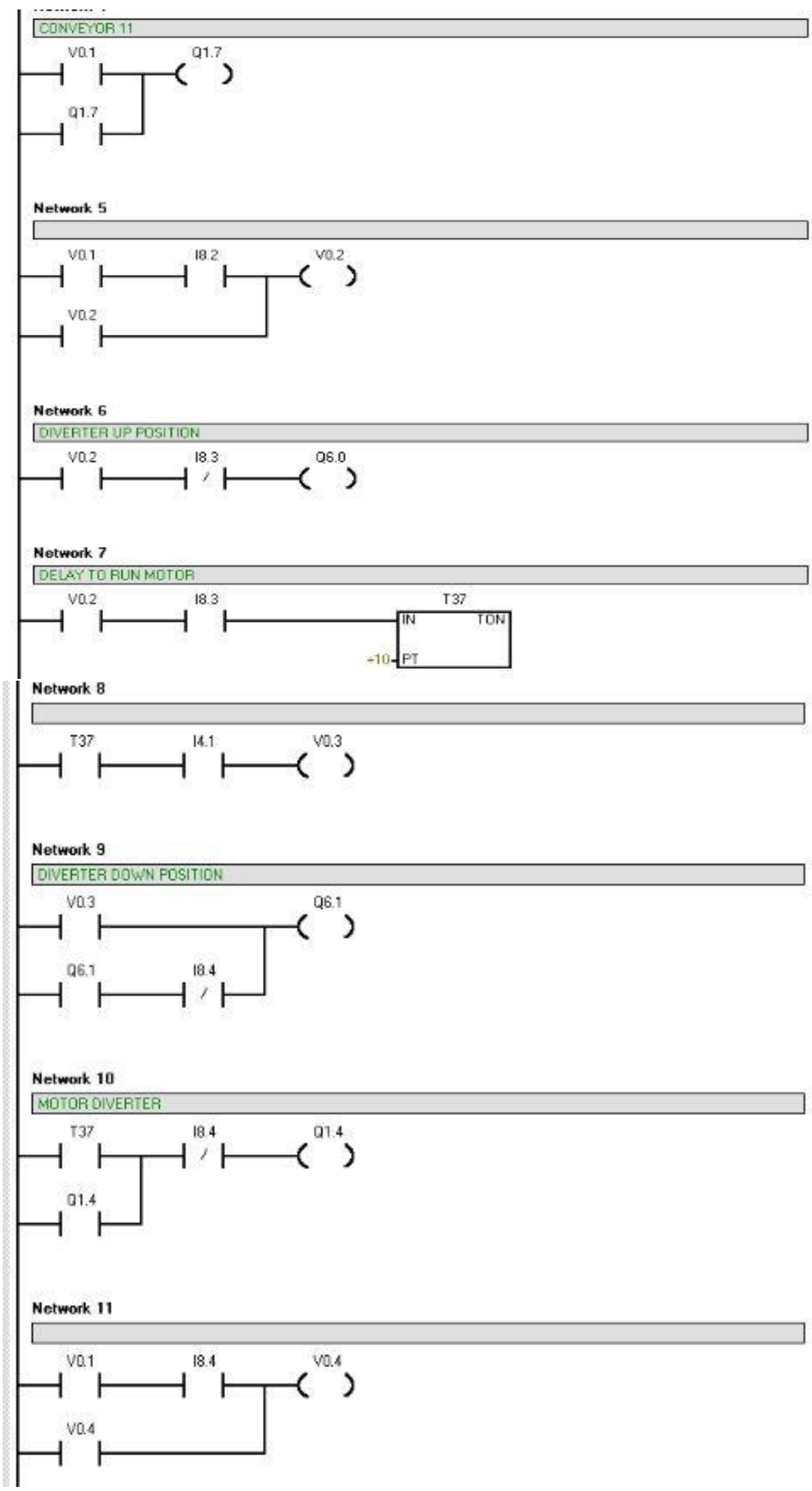
**Line 20**

**Q6.5** = I9.3

**Line 21**

**Q2.0** = (T41 + Q2.0) . $\overline{\text{I9.3}}$

### 4.2.5 Ladder Diagram



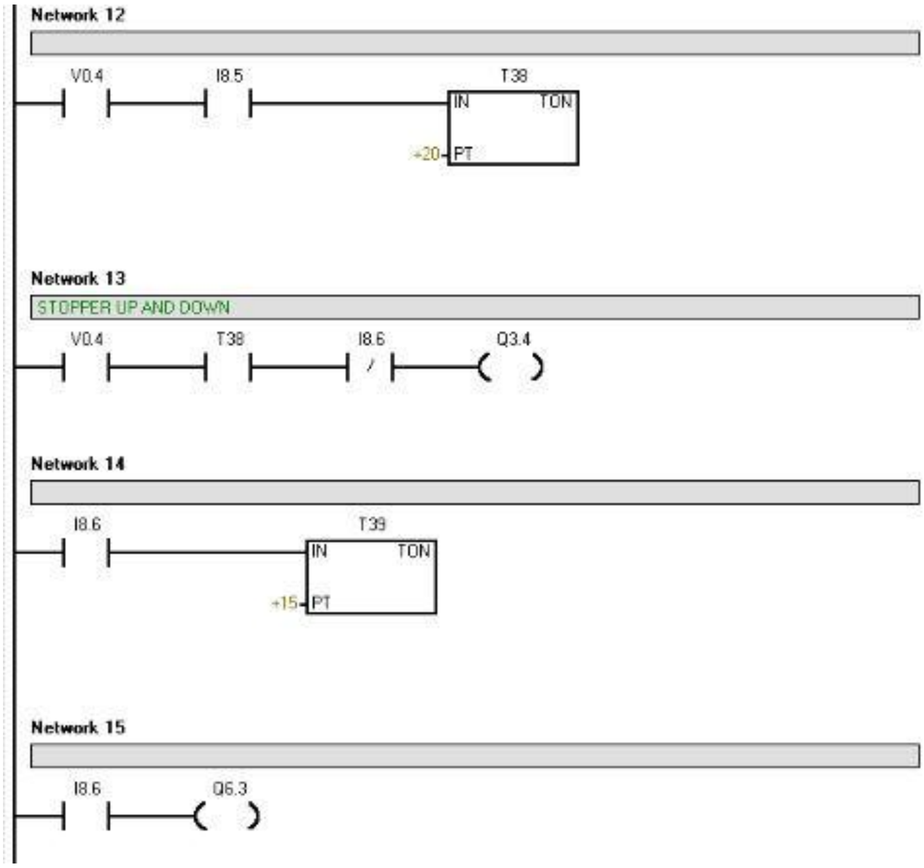



**Figure 23 : Ladder Diagram for System Conveyor II**

Ladder diagram above is developing step by step using structured method for the system conveyor 4 and 5. There are some recommendations that can be added into this ladder diagram.

1. Emergency button input can be added to increase safety of the system. Emergency button will stop the entire program automatically.
2. Reset input can be added in each rung to reset the input and output.

### 4.3 Discussion of system 3 and 4

To find the average speed of conveyor, the theory of speed is used.

$$v = \frac{d}{t}$$

$v$ = speed $d$ = distance $t$ = time,

The purpose of this experiment is to investigate the capability of conveyor to deliver the product from starting point until the end. How many pallet it can deliver to the production line. For this experiment, it is focused on the conveyor's section 3 and 4.

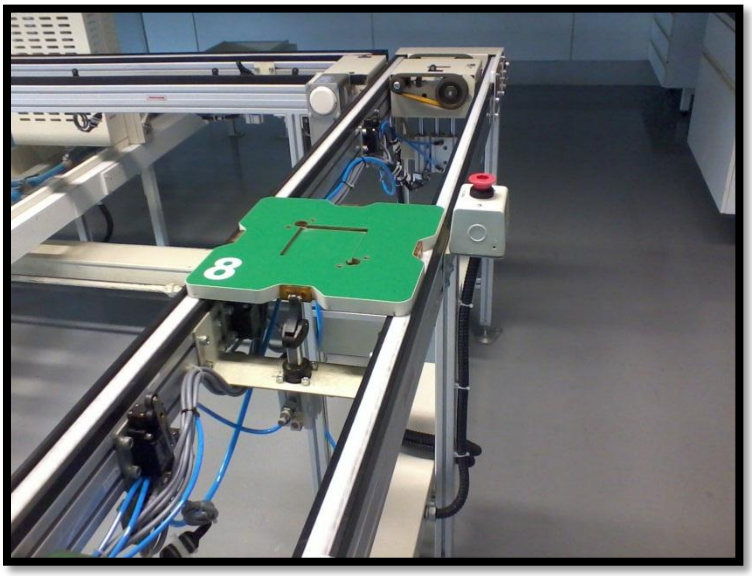


**Figure 24 : Conveyor System 3**

The experiment takes 100cm as a distance and with the maximum speed of conveyor is used to find time taken when pallet is released from 0cm until 100 cm. The result is the pallet takes about 5s to complete the distance when there are no barrier or blockage at the conveyor.

$$v = \frac{d}{t}$$

$$v = \frac{100cm}{5s}$$

$v$ = 20*cm/s* ~ 0.2*m/*s

From the experiment, speed for conveyor belt around the system indicates 0.2m/s.

Dimension of each pallet is $0.09m^2$ and length from sensor T09 Arrive to T09 Full/Pass is only 80$cm$.

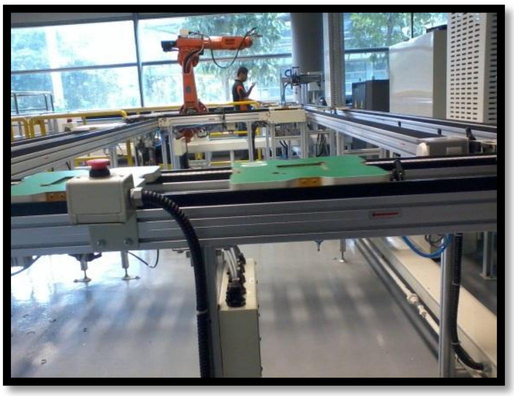


**Figure 25 : Conveyor system 4**

$$x = \frac{80}{30} cm$$

x= 2.667 ~ 2

*X*= maximum number of pallet

So, the maximum pallet that can be at one time for conveyor 3 is 2 pallets only. If there more pallets in one time, the excess pallet disturb the input T08 Full/Pass.

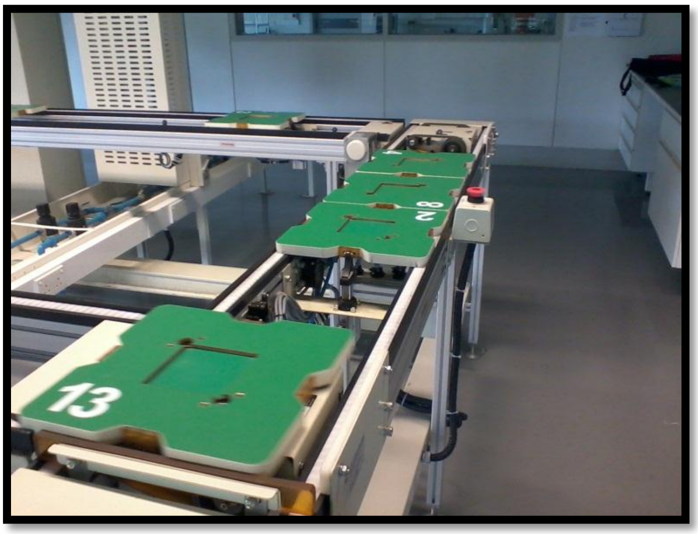


**Figure 26 : Maximum Pallet which cans Support Conveyor System 4**

$$y = \frac{102}{30} cm$$

y= 3.4 ~ 3

*y*= maximum number of pallet

Thus, the maximum pallet that can be at one time for conveyor 4 is 3 pallets only. If there more pallets in one time, the excess pallet disturb the input in the T09 Full cause diverter MT10 to malfunction.

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# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

As a conclusion, the objective of this Final Year project which is to establish communication link between PLC and conveyor system and also to integrate the capability of PLC as a controller in the FMS laboratory in Universiti Teknologi PETRONAS (UTP) by developing programming routine via ladder diagram using structure method is achieved with all software, hardware and supporting material such as I/O list, layout diagram and etc. In addition, using structure method as an approaches to designing and developing program for PLC has its own advantage which is help engineers to identify event that is problem to be troubleshoot. This project also is a platform for future Research and Development (R&D) in UTP. Lastly, it is important to integrate the knowledge and practical that has been applied through this project

### 5.2 Recommendation

As this project is done there are several recommendation and expansion that can be done in the future.

1. Install pneumatic pick and place robotic in the middle of conveyor 3 and 4. It will be interesting if pick and place robotic is using pneumatic as pneumatic supply is provided in the lab. There are also, many spare in the PLC in the box.
2. Install safety feature in conveyor so the system is safer and controllable. Safety is one of the very important elements in manufacturing industries besides product and quality.

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# APPENDICES

### 3.3.1 Gantt Chart for Final Year Project I (FYP I)

| No | Detail/Week | 1 | 2 | 3 | 4 | 5 | 6 | MID-TERM BREAK | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Selection of Project Topic: PLC-Controlled of a Conveyor System II | | ▲ | | | | | | | | | | | | | | |
| 2 | Preliminary Research Work: Literature Review | | | | ▲ | | | | | | | | | | | | |
| 3 | Preparation of Extended Proposal | | | | | | ▲ | | | | | | | | | | |
| 4 | Project Work: Study on the research scope and method of ladder diagram. | | | | | | | | | | | | | | | | |
| 5 | Proposal Defense | | | | | | | | | | ▲ | | | | | | |
| 6 | Ladder Diagram simple project and Simulation | | | | | | | | | | | | ▲ | | | | |
| 7 | Interim Draft Report | | | | | | | | | | | | | | ▲ | | |
| 8 | Improvement of Interim Report | | | | | | | | | | | | | | | ▲ | |

**Table 1: Gantt chart and Key Milestone for FYP 1**

▲ Suggestion Milestone

Proces

### 3.3.2 Gantt Chart for Final Year Project II (FYP II)

| No | Detail/Week | 1 | 2 | 3 | 4 | 5 | 6 | MID-TERM BREAK | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Training with vendor | ■ | ■ | | | | | | | | | | | | | | |
| 2 | Developing of Sequence Diagram | | | ■ | ■ | | | | | | | | | | | | |
| 3 | Developing Timing Diagram and Boolean Expression | | | | ■ | ■ | ■ | | | | | | | | | | |
| 4 | Developing Ladder Diagram | | | | | | | | ■ | ■ | ■ | | | | | | |
| 5 | Preparation of Progress Report | | | | | | ■ | | ■ ▲ | ■ | | | | | | | |
| 6 | Analysis and conclusion | | | | | | | | | | | ■ | ■ | ■ | | | |
| 7 | Preparation for Pre-EDX | | | | | | | | | | | ■ | ■ | | | | |
| 8 | Preparation for Report | | | | | | | | | | | ■ | ■ | ■ | ■ | | |
| 9 | Submission of Draft Report | | | | | | | | | | | | | | ■ ▲ | | |
| 10 | Submission of Dissertation | | | | | | | | | | | | | | | ■ | ■ |
| 11 | Submission of Technical Paper | | | | | | | | | | | | | | | ■ | |
| 12 | Slide preparation and Oral Presentation | | | | | | | | | | | | | | ■ | | |
| 13 | Submission of Project Dissertation (Hard bound) | | | | | | | | | | | | | | | | ■ |

■ Proces ▲ Suggestion Milestone

**Table 2: Gantt chart and Key Milestone for FY**