**PLC-CONTROLLED OF
A CONVEYOR SYSTEM (SYSTEM III)**

By

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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)

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CERTIFICATION OF APPROVAL

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Approved:

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Assoc. Prof. Dr. Nordin B. Saad
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TRONOH, PERAK

September 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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Adrien Muhammad Bin Idris

ABSTRACT

This project entitled PLC-Controlled of a Conveyor System (System III), which is an integrated system that is operated and controlled by the PLC used itself. A project that made to study the capabilities of the conveyor system installed in one of UTP's laboratory. Besides that, this project also requires study for developing the set of PLC programming routines using structured method as to allow the modifications of the system operation that is proper and preferable. This system has been rarely used and only operated for the demonstration purposes, which lead to the inflexibility of the system. In addition, none of work to develop and understand the system's programming routines ever conducted which also cause no research activities made for quite some time. As a solution, the study to develop the programming routines for the system through structured method is implemented. This method is a step-by-step method to develop the PLC programming routines using ladder diagram, which begins with the program description, to the timing / sequence diagram until the PLC ladder diagram is developed. Based on this method, the system capabilities can be studied in details and the system operation is successfully being modified along the project is conducted. In conclusion, the project was successful, and in future it is believed the development of PLC programming routines could be easily done for advance or complex operation. The system also could be improved to cope with the modern technological growth in the Flexible Manufacturing System (FMS) field, as well to assist the possible project and research activities later.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

EE	-	Electrical & Electronics
FMS	-	Flexible Manufacturing Systems
FYP	-	Final Year Project
I/O	-	Input/Output
PLC	-	Programmable Logic Controllers
R&D	-	Research & Development
RMS	-	Robot Manipulator Systems
S-Method	-	Structured Method
UTP	-	Universiti Teknologi PETRONAS

CHAPTER 1
INTRODUCTION

1.1   Background of study

Programmable Logic Controller (PLC) is a dedicated and specialized computer for the manufacturing processes and machinery operations. This is a computer that utilizes and / or produces the analog and / or digital signals to store instructions via its programmable memory as well as executing various functions including the on/off control, timing, sequencing, arithmetic, data handling.

This programmable controller is a common used device in industry especially to expand and / or enhance production compared to the old system. Today, with the PLC devices being developed in advance, it widely being used for modern and complex processes, such as *conveyor system* in manufacturing the PLCs has changed the speed accuracy, and efficiency of the industrial control scene in our modern technology evolution.

In UTP, the PLCs are installed for the conveyor system inside the Industrial Automation Lab. This system is an integrated system of other systems involved, including visual inspection, conveyor, and load/unload processes. This system not properly operate and currently used for demonstration. This project is a study specifically based on the load/unload processes as *System III* of the conveyor system.

1.2   Problem Statement

The PLC-Controlled Conveyor System which is installed on EE laboratory in Block 22 is rarely operated for research or study purposes due to several problems that has been identified that cause the system not well-functioning as listed below:

1.2.1 System Operation for Demonstration Purposes

Since the conveyor system being delivered and installed in UTP laboratory (22-00-12), it is only operated for demonstration purposes during guest's visitation to UTP. Based on this reason, only certain people do know how to handle this system operation very well, which include the people who involved with the installation process when it's delivered especially Mr. Azhar, the EE Department Laboratory Technologist.

1.2.2 No Proper Work for Programming Routines Development

The nature of this conveyor system seldom used leads to no detailed information or knowledge about the system physically, its integrated operation, and the method of systems being programmed. So, it cause the system operation is difficult to be modified via its programming since there is no proper work or methods used and studied for development. This study should be documented.

1.2.3 Fixed System – No Research and Development (R&D) Activities

The difficulties to modify the conveyor system programming routines are understandable. Thus, the system is not being operated for quite some time. So, the demonstration is still depends on the test program that being provided by the vendors involved in the system installation, which creates an inflexible system that is cause by less interest in R&D activities of the conveyor system field.

1.3 Project Objectives

The primary objective of this project is about to study and investigate the capability of the PLC as a controller used on the conveyor system. Besides that, the secondary objectives of this project are to be able to understand the FMS system introduction as the manufacturing mechanism, specifically to study the physical of the FMS system inside the university Industrial Automation Lab (block 22), In addition, the project objectives is to be familiarized with the PLC programming language (Ladder Diagram) and also to develop the set of programming routines through structured method as to allow the FMS system to be flexible for the Research and Development

(R & D) works. The objectives are shown as in diagram shown below
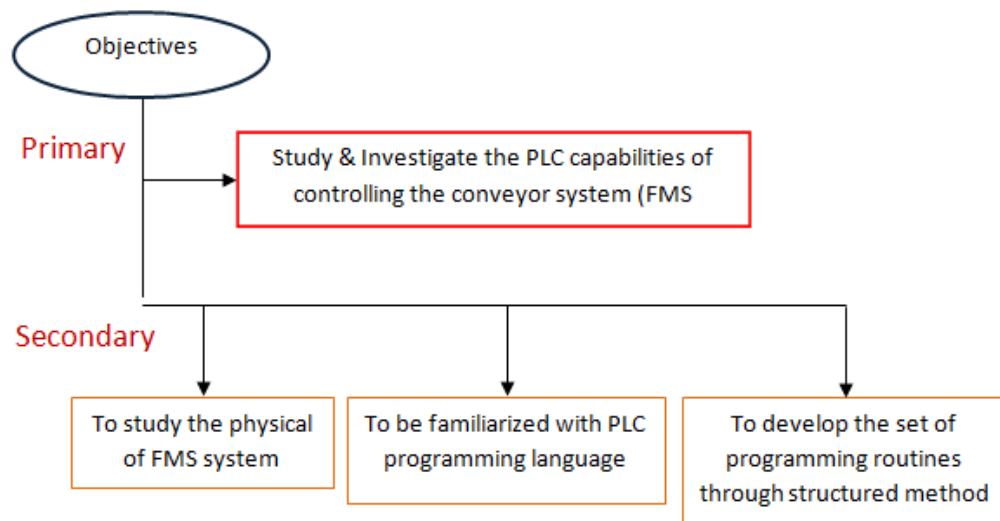
Figure 1   Project Objectives

1.4   Scope of Study

This project main scope is to familiarize with the conveyor system installed in the stated lab, both in hardware and software. In addition, the study scope also includes the development of the programming routines via PLC Ladder Diagram of the system. Based on this study, the interdependence of PLC and FMS could be able to understand. The programming routines for both simulation and real time operation could be corrected and modified for better also efficient system.

1.5   Project Feasibility

Upon the completion of this project, students of researchers of this conveyor system should able to understand the basic knowledge of the PLC and FMS. Besides that, the modification of the programming routines It is also expected after the project is completed; the conveyor system and the lab itself will be fully operated and well-functioning, as to allow the R&D activities and projects being done by the UTP students.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 PLC and FMS Correlation

This project is mainly use PLCs as the controller to control the conveyor system process. The PLCs are the controllers and the conveyor system is the sample of Flexible Manufacturing System (FMS) used. The PLC and the conveyor system are dependent to each other. These are the description of the PLC and FMS.

Programmable Logic Controllers (PLC)

Originally, PLC is used in manufacturing industries, where the process is handled manually or partially automated by using hundreds or thousands of electromechanical relays that made the system is very complex, that consisting rigid control circuits, electrical, hydraulic and pneumatic.

The old automation system made it difficult to be upgraded or expanded and could only handle simple process such as material lifting. Thus, it indicates the old system is inflexible. Since the invention of micro-computer, the manufacturing process is changed and controlled by codes reprogrammed inside the computer without requires skilled and trained workers for troubleshooting process of the system. The computer implementation in manufacturing process has lead to the PLC birth and its widespread use in manufacturing industries itself till today. Among the common PLC applications in industries are

- Pump control
- Process manufacturing control
- Traffic light system
- Car manufacturing plant

- Material handling
- Conveyor system
- *Flexible manufacturing system (FMS)*

The PLC consists of its 'brain' which is the Central Processing Unit (CPU) and its memory, and the Input and Output Interface modules. The PLC output interface modules / terminals is activated to switch ON or OFF the output devices as responses to the PLC input modules / terminals using some sort of input devices. Thus, the PLC complete overview can be described as below.
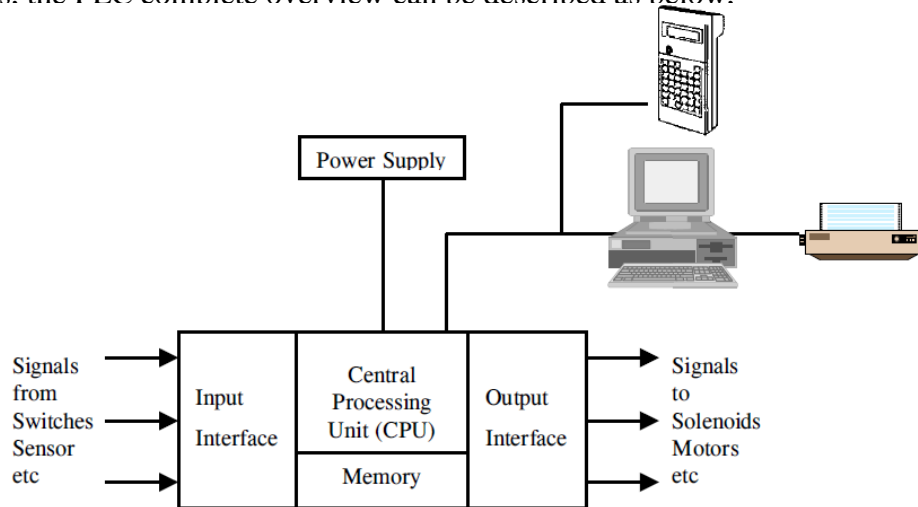
Figure 1 PLC Block Diagram System

Power Supply

Normally, the PLCs would be powered up either using 12 / 24 / 110 / 240 V DC or AC sources depending on PLCs power sources requirement.

Central Processing Unit (CPU)

The microprocessor that contains the Arithmetic Logic Unit (ALU) coordinates the PLC activities. It executes the program, processing the I/O signals and establishes connection with external devices (eg. computer, display, and sensor).

Memory

PLC could have various types of memory unit. It is where the operating system and user system are hold. While the PLC coordinated by operating system, the Ladder program, Timer and Counter are stored in user memory.

Among the memory units available are, Read-Only Memory (ROM), Random Access Memory (RAM), and Electrically Erasable Programmable ROM (EEPROM) where the contents can be erased and reprogrammed electrically within its limit number of times

Input modules / terminals

The PLC part which usually protected from high voltage and current pulses that could be generated from electromagnetic (EM) sources. This safety feature use opto isolator (electrically isolated) or protection relays.

Output modules / terminals

Contain switches activated by CPU to allow the current to flow for electrical connection between PLC and output devices such as motor, solenoid valves and other. Transistor or relay is commonly used.

Both terminals normally numbered, as it will be used in program.

Input devices

Sensors normally used to provide the data and feedback signals for the PLC input terminals, by measuring and monitoring the desired parameters (voltage, current, pressure, torque, etc.). It also may be placed on actuators or on machine to control the actuators position.

Example of common sensors used especially in a conveyor system:
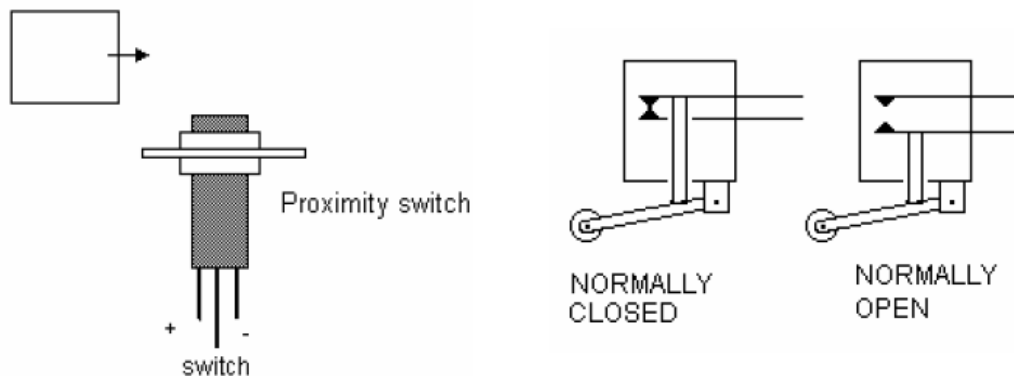
Figure 3   Magnetic Reed & Limit Switches

The type of switches, that switch ON whenever something closes it. The commonly use for metal detection system. Switches and valves could be N/O or N/C. It can also being used as the limit switches

.
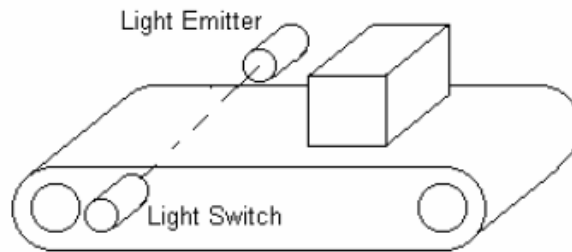
Figure 4   IR Sensors on Conveyor Line

By using infrared (IR) light and sensor (IR transmitter and receiver), the sensor either will switch ON or OFF when the light beam is interrupted and it is commonly installed and used on conveyor system.

Output Devices

Use to feed back the signals to CPU and input sensors, and also for indication and displays. Example – motor (DC motor for conveyor belt, AC motor for pump starter), light, alarm (buzzer) and others

The PLC is interfaced with computer and I/O devices, as to link them together, modems normally used and some common cables applied between it as its guided connection medium, such as using the Twister Pair, Coaxial and Ribbon cable. It used for the data transmission between PLC, computer, and I/O devices depending on either it is serial or parallel data. There are also several types of PLC used, which is

Unitary – contained in a single box that usually attached on the machine

Figure 5   Unitary & Modular PLC

Modular – Range of modules used in a system. Some module allocated for different usage. It may also contain the A/D converters, and number of terminals could be expanded easily.

Rack Mounting - Similar concept to the modular PLCs. But the modules is slotted into a standard rack which allows the better expansion to the system

Flexible Manufacturing Systems (FMS)

Since the industrial revolution, the manufacturing process primary concern is the cost. Until early 1970s, the quality and the speed of delivering products has become customer's priority.

As the technological growth continues, the market has become stressful and the manufacturers have to consider the efficiency, quality and flexibility of their systems

Figure 6   FMS as Industrial Applications

as to survive in business. Thus, the FMS implementation in manufacturing industries has become larger in-scale as to meet the market demands.

The FMS can be define as *a production system that consist a set of identical and/or complementary numerically controlled machines that are connected through automated transportation via processes that controlled by a dedicated computer* (computer controlling the PLC). Therefore, the PLC implementation in FMS is considerably significant In FMS, its equipment involved can be divided into the primary and secondary equipments, such as below

Primary	Secondary

Work Center
 	
   • Turning & universal machine
   • grinding machine
Process Center
 	
   • wash & coordinate measuring
	Support Station
	
	   • load / unload / pallet station
	   • tools commissioning area
	Support Equipments
	
	   • Pallet, tool & raw material

	storages
• robotic & manual workstations	• Robot, transport system and units

Table 1: FMS Equipments

There are 2 main types of *flexibility level of FMS*, which is

Dedicated	Random Order
o Produce limited variety of products / parts styles	o Suitable for large part family
o Part family are based on commonality	o New products / parts designs can be introduced
o End Products / Parts is known	o Production schedule is rely on the daily adjustments

Table 2: FMS Flexibility Levels

The conveyor system that being studied in this project has a combination of several FMS layouts as shown in Table 3 below,
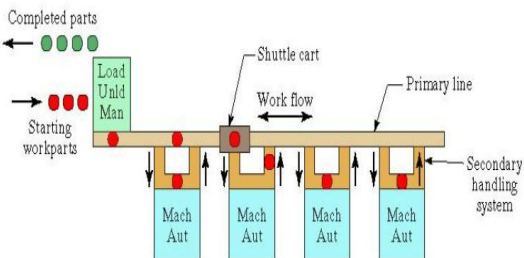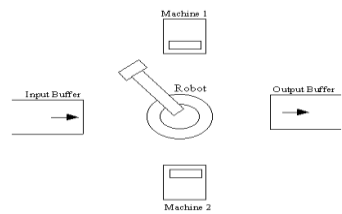
In-line Layout	Loop Layout
▪ Could be straight and / or reversible line flow ▪ Has either having or not having secondary handling system *Rectangular Layout* ▪ Allows recirculation of pallets from final to first station after loading / unloading process *Open field* ▪ Has multiple loop and ladders ▪ Suitable for large part families	▪ Has only 1 direction flow ▪ Process sequences can vary for different part types ▪ Has secondary handling system in each workstation ▪ Best for long process time and flexibility *Ladder Layout* ▪ Loop with rungs ▪ Allow better variation in process sequences *Robot centered cell* ▪ Use for rotational parts and turning operations

Table 3: FMS Layout Types

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Based on the PLC and FMS, it is proven that PLC is the main elements of the modern manufacturing system such as FMS. The PLC and FMS are dependent to each other, where PLC process, send signals to control, while FMS provide the status (input and output) for the PLC s to process. It is explained briefly as in figure below
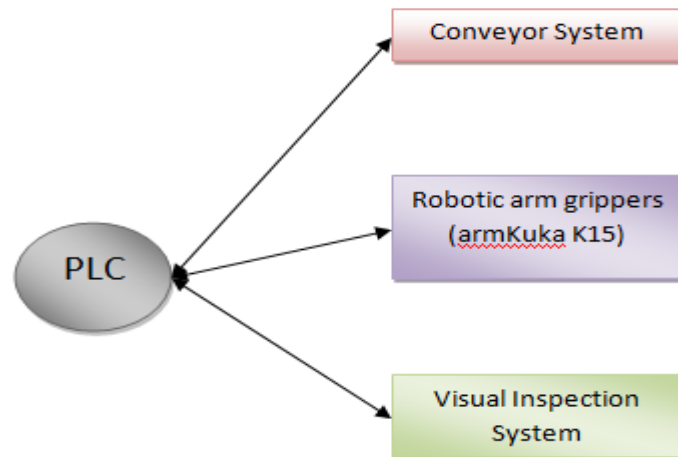
Figure 7   PLC and Systems Relation

The figure above shows the main device controlled by the PLCs inside the laboratory. The double way arrows indicates the input and output signals needed and sent for both ways as to ensure the system operates well. Thus, PLC and FMS (which is the other system including the conveyor system) are correlate to each other.

2.2 System III

The conveyor system installed in UTP's laboratory is located at Electrical & Electronics Engineering building block 22, named as the Industrial Automation Lab (22-00-12). This lab is equipped with a typical conveyor system and a robotic arm that controlled by PLCs and consoles.

Figure 8   PLC- Controlled Conveyor System in UTP lab

Based on studies, this system in the lab can be explained as the combination of conveyor system, the robotic arm system and PLC as its main controller, programmed and monitored from PC or monitor.

Besides that, this FMS system can be divided into three different systems as shown in the **Figure 9** below
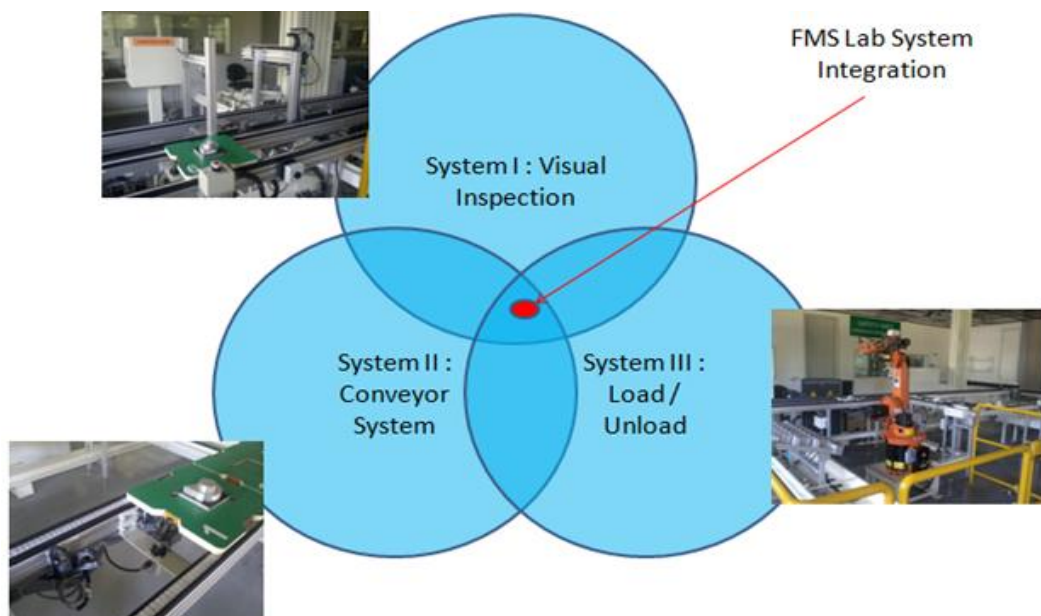
Figure 9   Conveyor System Integration

From Figure 14 shown above, the System III is referring to the robotic arm system that can be initially described as independent sequentially-controlled working system, since that the robotic arm is not being interfaced together with two other systems except for the electrical and pneumatic supply flow. In addition, System III is likely to be the load or unload station for the whole system integrated.

2.2.1 System Overview

Basically, the System III overview is as shown in figure below
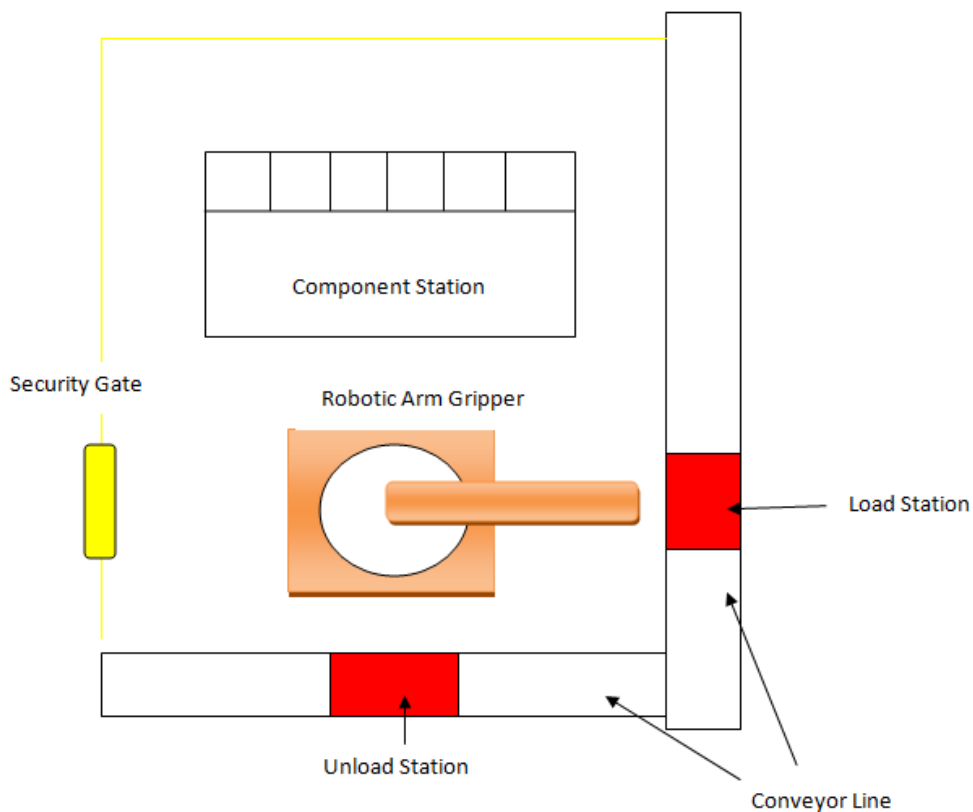
Figure 10   System III Section Overview

This section involves the conveyor line Block 5 (unload) and Block 1 (load) conveyor line, the robotic arm gripper which in this project use armKuka K-15 and the components station.

Thus, basically the System III is functioning for the "pick and place" or storage handling system

2.2.2   Load / Unload

The load and unload process of the objects / components is handled by the robotic arm gripper as in shown in figure below,

Figure 11   Robotic Arm Gripper (armKuka K15)

It rotates and grip the object before transferring it to the component station, which each process of the load and unload, the robotic arm will rotates towards the component station and the conveyor lines.

2.2.3   Component Station

The component station is used as to store the component or the object used for the conveyor system operation. It is load and unloads at the conveyor line (block 1 and 5)* before being moved to inspection station on next conveyor line. The station is as below,   *(* refer to Appendix D)*

Figure 12   Component Station

2.2.4 System Flow

The conveyor system flow of System III can be explained briefly by the diagram flows in Table 1
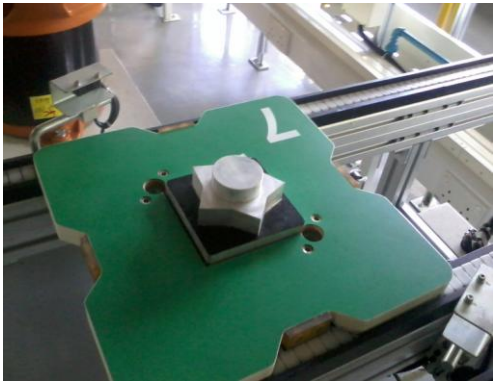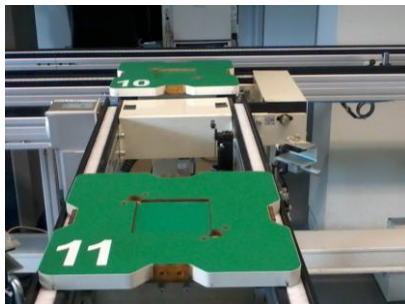
1. **Pallet moves along the conveyor until it reach the unload station for unloading process**	4. **The robotic arm grips and loads the object to the empty pallet**
2. **After the object removed, the pallet continue to move along the conveyor line 5 until it reach the conveyor line 1 diverter** 3. **The pallet movement diverted to conveyor line 1 and stop when it reaches the load station**	5. **Pallet continue to move until the next conveyor line for inspection process**

Table 1: System III Process Flows

CHAPTER 3
METHODOLOGY

This project is conducted in two semesters of studies, with two different case studies for each semester. Despite the differences, the methodology used to complete this project is similar. Starting from the physical study of the conveyor system until the development of the PLC programming routines using Ladder Diagram through structured method, the procedures and results is expected to be related for both semester of this project as well the objectives of this project is to be achieved. Although the literature review study is the critical initial step taken, there are several important methodologies used to complete this project, as listed

3.1   S-Method Implementation

S-Method is the abbreviation for the Structured Method. By using this method, the development of the PLC programming routines (Ladder Diagram language) could be achieved precisely which includes modifying and correcting the errors of the conveyor system operation. It is actually a step-by-step method to develop the PLC ladder diagram programming in which it can be used as own method to understand the system program without depending much on the manufacturer or programmer of the system
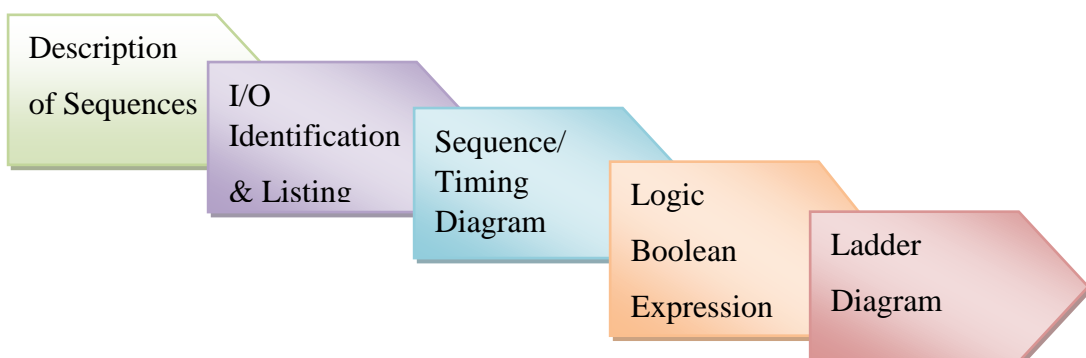
Figure 13   S – Method steps

Through this S-Method, the programming routines are expected can be created and modified easily. It also ease the system users to understand and correct the errors occurred from the system operation, the method is discussed in details in Chapter 4 of this repor

3.2 Documentation

The documentation of the system studied is a fundamental step of data gathered that must be accounted for, to help users or researchers to understand well on the hardware and software used for the system. In addition, the documentation is important, for which help to understand the system's characteristics and operations. Example of the system documentation is the System I/O address lists, the system's layouts and system flow charts as shown in *Appendices*. This methodology would also develop references and guidance for others.

SYSTEM III I/OASSIGNMENT LIST

Block 5 Conveyor Line			
Input	**Description**	**Output**	**Description**
X 02 03	T19 Locator Part Present	Y 02 01	T13 Conveyor
X 04 07	T19 Locator Up Position	Y 03 06	T19 Stopper Valve
X 05 00	T19 Locator Down Position	Y 06 06	T19 Locator Up Valve
X 09 04	T19 Stopper Arrive	Y 06 07	T19 Locator Down Valve
X 09 05	T19 Stopper Reset		
Block 1 Conveyor Line			
Input	**Description**	**Output**	**Description**
X 03 01	T02 Diverter Up Position	Y 01 01	T02 Diverter
X 03 02	T02 Diverter Down Position	Y 02 02	T14 Diverter
X 05 01	T14 Diverter Up Position	Y 02 03	T01 Inverter Run
X 05 02	T14 Diverter Down Position	Y 03 07	T20 Stopper Valve
X 05 03	T20 Locator Up Position	Y 04 00	T01 Stopper Valve
X 05 04	T20 Locator Down Position	Y 05 00	T02 Diverter Up Valve
X 07 02	T01 Stopper Arrive	Y 05 01	T02 Diverter Down Valve

Figure 14   Documentation Sample

3.3 Real Time Operation

As to test the S-Method credibility and for further documentation of data gathered, the programming routines must be tested and simulated using simulation and the system's software itself. For the simulation, the Automation Studio software has being used to test and verify the programming routines virtually. For the real-time operation which is using the system's software (Siemens SIMATIC S7-200 S7-

Micro/WIN software). This method used to monitor and ensure the system is working as programmed.
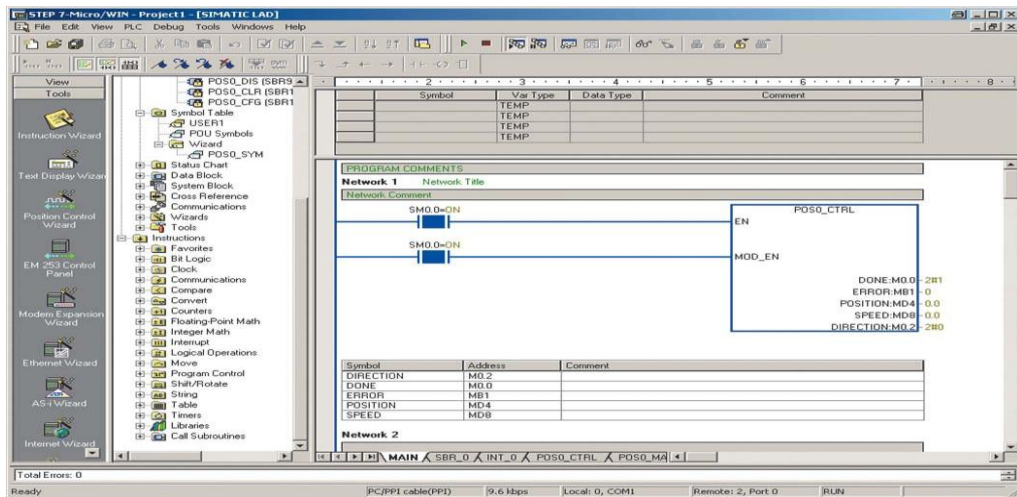
Figure 15   SIMATIC S7-200 S7-Micro/WIN software

3.4   Troubleshooting

A crucial methodology requires system users to troubleshoot the system either physically or the programming of the system themselves. A system monitoring and diagnose as well system manuals can be used to help the troubleshooting process. This method help users to eliminate the errors which occurs during system operated. This method is recommended to be repeated to ensure a well-functioning system and the troubleshooting data should be recorded for future references.

3.5   Hardware and Software

Main hardware of this project is the PLC module itself, which is using the SIEMENS SIMATIC S7-200 type.

Figure 16   *LEFT*: SIEMENS PLC S7-200   *RIGHT*: PLC Cabinet

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The PLC installed inside the PLC cabinet or rack as shown in figure above, the main module of this PLC can carries up to eight inputs and outputs each. The PLC can have its expansion for additional devices use in the conveyor system. Inside the cabinet, beside PLC there are also the necessary components and devices are installed, such as switches, a set of relays, supply transformer, circuit breakers, termination wiring, and other hardware for the controller needed.

For the software the Micro S-7/ Win software as in Figure 15 is used. The software use for the programming process of the system and could monitor the status of the system during the system is running.
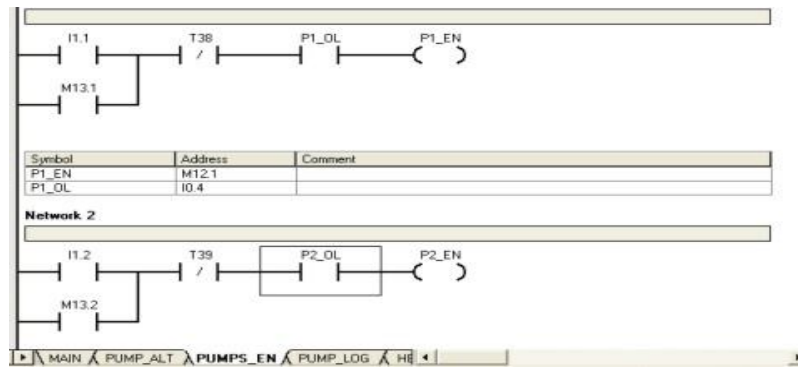
Figure 17   Sample : Siemens Ladder Logic Design

CHAPTER 4

RESULTS AND DISCUSSION

Throughout this 2 semester project, 2 different case studies are being given as to shows the implementation of S-Method of developing PLC programming routines.

4.1   Case Study I: Robot Manipulator Systems

- To analyze and develop ladder diagram for a robotic system and implement it on Automation Studio software
- Derive the appropriate timing sequence.
- Develop the corresponding ladder diagram for the electro-pneumatic manipulator system.
- To program the ladder diagram in Automation Studio software and to evaluate the operations of the robotic system.

FIGURE 6 shows the initial position of actuators that forms part of a robotic manipulator system used for moving pallets from point **X** to point **Y**. The double-acting-cylinder actuators A, B and D are to be energized individually by three different 5/2 normally closed (NC), electronic-actuated, electronic-returned solenoid valves. The actuator C is to be energized by a 4/2 normally open (NO), electronic-actuated, spring-returned solenoid valve. The sequence is to be initiated by a manual push button (PB) switch.
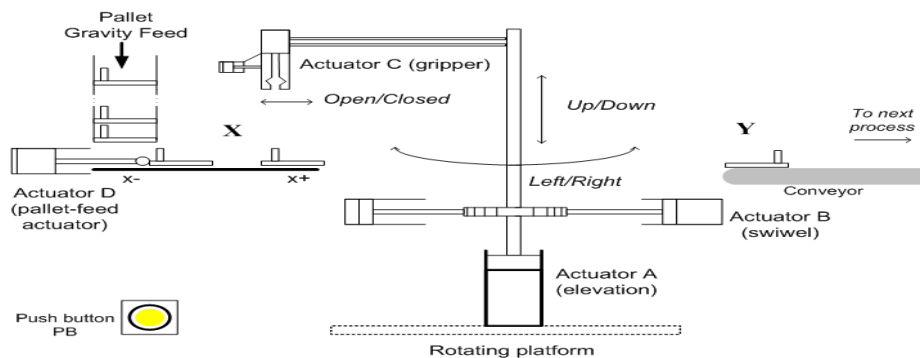
Figure 18   Robot Manipulator Systems

The sequence of this system is as given,

$$\{(D+D-|0.3s|C+A-C-A+B+A-C+A+C-B-)\} \times 20$$

After through the last 3 weeks, this study has being solved and the details as shown below.

System Description

This system is to simulate the robotic arm and its gripper movement to run the pick and place sequence. Initially, all actuator except for actuator A is at extend position (to lift up the robotic arm).An object is placed in front of actuator D, and then after PB (START) is pressed, the actuator D is extended to push the object until right beneath the position of the gripper (Actuator C) and retract to its initial position. When the object arrived beneath the gripper, the delay about 0.3 seconds is activated. Soon after the timer is out, the actuator C is extended to open the gripper. Then, the robotic arm elevator is retracted to grip over the object at position A-.

Later, the object is grip and the robotic arm is elevated again before the robotic arm is turn 180 degree to by its swivel actuator (Actuator B).

Lastly, after the actuator B is extended, the robotic arm being lift down and the gripper is open to place the object on the conveyor belt for the next process, and the robotic arm is swivel back to its original position before the system is reset and repeated for 20 times.

System Inputs and Outputs

Input: Three NO Push Button (START, STOP, RST)

                Eight Limit Switches (A+,A-,B+,B-,C+,C-,D+,D-)

Output: Four 5/2 Ways Pneumatic Solenoid Valves (A,B,C,D)

                Electronics Input: Timer and Counter

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Timing Sequence Diagram
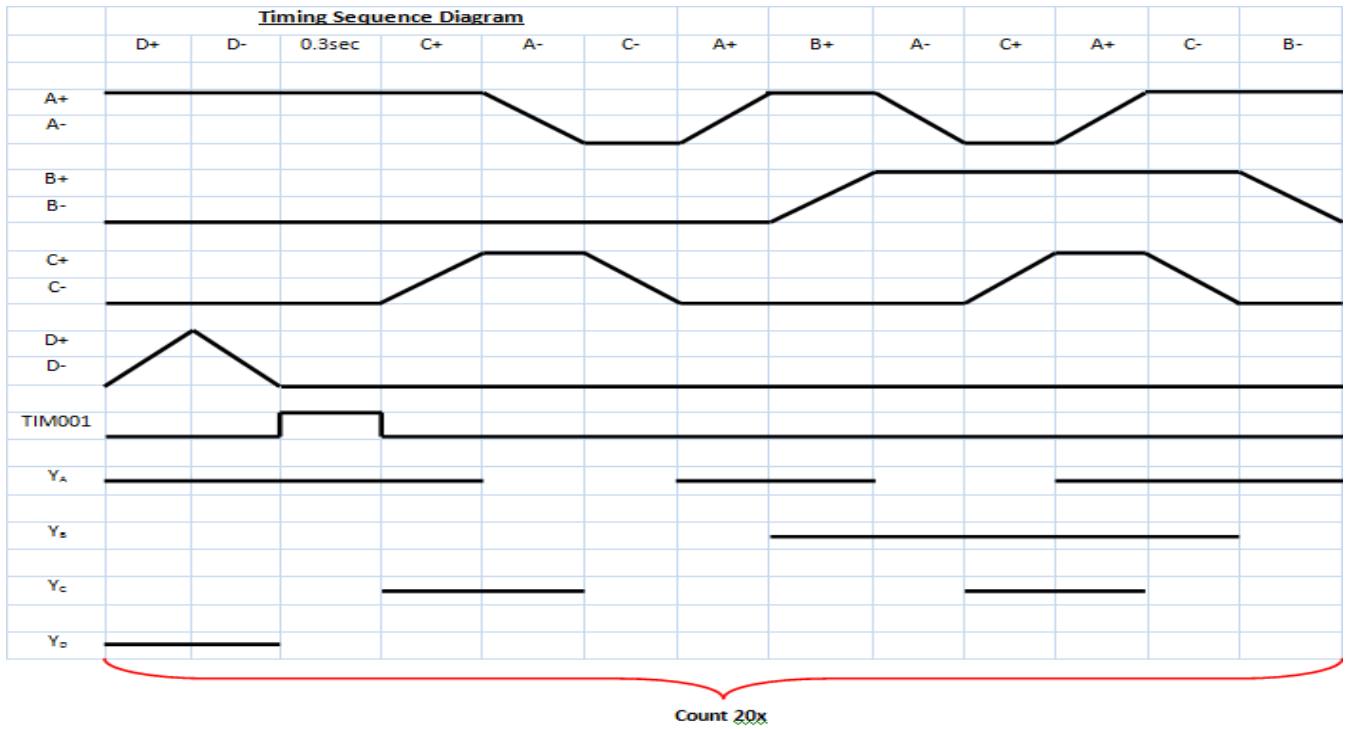
Figure 19   RMS Sequence Diagram

Robot Manipulator Systems Simulation Schematic
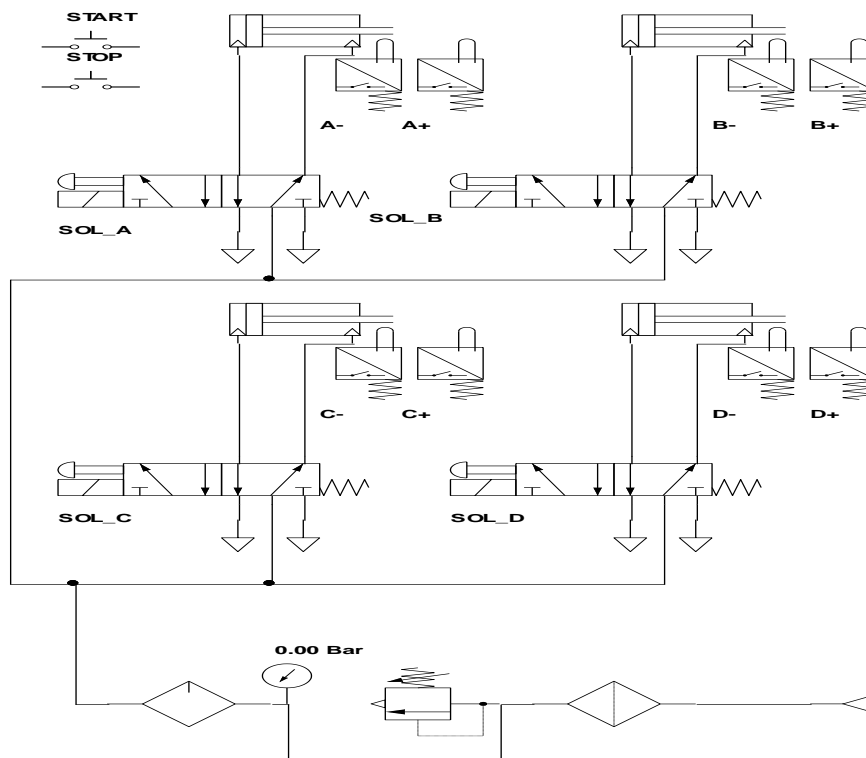
Figure 20   RMS Schematic (via Automation Studio)

The simulation process is completed after 3 weeks; some minor modification on actuator C is made. Initially, the actuator C used is the 4/2 Ways NO solenoid valve, but due to the compatibility problem of software and PC Windows, it cannot be edited. As to simplify the system, 5/2 Ways NC solenoid valve is used instead. This modification leads to simplify ladder diagram as shown in printed PLC Ladder Diagram based on Automation Studio software. The sequence is successfully repeated 20 times. Therefore, from this case study given, it helps all three of us to learn and understand better the PLC programming language that is commonly used (Ladder Diagram) and assisting us to illustrate and analyze the system sequence given before our group is being trained by vendors or contractors in few weeks time to program, simulate and experience the real-time system application that will be continued next semester for the Final Year Project II. The software that we have learnt, is as additional knowledge to help us to complete this whole project as well as to help us become a good engineer with excellent technical skills either using software or hardware and altogether.

The Robot Manipulator System is described in details as in table below.

1.A+B-C-D-	3.A+B-C-D- (timer ON 0.3s)
2.A+B-C-D+	
	4.A+B-C+D-
5. A-B-C+D-	9.A-B+C-D-
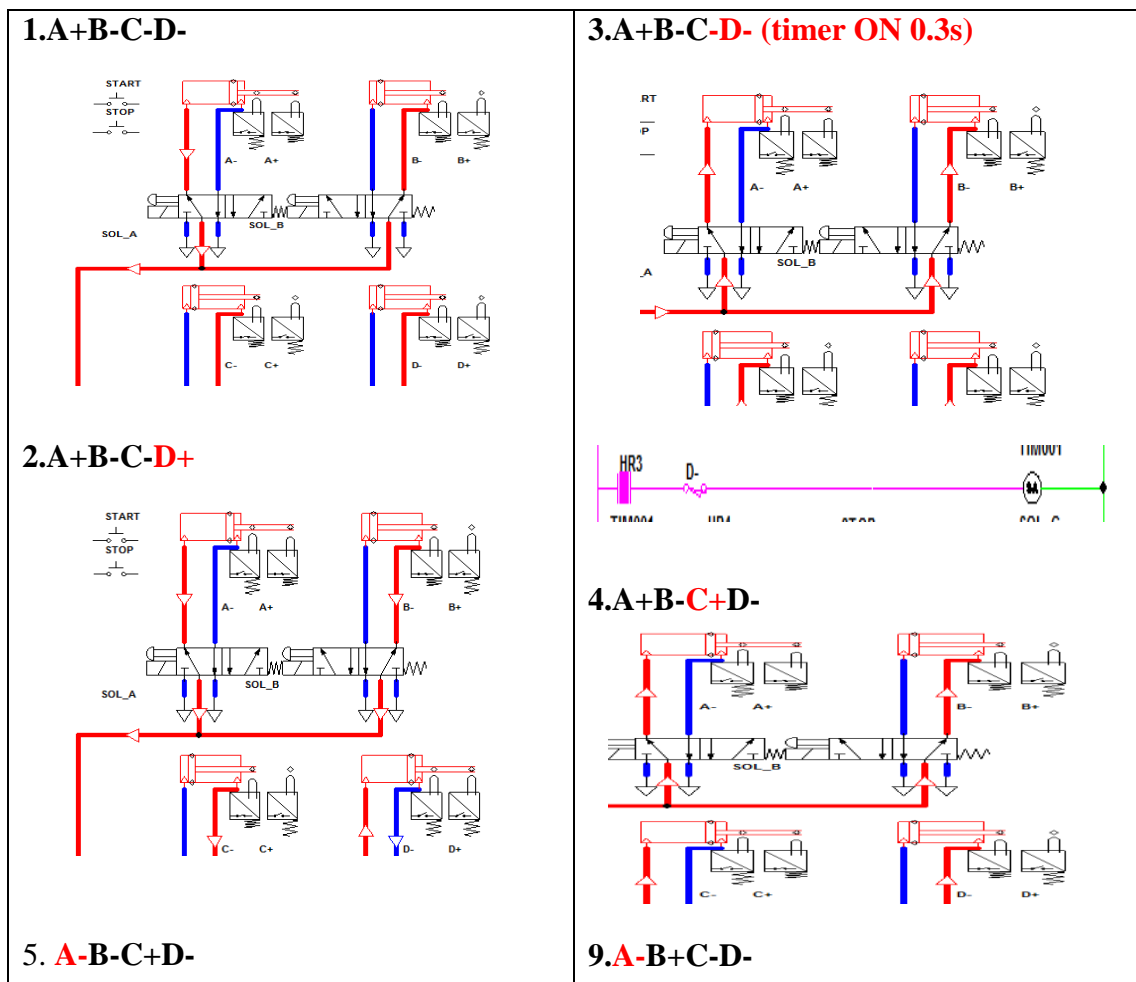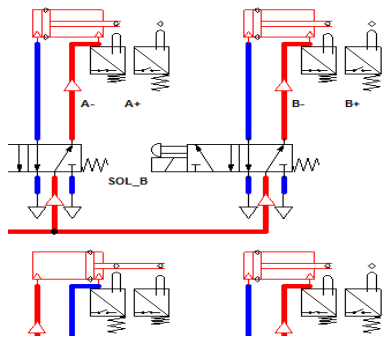
6. A-B-C-D-
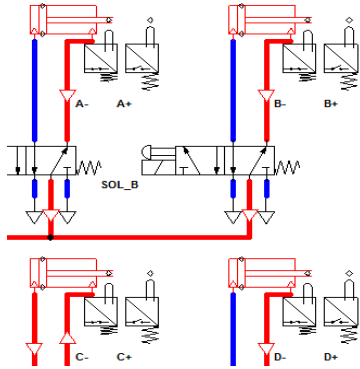
7. A+B-C-D-
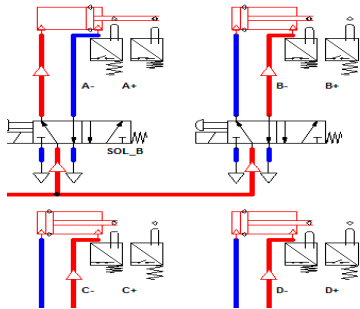
8. A+B+C-D-
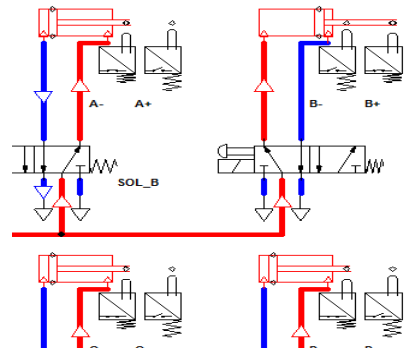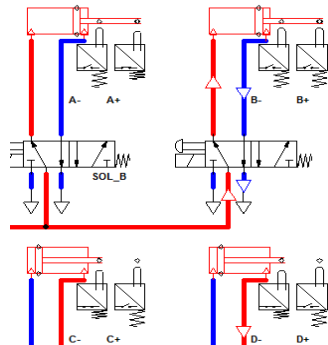
10. A-B+C+D-
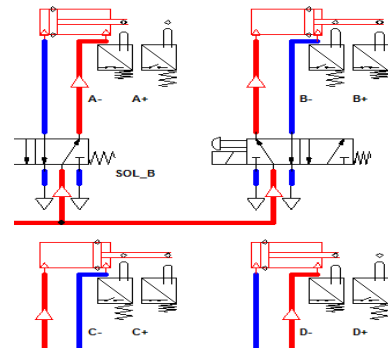
11. A+B+C+D-
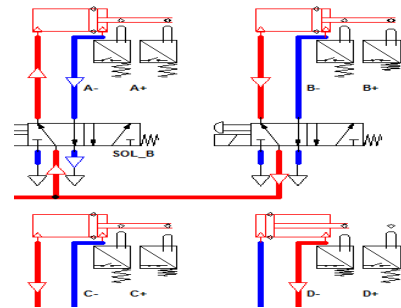
12. A+B+C-D-

13. A+B-C-D-

14. A+B-C-D- (counter ON)
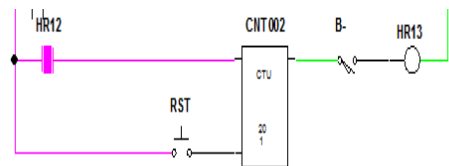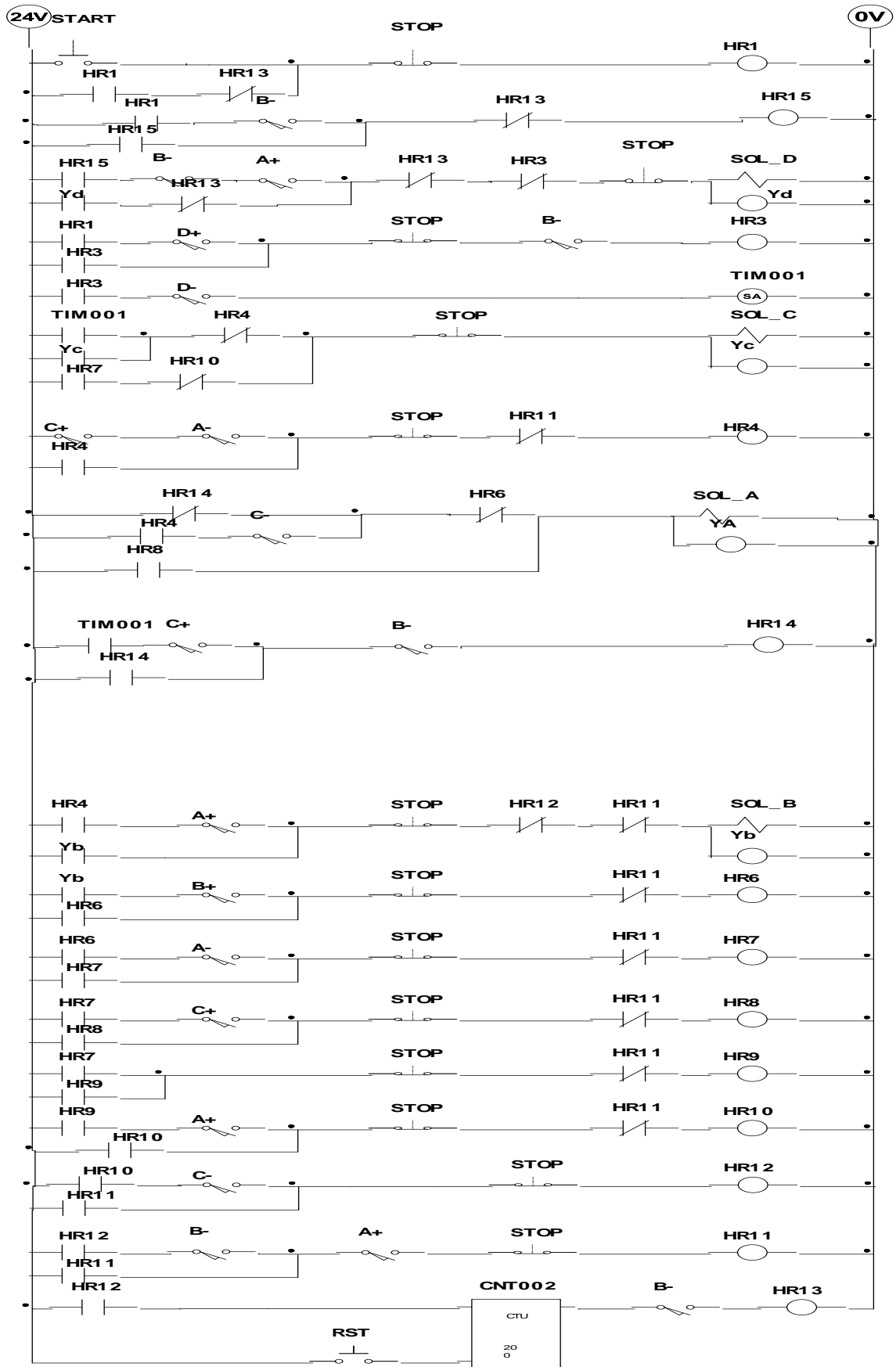
Figure 21   RMS Ladder Diagram Program

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4.2   Case Study II: System III

System III is based on the "pick and place" or "load and unload" process, it involves only several conveyor lines and several other equipments such robotic arm gripper (armKUKA K15) as well the component station, details shown in Appendix D

System III → Conveyor Line 5 + Conveyor Line 1 + Robotic arm gripper + Component Station
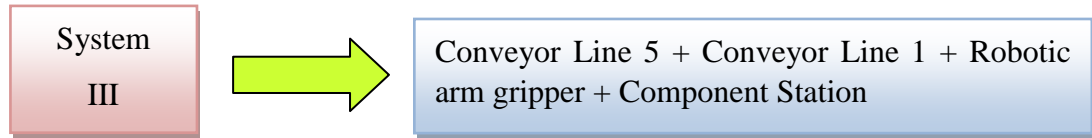
4.2.1   Ladder Diagram Development

For System III, only two conveyor line blocks are covered (See Appendices). Developing the programming routines for these lines has used similar approach (S-Method) as the RMS and modelled via simulation (Automation Studio).

Consider the conveyor line 5 where the unload process taking place, a pallet with object loaded move along this conveyor
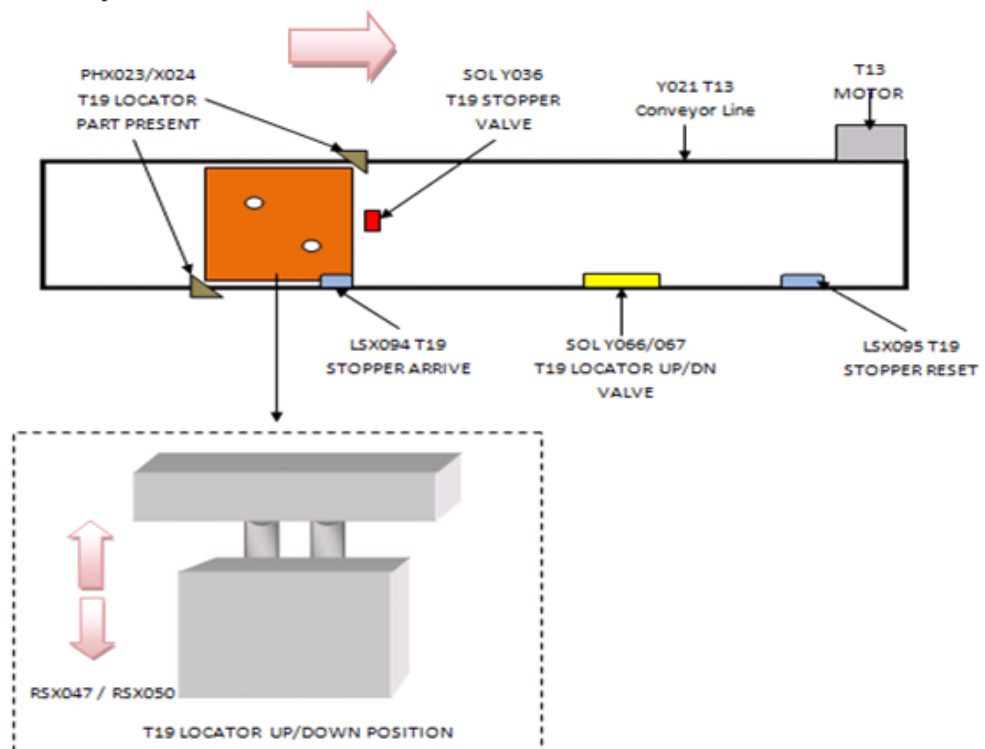
Figure 22   Conveyor Line Block 5

By implementing S-Method, the *sequences description* of this line is as below,

1) Start, auto start push button (X002) is pressed (turn ON)

2) Pallet move until it hit the X094 limit switch (T19 Stopper Arrive) ON.

3) Then, Y066 (T19 Locator Up) will turn ON and the pallet locator moves up to lift the pallet.

4) The locator lift until it turn ON the X047 switch ON

5) Next, the X023 Part Presence Sensors sense the object / components presence and timer TIM001turn ON simultaneously (delay from TIM001 2s use to hold the locator position and for the object detection process). If the object detected, it will be removed by the

6) After that, the locator lifted down to its original position (Y067 turn ON)

7) When the locator reach its original position, it will turn ON the X050 switch and later Y036 stopper will be lifted down to allow the pallet continue its movement along the conveyor line.

8) At the end of this conveyor line block 5, the pallet will hit and pass through the X095 switch to reset the stopper valve (Y036 turn ON again)

The I/O Identification and Listing for the conveyor line block 5 as in table below

Block 5 Conveyor Line			
Input	**Description**	**Output**	**Description**
X 02 03	T19 Locator Part Present	Y 02 01	T13 Conveyor
X 04 07	T19 Locator Up Position	Y 03 06	T19 Stopper Valve
X 05 00	T19 Locator Down Position	Y 06 06	T19 Locator Up Valve
X 09 04	T19 Stopper Arrive	Y 06 07	T19 Locator Down Valve
X 09 05	T19 Stopper Reset		

Table 4: Block 5 Conveyor Line I/O

Based on the I/O listing and the sequences description, the timing diagram is drawn to provide clearer sequences of this conveyor line and to understand the signals of the system.

*Note that timing diagram and ladder diagram development used for Automation Studio software as to simplify the visualization of the conveyor line block 5

Via Automation Studio, the conveyor line sequences are simulated and based on the result obtained on next page, it used as reference for the system user or programmers

Timing diagram for Block 5 sequences as in next page.
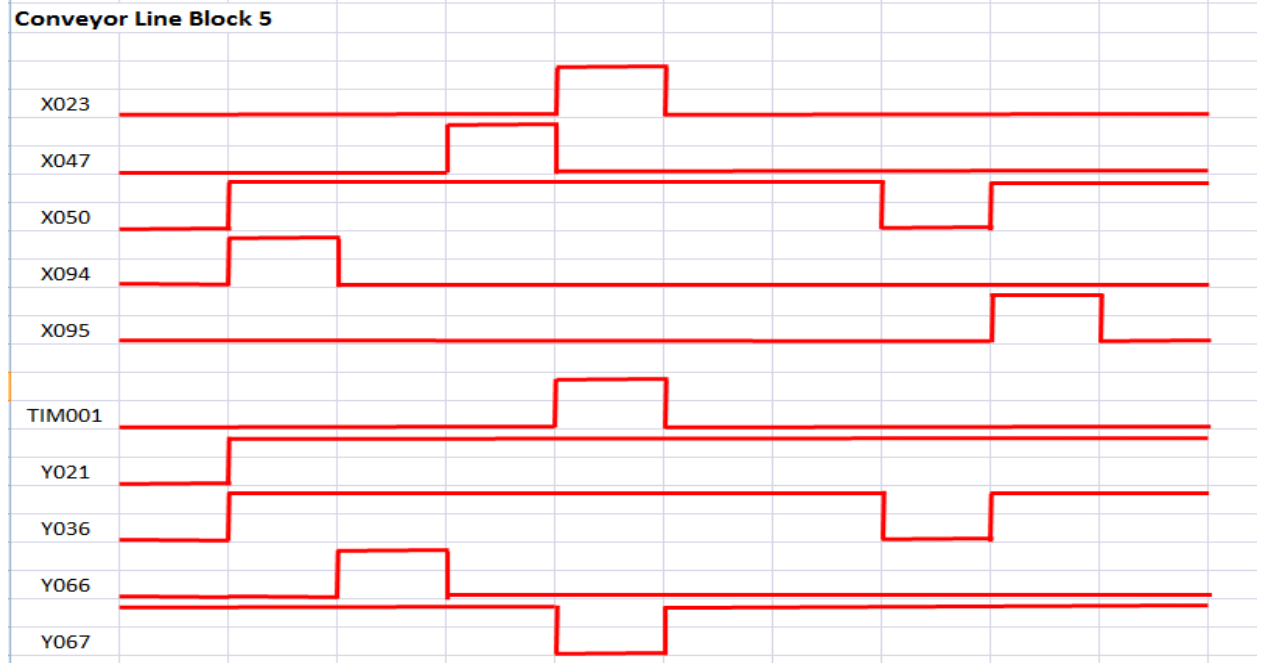
Then, after the timing diagram drawn, the ladder diagram and Boolean logic expression are developed. The circuits constructed using Automation Studio as below
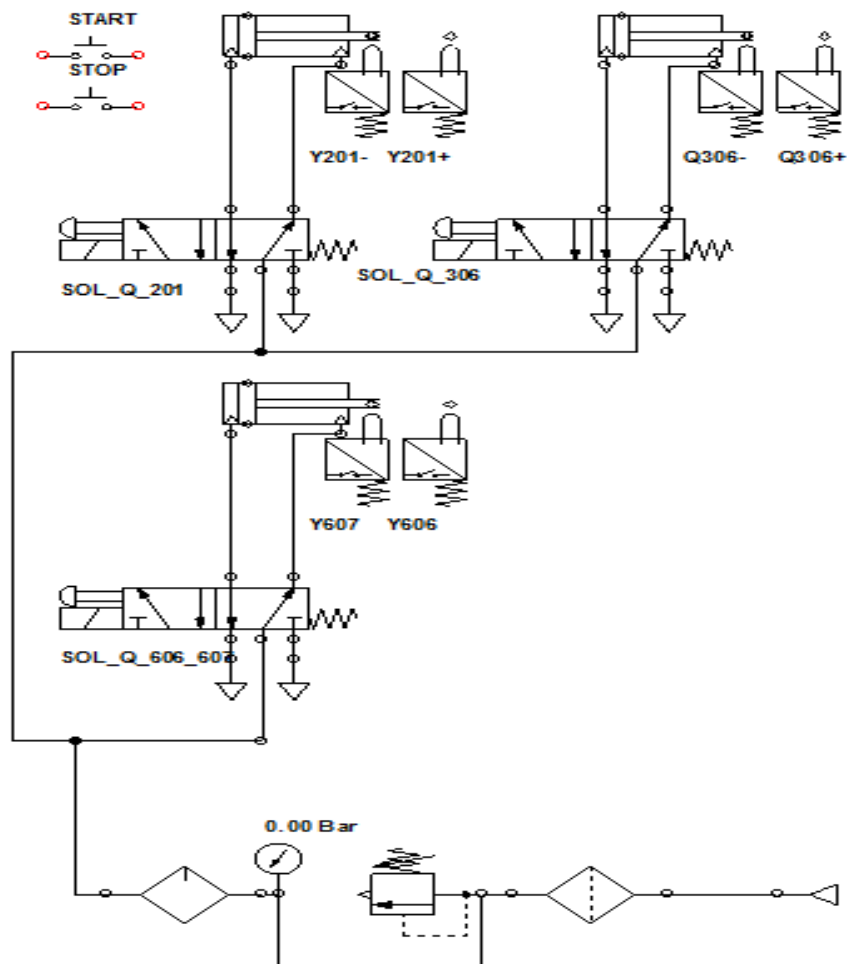
Ladder Diagram for Conveyor Lines Block 5
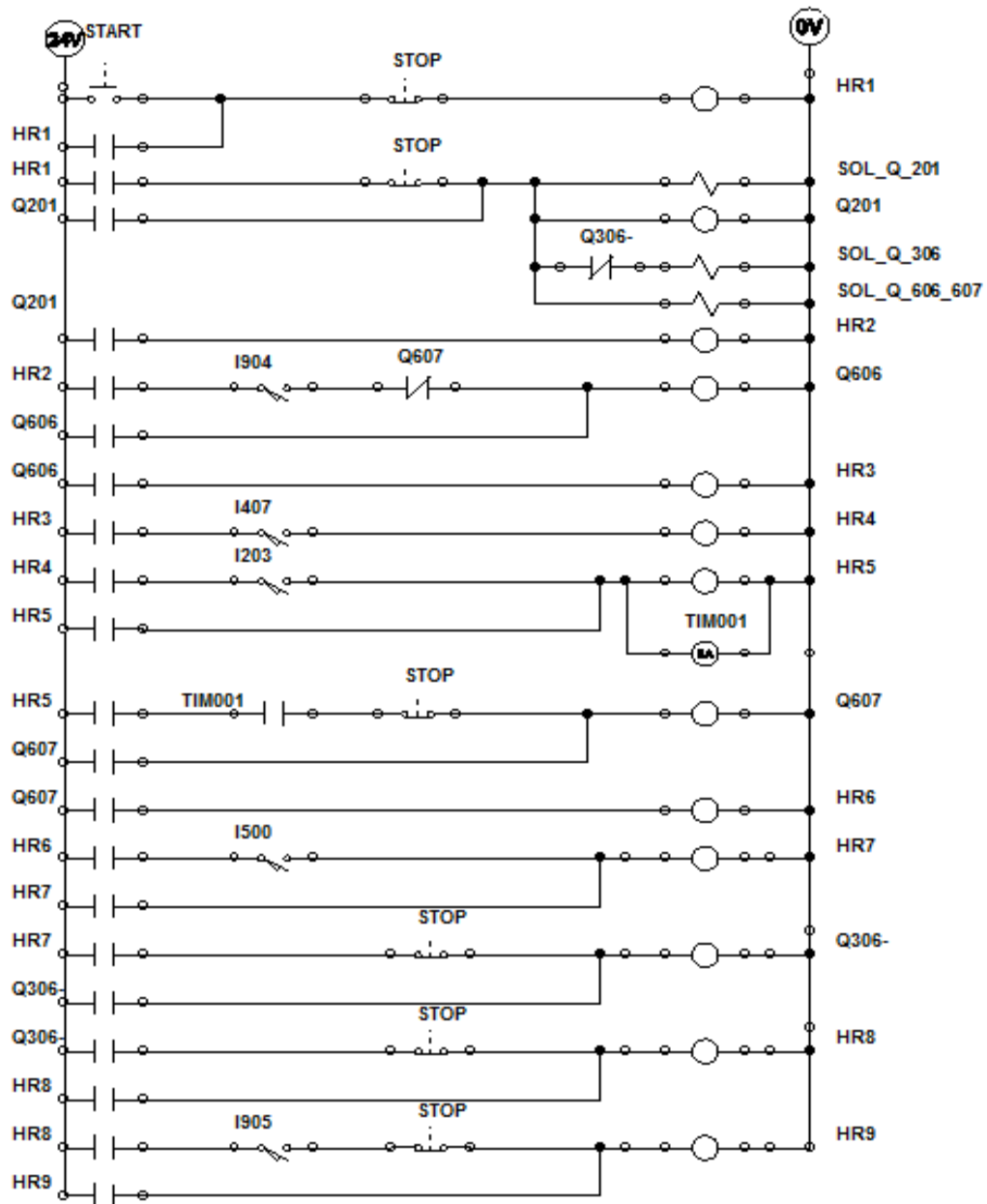
From the Ladder Diagram above, the Logic Boolean Expression can be deduced

Logic Boolean Expression for the network above is

Output = (Set+Latch)*Reset

HR4 = (HR3+0)*I407 = HR*I407

Same expression written for other Ladder networks based on the ladder diagram

shown for Conveyor Lines block 5 as above

4.2.2   System Analysis

Initially, the system has to be analyzed to understand its characteristics either hardware or software. Observation made, and the data also reminder is written to inform the current system status

PLC

Total used	: 12 (8 inputs & 8 outputs)
Total terminals	: 12 x 16 = 192

Conveyor system:

Max speed	: **12.21m/min @ 0.2m/s**
Min speed	: 0.01m/min @ 0m/s

Pallet:

Total Pallet	: 15
Pallet measurement	: **30cm x 30cm**

Robotic arm gripper status	: **MALFCUNTION**
Robotic arm manufacturer	: KUKA (armKUKA K15)
Laboratory Layout measurement	: **INACCURATE**

During the system operated, the factor such as conveyor line speed, distance between pallet and the pallet sudden removal could cause the system incomplete process as shown in picture below

Figure 23   LEFT: DIVERTER STUCK WHEN PALLET REMOVE RIGHT: CLOSE PALLET DISTANCE

As for the conveyor speed, it can be controlled manually by using the throttle meter

installed inside the PLCs cabinet in the lab. The speed can be varied and not depending on the programming routines or settings. However, the delay set in the process cycle is not affected by the conveyor line speed. Slow speed will somehow cause the pallet tripped by the stopper and cause the system process incomplete.

Besides that, distance between the pallets allocated along the conveyor lines must not close to each other. Closer distance could also prove cause the system to fail.

The details description of these problems as below
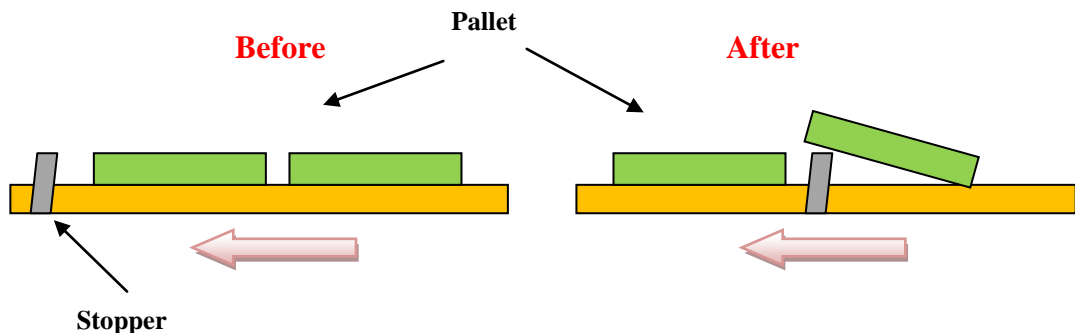
Figure 24   Pallets Movement on Conveyor Lines

Consider two pallets put closer along the conveyor lines. If the distances less than 10cm, the pallet located in front will move pass the stopper in figure above. But the next pallet movement will be tripped and stuck on top of the stopper. It is due to the stopper delay controlled by the routines is short, when the stopper lift down to allow the first pallet movement, it will quickly return to its original position and tripped the second pallet imprecisely.

These some are the findings of weakness of the programming routines, to solve the diverter problems, the diverter need to be installed with weight sensor to sense the presence of the pallet weight too and for the distance problem, the conveyor speed must be operated at maximum speed to avoid pallets collide and stop the process cycle accidentally. The recommended distance between pallets is
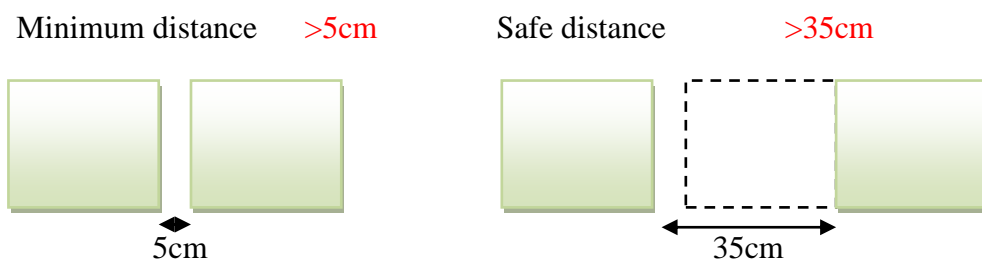
4.2.3 *Failure Analysis*

After vendors training session, the progress of this project faces difficulties of having long system breakdown and unavailability to run the system in quick as well as the maintenance works for the whole conveyor system.

Robotic arm MALFUNCTION

At first, the PLC programs for this system need to be redesigned as the major obstacle is to replace the robotic arm gripper operation with hand manual load and unload process, it does affect the programming routines designed and strictly need to be reconsidered carefully. So, this consume most of time offered. The system often to have errors while operated, but it is still running due to the Bypass Mode set on the PLC control panel. The source of this problem is believed to be the main board embedded inside the robotic arm. Since it have not being used for quite long time, it might experiencing the ageing effect which cause the internal malfunction of the robotic arm itself.

Regulator Valve Damaged

Besides that, the relief valve is damaged during operation. It cause no pneumatic air flow intake through the system even though the system is electrically working but the movement of the diverter and stopper is stopped and caused the possibility for the object pallets to clash each other while the conveyor belt is running.

Figure 25   Air Regulator Valve

This problem might also cause by the old valves which obviously have some air leaks on it. It cost this project 4 weeks being postponed due to no replacement stock of valve before recommencement of this project.

Programmer Computer Interface Problems

The computer used in this lab is outdated in many ways, both hardware and software. It uses Microsoft Windows 98 which is not support most of the hardware nowadays including printer, and external storages. Later, it is noticed the computer have the network connection problems since the network setting currently much more different. It cause difficulties on this project as our team working on to extract the programming sample given by the vendors for study purpose.

Sample Programming Issues

Although after the training the vendors provide us with the sample program of the system, it still contains errors when the system operates, which leads to incomplete cycle of system process. It caused by the visual inspection station which located at the next conveyor line from the conveyor line 1 (load station). The sample provided, contain errors of incorrect initial condition for the stopper, limit switches, and others nearby that station.

As consideration, it is expected the system will show various problems since most of devices is quite old and requires replacements or upgrades. It still being solved to ensure the whole conveyor system is working. The modification of the programming routines is still manage to be successfully done as the system working as expected, but with less time, it is difficult to do the new routines. In the end, the routines is successfully being modified for a normal operation.

4.2.4   Solutions

Replacing or Upgrading the Robotic Arm Grippers

Although expensive, but this step is necessary to avoid any complication on the PLC devices as the system critical errors because of the malfunction problem of the robotic arm. Several ideas is recommended for this solution.

- Replace with robotic arm that has multiple functions (gripping, drilling, shaping, welding on small scale)
- Replace with small size robots to save cost in future

Upgrading the Programmer's Computer

To allow more user friendly interfaces connected with the PLC and allow better communication link with the PLC modules. By upgrading the hardware and OS software especially, the network communication setting could be simplified and allow the software being updated and the new hardware type could be interfaced.

Providing the Details Documentation of the System and Laboratory

Most notes, manuals, and layouts provided have lots of inconsistency and inaccurate measurement. This cause confuses argument between the students and vendors and as well the system is difficult to be expanded in future. Thus, to solve this problem, several steps is required such as

- Redo the laboratory and equipment measurement
- Redraw the layout according the new measurement taken using detail software such as AutoCAD
- Put the programming samples into a book form for better reference, extract the samples programs earlier.
- Record the common errors together with analysis and solutions for future use.

CONCLUSION AND RECOMMENDATIONS

This project is focusing more on the developing the sets of routines of programming for the PLC of the Conveyor System (System III) of university lab to prepare the facility for Research & Development (R&D) as well as the Final Year Project activities. By developing these routines, it would increase the system value for university and industry. Thus, the system capabilities can be monitored and analyzed for present and future development. Through details introduction of PLC and FMS, it could help to develop the basic understanding and proceed further of these project.

Along this two semesters project, a case study is completed using simulation software Automation Studio is a success, and has improve our progress on this project by completing the target of this semester Final Year Project I which to study the physical of the FMS system, to learn the PLC Ladder Diagram programming based on simulation view and also to develop self routines for the illustrated robotic arm system for the pick and place sequences before our group using the real-time application FMS system as shown

For the Final Year Project 2, the System III from the conveyor system is discussed in details and the programming session for the system is still being conducted although for the first few weeks of the second part of the project is suffered by several setbacks due to system breakdown due that take weeks to be maintained before being operated again The modifications is will be a continuous process along the system lifetime. The system value were successfully increased as the final result is a success, justified by the whole conveyor system is working properly and project objectives has been achieved. In future, the industrial automation scope for UTP students will be widen and the R&D activities can be developed to improve the university values in industrial automation engineering field.

Recommendations

There are several recommendations that suggested and are considered for the system usage in future.

- *Installing Additional Secondary Handling Systems / Devices*

While working on this project, the I/O Assignment List indicates lots of spare terminals both inputs and outputs which is not being used. As to pursue modern manufacturing system knowledge, it is better to utilize some of the remaining terminals such as by installing sensors (shock sensors, weight sensors, etc.) and other safety devices. The secondary handling system addition such the reject station, manual assemble station, other machinery equipments might increase the complexity of the system for a better research activities for students.

- *Possible Layout Modifications*

The current this conveyor system layout is was poor. The wiring for the air flow tube is a mess compared to the PLC electrical wiring, thus it cause loose air tube connection between the supply and devices. The main reason of the poor layout is the shorter distance between supplies, devices and the conveyor line. Although this made to save cost, but it might become unaware severe hazards, such electrical shock hazard since the electrical wiring is close to the programmer computer station and user might accidentally tripped by the cables and the air tubes which can cause injuries.

Therefore, the layout as below is recommended.
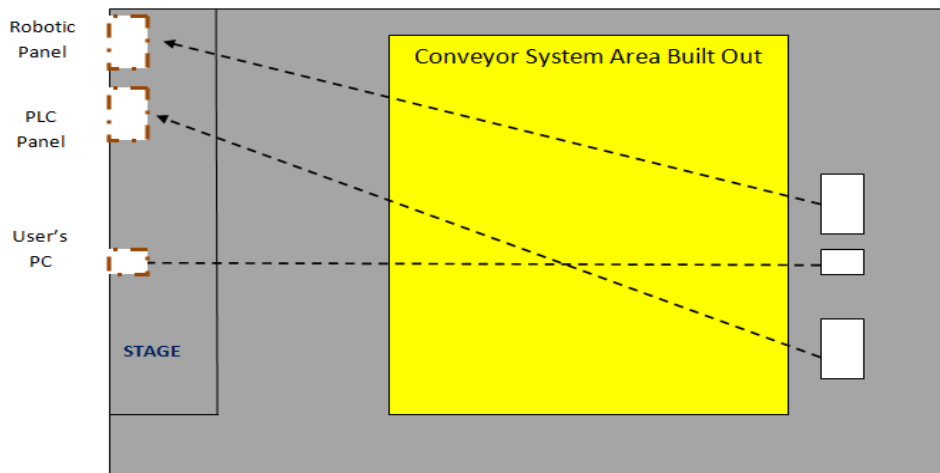
Figure 26   Possible Laboratory Layout

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[3]   H.K. Shivanand, M.M Benal, V. Koti , 2006, *Flexible Manufacturing System*, New Age International Publishers

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[6]   Norhayati, Mat Noor 2006, *"Development of Pick and Place System using IRB 1400 Robot,"* B. Eng Thesis, University of College Engineering & Technology Malaysia, Malaysia.

[7]   Frank D. Petruzella , 2011, Programmable Logic Controller 4th Edition, McGraw-Hill

[8]   SIEMENS, 2007 SIMATIC S7-200 Programmable Controller System Manual, Edition 09 / 2007

[9]   Sample Program in computer inside the Laboratory 22-00-12, "Main_File_TRY"

APPENDICES

FYP 1 GANTT CHART

FYP1 Activities Timeline / Gantt chart and Milestone

No	Detail / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	■													
2	Preliminary Research Work: Research and Writing the Project's Literature Review		■	■	■	■									
3	Submission of Extended Proposal Report						●								
4	Viva : Proposal Defense and Progress Evaluation							■	■	○					
5	Project Work Continues										■	■	■		
6	Submission of Draft Report													●	
7	Project work continues: Further investigation and modification on the project if necessary							■	■	■	■	■	■	■	■
8	Submission of Final Report														●

(Mid-Semester Break between weeks 7 and 8)

● Key Milestone
○ Suggested Milestone
■ Process

APPENDIX B

FYP 2 GANTT CHART

FYP2 Activities Timeline / Gantt Chart & Milestone

No.	Details/Week	1	2	3	4	5	6	7	Mid Semester Break	8	9	10	11	12	13	14	15
1	Project's work & progress	■	■	■	■	■	■	■									
2	Progress Report									●							
3	Project Further Progress & Activities									■	■	■					
4	Pre-EDX												●					
5	Draft Report														●			
6	Technical Report Submission															●		
7	Final Report															●		
8	VIVA																	●

● Key Milestone

■ Process

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APPENDIX C

SYSTEM III LAYOUT OVERVIEW
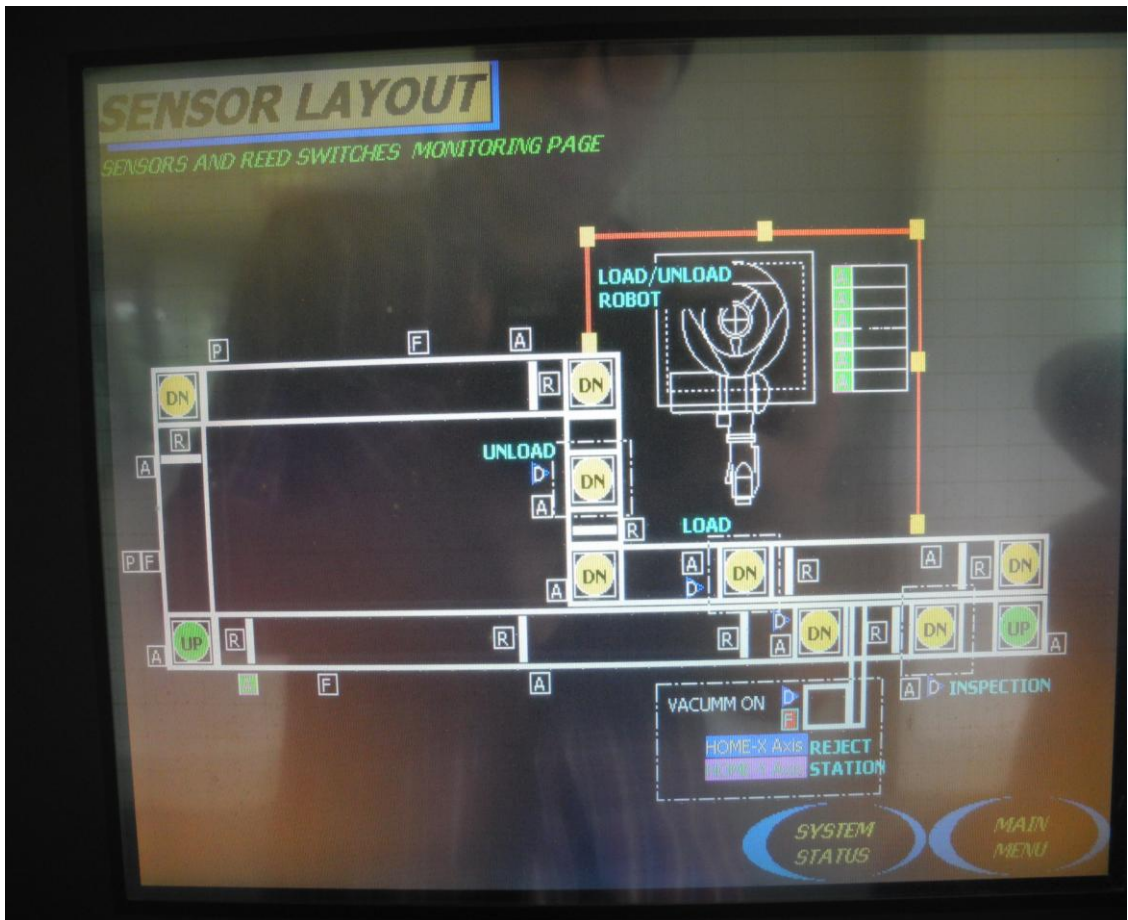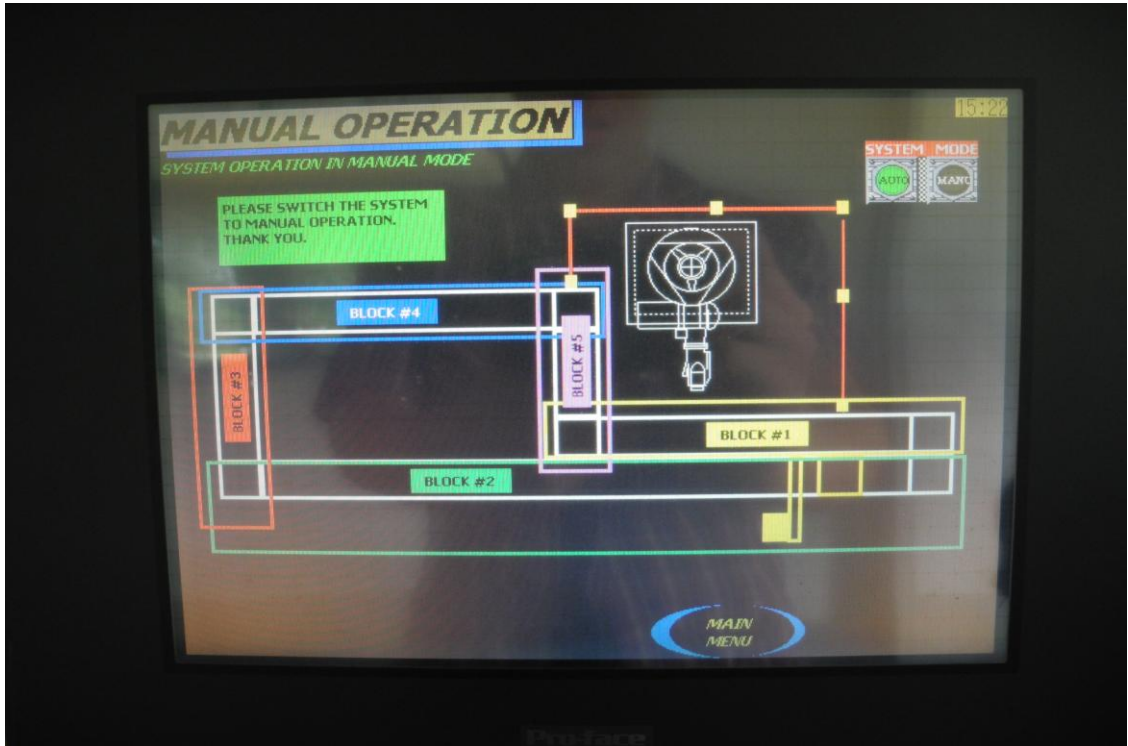
APPENDIX D

SYSTEM III I/OASSIGNMENT LIST

Block 5 Conveyor Line			
Input	**Description**	**Output**	**Description**
X 02 03	T19 Locator Part Present	Y 02 01	T13 Conveyor
X 04 07	T19 Locator Up Position	Y 03 06	T19 Stopper Valve
X 05 00	T19 Locator Down Position	Y 06 06	T19 Locator Up Valve
X 09 04	T19 Stopper Arrive	Y 06 07	T19 Locator Down Valve
X 09 05	T19 Stopper Reset		

Block 1 Conveyor Line			
Input	**Description**	**Output**	**Description**
X 03 01	T02 Diverter Up Position	Y 01 01	T02 Diverter
X 03 02	T02 Diverter Down Position	Y 02 02	T14 Diverter
X 05 01	T14 Diverter Up Position	Y 02 03	T01 Inverter Run
X 05 02	T14 Diverter Down Position	Y 03 07	T20 Stopper Valve
X 05 03	T20 Locator Up Position	Y 04 00	T01 Stopper Valve
X 05 04	T20 Locator Down Position	Y 05 00	T02 Diverter Up Valve
X 07 02	T01 Stopper Arrive	Y 05 01	T02 Diverter Down Valve
X 07 03	T01 Stopper Reset	Y 07 00	T14 Diverter Up Valve
X 09 06	T14 Stopper Arrive	Y 07 01	T14 Diverter Down Valve
X 09 07	T20 Stopper Reset		

Component Station			
Input	**Description**	**Input**	**Description**
X 06 02	Component Row 1 Product Present	X 06 06	Component Row 5 Product Present
X 06 03	Component Row 2 Product Present	X 06 07	Component Row 6 Product Present
X 06 04	Component Row 3 Product Present	X 07 00	Component Station Product Block
X 06 05	Component Row 4 Product Present		

Control Panel & Safety			
Input	**Description**	**Output**	**Description**
X 00 00	Emergency Stop Relay	Y 00 00	Buzzer
X 00 01	Auto / Manual Selector Switch	Y 00 01	Tower Lamp
X 00 02	Auto Start Push Button	Y 00 02	Auto Start Lamp
X 00 03	Auto Stop Push Button	Y 08 07	Safety Fencing Door Open
X 00 04	Reset Push Button		
X 00 05	Buzzer Stop Push Button		

APPENDIX E

SYSTEM III LAYOUTS

Block 5 Conveyor Line

PHX023/X024
T19 LOCATOR
PART PRESENT

SOL Y036
T19 STOPPER
VALVE

Y021 T13
Conveyor Line

T13
MOTOR

LSX094 T19
STOPPER ARRIVE

SOL Y066/067
T19 LOCATOR UP/DN
VALVE

LSX095 T19
STOPPER RESET

RSX047 / RSX050

T19 LOCATOR UP/DOWN POSITION

Block 1 Conveyor Line

LSX096 T14
ARRIVE

Y023

PHX025/X026
T19 LOCATOR
PART PRESENT

SOL Y037
T20 STOPPER
VALVE

SOL Y040 ST01
T01 STOPPER

Y022

LSX097 T20
STOPPER RESET

Y011

T10
MOTOR

SOL Y070/071
T14 DIVERTER
UP/DN VALVE

SOL Y072/073
T20 LOCATOR
UP/DN VALVE

LSX071 T14
STOPPER ARRIVE

LSX072 T01
STOPPER ARRIVE

LSX073 T01
STOPPER RESET

DIVERTER

SOL Y037/040
T20/T01 STOPPER

SOL Y050/Y051 T02
DIVERTER UP/DN
VALVE

1   2   3

RSX051 / RSX052 - T14 DIVERTER UP/DOWN POSITION

RSX053 / RSX054 - T20 LOCATOR UP/DOWN POSITION

RSX031 / RSX032 - T02 DIVERTER UP/DOWN POSITION

Component Station

PHX070 T16 Component Station Product Block

Unloading Process

Objects

PXX062 – PXX67 T16 Component Row 1 -6 Product Present

Loading Process