Automated Packaging Machine Using PLC

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Abstract

This paper presents final year project prototype with the use of programmable logic controller in automation industry for packaging process. The main idea of the project is to design and fabricate a small and simple conveyor belt system, and automate the process for packaging small cubic pieces $(2 \times 1.4 \times 1)\ cm^3$ of wood into small paper box $(3 \times 2 \times 3)\ cm^3$. Inductive sensor and photoelectric sensor were used to provide the information to the controller. Electrical DC motors used as output actuators for the system to move the conveyor belts after get the orders from the control system. Programmable logic controller Mitsubishi FX2n-32MT was used to control and automate the system by ladder logic diagram software. The experimental result of the prototype was able to fully automate the packaging system. This results show that the machine were done to package 21 boxes in one minute. In addition, the results obtained show that the system able to decreases product time, and increase product rate as compared with traditional manual system.

Keywords: *Packaging Machine, Automated, PLC, Switches, Inductive Sensor, Photoelectric Sensor.*

1. Introduction

Industry automation becomes the global trend in manufacturing, packaging process is one of the most uses in industry; more and more companies are switching to automation. This project is devoted to the use of automatic control system in process machine system; the control system will play a major role in control on all parts of the project. This project report is about design and fabricate an automated packaging machine system. Electrical DC motors control were used as actuators for the entire process to move the upper and lower conveyor belts, and the sensors used to feed the control system by system information.

Conveyor belt used for transporting samples from location to another one, which would be packaged into a specific paper boxes later. The control system for the hardware project is to be controlled by the Mitsubishi FX2n-32MT programmable logic controller (PLC) device. Ladder logic diagram for programmable logic controller were used for control the actual prototype for the experimentation. The whole system executes to package 4 wood samples (2 cm × 1.4 cm × 1 cm) into paper boxes (3 cm × 2 cm × 3 cm). Finally, the prototype with system controller were successfully done to package 21 boxes in one minute, every box include 4 samples.

1.1 Conveyor Belt

A conveyor belt is one of many types of conveyor systems. The belt is a loop of flexible material as shown in Figure 1(a) used to mechanically link two or more rotating shafts, most often parallel. A belt conveyor system consists of two or more pulleys (sometimes referred to
as drums), with an endless loop of carrying medium that rotates about them as shown in Figure 1 (b). One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler pulley.

There are two main industrial classes of belt conveyors; Those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transport large volumes of resources and agricultural materials, such as grain, salt, coal, ore, sand, overburden and more [6].

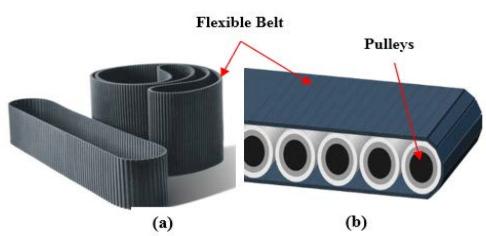

Fig. 1 (a) Belt Type, (b) Conveyor Belt with Pulley.

1.3. Packaging

Packaging is the technology of using conveyor belts for enclosing or protecting products (food, wood, and material) for storage, pack objects together into containers, sale, and use. Packaging also refers to the process of design, evaluation, and production of packages. Packaging can be described as a coordinated system of preparing goods for transport, warehousing, logistics, sale, and end use. Packaging contains, protects, preserves, transports, informs, and sells [7].

2. Components Selection and Hardware Structure

The Automatic Packaging Machine system is a combination of electronic, electrical and mechanical parts, Figure 2 shows the whole system proposed.

- Input Devices are devices used to gather information about the system, which consists switches (toggle switch) and sensors (photo and inductive sensor), in order to feed the controller (PLC) by an information about the belts status and objects.
- The controller, which is the main element that operate the whole system, by using the information from the sensors to take the counting and movement decision before sending the orders to the output devices by the actuators and the relays.
- Output Devices are the actuators that converts an electrical signal into mechanical movement; the principle types of actuators are relay, solenoid, and motors.

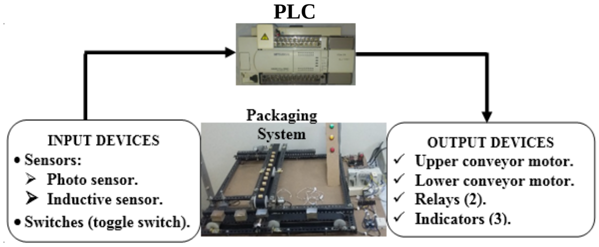

Fig. 2 Automated Packaging System.

2.1Sensors

A sensor is a device that measures a particular characteristic of an object or system. Some sensors are purely mechanical, but most sensors are electronic, returning a voltage signal that can be converted into a useful engineering unit. Sensors are used in everyday objects such as touch-sensitive elevator buttons (tactile sensor) and lamps, which dim or brighten by touching the base. There are also innumerable applications for sensors, which include cars, machines, aerospace, medicine, manufacturing and robotics [3].

2.1.1 Photoelectric Sensor

A photoelectric sensor, or photo eye, is a device used to detect absence, or presence of an objects by using a light transmitter, often infrared, and a photoelectric receiver. They are used extensively in industrial manufacturing. There are three different functional types: opposed (through beam), retro-reflective, and proximity sensing (diffused), figure 3 shows one of Photo types [8].

Fig. 3 Photoelectric Sensor Sample.

In the project prototype, the photoelectric sensor is placed at the upper belt to sense and count the samples before dropping them in the box as shown in Figure 4 below.

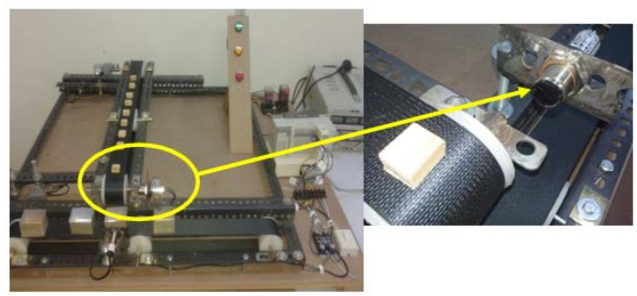

Fig. 4 Photoelectric Sensor Setup on the Project.

2.1.2. Inductive Proximity Sensors

Inductive sensors use currents induced by magnetic fields to detect nearby metal objects. All of inductive sensors consists of four basic elements; the *oscillator*, which produces the electromagnetic field, the *coil*, which generates the magnetic field, the *detection circuit*, which detects changes in the field when an object enters it and the *output circuit* which produces the output signal as shown in figure 5 [1].

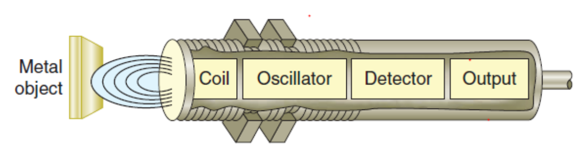

Fig. 5 Inductive Proximity Sensor Structure [9].

The inductive sensor was installed above the lower conveyor belt (about 3 cm) and in front of the particular upper belt to sense the coming boxes of the samples for packaging. This sensor can be able to sense from (0.5 mm to 5 mm) and it sense iron only (*so that metal sheets were used to cover the boxes*) as shown in Fig. 6 below.

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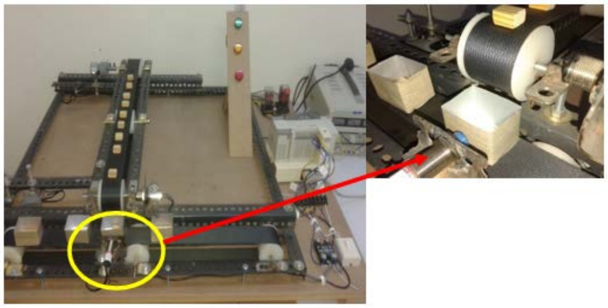


Fig. 6 Inductive Sensor Setup on the Project.

2.2. Switches

Switches are electrical or electronic contact devices used to turn (ON) or (OFF) the flow of electricity through a circuit. Switches are essential components in almost all the electronic devices used today. Switches require another device or action (Force) to change their state from open to close or close to open. Switches might operate manually or mechanically.

- Manually Operated referred to types operated by hand, which the operator must do an action, in order to start, stop or reverse the state. Manually switches such as (***toggle and pushbutton switches***).
- Mechanically Operated referred to switches those controlled automatically (Mechanically) by factors such as pressure, position, flow, or temperature. These include (***limit switch, inductive limit switch***) [1].

2.2.1 Toggle Switch

Toggle switch is operated manually by external action (force) and come in two types:

- Momentary: where the contacts are operated only while the actuator is operated. Sometimes referred to as spring return.
- Non-Momentary (Latching): sometimes called on-off or, with a button actuator, where the contacts lock in one position when the button is pressed then released and only change back when the button is pressed a second time. [4][5]. In the project, the switch is used for starting up and shutting down the system by the designer as shown in figure 7 below.

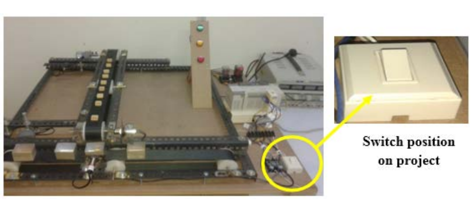


Fig. 7 Toggle Switch Used.

2.3. Actuators

Actuation defines as the result of a direct physical action on the process, such as drilling a work piece or rotate the object from side to another side by rotating the upper rotary disk.

2.3.1 DC Motor

DC motors have been used in industrial applications for years. Coupled with a DC drive, DC motors provide very precise control. DC motors can be used with conveyors, elevators, extruders, marine applications, material handling, paper, plastics, rubber, steel, and textile applications [2,3].

As shown below Figure 8, two DC motors were installed on the project; one of them mounted with a pulley to rotate the upper belt (Y1), and the other one, mounted with a pulley to rotate the lower belt (Y0). The two motors used to do next tasks:

1. The lower DC motor starts first to bring empty boxes at desired position.
2. The upper DC motor starts after the box reach desired position, to bring some samples for packaging into the box.

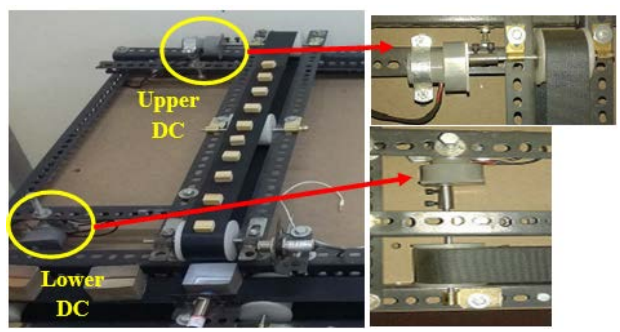


Fig. 8 Upper and Lower DC Motors Installation.

2.4 Relays

Relays are simple switches operated both electrically and mechanically . Relays consists of an electromagnet and set of contacts .There are also other operating principles for its working which differ according to their applications, Figure 9 shows type of electro-mecanical relays used in the project [3].

Fig. 9 Type of Relays.

Figure 10 shows the mechanical relays used on the project as interface between the PLC outputs and DC motors inputs.

Fig. 10 Relay's Setup on the Project.

A solid-state relay is an ON-OFF control device in which the load current is conducted by one or more semi conductors. Like all relays, the SSR requires relatively low control circuit energy to switch the output state from OFF to ON. Since this control, energy is very much lower than the output power controllable by the relay at full load [7].
In this prototype, since the photoelectric output voltage is very small, we used them as interface between the output of the sensors and the input of PLC. Figure 11 shows the SSR positions on the prototype.

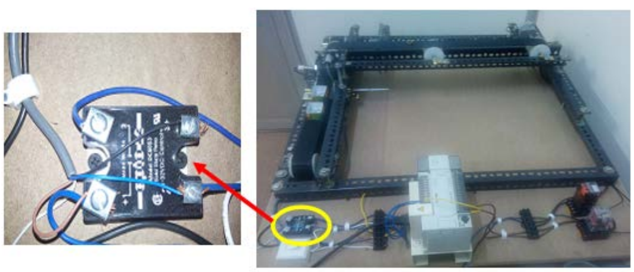


Fig. 11 Solid State Relay Installation.

2.5 Indicators

Indicators are used to monitor the system operation or condition and the telecommunication and electrical circuit for indicator signal, accident signal, fault signal and other indicator signals [4].
In our project as shown in Figure 12, we have chosen three types of indicators in order to monitor different operations, this indicators are:

- Green indicator: To indicate and show system running state.
- Yellow indicator: To indicate lower belt moving state.
- Red indicator: To indicate upper belt moving state.

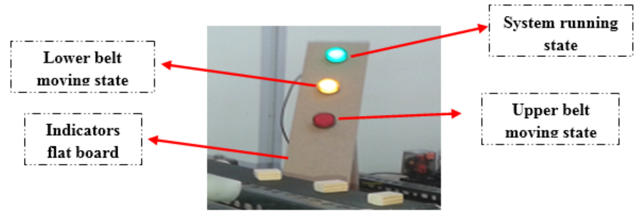


Fig. 12 Indicators.

2.6 Mechanical Structure and Design

The project prototype designed and fabricated with metal rods by dimensions 80cm × 80cm (length x width) as shown in Figure 13 below in order to carry the completely packaging components.

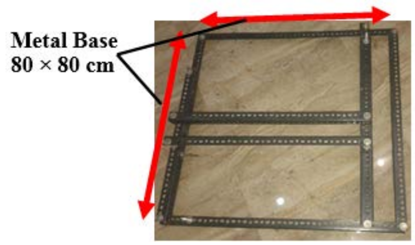
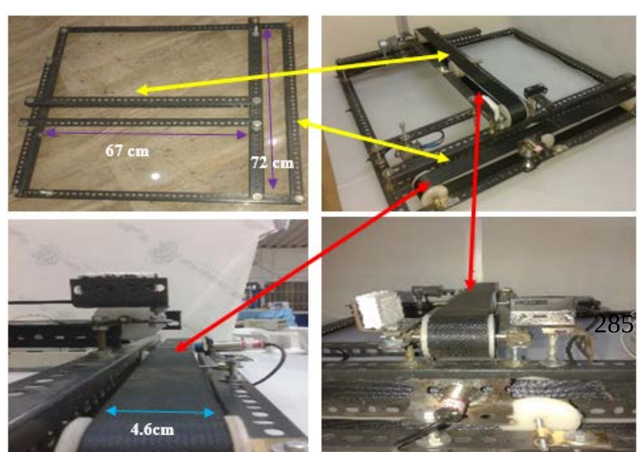


Fig. 13 Project Prototype Main Base.

Conveyors are a strip of belt mounted on pulley at two ends, driven by one or two of the pulleys. In the prototype as shown in Figure 14, two belts were used as upper and lower belts; the upper belt is 67 cm length with 4.6 cm width installed on the 67 cm rod. The other belt with is 72 cm length with 4.6 cm too, installed on the 72 cm rod

Fig. 14 Upper and Lower Belts Setup on the Project.



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Two DC motors (12 volts) mounted with main pulley for each to derive and rotate the belts (Upper and Lower belts) as shown in Figure 15, Red arrows indicate belt direction moving.

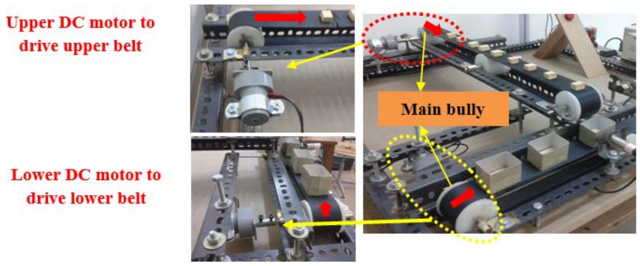

Fig. 15 DC motors with pulley Installation.

Figure 16 below shows the pulleys and motors dimensions on the prototype.

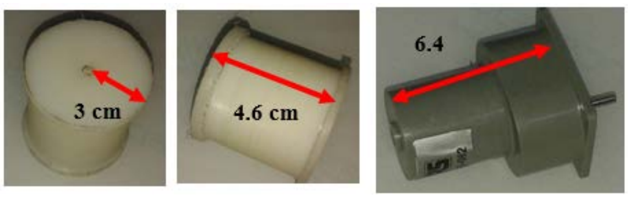

Fig. 16 Pulley and DC Motor in the Prototype.

Figure 17 below shows the size and dimensions of the boxes and samples which used in the prototype.

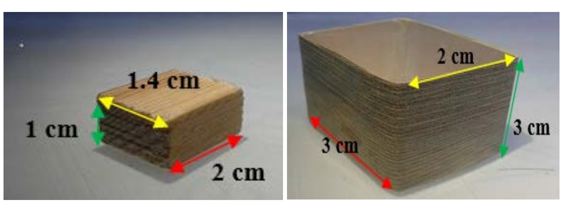

Fig. 17 Size of Boxes and Samples.

3. Block Diagram and Wiring the System

The block diagram of the proposed system is shown in figure 18, which consists of three inputs (toggle switch , photo sensor, inductive sensor) to provide the control by system state. Also the system consist of three output (the dc motor, indicators)

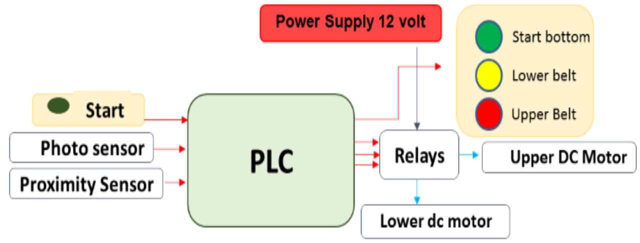

Fig. 18 Block Diagram of the System.

- ❖ **Toggle Switch:** It have two wires connected as sourcing to the PLC one of the wirers is connected to 24 V DC, while the other wire is connected to 0VDC.
- ❖ **Inductive Proximity Sensors:** The first wire of inductive proximity sensor is connected to X0 at the PLC and the other wire is connected to 0 VDC.
- ❖ **Photoelectric Sensor:** The first wire of photoelectric sensor is connected to X1 at the PLC and the other wire is connected to 0 VDC.
- ❖ **Lower DC Motor:** Since the DC motor works under 5V and the PLC gives 24VDC, then 24VDC relay used. The lower DC motor is connected to (Y1) in the PLC.
- ❖ **Upper DC Motor:** since the DC motor works under 5V and PLC gives 24VDC, then 24VDC relay is used. The upper DC motor is connected to (Y2) in the PLC.

Figure 19 below shows the wiring of the whole component of the prototype with the PLC

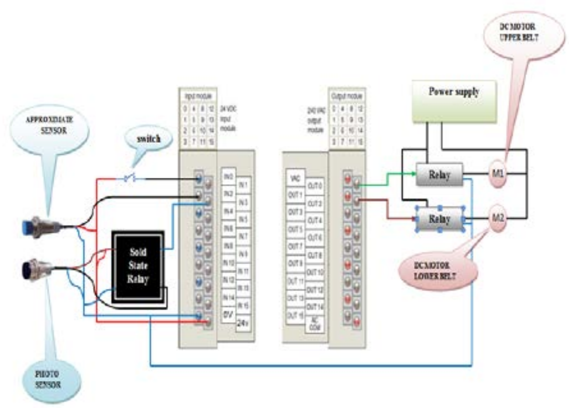

Fig. 19 Wiring of PLC.

3.1 Programmable Logic Controllers (PLC)

Technical specifications of PLC Mitsubishi FX2n-32MT on the Table 1 [2].

Table 1: Technical Specifications of Mitsubishi PLC

General features	
Max .number inputs/outputs	16
Power supply	100-240 VAC
Output type	Transistor
Power consumption [W]	30 V A
Weight [Kg]	0.65
Dimensions (WxHxD) [mm]	136x90x87

4. Experimental Results and Discussions

Figure 20 shows the whole system prototype for the automated packaging machine, as shown in the figure, it consists of sensors (inductive and photoelectric), actuators (two DC motors, two mechanical relays and solid-state relay), and indicators (red, green, yellow), PLC, power supply, boxes, samples.

Each component have a specific function to perform, which can be explained as follows:

Toggle Switch: was use as main switch to start up, and turn off the Packaging system.

Lower Motor (Y0): it is responsible for the movement of the lower conveyor belt, to bring empty boxes in sequence to the desire location.

Inductive Sensor (X0): This sensor has two main missions, the first one is to detect the empty boxes as arrival at the desired location, the second one is to stop the lower belt and activate the upper belt to drop the samples into the box.

Upper Motor (Y1): it is responsible for the movement of the upper conveyor belt, to bring the cubic samples in sequence to package them into the box.

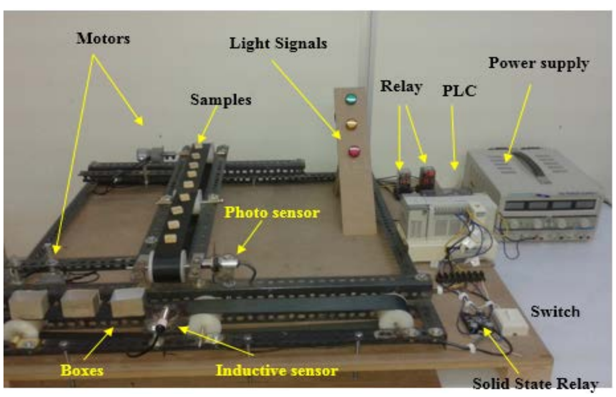

Fig. 20 Packaging Machine Prototype.

Photoelectric Sensor (X1): It used to count the dropped samples during packaging process.

Relays: the works as interface between the motors, photoelectric sensor and the PLC.

Indicators: were used to light different colors to show system states.

Power Supply: It feed the system with different voltages.

The prototype experimental testing and running divided to next steps as following:

Step one:

When the toggle switch pressed ON, the system start ruining by moving the lower belt by DC motor (Y0), which carrying and bring the empty boxes, as the empty box reach the inductive sensor (X1) as shown in Figure 21, that the inductive sensor will activate and send signal back to the PLC to stop the lower belt moving. In the same time when the system start running, the green indicator lights ON, to inform the operator system states. Although, the yellow indicators lights ON for lower belt moving.

Fig. 21 Inductive Sensor Activated as the box be in location.

Step two:

As the box, reach the desired location, the lower belt stop moving and the upper belt start moving. Upper belt starts to bring the samples one by one and drop them into the box. This operation running until four samples. Meanwhile, the red indicator lights on to show that the system is packaging. Figure 22 show packaging operation of the samples.

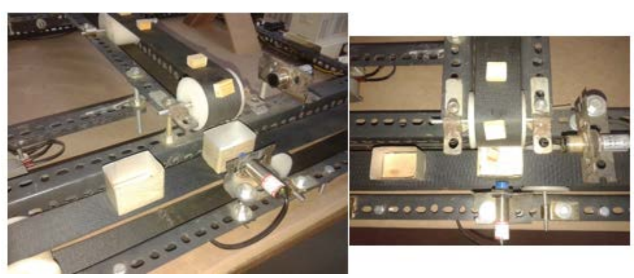

Fig. 22 Packaging Operation.

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The photoelectric sensor used to count the samples while packaging, when the box fill by four samples, the sensor give information back to the PLC to stop the upper belt and bring another empty box to package it.

After the photoelectric sensor, count four samples, the upper conveyor belt stop moving and the lower conveyor start moving to carry the filled box away and bring another empty box to package it with another four samples. Figure 23 below shows the final operation of the packaging.

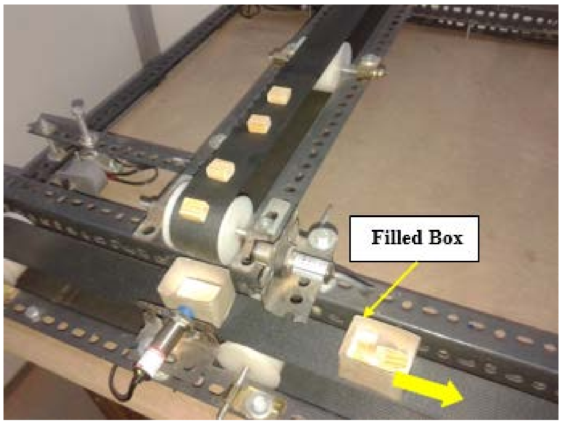

Fig. 23 Carrying filled Box and Bring Another.

4.1 Product Rate of the System

The experimental results for the automatic and manual operation shows different products rate as shown in Table 4.2 below.

Table 4.2: System Product Rate

Product Time	Manual Packaging	Automatic Packaging
One Minute	14 Boxes	21 Boxes
One Hour	840.00	1260.00
One Day (8 hours)	6720.00	10,080.00
One Week (5 working days)	33,600.00	50,400.00
One Month	**134,400.00**	**201,600.00**

5. Conclusion

An automated packaging machine prototype using PLC Mitsubishi FX 2N has been successfully design, constructed and implement based on control system concepts. Mitsubishi ladder diagram applied for the programming and operation of the presented prototype, in which the operation is passes through two stages, carrying empty boxes to desired location, and packaging the samples into the boxes. The experimental prototype tested to improve the automation processes with the use of the PLC ladder diagram. The packaging prototype was done to package four sample per a box in very short time. From the experimental result, the automatic packaging machine was able to package 1260 boxes per one hour, otherwise the manual packaging able to package just 840 boxes at the same time.

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