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# Human Machine Interface System for Filling and Capping Process

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**Abstract**: In this research, bottle filling and capping processes are performed simultaneously in the pharmaceutical factory by using the PC based human machine interface (HMI) control system**.** In the traditional method of bottle filling process, the bottles are placed onto a conveyor and only one bottle is filled at a time. So, this method is time consuming and expensive as wide working place and many human labors is required**.** In this research, the proposed design can solve this problem without any complex control by using the HMI automation control system. The monitoring and running conditions in the packaging system are shown on the monitor of computer by using the composed of Visual Basic.Net and Mikro C. It also includes the volume of medical powder is limited by changing the size of filling funnel which is set up of shutter at the top and bottom of funnel. The entire system is more flexible and time saving. A prototype is implemented by using the DC motor, sensing devices; limit switches, peripheral interface controller (PIC) device and serial port communication. These control systems is very flexible, cost effective, space efficient and reduce complexity. PC based HMI control is used for monitoring the process.

**Keywords**: Bottle filling and capping process; Serial Interfacing; Motor Driver; HMI Control System; Manufacturing System

## 1. INTRODUCTION

As Myanmar is developing country; many pharmaceutical industries are being improved in health care sector by using the automation control system. For these kinds of applications, the trend is moving away from the individual devices or machine toward continuous automation solution. The filling and capping operation is implemented for packaging the medical powder and this can be used other system of various industries. Nowadays, most of the modern industrial plants have applied the automation control system. Automation is the use of control systems and information technologies to reduce the need for the human labours in the production of goods and services [2].

Among many industries, the pharmaceutical factory is one of the powerful players in the developing countries. In the manufacturing process of pharmaceutical products, the many steps are needed for companies and individuals to gain a complete process. In many production steps, packaging is a critical tool in the pharmaceutical industry for the product delivery. Packaging is composed of primary and secondary packaging processes. The primary packaging components (e.g. bottles, vials, closures, blisters) are in direct physical contact with the product, whereas the secondary components are not (e.g. carton, cardboard, boxes) contact with the product [3]. In this research, primary packaging system is emphasized for the medical powder filling and capping processes of bottles.

The packaging of a pharmaceutical product is aimed that the medicines arrive safely in the hands of the vendees. In the qualities of the pharmaceutical products, the quality of the packaging of pharmaceutical products plays a very important role [1]. So, this research is mainly aimed on the integration of primary packaging system in which filling and capping operation is done simultaneously at the same place by using the human machine interface in the industries. The advantages of this system are that taking low space, saving labors cost due to one or two operators is needed and reducing the time consuming.

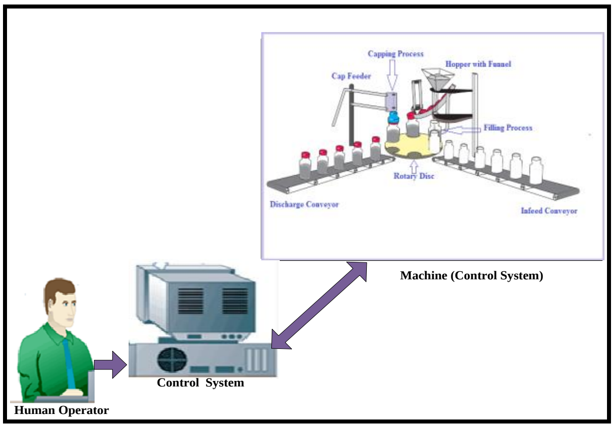



Figure 1.Sketch diagram of PC based Monitoring System for Primary Packaging System

This system allows the user to control the process, monitoring production data and correct malfunction. This user-friendly interface minimizes system complexity, operator training and troubleshooting time. The real-time monitoring for the primary packaging system is designed with the signal sensing by using the controller and interfacing programs. The sketch diagram for the packaging operation is shown in Figure1.

## 2. METHODOLOGY

This research is emphasized on the PC based HMI control system for the primary packaging process in which the automation of filling and capping processes. In this system, belt conveyor is used for carrying the bottles to the rotary disc which is used for the bottles filling and capping processes simultaneously.

DC motors are used to control the motion of conveyors and capping processes. Peripheral interface controller 16F887 microcontroller is used because of providing the serial communication interface and controlling the motor motion. LDR sensors are used for the position sensing circuit. In the firmware sector, Mikro C and VB.Net programming language is used. Personal Computer (PC) is used as human machine interface (HMI) system and provided the series of episode for monitoring and controlling the process. Visual Basic.Net programming is provided in the implementation and displaying of packaging processes for the monitoring system. The block diagram of this system is shown in Figure 2.

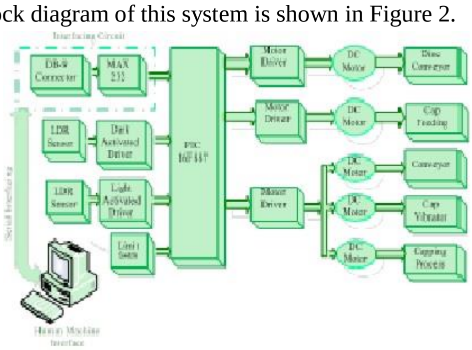


Figure 2. Overall Block Diagram of Primary Packaging System

## 3. CONTROL SYSTEM AND ELECTRICAL SETUP

This system is composed of four portions; interfacing system, control unit, position sensor input portion and output motors driving circuits. The pin connections of the PIC16F887 are very important to control the processes and it is also a brain of a whole process [4]. These connections of the PIC16F887 are described in Figure.3.

In this interface controller, port D is assigned as input pins and port B is used as output pins. RD0, RD1 and RD2 from port D are used to sense from the position sensors of the rotary disc. RB0, RB1 and RB2 from port B are used as output pins to drive the motors for the conveyor, disc and capping processes. RC6 and RC7 are used as interface ports between the PIC and PC.

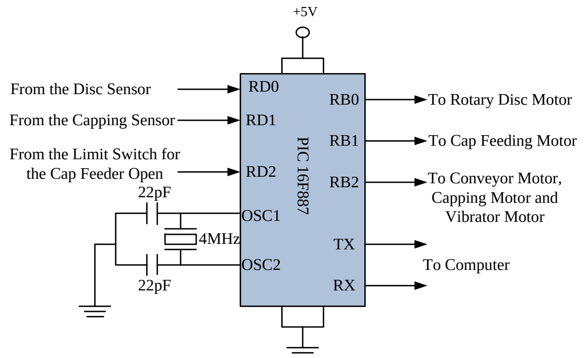



Figure 3. Pin Connection of PIC 16F887

### 3.1 Interfacing System

In the interfacing system, serial communication method is used in which DB 9 connector and RS232 protocol is implemented. In the serial interfacing system, MAX 232 level converter is needed to convert the voltage level between the PC and PIC controller. It is used to convert RS232 logic level into the TTL logic level because microcontroller is compactable with TTL logic. In TTL, logic ‘1’ is used +5V and logic ‘0’ is +0V. In RS232, logic ‘1’ is -12V and logic ‘0’ is +12V [5]. The pin connection of MAX 232 is shown in Figure 4.

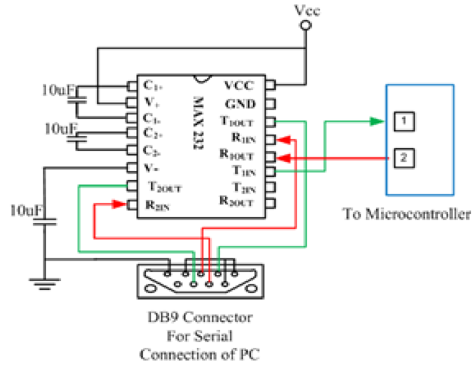



Figure 4. Pin Connection of MAX 232

### 3.2 Position sensor Input Portion

The position sensor circuit is used to know the arrival of the medical powder bottle. LDR (Light Dependent Resistor) sensor is designed as dark active circuit. The signal is sent when the bottle passes through the sensor. The output signal of the position sensor circuit must be 0V all the time and nearly 5V output is sent to the PIC when the bottle is passed.

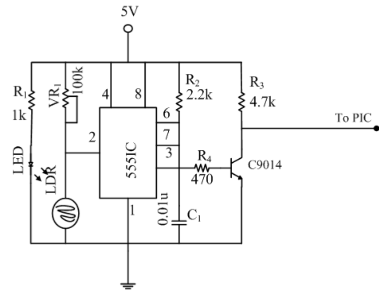



Figure 5. Position Sensor Drive Circuit

Two LDR sensor or positions sensors are placed on the disc conveyor for the filling and capping process. The counter starts counting at the cap feeding position. When the bottle reaches in the light of the LED, the resistance of the LDR will be taken 1MΩ. In Figure 5, the output waveform of the circuit is low pulse signal. To generate this signal, the 555 timer monostable circuit is used to generate the required input voltage for microcontroller.

## 3.3 Motor Driver Circuit

The DC motor driver is needed to control the magnitude of supply voltage for controlling the speed of DC motor. Moreover DC motors cannot be driven directly with a microcontroller as they require high current and high voltage than a microcontroller can handle. The DC motor driver circuits that will be used in this research are a relay driver, and the SG3525 pulse width modulator control circuit that offers improved performance and lower external parts count when implemented for controlling all types of switching power supplies [7]. The conveyor, rotary disc, cap holder, capping process and cap feeder are driven by DC motors. In this driven system, relay driver with transistor C9014 switching circuit is used as shown in Figure 6.

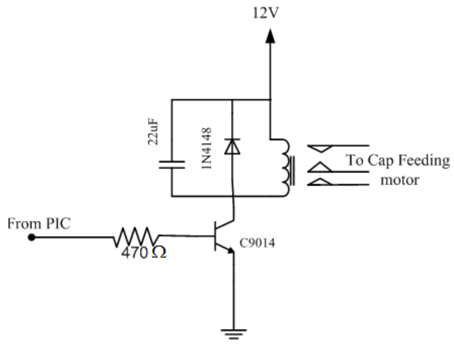



Figure 6. Relay motor drive Circuit

Transistor C9014 is being used to control the relay with a 12V coil, operating from a +12V supply. Series base resistor 470Ω is used to set the base current for the transistor, so that the transistor is driven into saturation (fully turn on) when the relay is to be energized [8]. That way, the transistor will have minimal voltage drop, and hence dissipate very little power as well as delivering most of the 12V to the relay coil.

(a) (b)

Figure 7. (a)Electrical Setup and (b) Control box

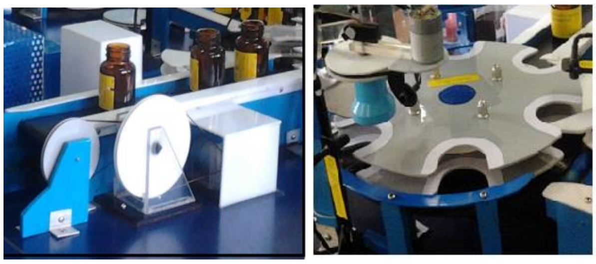
A power diode 1N4148 is connected across the relay coil, to protect the relay coil from damage due to the back-EMF pulse generated in the relay coil's inductance when the transistor turns off. Electrical setup and control box of this system is shown in Figure 7(a) and (b).

## 4. HARDWARE COMPONENT OF THE SYSTEM

The filling and capping operation is implemented in a sequential manner. In this system, it is composed of the conveyor which is used for transporting, cap slide and cap feeder for capping process, rotary disc and hopper for filling process.

## 4.1 Belt Conveyor and Rotary Disc Conveyor

Belt conveyor which is constructed by rubber belt and its guide way which is is made up of fiber plastic is used to carry the bottles. Its length is 16inches and its width is 2 inches. Photo of belt conveyor is shown in Figure 8(a). Disc conveyor is used for the filling and capping process and is constructed by fiber plastic. It is composed of six plots and its diameter is 11inches. Photo of rotary disc is shown in Figure 8(b).



(a) (b)

Figure 8. (a) Belt Conveyor and (b) Rotary Disc

## 4.2 Hopper for Filling Process

Hopper is used for filling process where hopper is set up with the funnel to drop the medical powder. This is made up of the fiber plastic which is lightweight and cheap to build the prototype. Funnel is designed with its length is 3.5 inches and its area is 0.5625 sq.-inches. Filling process is controlled by placing the shuttle valves at the top and bottom of the funnel. Photo of hopper with funnel is shown in Figure 9.

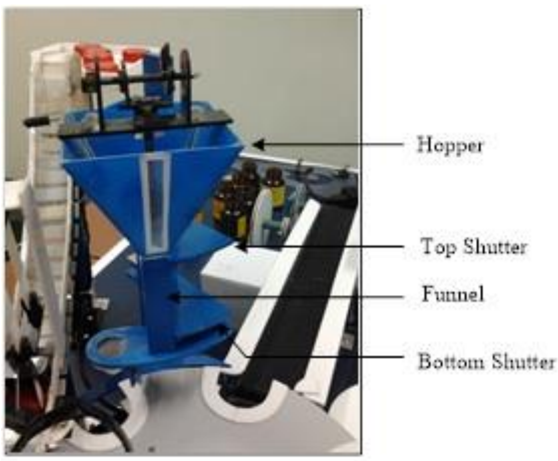



Figure 9. Hopper for Filling Process

The top shuttle valve is set up between the bottom of the hopper and the top of the funnel. When the filling process start, the top shuttle valve is closed and the bottom shuttle valve is opened by rotating the disc with carrying the bottle. If the bottle don't present at the filling position on the disc, the filling process will not start. If the filling process doesn't start, the top shuttle valve is opened and the bottom shuttle is closed. The filling process is constructed by the mechanically design and control.

### 4.3 Capping Mechanism

A cap is applied to a bottle at station two on the rotary disc, which is a pre-tightening station. The capping mechanism consists of a caps holder, a stationary arm and a capping arm/head. There is a vibrator motor is employed to vibrate the cap holder for moving the caps to the cap slide. The cap feeder is applied for tightening the capping process. The capping head can move up and down in a controlled manner. Whenever the cap feeder sensor gets the signal from detecting the bottle, the cap feeder moves down and tightens the cap against the bottle. The limit switch is used to move up the cap feeder. Capping Mechanism is shown in Figure 10.

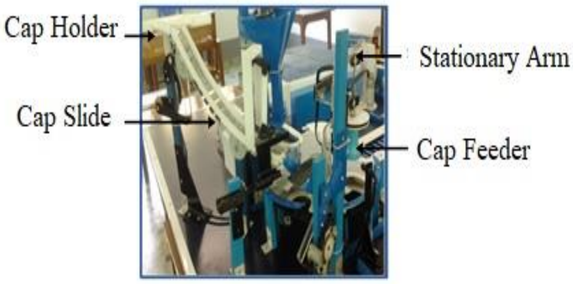



Figure 10. Capping Mechanism

### 4.4 Cap Feeding Process

In the cap feeding system, DC motor is used for the cap feeding process. At this position, LDR sensor is used as the position sensor. When the bottle reaches at the cap feeding position, the disc conveyor will stop as the position sensor gets the signal. At that time, the capping motor come down and operates the cap feeding process. The capping time is limited by the limit switch. Cap feeding photo is shown in Figure 11.


Figure 11. Cap Feeding Process

### 4.5 Position Sensor

The position sensor circuit is used to know the arrival of the medical powder bottle. LDR (Light Dependent Resistor) sensor is designed as dark active circuit. The signal is sent when the bottle passes through the sensor. The output signal of the position sensor circuit must be 0V all the time and nearly 5V output is sent to the PIC when the bottle is passed. Two LDR sensor or positions sensors are placed on the rotary disc for the filling and capping process. The counter starts counting at the cap feeding position. The counter is used to show how many bottles have been filled and capped during the operation process. Position sensor 1 is used for filling process and position sensor 2 is used for capping process. Position sensor design is shown in Figure 12.

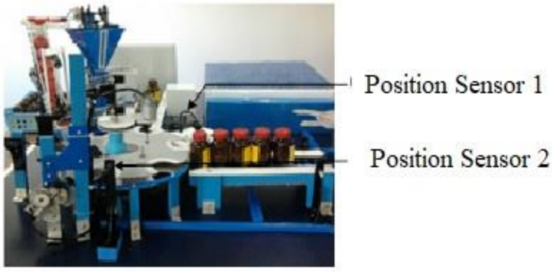



Figure 12. Position Sensor Design

## 5. SOFTWARE DEVELOPMENT OF THE SYSTEM

Human machine interface (HMI) control system is a computer control software application. HMI Systems provide the automation control system. PC based HMI system is divided into two major portions; the first one is to interface the control unit with PC and the next portion is to monitor the whole process. The VB.Net programming from Visual Studio 2010 IDE is utilized as the monitoring program. Micro C programming language is used as controlling software for the PIC controller. Block Diagram of linking window for control and simulation is shown in Figure 13.

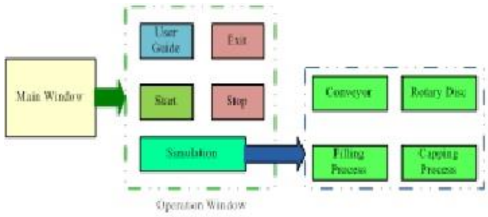



Figure.13. Block Diagram of Linking Window for Control and Simulation

In HMI applications with a graphical interface, the complex operations in the real time system can be monitored and controlled by commanding from the PC. In this research, the implementation and displaying of filling and capping process for the monitoring and control system use Visual Basic.Net programming language as HMI software. The serial communication method is used as the interfacing system between the PC for the monitoring and hardware system [9].

To start the serial communication, initialize the UART module and assigned the baud rate as 9600. The interfacing component for the serial communication method is very simple. It has to use only MAX 232 level converter to convert the voltage level between PIC and PC. The flow chart of the system is shown in Figure 14.

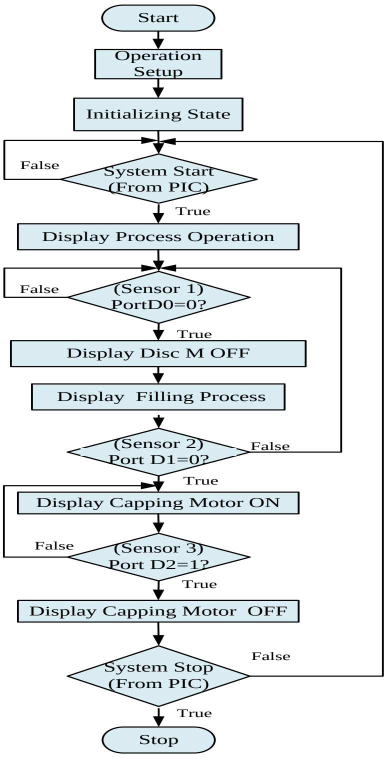



Figure .14.VB.Net Programming Flow Chart of the System

## 4.5 **Linking Window System for the Process**

The operation of the filling process can be run and stopped from main page by the operator.

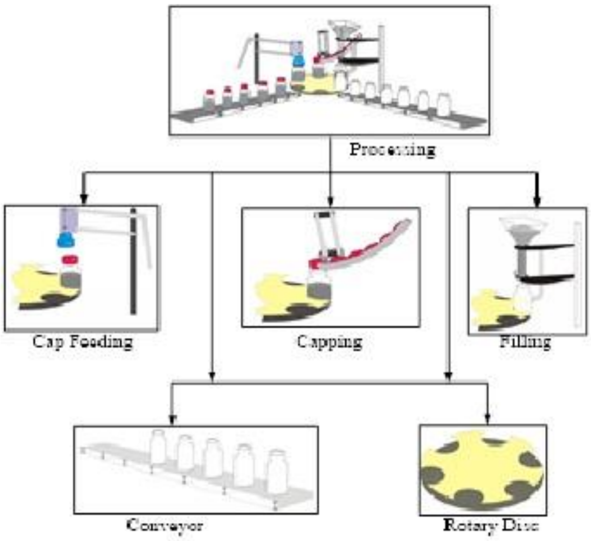
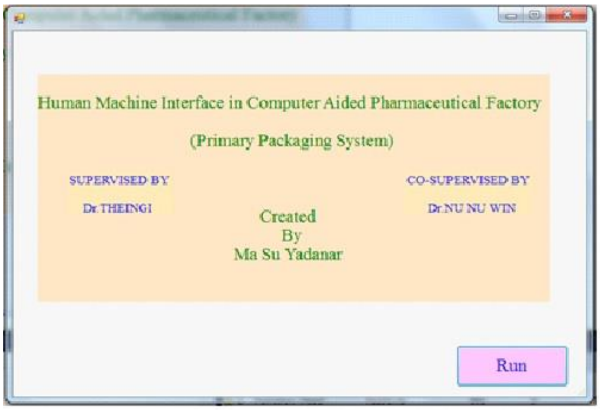



Figure 15. Linking Window Pages with Operation Page (Processing)

The main page serves to collect data from the operation window and to display in real-time running condition. When the main window is shutdown, the processing is shutdown all process except receiving command from the main window. So, the application software can be viewed in window frames, linking windows with processing page are shown in Figure 15.

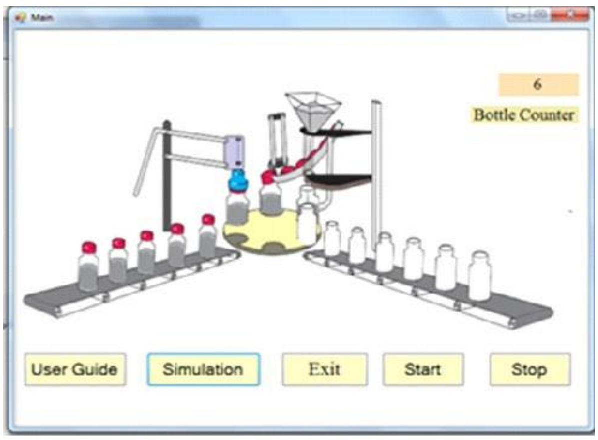
## 4.6 Displaying the System

The display system only intends to monitor and control for the process. For the overall system, the hardware devices for control unit are connected to the computer including window application software using the serial port connector. Serial communication method is used to communicate between the operating system and the displaying system. The monitoring software is implemented by the seven pages. They are the main page, simulation page, instruction page, filling page, capping page, cap feeding page and disc page. The first page is the title name of the project and also includes run button which is linked to the main page. The title page is shown in Figure 16.




. Figure 16. Simulation Result of the Title Page

The title page can firstly be seen when the software is run. The name of the research is expressed in this page. By pressing the run button on this page, the main page will be appeared.




. Figure 17. Simulation Result of the Main Page

The main page which links other pages is composed of user guide, simulation (operating) which links the devices operations, start, stop and exit buttons.The main page also includes the bottle counter box. This bottle counter shows the number (quantity) of bottles which are completed with filling and capping processes. The main page is shown in Figure 17.

The simulation page is the main process of the monitoring system to show for all operations. The simulation page is designed with the sample components for the real devices of packaging process by using the images of the devices. It shows the monitoring of the changing or moving of components. It uses I/O signal from serial port for the operation sequence by using each their signal. By clicking the simulation button on the main page, the running condition of the operation page is appeared as Figure 18.

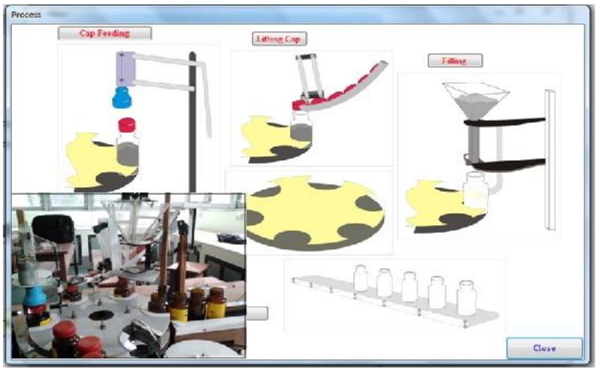
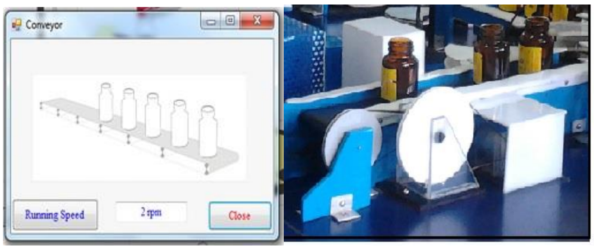


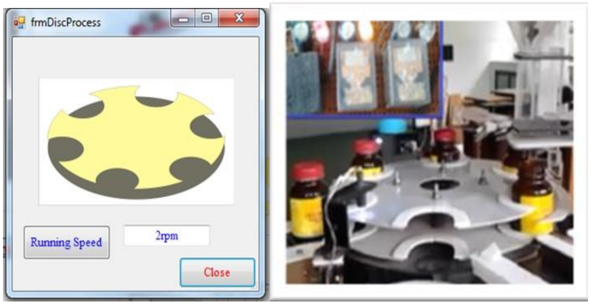

Figure 18. Displaying of the Simulation Page

The simulation of conveyor can be seen by clicking the figure of conveyor on the simulation page, is shown as Figure 19(a) and the photo of conveyor is shown in Figure 19(b).



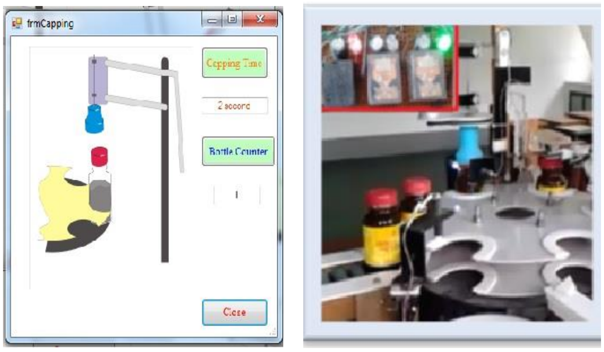

(a) (b)
Figure 19. Simulation and Photo of Conveyor
(a)Simulation of the Conveyor Page and (b) Photo of the Conveyor

The text box contains in this page to define the moving speed of the conveyor motor. The close button is used to close the conveyor moving page and go back to the process simulation page. In the control circuit, three LEDs; red, yellow and green are used to show the running conditions of the process respectively. The red LEDs will be displayed when the conveyor is moved. The red LEDs will always be displayed as the conveyor will be ON as soon as the process start operates. The figure for the conveyor is implemented as the image of the real conveyor in the hardware design. Displaying of the rotary disc is shown in Figure 20(a). The figure for the rotary disc is implemented in the monitoring system as the image of the real disc in the hardware design. Photo of the rotary disc is shown in Figure 20(b).




(a) (b)
Figure 20. Simulation and Photo of the Rotary Disc
(a) Simulation of the Rotary Disc Page and(b) Photo of the Rotary Disc

In the bottle filling page, the counter and timer tools are used to fill the medical powder into the bottle as the real filling process. Bottle filling page contains the text boxes to define the filling time and the amount of medical powder which is filled into the bottle. By clicking on the figure of cap feeding process on the simulation page, the cap feeding process will be shown as in Figure 21(a).




(a) (b)
Figure 21. Simulation Result and Running Condition of Cap Feeder

The cap feeder will operate when the signal is received from the PIC. The PIC will send this signal when the bottle reaches near the position sensor (light sensor). If the signal from the PIC is not received, the cap-feeder will not operate. The green LEDs will be lighted when the cap-feeder is running condition as shown in Figure 21(b).

Figure 22. PC Based HMI Packaging System

In this research, the operation conditions of the whole system are displayed by the PC based HMI system. This research aims to verify that the machine can fill and cap for six medical powder bottles in one minute. So the production rate is roughly 360 bottles per hour. The experimental results of the system is shown in Figure 22.

## 5. CONCLUSIONS

This research is a development of PC based HMI system for the packaging system. In this research, design and implementation of the filling and capping processes that used Visual Basic.Net programming for the monitoring and control of PC based HMI system have been studied. Serial interfacing system for this process which is used for communication between the PC and control system is designed and constructed and tested by connecting both hardware and software. PIC microcontroller is used in this system instead of PLC. Hardware of packaging process is designed with the prototype and tested by connecting hardware and software for monitoring of the running condition. This system provides a platform for further advancement in the field of industrial use of the filling process. It is possible to automate any system, improving the production time, saving cost, and the repeatability of the end product.

## 6. ACKNOWLEDGMENT

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