Detection Of Metallic And Non Metallic Objects On A Conveyor Belt Using VFD. PLC Logics, HMI screen, VFD.

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Abstract

This project was created to control and monitor movable parts on the conveyor belt by a Human Machine Interface (HMI).In our application, we separate metallic and non-metallic objects. This application could be used in pharmaceutical, electronic industries or any industry which deals with metals/plastic. An eye sensor and a proximity sensor have been used to detect the non-metallic and metallic objects respectively. According to that the counter counts non-metallic and metallic objects and display the value on the HMI, whenever a metallic object is detected Air cylinder pushes it out of the conveyor belt and allows non-metallic objects to reach till the end of conveyor. PLC with series FX3U-16MR/ES manufactured by Mitsubishi is used in this project. This logic can handle a series of metallic and non-metallic objects. To control the speed of the conveyor VFD (Variable Frequency Drive) is programmed and used.E-Designer-7 software is used to design the screen. GX Developer software has been used to create PLC logic.

Keywords: PLC (Programmable Logic Controllers), VFD(Variable Frequency Drive),Conveyor belt, Proximity Sensor, HMI(Human Machine Interface)

1.1 INTRODUCTION

This project is aimed to separate Metallic and Non Metallic objects on a conveyor belt using PLC (programmable logic control). PLC's have been a tool for automation in many industries where one PLC can replace lots of circuitry. In our project, we used VDF (Variable Frequency Drive) to control the speed of the conveyor belt, HMI screen for users to operate the system, inductive proximity sensor for detecting metal objects, eye sensor to detect non-metallic objects, air cylinders to push the object out of conveyor belt, motor to run the conveyor belt, relays, switches and 24 VDC power supply unit. All these components are integrated together using PLC as shown in figure 1.1.

The function of metal separators is to detect metallic contaminants in non-metallic products such as plastic, food, tablets and pills. Unless monitored properly, contaminated products will not only cause significant production losses, but could be harmful to the consumers mainly in Pharmaceutical industries. We used small blocks of metals and non-metals to show the operation of this project as shown in figure 2 and 3.PLC is programmed in such a way that a series of objects can be placed randomly based on the type of object it is discriminated.
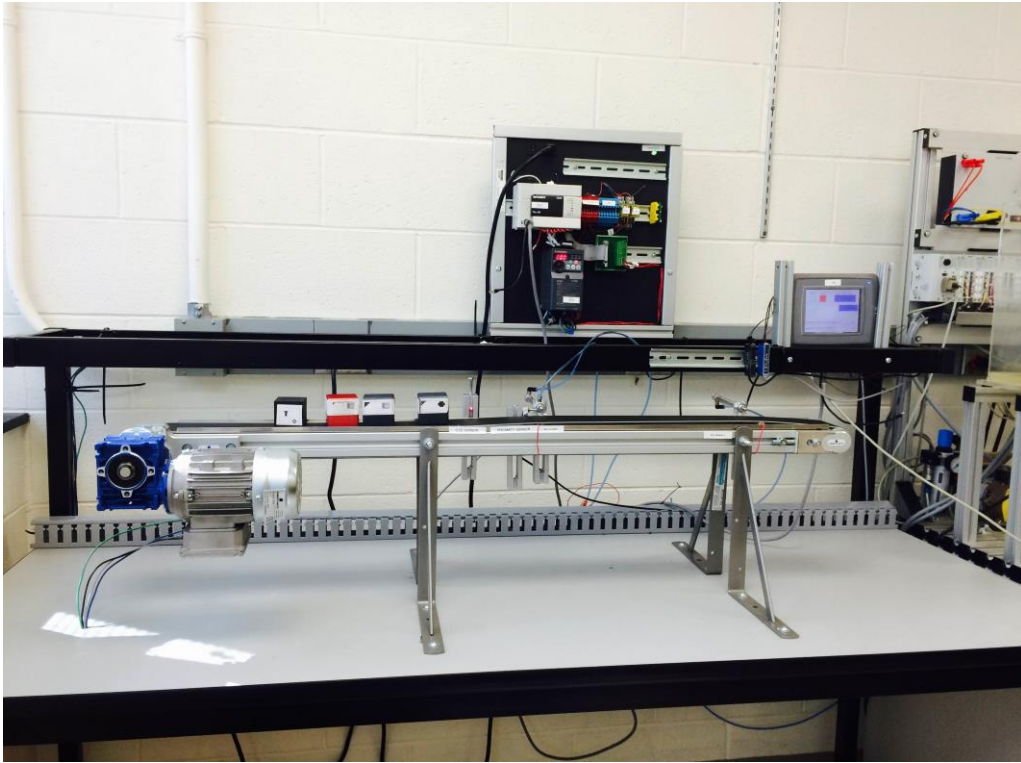
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Figure: 1.1-Front view of the project

Figure: 1.2- Non-Metallic object

Figure: 1.3- Metallic object

2 Design Consideration:

2.1 Main Components

- PLC (Programmable Logic Control): Manufacturer: Mitsubishi,Model: FX3U-16MR/ES,Inputs type: 100-240 VAC 50 /60Hz 30 W,Output:24VDC 2A

- A Variable-frequency drive (VFD): Manufacturer: Mitsubishi,Model: FR-D710W-014-NA,INPUT : 6.2A 1PH AC100-115V 50/60Hz,OUTPUT: 1.4A 3PH AC200-230Vmax/ 0.2-400Hz

- Human Machine Interface: Manufacturer: Mitsubishi,Type: 06705A,No: 1106-144,Name: E1061,Power: 24VDC 0,45A.

- Sensors: Proximity sensor , Eye sensors

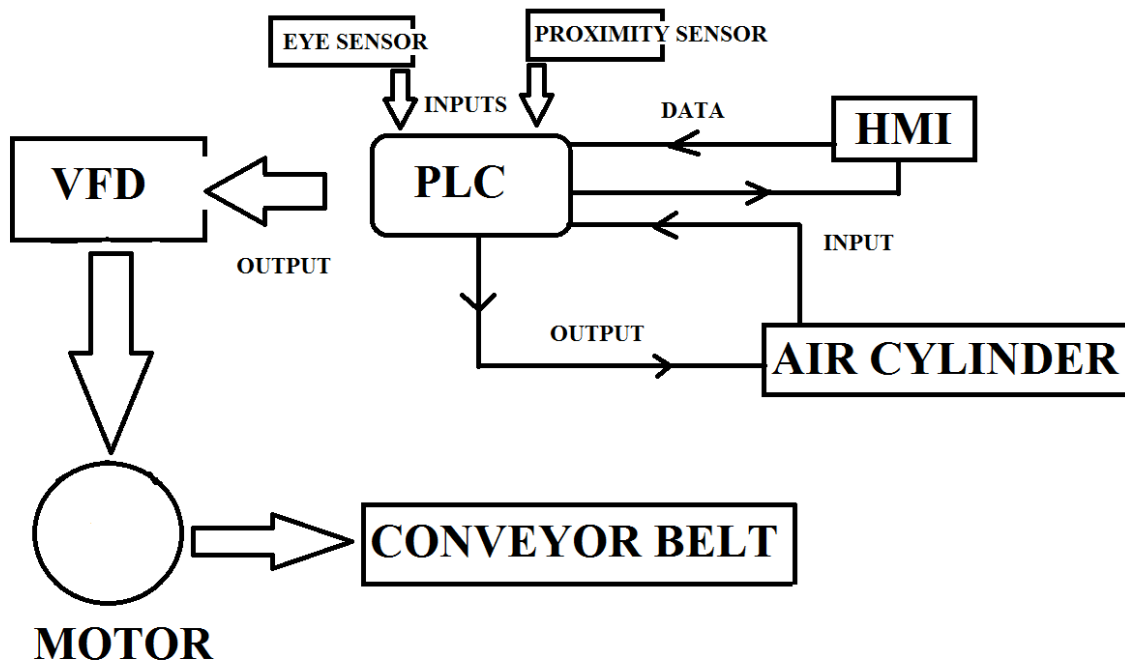- Air cylinders

2.2 BLOCK DIAGRAM

Figure: 2.1- Block diagram

2.3 Project Description

PLC Mitsubishi,Model: FX3U-16MR/ES is used in this project FX 3U- is the series name,16 indicate no. of inputs/ outputs. R/ES : AC power supply/24V DC (sink/source) input/relay output, this can be operated in both sink/source mode. Input side is connected to Inductive proximity sensor which generates electromagnetic field over the sensing surface .The presence of a metallic objects (actuator) in the operating area causes a dampening of the oscillation amplitude. The changes in such oscillation is identified by a threshold circuit that changes the output of the sensor which is connected as input to PLC.

Two eye sensors are used to detect the objects. This eye sensor sends a light beam and when obstructed by any object, this light beam is reflected back to the receiver. Now, the eye sensor gives an output signal which is input to PLC. Landscape touch screen HMI screen is programed using E-designer software and connected to PLC for data exchange as shown in figure 4. HMI screen makes it easy to use than using conventional push buttons. This project can be operated from the office room instead of workstations by using HMI screen, as this can be routed through wire. This will be an advantage for user as he can check the number of metallic and non-metallic objects on the screen.

VFD(Variable Frequency Drive) parameters are set and installed to output side of PLC. Motor is connected to VFD using delta type connection .VFD takes signals form PLC and based on the set parameter list it makes the conveyor belt run in preset speed. VFD gives a flexibility to move the conveyor belt in forward/ reverse direction but in our application we are using only one direction at constant speed. Festo's self-adjusting cushioning PPS air cylinders are used to push objects out of the conveyor belt. This air cylinder is installed with a proximity sensor and once the piston moves to and fro, it gives an output signal which in turn is connected as input to PLC.

Circuit diagram of this project is laid using Autocad 2015 which is shown in figure 6.Power supply for PLC and VFD is 110v-AC. Sensors, HMI screen are operated at 24 VDC power supply.
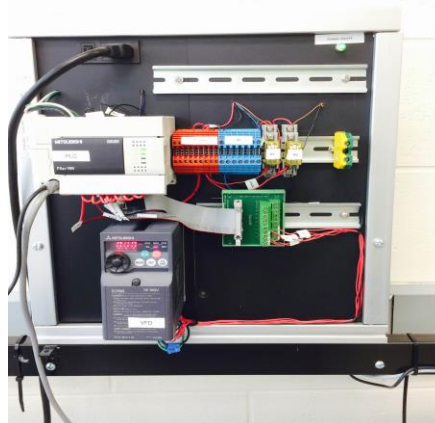
Figure: 2.1- Front view of the pannel

2.3 Auto-Cad Circuit Diagram
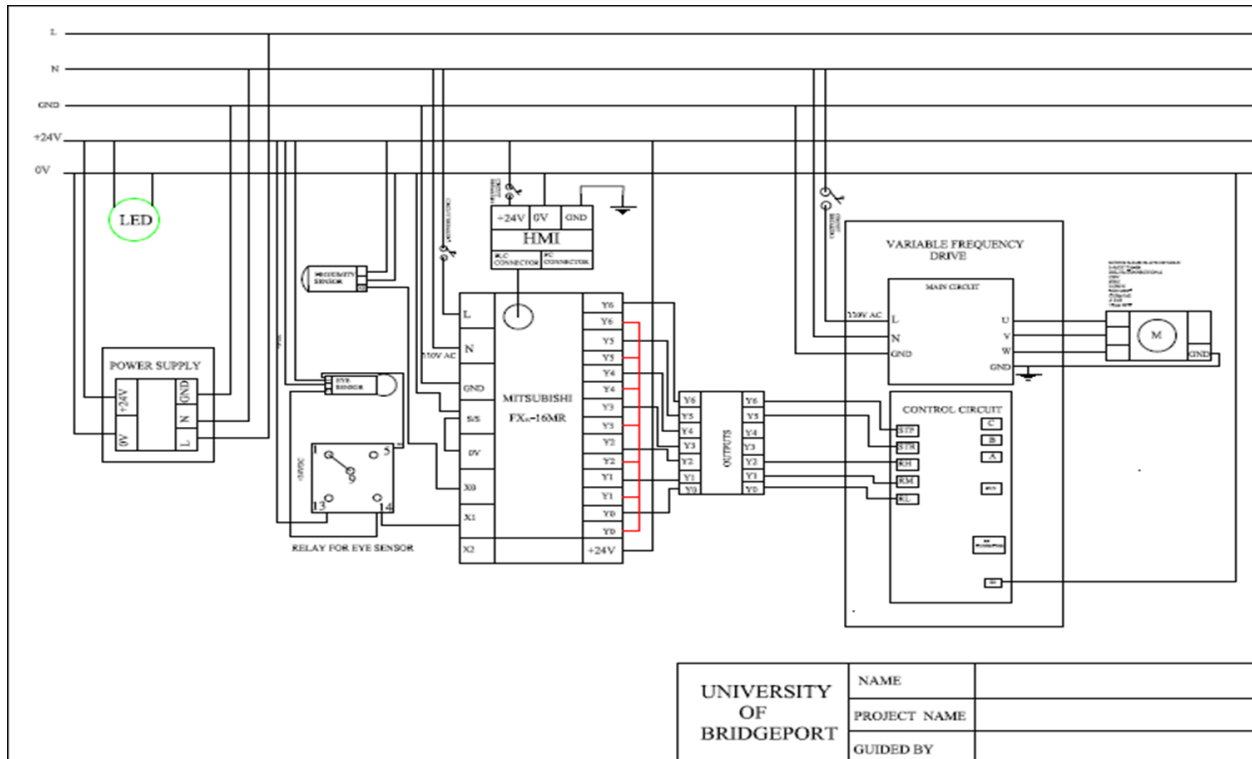
Figure: 2.2

3. How System Works

- First click on HMI screen which has a welcome page, user can touch on any part of screen to jump to main page as shown in figure 4.1
- On main screen there are two touch buttons one to start the motor other to stop, one for going back to welcome page.
- Our HMI screen has a configuration button which will ask user to enter password to go to that page so user can protect his data which is in configuration page.
- Number of metallic and non-metallic objects are counted and shown on HMI screen as shown in figure 4.2

- When user touch's start button conveyor belt starts running, then user can place his objects on the belt. Whenever metallic object is detected, conveyor belt stops at air cylinder. Air cylinder will push object out of conveyor belt and immediately conveyor belt will start running.
- When non-metallic object is detected it will go till the second Air cylinder is pushed out of conveyor belt.
- User can hit Stop on HMI screen when the job is completed, immediately everything will stop.

4 Programming:

4.1 VFD Programming

VFD(variable frequency drive) has different parameters which can be programmed to make it run with different frequencies , which will change the speed of conveyor belt, We have different slots in VFD each one is designated to one operation, which are connected to output side of PLC. Three different speeds are in VFD high, low and medium speed.In this project we used speed 2 that is medium speed. Setting is given in the manual of VFD,we used VFD Model: FR-D710W-014-NA Manufacturer Mitsubishi so, these are the ranges and factory settings given in manual shown in (Table 1). In this application we used a constant speed in forward direction.
To set up VFD we need to first click on mode button on VFD on screen P0 will appear, from the above table P4 is used for high speed we give that as 45Hz. Use the roller to adjust the frequency .To set acceleration time for P7 and P8 click on set this value will be in sec that is how many seconds will it take to go to 45Hz from present frequency. In our requirement we set it to .5s.Table 1 below shows the parameter list.

PARAMETER LIST

Pr	NAME	SETTING RANGE	Factory Setting	Customer Setting
P4	Multi-speed setting (High speed)	0 to 120 Hz	60 Hz	45Hz
P5	Multi-speed (middle speed)	0 to 120 Hz	30 Hz	25Hz
P6	Multi –speed (low speed)	0 to 120 Hz	10 Hz	20 Hz
P7	Acceleration Time	0 to 999S	0.1S	0.5S
P8	Deceleration time	0 to 999S	0.1S	0.5S

4.2 HMI Screen Programming

E-designer software is used to program HMI screen first this screen is created by following the instructions and then link these touch buttons with internal memory bits used in PLC programming.Here we set up 2 touch keys START and STOP which are given to internal memory bits M0,M1 in PLC programming. One jump key which will move back to main page, one static text which is given to output Y2 which will specify the speed of running conveyor .We have to connect HMI with PC through RS-232 wire and this program is sent to HMI memory which takes few minutes and then HMI is connected to PLC for its internal operations.
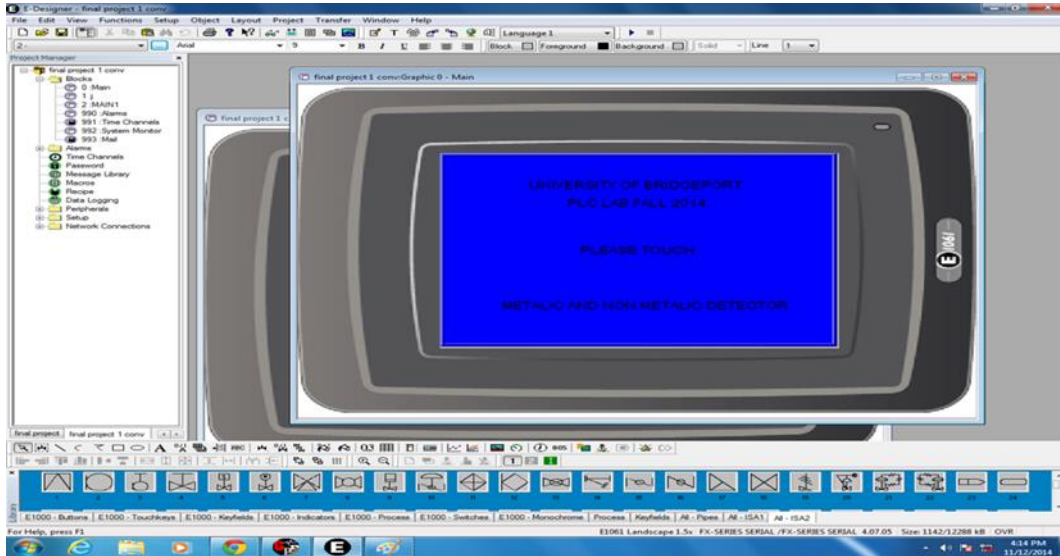
Figure: 4.1-HMI welcome page
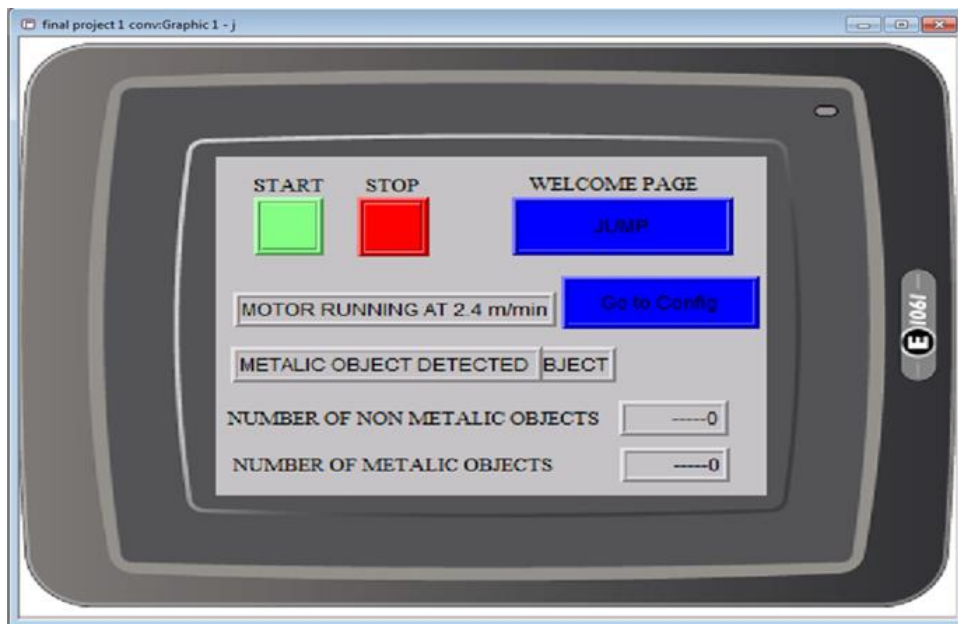
Figure: 4.2-Main page

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4.3 PLC PROGRAM

GX-Developer software is used to build ladder logic, by making a list of inputs and outputs. After developing this logic PLC is connected to PC using USB wired connection. PLC has an option to put it in run mode or stop mode, while sending the program into PLC it is recommended to put it in stop mode, for safety issues. Then by using transfer setup ladder logic is sent to PLC memory it is unplugged from PC. When PLC is ready to use it is changed to run mode until then it will not work. PLC input output and ladder logic is explained below, Rung specifies the operation of each line. PLC scan cycle is Read-Execute-Write so in each scan cycle PLC will read from all inputs, execute as per ladder logic and corresponding outputs are turned ON.

4.3.1 Inputs-Outputs

Inputs: X0- Proximity Sensor

X1- Eye Sensor

X2- Eye sensor 2

Outputs: Y2 – The speed (RM)

Y5 – Speed forward (STF)

Y4-Air cylinder 1

Y7-Air cylinder 2

Timers: T4– It is used to stop the conveyor

T5– It is used to start the conveyor again

Counters: C1 – It is used to count the metallic objects

C2 – It is used to count the non-metallic objects

Internal Bits: M0 – start button / M1 – stop button,

M12, M8, M4- Used for internal operations.

Data registers: D6, D7, D10, D7 and D11.

4.3.2 Ladder Logic

This ladder logic consists of normally open, normally closed switches, internal memory bits, data registers, timers, counters and compare function. Each rung is explained in 4.3.3

```
* M0 will start the conveyor belt in forward direction
* When M1 orT4 or M12 are on it will stop the conveyor belt
        M0       M1       T4       M12
   0 ───┤├───────┤/├──────┤/├──────┤/├────────────────────────(Y002 )
       Start    Stop    timer 4                                SPEED 2



                                                              (Y005 )
                                                               STF




* eye sensor will increment the value of d6 by 1
* It will move D6 value to D7
        X002
   8 ───┤├───┬──────────────────────────────────[INCP    D6  ]
       eye   │
      sensor │



          └──────────────────────────────[MOV    D6     D7  ]




* Proximity sensor will set internal bit M8
* Count the no of metalic objects and move to register
* This will decrement D7 and compared to D6
        X000
   17 ──┤├───┬──────────────────────────────────[SET     M8  ]
     Proxmity│
      sensor │
             │
             │                                        K200
             ├───────────────────────────────────────(C1  )
             │
             │
             └──────────────────────────[MOV    C1     D10 ]
```

D6					
A/S	12	30			
B/D	9				

D6					
A/S	12	30			
B/D	9				

D7					
A/S	30				
B/D	12	27			

M8					
A/S	18	38	39		
B/D	46				

C1					
A/S	22				
A/S					

C1					
A/S	22				

	A/S				
D10					
B/D	22				
B/D					
D7					
A/S	30				
B/D	12	27			
D7					
A/S	30				
B/D	12	27			
D6					
A/S	12	30			
B/D	9				
M4					
B/D	30				
B/D					

─────[DECP   D7]

─────[CMP   D7   D6   M4]

* If d7 is less then D6 M6 turns on setting M8

```
        M6
37 ─────┤ ├────────────────────────────[SET    M8 ]
     less
     than
```

M8				
A/S	18	38	39	
B/D	46			

* M8 will turn on a timer

```
        M8                                    K10
39 ─────┤ ├──────────────────────────────────(T4    )
                                              timer 4
```

T4				
A/S	43			
B/D	2			

* When timer is done aircylinder turns ON

```
        T4
43 ─────┤ ├──────────────────────────────────(Y004  )
     timer 4                                   air
                                               cylinder
```

* When air cylinder operation is completed X3 will reset M8

```
        X003
45  ----| |--------------------------------[RST    M8  ]
        air
        cylinder
        1
```
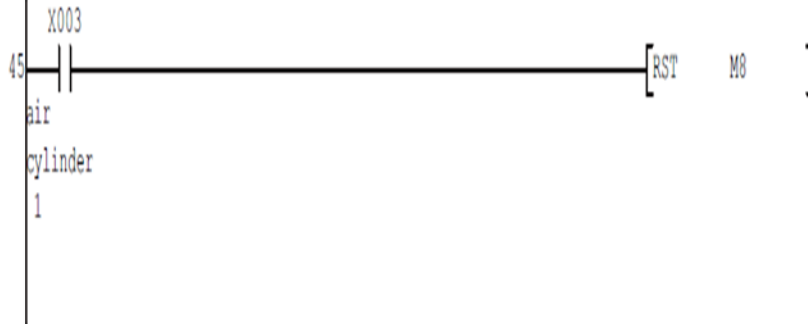
M8				
A/S	18	38	39	
B/D	46			

* When eye sensor detects an object it is counted
* The value is moved to D11
* This will set M12

```
        X001                                    K200
47  ----| |------------------------------------(C2   )
        Eye
        Sensor 2
```

C2				
A/S	51			
A/S				

```
                              [MOV    C2     D11  ]
```
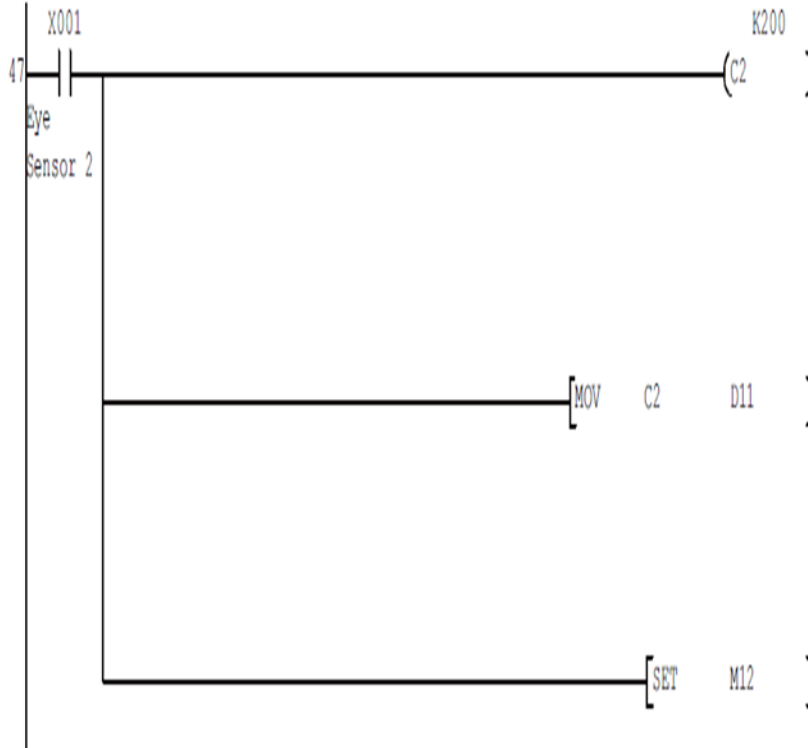
C2				
A/S	51			
A/S				

D11				
B/D	51			
B/D				

```
                              [SET    M12  ]
```

M12				
A/S	56	57		
B/D	4	64		

* M12 will turn on timer T5

```
        M12                                     K5
57  ----| |------------------------------------(T5   )
                                                timer 5
```

T5				
A/S	61			
A/S				

```
* Timer 5 will start air cylinder 2
              T5
    61 ┤ ├──────────────────────────────────────(Y007  )
       timer 5                                    cylinder
                                                  2



* air cylinder 2 input will reset M12
              X004
    63 ┤ ├──────────────────────────────[RST    M12 ]
       air
       cylinder
       2 input


    65 ─────────────────────────────────────[END ]
```

M12					
A/S	56	57			
B/D	4	64			
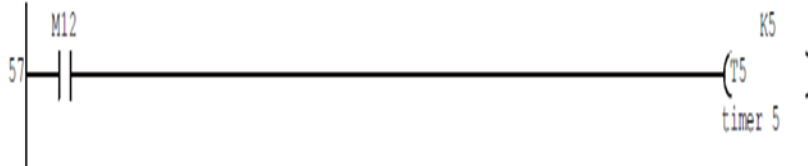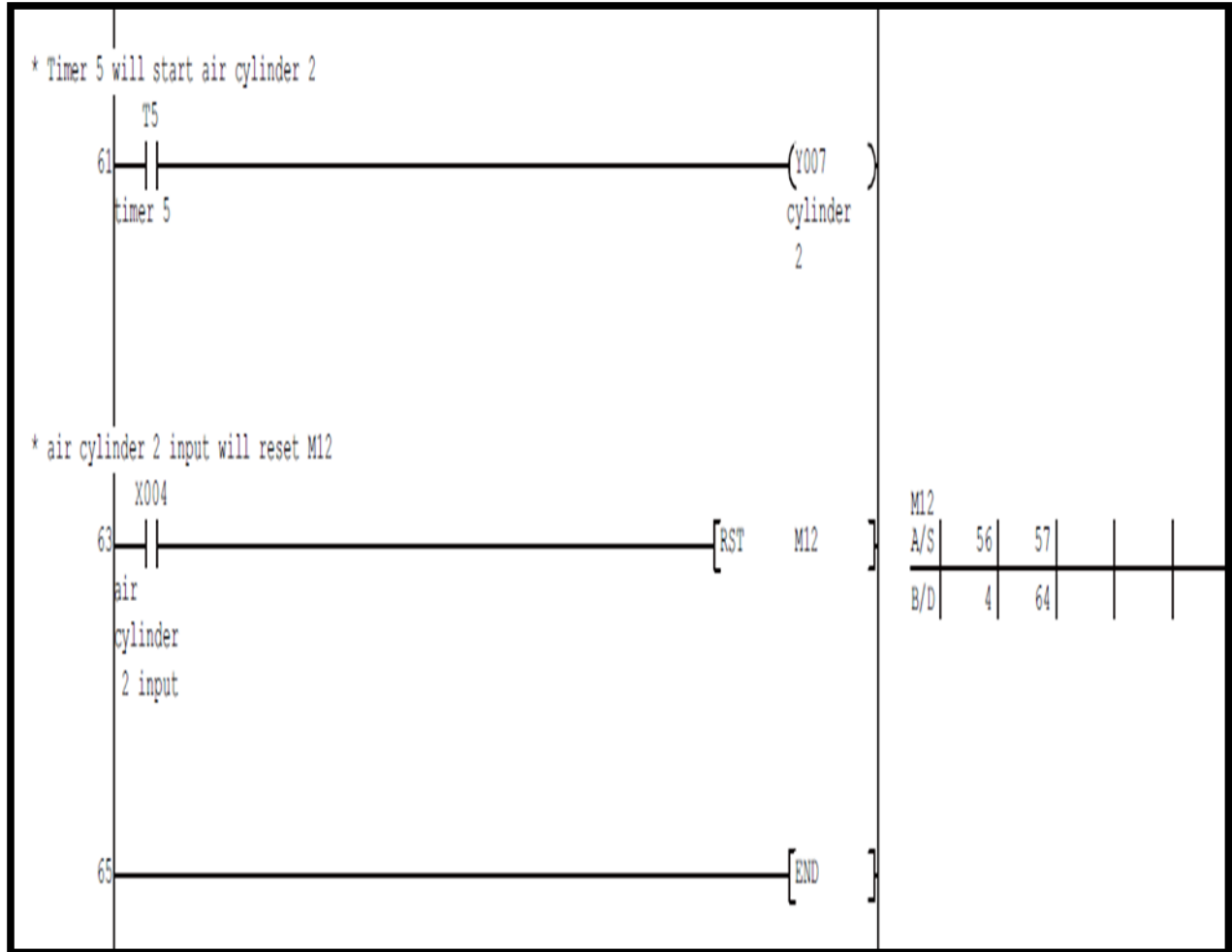
4.3.3 Ladder logic explanation.

RUNG 0: When internal memory bit M0 is ON it will start the conveyor belt in forward direction.M1 or T4 or M12 are on it will stop the conveyor belt.

RUNG 1: The eye sensor(X002) is used to increment the value of data register D6 by 1 and it will move D6 value to data register D7.

RUNG 2: The proximity sensor will set internal bit M8. The counter will count the number of metallic objects and move to register. This will decrement data register D7 and the value stored in D7 is compare to the value stored in data register D6.

RUNG 3: If the value in D7 is less than D6, then M6 is ON and it will set internal memory bit M8.

RUNG 4: Internal memory bit M8 will activate the timer T4.

RUNG 5: As soon as the timer T4 is done, it will activate the air cylinder (1).

RUNG 6: When first air cylinder(X003) operation is completed it will reset internal memory bit M8.

RUNG 7: When eye sensor detects an object the counter will count and the value is moved to data register D11, and it will set the memory bit M12.

RUNG 8: M12 memory bit will activate timer T5.

RUNG 9: When timer T5 is done, it will start the second air cylinder.

RUNG 10: As soon as the second air cylinder is ON it will reset the internal memory bit M12.

Conclusion and Future Aspects

PLC is the modern day tool for control and Automation industries. We commissioned and integrated different components to work together on one platform. This project finds its place in Pharmaceutical industries. Future aspects of the project is to replace air cylinders with robot arm which is compatible with PLC, this arm can be used to pick metal and non-metallic objects and place them in their respective places.

References

1. Mitsubishi PLC FX3U Hardware manual.

2. Mitsubishi PLC FX3U Programming manual.

3. VFD FR-D700 Instruction Manual.

4. HMI MANUAL

5. Festo pneumatic cylinder manual.