Design and Implementation of Industrial Scrap Segregation System using PLC

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Abstract— As the population rate is growing very fast nowadays, with this not only the waste being produced is increasing beyond levels but also the problem to manage this waste is rising. Throwing waste into bin is a good thing but it is not where the problem of waste management ends, but it is where it actually begins. Till now there is no such remedy to manage this amount of waste with safety and better efficiency but by introducing the concept of automation in waste segregation process numerous advantages can be gained. Using PLC (Programmable logic controller) for this purpose will add more plus points in it like less human intervention, elimination of hardwiring, time consumption. In this discussion, the author is intended to put forwarded an arrangement of a system which is capable enough in itself to monitor and control the level of an overhead as well as underground water tank. This home automation system has been designed with the use of complete tools i.e. hardware and software modules provided by Mitsubishi. The PLC used in this system has been operated with the help of GX Work 3 software and Ladder Diagram based programming approach. The complete simulation work of the overall system has been carried out with the use of HMI and GX Design 3 tool again provided by Mitsubishi.

Keywords: Mitsubishi PLC (QR Series), GX Works3, Inductive Proximity Sensor, Capacitive Proximity Sensor, IR Sensor, DC Motors, Relays

I. INTRODUCTION

In today's era, the whole world is facing an acute problem in the management of the water resources existing on the earth. We all know that this water is required for irrigation purpose, industries and in houses for various uses. The basic need of this water management is to minimize the wastage of water in all the domain of it utilization, especially, the check on the wastage due to overflow of the tank in houses or industries. For this same, there are number of system exist in the market which are in use to monitor the flow of the water in houses and industries. These systems are based on various different algorithms of the controllers that could be PID, AI, DCS, PLC, etc. As we know that out of these methods, PLC is the most common in use due to its flexible features such as accuracy, ruggedness, reliability, etc. There are ample of applications in a house automation that could be monitored and control so as to optimize the energy consumption of the house as well as quite interactive in operating this system due to its GUI based features. The most common application or module of an automation system for a house is the check and control over the use of the water. Practically, there are number of controllers available in the market with the desired features but here the author has put forward an innovative system with all required features with better performance. This system has got the flexibility and of monitoring the both end level of the water tank so as to avoid the wastage of water due to water flow as well as running of motor without water i.e. an empty tank. In this system, the water level of the tank can be controlled using programmable logic controller (PLC) and various industrial wireless modules of hardware. Here the Programmable Logic Controller (PLC) starts the pump when the water level is minimum and allows it to run until the water reaches the maximum level. In this home automation system for the monitoring and control of the water tank, there are provision to acquire the dominant input parameter from the user which in turn enhances the accuracy of the system. The basic merits of this system are that it is capable of maintaining a constant level of water in the tank, minimizes the possibility of the shocks due to the various electrical connections of the components, etc. The main limitation in this system could be the cost due to the existing hardware modules such as relays, level sensors, motors, drives, frequency converters, etc [1-5].

Through this project, a prototype is produced to segregate out metal and non-metal waste for industrial level use. With the increasing rate of raw materials, segregation of waste is a global topic. Proper waste segregation will not only enhance the results in energy savings but will also provide good environmental performance and reduction in raw material wastage and manufacturing costs. Introduction of PLC will automate the whole process waste segregation. PLC is a ruggedized computer used for industrial automation. Programmable logic controllers are a flexible and robust control solution, adapted to almost any application. The benefits of PLC are the automation with a less amount of cabling and a low error rate. Automation or automatic control is the use of electronics and computer-controlled devices to assume control of processes [6].

II. BASICS OF PROGRAMMABLE LOGIC CONTROLLER (PLC)

The PLCs are behaving as heart and brain of the automation system which are designed and implemented in various domains of the applications such as factory, home, plant, etc. due to its enormous features which are best suitable for such applications. It has got inbuilt modules of hardware and software with excellent GUI capabilities with which it is quite common in the development of automation systems. The most common applications of this type of system are quality based sorting, monitoring of the functioning of various modules in power plants, bottling applications etc. with quite acceptable level of accuracy in the output. For example, in Food and Beverage industries, the bottle filling task is carried out by a machines as manual filling process has many shortcomings such as spilling of water while filling it in bottle, equal quantity of water may not be filled, delay due to natural activities of human and hygiene conditions. The automatic process can be smooth and the

process of refilling can reduce worker cost and operation cost [7-9].

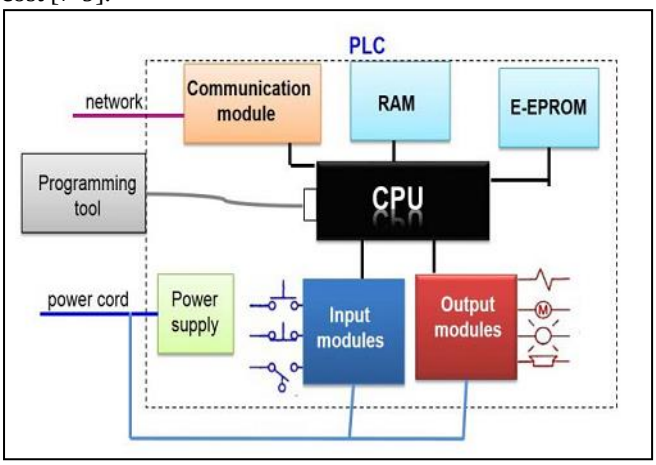


Fig. 1: Architecture of PLC [10]

The above figure shows the architecture of a typical PLC which is quite commonly used for the development of automation system. The most important module of a PLC is CPU, power supply and various input output hardware modules. In addition to this, it could have designated memories, communication modules such as RS 232, IEEE standard protocols, wireless tools, etc. The below shown figure 2 depicts the block diagram of a typical PLC system which is quite common in use for various applications.

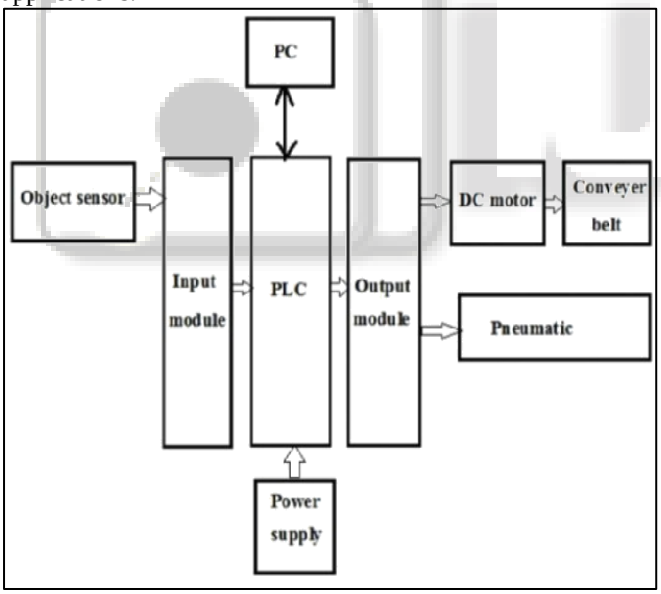


Fig. 2 (a): Block Diagram of PLC [11]

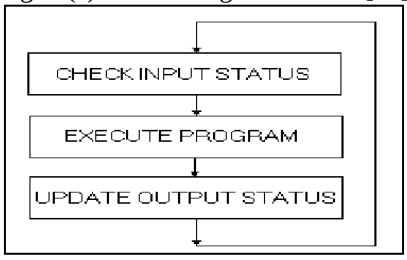


Fig. 2 (B): PLC Scan Logic Diagram

The performance as well as the proper functioning of a PLC mainly depends upon its software module i.e. the tool used to program the PLC. There are number of tools that can be used to carry out the programming of the PLC, say, Ladder Diagram, Functional Block Diagram, etc. Out of these, the ladder diagram is quite common in use due to its simplicity and availability of built in function which are quite important and needed in the development of automation system.

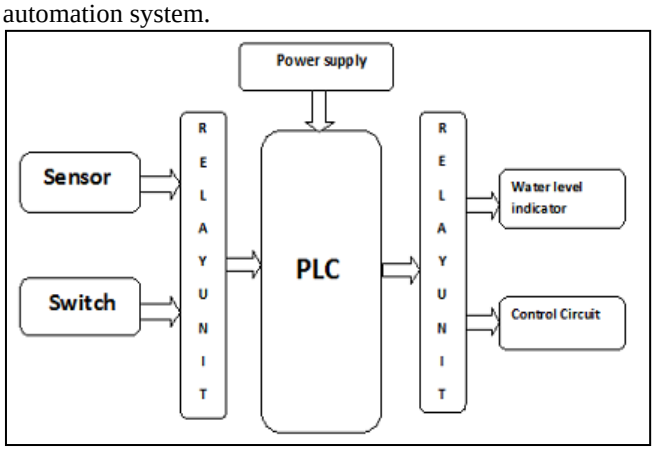


Fig. 3: Block Diagram of PLC [12]

This PLC has got enormous applications in the automation process of the industries and factories say, automatic segregation of objects depending upon colour, class, quality, etc. and then directing them towards designated module as per the requirement of the process. This system enhances the output of from the designated application thereby reducing the inter module development. The operation of the PLC is known as scan time i.e. it always scan the written code using ladder diagram which is quite clear from the below figure 3 i.e. a flowchart diagram which reflects that how a PLC scans the updated data signal and accordingly operates the attached load with the machine [9-11]. For example, an electrical input signal is fed to the PLC with the help of programming tool i.e. Ladder diagram, the desired instruction will get executed by the machine which in turn will switch ON/OFF the hardware module i.e. a relay or solenoid. This switch in turn controls the operation of a motor that could be used to pump the water in overhead tank. This switching i.e. ON/OFF mechanism of a motor can be understood easily with the help of the below given block diagram i.e. figure 4 [13-18].

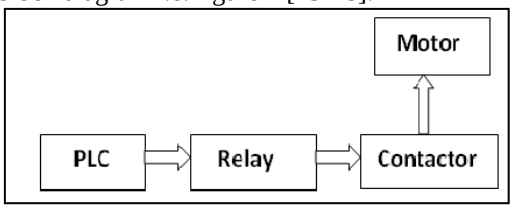


Fig. 4: Mechanism of Motor ON/OFF [19]

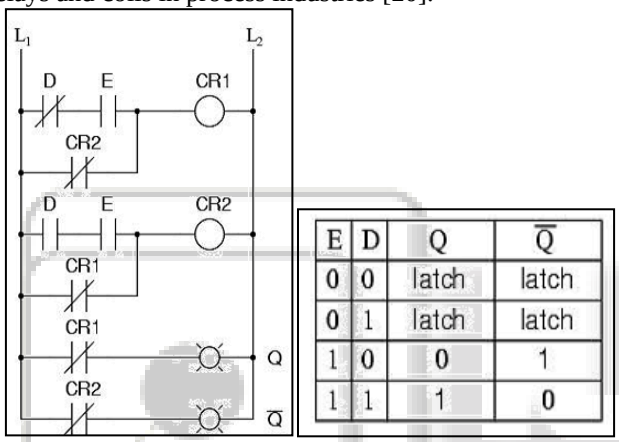
III. BASICS OF PLC PROGRAMMING

We have discussed the importance of PLC & SCADA in the design and implementation of the automation system for industries, Plants, Factories, Home, etc. The most important aspect of these systems is the capability and features which are available to the user for its proper functioning i.e. the software tool and its functions. So during this discussion, a lot of bench marking has been done so as to find the various tools of the software which can be suitably used to program

these hardware modules. There are basically, five different approach to operate the PLC for any system properly i.e.

- Ladder Diagram Approach (LD)
- Functional Block Diagram Approach (FBD)
- Sequential Function Chart Approach (SFC)
- Structured Text Approach (ST)
- Instruction List Approach (IL)

Out of above these, the most common and easiest language used to operate a PLC is the LD approach i.e. Ladder Diagram. This language is quite easy since it is totally based on the C programming language. In addition to this, the programming syntax of this language is also very similar to the assembly language programming of the microprocessor and microcontrollers. The name of this programming language is depicted from its structure i.e. look wise which is simply the combination of the power rails and rungs. This programming language come into existence to tackle the problems related to the functioning of relays and coils in process industries [20].



E	D	Q	$\overline{Q}$
0	0	latch	latch
0	1	latch	latch
1	0	0	1
1	1	1	0

Fig. 5: Basic Ladder Logic Program [21]

The above figure 5 shows the structure of a latch operation with the help of Normal Open (NO) contacts, Normal Closed (NC) contacts and coils representing the output of the latch which is nothing but simply a flip flop device. The operation of this program of the latch can be explained with the help of the truth table shown above. It means that all the basic issues related to the automation system can be very easily solved with the help of simple NC, NO and coil which act as the basic tool of this programming language. The operating process of this language i.e. scan process is always starts from left and moves towards right so as to complete one scan cycle and then move to next rung and keep on going till the program gets terminated by the user. Due to this nature of the program, we have to be very cautious while providing the input signal to the system i.e. the input signal should be available at the input of the system before the start of the scan cycle otherwise, the program will generate a syntax error and the output value may get distorted i.e. full of error. In addition to these basic symbols of operation, this programming language also got all the features that other languages have i.e. there are Timers, Counters, Loop, etc. It means that while we are tackling bit complicated problem to be solved by this programming langaue then we have got all the tools to operate with. In this system design problem, the author has made the use of all the conditional logics based tools to develop an excellent model that in turn enhances the overall performance of the system. [22].

IV. HARDWARE MODULES OF THE SYSTEM

The basic and important components of the home automation system in terms of the hardware modules are as below i.e.

1) IR Sensors
2) Inductive Proximity Sensors
3) Photo-Electric Sensors
4) Relays
5) DC Motors
6) Conveyor Belt
7) PLC (programmable Logic Controller) i.e. Heart & Brain of the Automation System

1) IR SENSORS:

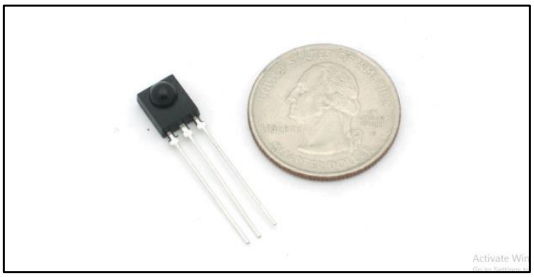


Fig. 6: IR Sensor [24]

IR detectors or IR sensors are little microchips with a photocell that are tuned to listen to infrared light. They are almost always used for remote control detection - every TV and DVD player has one of these in the front to listen for the IR signal from the clicker. Inside the remote control is a matching IR LED, which emits IR pulses to tell the TV to turn on, off or change channels. IR light is not visible to the human eye, which means it takes a little more work to test a setup.

2) INDUCTIVE PROXIMITY SENSOR:

A proximity sensor detects the approach of an object without making a contact. There are three types of proximity sensors:

- High-frequency oscillation type using electromagnetic induction.
- Magnetic type using magnetism.
- Electrostatic capacity type which senses the changes in the electrostatic capacity between the sensing object and the sensor. The detection coil located at the front end of the sensor produces a high-frequency magnetic field as shown in the figure below. When an object (metallic) approaches this magnetic field, induced currents flow in the metal, causing thermal loss and resulting in the reduction or stopping of oscillations. This change in state is detected by an oscillation state sensing circuit which then operates the output circuit.

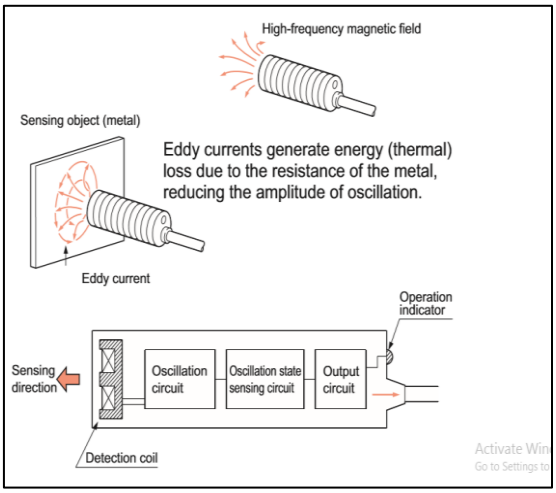


Fig. 7: Operation of proximity sensor [25]

3) PHOTO-ELECTRIC SENSORS:

Photoelectric Sensors detect objects, changes in surface conditions, and other items through a variety of optical properties. A Photoelectric Sensor consists primarily of an Emitter for emitting light and a Receiver for receiving light. When emitted light is interrupted or reflected by the sensing object, it changes the amount of light that arrives at the Receiver. The Receiver detects this change and converts it to an electrical output. The light source for the majority of Photoelectric Sensors is infrared or visible light (generally red, or green/blue for identifying colours).

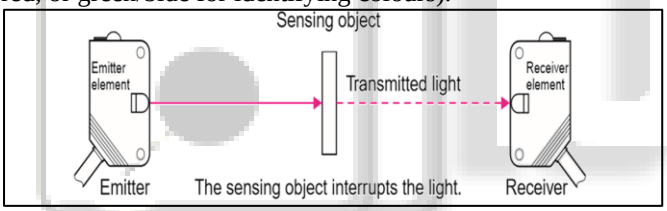


Fig. 8: Operation of Photo-electric sensor

4) RELAYS:

Relays are the primary protection as well as switching devices in most of the control processes or equipment regardless of whether they are electronic or electromechanical. All the relays respond to one or more electrical quantities like voltage or current such that they open or close the contacts or circuits. A relay is a switching device as it works to isolate or change the state of an electric circuit from one state to another. These are found in all sorts of devices. Relays allow one circuit to switch over to a second circuit that can be completely separated from the first. There is no electrical connection inside the relay between the two circuits – the link is magnetic and mechanical only.

Fig. 9: Relays

5) DC MOTORS

An electric motor is an electric machine which converts electrical energy into mechanical energy. The basic working principle of dc motor is "whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force." The direction of this force is given by Fleming's left-hand rule. DC motor in scrap segregation system is used for the rotation of conveyor belt on which the scrap will be made to move.

Fig. 10: DC motor

6) CONVEYOR BELT

Conveyor belt is one of the basic tools in many small and large-scale industries. It is basically an endless loop of some carrying medium which rotates on two or more pulleys or drums. To move the material in forward direction, one or both the pullies are powered. The pulley which is powered is known as the 'powered' pulley and the unpowered one is known as 'idler pulley [21-25].

V. METHODOLOGY OF THE SMART SYSTEM

The whole process of scrap segregation will begin with the pouring of industrial scrap over the conveyor belt which will usually contain metal and non-metal objects. All the various sensors like IR sensor, inductive proximity sensor,etc. will be interfaced with the input module of PLC. On the other hand the conveyor belt, dc motor will be the function of output part of the PLC. The first sensor which will be incorporated along the conveyor belt is IR sensor which will detect the presence of any object along the belt and will start the dc motor and hence, the rotation of the belt. The next sensor on the way of conveyor belt will be the inductive proximity sensor which will detect the presence of metal objects and the pneumatic used for the pushing action will push that sensed material into its respective bin. For the plastic and other materials, photo-electric sensor is used. Whenever any detecting sensor will have high input, it will halt the conveyor belt for 5 seconds so that the material is successfully pushed into its respective bin. This operation is achieved by the help of timers which will be provided with each sensor to halt the belt and stop the motor for a pre-set time, in this case 5 seconds.

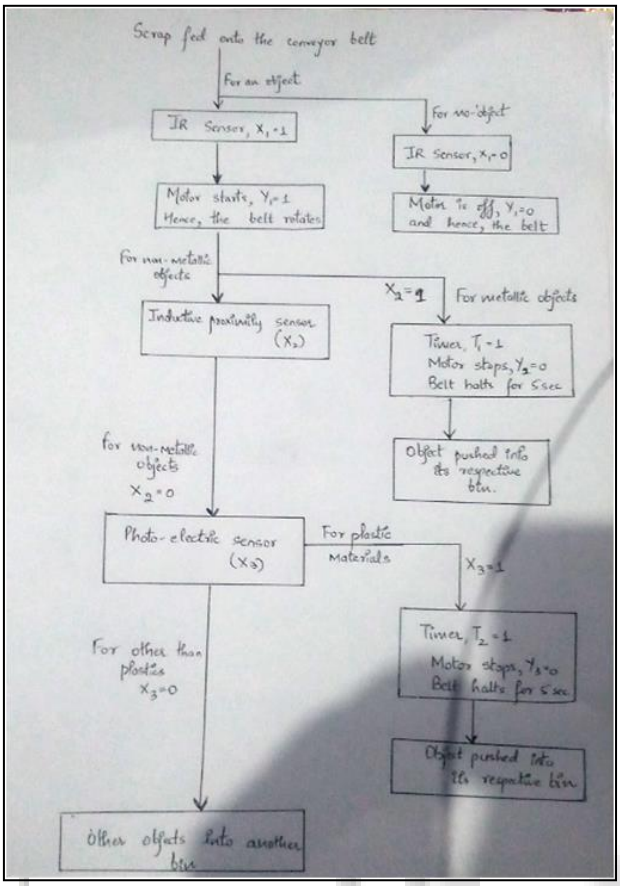


Fig. 11: Flow Diagram of the System

The above figure 12 depicts the logical program of the one of the module of the home automation system i.e. the monitoring and control of the level of water tank. In this module, there are two input signals which are fed to the logical controller i.e. PLC. These inputs are taken with the help of sensors installed in the overhead tank as well as underground tank of the house so as to check the availability of the water in underground tank as well as wastage of the water due to overflow in overhead tank. Based on these inputs, a logic is prepared and then as per this data the pumping of the water is done.

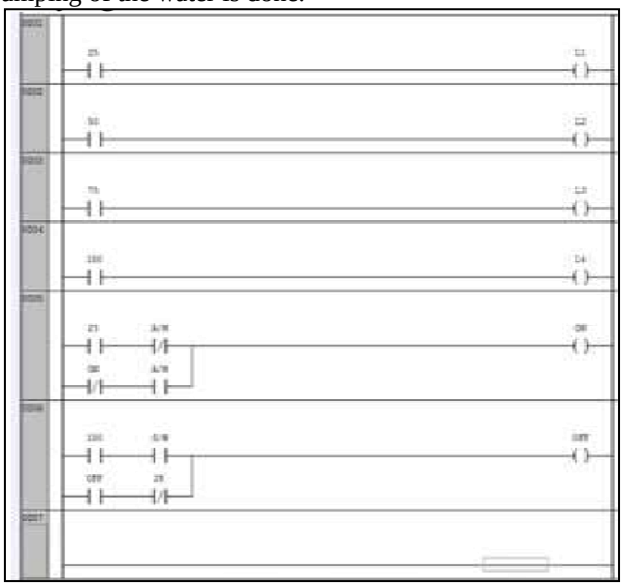


Fig. 12: Ladder Logical Program for System

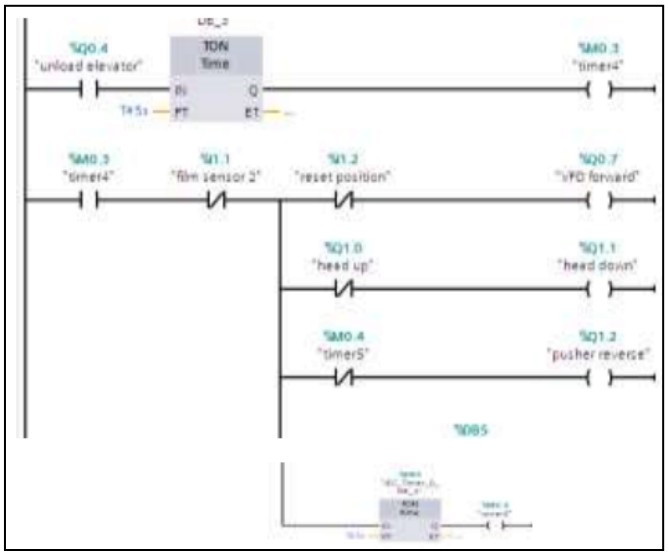


Fig. 13: Logical Program for Status of Devices

The above figure 8 shows the logical flow diagram of the status of various devices installed in the system i.e. part of monitoring of each modules of home automation system.

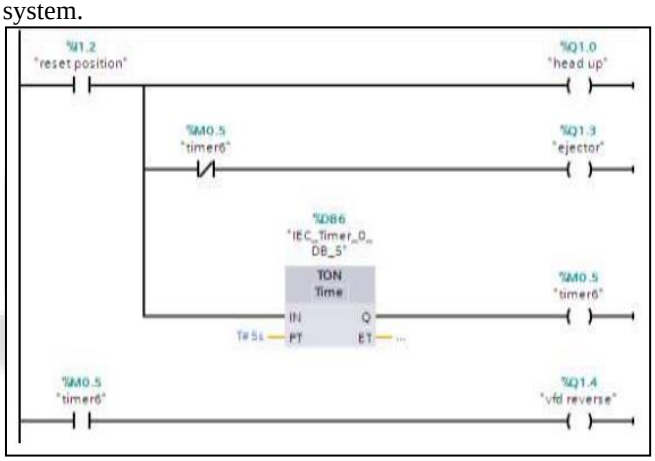


Fig. 14: Logical Program for Switching Motor ON/OFF

VI. CONCLUSIONS & DISCUSSIONS

In this paper, we proposed an automated system to segregate metallic and non-metallic wastes produced in small-scale industries which can also be implemented at municipal level. The main advantages of automating the scrap segregation system is the reduction in human intervention and the safety of the workers associated with waste mdisposal and management area. As the conventional method of waste disposal involed rag pickers who by their bare hands used to dispose off the waste. This can lead to cuts and bruises due to glassy items including severe infections and illness of their health. Also the RFID system and microcontroller based scrap segregation is not effective enough in harsh environments. Use of PLC will reduce the hard-wiring involved in the whole system as it is purely software oriented system. Any change in the system can be done without changing the whole architecture through software. There is a humangous need of such an advanced system to cure the rising waste production and management issues.

In this discussion, the author has put forward a logical concept of a system that is capable of monitoring and control of the various modules of a home i.e. a complete solution to the different activities carried out in a home. Out of these activities, the most important one has been chosen i.e. water level controller of the tanks available in home. It is so because the role of water is very important in a home and is also quite crucial in today's time. Thus, this discussion has provided a complete pack of automation of the pumping of the water in the overhead tank by keeping in mind all the consequences related with this process. The advantages of a design based on a PLC are simplicity, flexibility and reliability. The water level control system using PLC, sensors and servo motors is quite simple with better performance. This method of automatic water distribution and monitoring system can reduce the wastage of water due to overflow substantially proves to be much more effective with societal impact.

ACKNOWLEDGEMENTS

The author is thankful to Prof. (Dr.)Arun Gupta, Hon'able Chairman, MIER Group, Dr. Renu Gupta, Vice-Chairman, MIER Group, Prof (Dr.) Ankur Gupta, Director, MIET Jammu, Prof. S K Sharma, Director Academics, MIET Jammu, Mr. Jamini Sharma, HoD, ECE, friends, colleagues, and staff of MIET for their motivation, kind cooperation, and suggestions.

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