PLC based Sorting System using Metal Detection

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Abstract *In today's world of technology and due to speed running industries, the production rate has increased tremendously. Generally, industries manufacture similar models with little variation in material, height, color, weight or shape. This is where sorting plays an important role. Sorting can be done by using many ways like sorting of objects according to their dimensions, according to their colors, according to their weight, using machine vision (image processing), according to the material of an object etc. In such cases there can be no place for human errors in industries. Thus, it becomes necessary to develop a Low-Cost Automation (LCA) for sorting in an accurate manner. This thesis proposes the development of an LCA system to sort objects according to their metallic property, using DC geared motors which are controlled by a Programmable Logic Controller (PLC). This paper is based on Delta PLC which is a basic type of PLC having 8 inputs and 6 outputs. It has a 24V input slot which acts as a power source and a USB slot which is used to run the program. The work consists of two parts. The first consists of the software, which contains a ladder logic program used to program the PLC that controls the whole process of the project systematically according to input data sequence. Then we have the hardware part, which consists of conveyors, used to transport the objects; sensors used to sense the metallic property of the objects; pneumatic systems used to sort the objects and motors to drive the conveyor belt.*

Key Words: PLC, LCA, CPU.

1. INTRODUCTION

With the ever-growing industry, the efficiency of work is also expected to increase. In countries where the markets have moved onto automation in their industries, the efficiency of those industries has increased remarkably. Keeping this in mind, we are developing a
system that will reduce the burden of manual labor along with the errors that can be caused by it. This system

would help spend less energy and effort, so that there would be a definite increase in efficiency. There are many such systems that can help in metallic property, etc. We have selected the situation of sorting objects on the basis of their metallic characteristics. This system of sorting products is optimized to differentiate between products on the basis of their metallic property, which is done with the help of a metal detector. It uses sensors in order to sort them accordingly and into their respective boxes. Though it can be achieved using a microcontroller, using a PLC guarantees higher speed, performance and reliability. A continuous conveyor belt carries the products and a pair of pneumatically actuated pistons pushes them into the sorting bin. If it is a metal product the first piston pushes the product into the container, and the skipped product goes further towards the second piston, which detects the oncoming product using the proximity sensor and pushes it into another container. All these functions are precisely controlled by the PLC. We can further modify the project by replacing DC motors by stepper motors to increase accuracy. Sensors can be replaced by cameras for digital Processing which can be done using MATLAB. We can also segregate them on the basis of size, height, etc. Robotic arms can be used instead of pneumatic pistons to place the objects in the desired locations. Such a system can not only be used in industries, but also for segregation of wastes, mineral sorting, agricultural grading, etc.

Our main aim is to build a system that can effectively sort metals from nonmetals. Since such systems can form an integral part of industrial processes, our objective would be to further increase the speed of performance, reduce labor, increase accuracy as well as efficiency. In this project, we create a setup that will decrease human effort to an extent by using the LAC to avoid risk, improve accuracy, increase speed of production and reduce the cycle time. Limitations will be there due to the practical difficulties in programming the project according to the availability of the materials and components. This setup can be further improved to a sorting system that sorts the items based on the other physical consideration. This can be achieved using the various sensors. In industry it can be used for sorting of various objects, tools, with a high degree of accuracy and quality.

2. RELATED WORK

In order to achieve a deeper interpretation of this problem statement, we need to look at the various parts in which it is fragmented. Firstly, a logic has to be built that will help to carry out the whole project with the least human intervention possible. Therefore to achieve the key target, which is the separation of metals and non-metals; there should be sensors to detect the

materials needed to separate. The next aspect would be sorting of the items, which could very easily be accomplished with the use of pneumatic pistons. The auto industries complained that the cost of purchasing and changing a single relay is highly cost. The second factor involved time, expenses and labor required when a change of control needs to be done by modifying the control panel itself.

2.1 PROGRAMMABLE LOGIC CONTROLLER (PLC)

A programmable logic controller is a digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions for implementing specific functions, such as logic, sequencing, timing, counting and arithmetic, to control through digital or analog input and output, various types of machines or processes. PLC is also referred to as programmable controllers that are used in commercial and industrial applications. It consists of input modules, a Central Processing Unit (CPU), and output modules. The PLC accepts inputs from switches and sensors that measure or senses from the system. An input module accepts a variety of digital or analog signals from various field devices (sensors) and converts them into a logic signal that can be used by the CPU. The Central Processing Unit evaluates, makes decisions and executes these signals based on a program instructions or logic sequence. Output module converts control instructions from the CPU into a digital or analog signal that can be used to control various field devices such as a machine or process.

Basic hardware components of a PLC system consist of a central processor unit (CPU), input and output modules, power supply unit and programming device. The central processor unit (CPU) is a microprocessor system that contains the system memory and is the PLC decision making unit. The CPU monitors the inputs and makes decisions based on instructions held in the program memory.

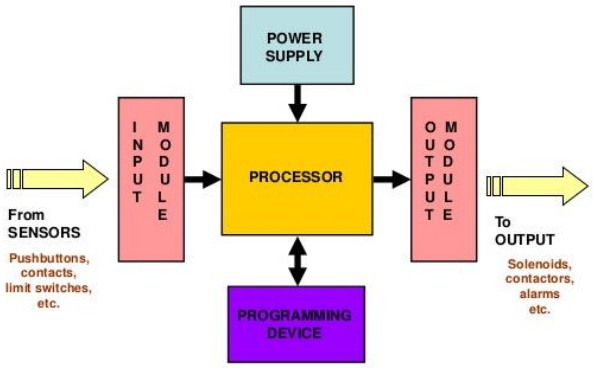


Figure 1 : PLC Block Diagram

2.2 DELTA DVP14SS PLC

After an exhaustive literature survey, the usage of a Delta PLC was decided; the model used is 'Delta DVP 14SS2'. Delta's DVP series programmable logic controllers offer high-speed, stable and highly reliable applications in all kinds of industrial automation machines. In addition to fast logic operation, bountiful instructions and multiple function cards, the cost-effective DVP-PLC also supports various communication protocols, connecting Delta's AC motor drive, servo, human machine interface and temperature controller through the industrial network into a complete Delta Solution for all users.

The 2nd generation DVP-SS2 series slim type PLC keeps the basic sequential control functions from the DVP-SS series PLC but with faster execution speed and enhanced real-time monitoring capability.

Figure 2: Delta PLC Module

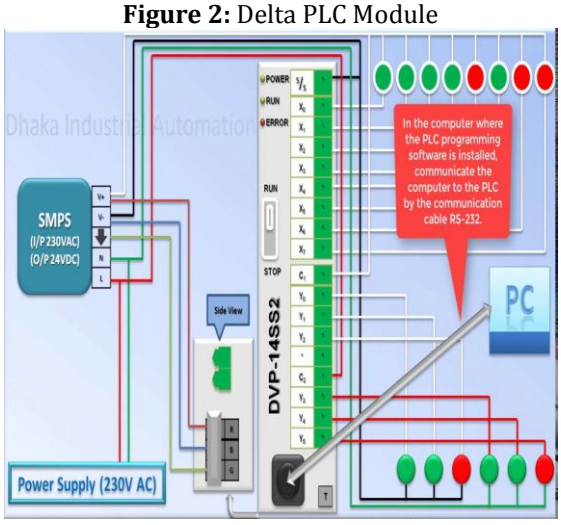


Figure 3: Delta PLC DVP-14SS2

Specifications:

1. MPU points: 14 (8DI + 6DO)
2. Max. I/O points: 494 (14 + 480)
3. Program capacity: 8k steps

4. COM port: Built-in RS-232 & RS-485 ports, compatible with Modbus ASCII/RTU protocol. Can be master or slave.
5. High-Speed Pulse Output : Supports 4 points (Y0 ~ Y3) of independent high-speed (max. 10kHz) pulse output
6. Supports PID Auto-tuning : DVP-SS2 saves parameters automatically after the PID auto temperature tuning is completed.

3. RESEARCH METHODOLOGY

It works on the method of utilizing electric energy to mechanical energy to carry the objects to the sorting station. The operation starts when the user presses the Push Button 1 button to launch the logic. When the predefined logic is satisfied, i.e. no objects must be initially placed on the conveyor belt, the belt starts moving. The Green Bulb lights up as soon as the button is pressed, signaling that the process has started. Power is down-converted and supplied to the 12V DC motor to power the conveyor belt. We have defined 4 inputs and 5 outputs in the PLC module. The user then starts placing the materials for sorting. The material, say X, goes through the metal detector coil first. If X is a metal, a specific frequency is detected, signaling that X is a metal. This data is then transmitted to the PCB board, which functions as a metal detector circuit.

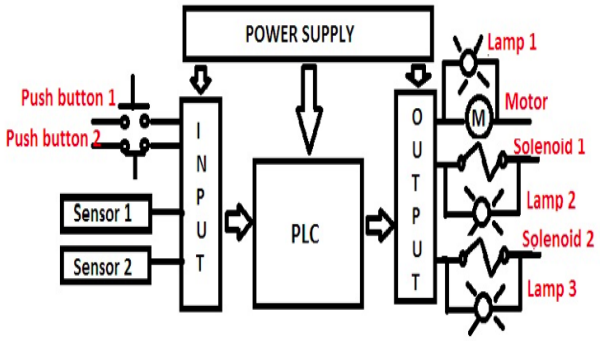


Figure 4: Overall Block Diagram

It consists of a conveyor belt, electric motor. In this system we use the electric supply as a source of energy. When the current supply is switched ON the current goes to the system through a step-down transformer, it converts the high-power current into low power up to 12 volts.

Table 1: Input/output Modules of PLC

Input Module	Output Module
Start Push Button	Conveyor Belt(12V Motor)
Stop Push Button	Solenoid Valve for Metal
Metal Detector Coil	Solenoid Valve for Non Metal
Photoelectric Sensor	Light Indicators

The current voltage goes to the DC motor through a capacitor filter to relay and the motor gets started, it converts electrical energy into rotational energy. This rotational energy is transferred to the roller. As the conveyor belt mounted on the roller is also rotated and the objects placed on the conveyor goes in forward. When the object comes in front of the sensor, the object is detected accordingly and the respective piston gets activated which is connected with the solenoid valve and the objects are collected in the respective bin. As the DC motor has a capacity of 30rpm this process goes on and the cards on the conveyor belt get sorted.

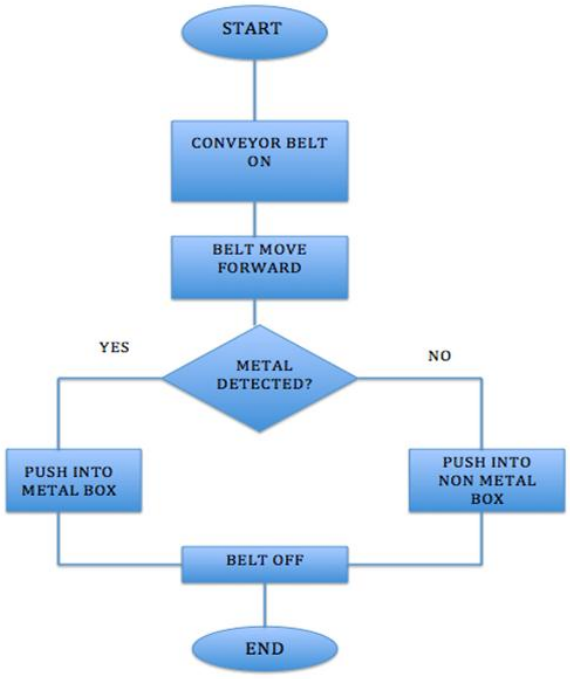


Figure 5: Flowchart

Description of the flowchart:

1. Switch ON the power Supply
2. Place the object on the moving conveyor belt

A) A Metal Detector is placed below the conveyor belt and once the belt moves forward, we determine following things
B) If the object detected by coil is metal, it is sorted by the help of a piston which is connected on the side of the belt

3. If the object turns to be non-metal then by the photoelectric sensor, which has been positioned perpendicular to the conveyor, the Non-Metal Object is sorted by another piston.
4. This will keep sorting objects N number of times, till the user wants.
5. Once the sorting is DONE, we turn-off the power supply.

4. SOFTWARE IMPLEMENTATION

ISPSoft is a highly accessible programming software application for Delta's programmable logic controllers (PLC). With its modular editing interface, ISPSoft integrates hardware configuration, network configuration, and motion control programming into the same editing platform. Our current implementation is based upon the software building for the project model. As mentioned initially, we are using ISPSoft 3.03 software for implementing the PLC ladder logic. The logic we have built is compiled error free in the software atmosphere. We have tried using the least number of networks for functioning of each part, at last we acquired a logic of total 18 Networks. Each network corresponds to the functioning of our model. The ladder logic is uploaded on the PLC using Cadyce Cable.

Inputs of the Ladder Logic:

1) X0 - cycle_start_pb
2) X1 - proxy1
3) X2 - proxy2
4) X4 - cycle_stop_pb

Output of the Ladder Logic:

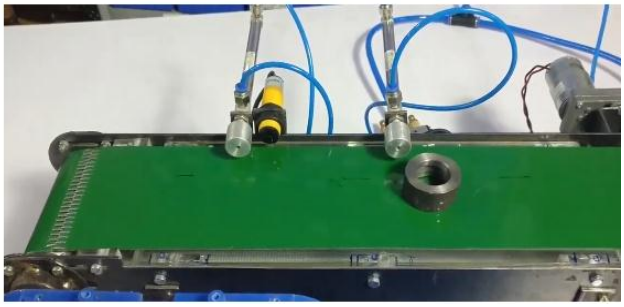
1) Y0 - conveyor _start
2) Y1 - cycle_on_lamp
3) Y2 - pusher_1
4) Y3 - pusher_2
5) Y4 - cycle_stop_lamp

5. RESULTS AND ANALYSIS

Analysis includes the performance of the device with various inputs and by using different topologies applying to the device. The Delta DVP PLC requires a Cadyce Cable in order to upload the respective ladder logic. In our performance testing, we placed several objects; the system was successfully classifying the objects based on the ladder logic.

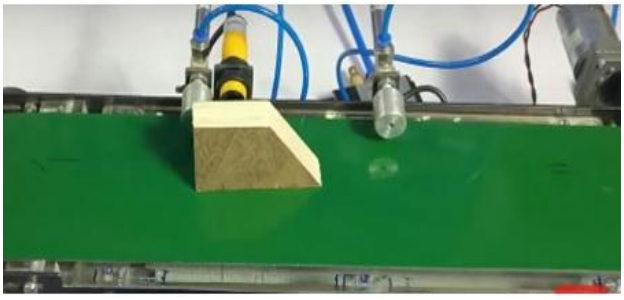
For Metal Sorting:

The object placed on the conveyor belt is sensed by a metal detector located under the belt and thus detected as a metal. As soon as the metal is sensed after a delay of 8ms, it is pushed forward by the piston into the corresponding box. The same operation is carried out in the above ladder logic.



For Non-Metal Sorting:

If the object is not detected as a metal by the frontier metal detector, it is considered to be a non-metal system. Hence, the object moves forward on the conveyor belt; the object is sensed by the proximity sensor, which has been fixed in a perpendicular manner towards the conveyor. After a delay of 15ms to cover the distance till the piston, the non-metal is pushed into the respective box and therefore segregated.



6. CONCLUSION

In this project report, we have tried to create a setup that will decrease human effort and succeed to an extent by using the LAC system to avoid risk, improve accuracy, increase speed of production and reduce the cycle time. The project can be used to meet demands of high-speed production using the least mechanism requirements. The system also provides high accuracy and precision of

incoming metals or any other non-metallic products. Though it is true that the use of PLC is a costly affair particularly for small industries it offers many advantages like it can be easily programmable and it is easy to handle. Limitations will be there due to the practical difficulties in programming the project according to the availability of the materials and components. In the industrial field, it can be used for sorting of various objects, tools, with a high degree of accuracy and quality with automation. Also, this system can come in handy nowadays to segregate the metal and nonmetal waste for the industrial and domestic use.

PLC based automated sorting machines are able to consistently perform the same repetitive motion to the same standard, lowering the prospect of injuries and, even worse, accidents. Injuries can lead to time off for the affected party and rising costs for the manufacturer. The advantage for workers is the opportunity to learn other skills in the company away from uninspiring jobs that require them to repeat the same motion time and again. PLCs are completely solid-state devices and hence are extremely compact in comparison to hard-wired controllers where electro-mechanical devices are used. There is no requirement of rewiring if any change is required to be implemented. It can carry out complex functions like arithmetic operations, counting, comparing, generation of time delay etc. It has a very high processing speed and greater flexibility in both analog and digital processes. "On Line"/ 'Off Line' programming is also possible in it.

Automated system is more expensive up front than manual equipment. However, what you save in man power and what you gain in increased productivity, means the equipment will eventually pay for itself and then some. The efficiency of the system is affected by variations in the conveyor speed. This is because, with increasing speed the precision of the components reduces and uses lesser speed will give the components the required time to execute the operations accurately. By increasing the amount of automation, there are less employees required causing high unemployment rates.

The application based on the system can be used if the height of the solid material is taken as a criteria in the quality check of that object then this system can be used effectively. The filled water bottles in industry during dispatch can be sorted according to their volume capacity. It's used to increase productivity, better quality and quantity of liquid in a given time. The main purpose of this whole system is to control the plant with less human interference and also cost is minimized so that it can be used in small scale industries. The food packing of the food stuffs of different sizes can be sorted in such types of industries where various quantities of packed food are running on a single line. The system separates out the wet and dry waste along with few dry components detection and separation. This system can be implemented at the municipal level or in some small-scale industries to segregate out the metallic, plastic, glass and paper wastes more efficiently at an affordable cost

7. FUTURE SCOPE

It is very useful in wide varieties of industries along with the help of PLC, especially in the sorting process. It ensures remarkable processing capacity as well as peerless performance including color detection. Of course, we need to add high speed DC Motors and sensors with appreciable response to speed up the system for industrial application.

The model can be improved by making some changes in the program and components. Some suggestions are given below:

1. We can add a load cell for measurement and control of weight of the product.
2. We can also add a counter for counting the number of products.
3. Speed of the system can be increased accounting to the speed of production.
4. The system can be used as a quality controller by adding more sensors.
5. The sensor can be changed according to the type of product.
6. The DC motor can be replaced with a stepper motor.

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