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REVIEW AND ANALYSIS OF AUTOMATIC WATER BOTTLE FILLING AND CAPPING MACHINE USING PLC

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ABSTRACT— Filling is an important process of the automatic machine and is used in different industry such as mineral water, beverage, chemical, food and dairy as well as pharmaceuticals. In today's manufacturing environment, with the need for higher production rates, better product quality and less manual effort, industrial automation is becoming a key requirement. The primary goal of this project is to design, develop and control an automatic bottle filling and capping system using Programmable Logic Controller (PLC). The aim of this system was to determine the accuracy and efficiency of the automation of detection, filling and capping of bottles with more precision. Prototype model has been fabricated to verify the working principle of system in a controlled environment. The PLC is the master controller and controls all the operations as programmed in the ladder logic. The conveyor belt is powered by a DC motor, which ensures a smooth and efficient movement of the bottles between the different loading stations. The proximity sensors are able to locate the position and presence of the bottles in order to fill and cap them exactly, thus minimizing waste. The PLC's are programmed using one of the most common and easy to use industrial automation programming languages, that is, the ladder logic. The developed system has the following advantages: low power consumption, low operating cost, low maintenance, high reliability, repeatability and high production efficiency. The prototype is also an excellent learning and training instrument to better understand the concepts of PLC based automation system and its application in bottle filling and bottle capping process.

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INTRODUCTION

In today's computer age, automation is very important. It helps in sensing, monitoring changes, and storing data very quickly and accurately. Machines can repeat the same task many times with the same accuracy and sensitivity without mistakes.Industrial automation helps industries to increase production, improve accuracy, and maintain better quality. It also makes good use of resources and manpower. With better control, production becomes faster and more efficient, giving more output with the same effort.Automation changes manual work into semi-automatic or fully automatic work using machines, computers, and electronic systems. This improves the efficiency of machines.In this project, an automated machine is used for bottle filling and capping. It also works as a training model to understand the process. The system uses a DC motor and a pneumatic system, which are controlled by a PLC (Programmable Logic Controller).PLC is a very important part of automation. It controls the whole system and makes the process simple, flexible, and accurate. The bottle filling system using PLC allows filling up to the required level without wasting liquid [1].

Ladder logic is used to program the PLC. It is easy to understand and simpler than other programming methods. The main aim of this project is to create a system using industrial automation. In this system, the PLC works like the brain because it controls all operations and takes decisions automatically.To make the project work properly, we need two main parts: hardware and software. The hardware includes devices like sensors, motors, and valves, while the software is used to program the PLC. Both are important to run the system smoothly and correctly [2].

In the rapidly advancing arena of industrial automation, manufacturers are turning to more ways to enhance production speed, minimize costs, and ensure a consistent product. The manual processes for filling and capping bottles can be error-prone, leading to inconsistencies in bottle fill, and more time and labour are needed for the work, effecting production efficiency. To solve these problems, many industries are using automated systems which are controlled by Programmable Logic Controllers (PLCs). Process control is accurate, operation is reliable, and production sequences can be easily modified based upon industrial requests with PLC based systems. This helps not only in increasing productivity but also decreases and keeps a check on the material loss and also keeps uniformity in the final product [3].

I. LITERATURE REVIEW

Researchers have mainly addressed automatic bottle filling and capping systems with PLC technology to boost the production profits, accuracy and to minimize human interference. An automatic bottle filling and capping machine using PLC and user defined bottle filling volume was developed to automatically perform filling and capping operation using PLC which has a flexibility to select the required volume of the liquid to fill in to the encountered bottle. The system proved to be very useful to utilize the concept of PLC control to obtain uniform and repeatable filling operation [4].

Uses of its automatic bottle filling and capping system have been done using a DC motor propelled conveyor along with the use of proximity sensor were developed. The entire sequence was controlled via ladder logic on the PLC, from detecting the bottles, conveyor motion, filling/capping. The system has proven to be highly stable and consistent in operation with lesser manual efforts, with very little operation requirements for the system [5].

A water bottle filling conveyor system was developed using PLC technology, which include sensors, DC motors, solenoid valves and actuators. There is a good coordination between the bottle detection system, conveyor movements and water filling operations showed. The connectivity of using PLC based control enabled the different operations to be executed in a sequential and controlled manner [6].

The automation based on PLC and HMI has also been used in the filling, capping and labelling of bottles into a single integrated process. Bottle detection sensors, conveyor mechanisms with actuators were added to the system to regulate and monitor the entire bottle production process. The findings showed that PLC- based automation would be good enough to control and monitor various stages of the bottling process [7].

After the literature reviewed, it seems that PLC-based automation can be used as a good solution for filling and capping process for producing bottles [8]. The main thrust of previous research has been related to the improvement of filling accuracy, reduced human intervention and synchronicity of the sensors, conveyors and actuators to operate continuously [9]. An easy to use and relatively inexpensive system, however, would be desired for small scale implementation and educational use. The prototype designed in this work is an easily made and low-cost prototype that involves the integration of bottle detection, conveyor control, filling and capping using PLC and ladder logic. The developed model can be utilized in the small-scale industrial automation and also is a practical model to be utilized to comprehend an automated system in PLC [10].

II. OBJECTIVE

The main aim of this project is to create an interface between human workers and industrial systems. Once implemented, this system helps save a significant amount of time, allowing workers to focus on other important tasks. The entire process is controlled by a PLC, which acts as the brain of the system. Since PLCs are easy to program, they are highly suitable for such applications.

The project consists of two main operations: bottle filling and bottle capping. These processes are widely used in manufacturing and processing industries to make production faster, simpler, and more efficient. In today's industrial world, machines perform more work than humans because they can be programmed to carry out specific tasks accurately and repeatedly without errors.

The bottle filling process is one programmable part of this project. In this stage, bottles are filled while moving on a conveyor belt driven by a DC geared motor.The second programmable part is bottle capping. After the bottles are filled, the PLC controls the system to place caps on them automatically. PLC is used in this project because it is easy to maintain and implement. It has strong decision-making capabilities, which help in controlling important tasks and adjusting the process as needed. Another advantage of using PLC is that it reduces complex wiring, making the system simpler and more reliable. It can also be easily connected to plant computer systems.

Keeping a close check on the duration of the filling process and movement of the conveyors is another crucial goal of this project to reduce any loss of the liquid and ensure a consistent filling process. The project will also emphasize the reduction of Human intervention, system Maintenance and will endeaviously deliver an economical Automatization solution that will be easily understood and applied to teaching and training in Industry. The developed prototype is also a practical demonstration of the PLC automation technology.

III. DESCRIPTION OF SYSTEM

The bottle filling and capping system includes both hardware and software development. The hardware part consists of the mechanical setup, DC motor, electrical system, pneumatic system, PLC, and sensors. In this system, the PLC works as the main controller that manages all operations.

The software part involves programming the PLC using Delta software. Delta PLCs provide a wide range of controllers and modules that offer high performance, multiple functions, and easy program editing. The overall working of the system is explained with the help of a block diagram shown in Fig. 1, 2.

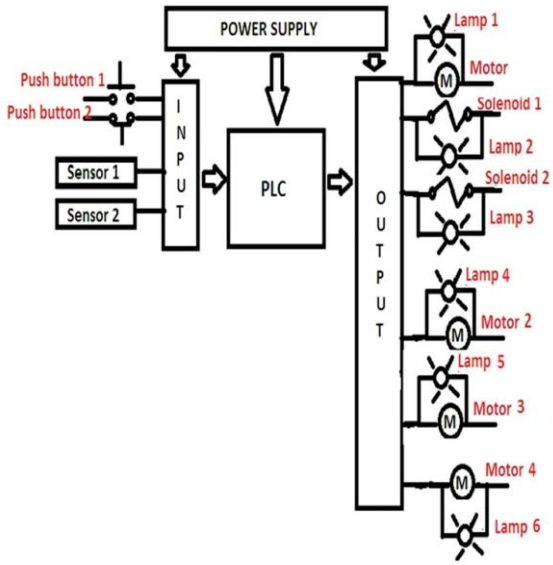
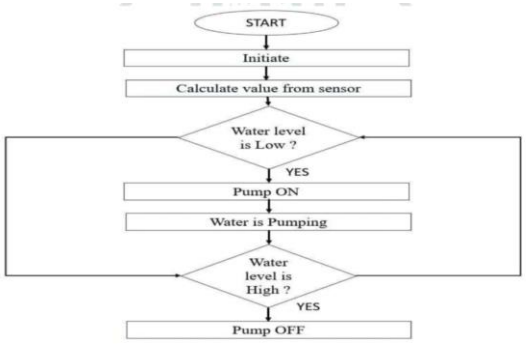


FIG.2. Flow Diagram of Automatic Water Bottle Filling and Capping Machine Using PLC

FIG.1. Block Diagram of Automatic Water



IV. HARDWARE DESCRIPTION(COMPONENTS)

1. PLC (Programmable logic control)

FIG.3.Programmable logic control

A Programmable Logic Controller (PLC) is a rugged, industrial-grade digital computer used to control machines and processes automatically in industries. It replaces traditional relay-based control systems with a flexible, programmable solution that improves efficiency, accuracy, and reliability [Fig. 3].
PLCs in industrial automation offer a fast processing speed, a reliability of performance, and flexibility in changing-out the control programme without rewiring the hardware. They are readily able to connect to different input/output devices (sensors, motors, relays, pneumatic actuators etc). PLCs is used in both small and large industrial automation systems owing to its extensive use of ladder logic programming, which makes troubleshooting or maintenance much easier. Their robust build can also guarantee high durability with severe industrial applications.

2.DC MOTOR

A Direct Current (DC) motor is an electromechanical device that converts electrical energy into mechanical energy through the interaction of magnetic fields and current-carrying conductors. It operates on the fundamental principle of the Lorentz force, which states that a current-carrying conductor placed in a magnetic field experiences a force perpendicular to both the field and the direction of current.

The choice of a DC motor has been made because it is easy to speed control, operates smoothly and is easily made. It sets up the continuous movement of the conveyor belt, so that the bottles can be transported accurately between filling stations and filling and cap stations. The motor has a relatively low operating power and low maintenance as per automation applications [Fig. 4].

FIG.4.DC MOTOR

3.CONVEYOR BELT

A conveyor belt is a mechanical system used to transport materials, products, or goods from one location to another within a defined area. It is widely used in industries such as manufacturing, packaging, mining, and food processing to improve efficiency and reduce manual labor.The basic structure of a conveyor belt consists of a continuous moving belt made of rubber, fabric, or metal, which is mounted on rollers or pulleys. The belt is driven by an electric motor, allowing it to move continuously and carry materials [Fig. 5].

FIG.5.CONVEYOR BELT

V. IMPLEMENTATION OF AUTOMATIC WATER BOTTLE FILLING AND CAPPING MACHINE USING PLC

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S.no	Address	Name	Input/output
1	I:0/0	Start	Input
2	I:0/1	Stop	Input
3	I:0/2	Proximity Sensor	Input
4	O:0/0	Conveyer Motor	Output
5	O:0/1	Solenoid Valve	Output
6	B3:0	Memory bits	Memory

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Fig. 6 Ladder Diagram Process

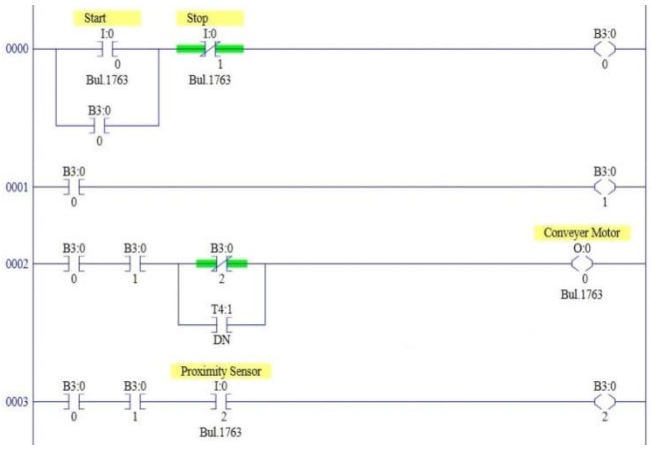

Fig. 7. Ladder Diagram for Start/Stop, Conveyor Motor And Proximity Sensor Control

Fig. 8. Automatic Water Bottle Filling System

RUNG 000

Start and stop system

RUNG 0001

Turn on Conveyor motor

RUNG 0002

To turn on Conveyor motor using memory bit of start latching PB and B3:0/1, it will automatically turn off when B3:0/2 turns on once Proximity sensor activates

RUNG 0003

Proximity sensor output saved in memory bit [Fig. 6,7,8]

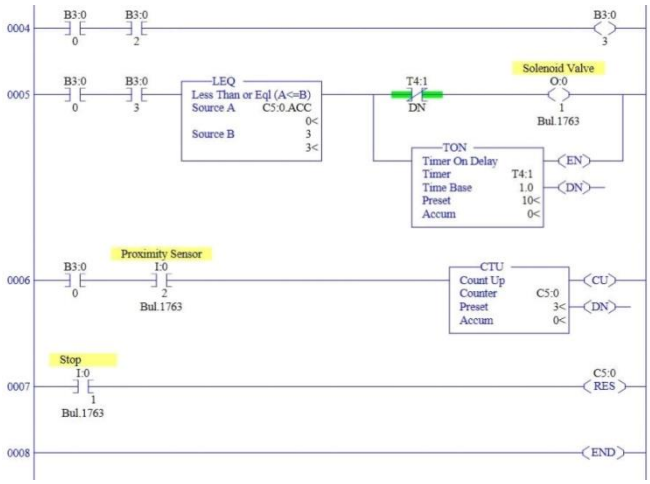

Fig. 9. Ladder Diagram for Solenoid Valve, Bottle Counting and Stop Control

RUNG 0004 &0005

B3:0/3 is a memory bit used to store ON/OFF status of the proximity sensor.
A Comparator block checks the counter value.
When the counter reaches 1bottles, the comparator stops the process.

RUNG 0006

To Count the number of Bottles by sensor [Fig. 9]

RUNG 0007

Stop Input.

B. Bottle Filling Operation

The filling process is controlled using a timer. The pump stays ON for a fixed time and turns OFF automatically when the set time is completed. After filling, the conveyor starts moving again.The bottles are then moved to the capping section. Inductive sensors are used to detect and stop the bottles at the correct position for capping. When the bottles reach the position, the conveyor motor stops.Capping is done using actuators. Three actuators move forward and backward to place caps on the bottles. These actuators apply force on the caps so they fit properly onto the bottles.If a bottle is not present, it will not be capped, just like in the filling process. After capping is completed, the conveyor starts moving again.While one batch of bottles is being capped, another batch is being filled at the same time. This process continues until no more bottles are available at the input side.All operations are controlled automatically by the PLC. It receives signals from input devices and sends commands to output devices based on the programmed conditions. In this way, bottles are filled and capped efficiently.

VI. CONCLUSION

In this paper the design and implementation of an automatic water-bottle filling and capping system with a Programmable Logic Controller (PLC) is presented. The developed system consists of a flat belt conveyor, DC motor, proximity sensor and PLC to automate the bottle filling and capping process in an efficient manner. This conveyor system ensures that bottles move smoothly through the various processes, minimizing the need for manual handling and streamlining the overall workflow. When the filling station opens, as the main control system, the PLC controls the entire operation by running the ladder logic for bottle detection, filler movements, bottle conveyor, and bottle capping in the desired sequence. With the use of proximity sensors, the exact position of the bottle to be filled is obtained and with a time-based control mechanism, the correct filling level is obtained with minimal waste of liquid. The prototype designed in this project is a reliable and efficient design with high accuracy, power efficiency, cost-effectiveness and low maintenance. The small industries, beverage manufacturing units, dairy industries, coffee shops, juice centers and cold drink shops where filling and capping operations should be automated can utilize the proposed system. It's also an excellent educational platform for the learning of PLC-based industrial automation and ladder logic programming. This research study has confirmed the benefits of

automation for increased efficiency, minimisation of human intervention, improved process reliability and product quality in filling and capping operations.

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