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Bottle Filling System by using PLC control and SCADA

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Abstract:

This work describes the use of PLC control and SCADA technology to automate a bottle filling system. The objective of the developed system is to facilitate the process of filling a bottle with liquid substances in manufacturing plants using a controlled process rather than manual operation, which enhances performance, precision and consistency. The PLC is the primary system component, and the sensors and actuators work in conjunction with it to ensure compliance with certain levels and standards for the filling process. The SCADA also provides a means of remotely monitoring and controlling the system, supporting alarms and records, and data acquisition and display. The integration of PLC and SCADA offers a comprehensive solution for bottle filling applications, enhancing productivity and quality while reducing human intervention. Experimental results demonstrate the effectiveness and robustness of the proposed system in industrial environments.

Keywords: Bottle filling system, PLC, SCADA

I. Introduction:

Automation is a critical factor of production in today's modern industrial environment. It helps to enhance efficiency in all the works and guarantees that the output products are very consistent in quality. One of the vital aspects of manufacturing is bottle filling whereby liquids are dispensed in a controlled manner to meet the high demand. This paper presents an automatic bottle filling system that utilizes the advantages of the Programmable Logic Controller and Supervisory Control and Data Acquisition technology. Through automation, the process is made efficient, free from human error, and ensures high productivity. The amalgamation of PLC and SCADA provides a solution to the problem enhancing real-time control, monitoring, and data acquisition which is essential for the operators.

In summary, this paper conducted a comprehensive investigation into the system architecture, design aspects, implementation process, and experimental outcome. By integrating programmable logic controller control and supervisory control and data acquisition technology, the bottle filling system delivers sophisticated capability for the workers to monitor and control the filling process at a distance without compromising its efficiency and accuracy. Therefore, manufacturers can increase the level of efficiency and dependability in their bottle filling activities, thereby enhancing the overall productivity and product quality.

THE KEY PROCESS OF OUR SYSTEM INCLUDES:

- Initialization: The system initializes by powering on the PLC and SCADA components. The PLC program and communication settings are loaded.
- Sensor Monitoring: The sensors continuously monitor various parameters such as liquid level, flow rate, temperature, pressure, or weight. This data is fed to the PLC for processing.
- Filling Sequence: The PLC receives input from sensors indicating the need for a bottle to be filled. It activates the necessary valves and pump/motor to initiate the filling sequence.

- Liquid Measurement and Control: The PLC plays very crucial role for the liquid flow based on the desired filling quantity. It monitors the liquid level in the bottle using sensors and adjusts the valve opening accordingly to achieve accurate filling.
- Safety Checks: The system may include safety checks to ensure proper functionality. For example, it may detect if a bottle is not properly positioned or if there is an abnormal pressure buildup.
- Error Handling: The PLC program incorporates error
- handling routines to address any faults or anomalies that may occur during the filling process. This could include detecting leaks, low liquid supply, or any other unexpected situations.
- HMI/SCADA Interaction: Operators can interact with the system through the HMI/SCADA interface. They can monitor the real-time status of the system, view sensor data, and make adjustments or override commands if needed.

By integrating PLC and SCADA/HMI with Bottle Filling System, this project provides a robustness. The bottle filling process involves an elaborate system design that leverages various components and stages to achieve accurate and efficient liquid filling. The system design starts with the initialization stage, where the system powers on and initializes the necessary components such as the PLC, HMI/SCADA, and other system configurations.

Once initialized, the system continuously monitors various sensors such as liquid level sensors, flow rate sensors, temperature sensors, pressure sensors, or weight sensors to gather relevant data. When a bottle requires filling, the system triggers the filling process, activating the necessary valves and pump/motor to initiate the flow of liquid into the bottle. During this filling process, the system measures and controls the flow rate to achieve the desired filling quantity. Safety checks are incorporated to ensure proper operation and detect any abnormalities or potential hazards, and error handling routines are implemented to address faults or anomalies that may occur during the filling process. Operators can monitor and control the system using the HMI/SCADA interface, where they can view real-time data, adjust settings, and respond to any alerts or notifications.

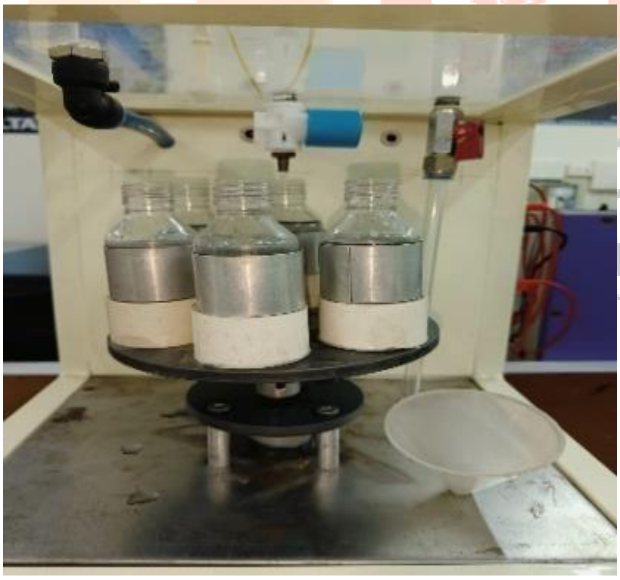

Fig. 1 Internal framework of Bottle Filling system

The system logs important data such as filling quantities, error logs, timestamps, and operational statistics to generate reports and perform quality control. Finally, the system design includes regular maintenance tasks such as cleaning, calibration, and equipment inspection to ensure proper functioning of the system.

Fig. 2 .SYSTEM HARDWARE DESIGN AND IMPLEMENTATION

CONNECTION OF PLC (ALLEN BRADELY) WITH BOTTLE FILLING SYSTEM

When connecting a bottle filling system with an Allen Bradley PLC, the hardware connections involve connecting the power supply to the PLC, connecting input devices such as sensors to the input terminals, connecting output devices such as pumps and valves to the output terminals, establishing communication interfaces with external devices or systems, connecting HMI/ SCADA devices, wiring safety devices to safety input terminals, establishing network connections if required, and ensuring proper grounding for electrical safety. It's essential to refer to the manufacturer's documentation and guidelines for specific wiring and configuration details based on the model and specifications of the Allen Bradley PLC and the requirement of your bottle filling system.

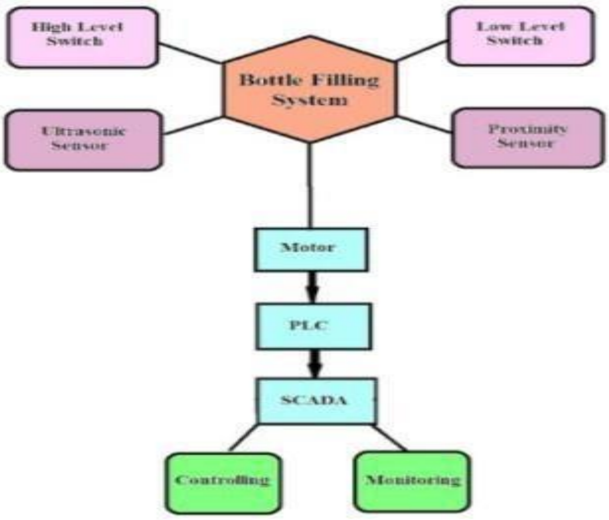

Fig. 2 Hardware Framework flowchart

The flowchart depicts the sequential steps involved in the bottle filling system with PLC control and SCADA integration. The process initiates with the detection of bottles at the filling station, branching into two paths based on whether a bottle is detected or not. Upon bottle detection, the liquid filling process commences, controlled by the PLC to regulate the flow of liquid and monitored by sensors to ensure precise filling. Ultimately, the flowchart illustrates the coordinated interaction between PLC and SCADA components to facilitate efficient and reliable bottle filling operations.

II.SYSTEM SOFTWARE DESIGN:

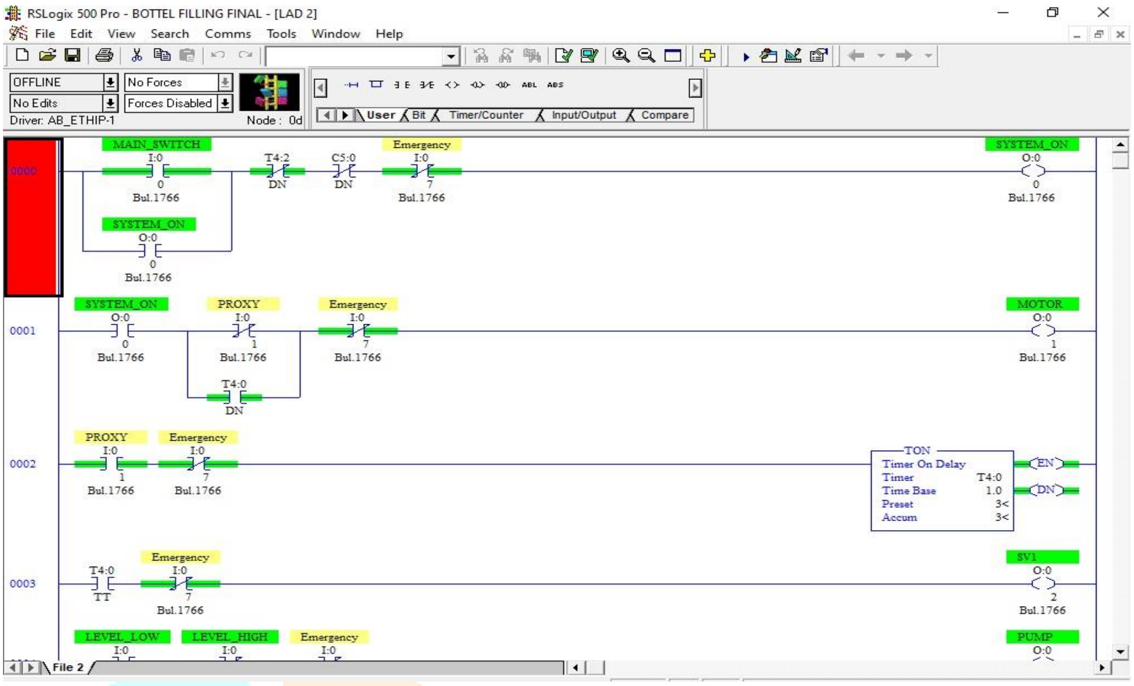

Fig.3 Program Logic for the bottle filling station – part A

A. Programming of Bottle Filling System :

We develop such a ladder logic programmed which is crucial for a bottle filling system using PLC control because it allows for the efficient and precise control of various components of the system, such as sensors, valves, and actuators. Ladder logic is a graphical language that uses ladder diagrams to represent the ladder rungs, which contain conditions and actions that control the system's inputs and outputs. The simplicity and visual nature of ladder logic make it easier to understand and maintain the logic of the control system. By using ladder logic programming, the PLC can execute control logic at high speeds and with high precision, ensuring that the production line produces correctly filled bottles without overflow or underfill. Additionally, ladder logic makes it easier to troubleshoot, debug, and modify the system when needed, making it a valuable tool in industrial automation.

LOGIC OF OUR PROGRAMME –

- Start Button: The start button is used to make the process active. When it is pressed, the process is activated.
- Stop Button: When it is pressed, the process should be stopped
- Level Sensor: The level sensor detects the presence of bottles-on the conveyor.
- Motor: The motor is used to drive the moving conveyor, it determines the movement of the bottles.
- Filling Valve: This is used to control the flow of liquid into the bottles.

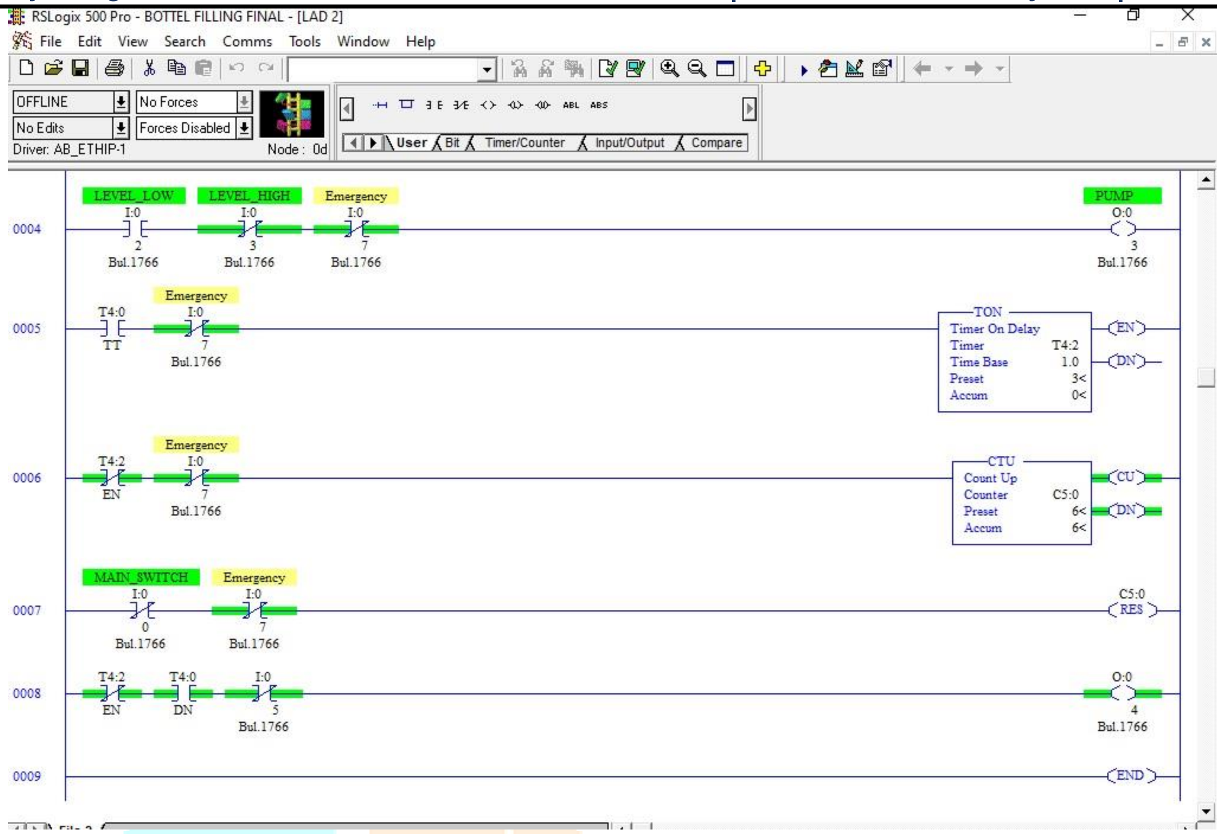

Fig 4. Program Logic for our System – part B

- PLC Control Logic: - On pressing the start button, and the level sensor detect an empty bottle, and then; Conveyor motor is activated and bottle moves to filling station. When the bottle reaches the filling station, the filling valve is opened, and liquid flows into it. The level sensor continues to monitoring bottle’s level. When it detects a full bottle, the filling valve is closed and the conveyor motor moves it to the sealing station. Another logic can be included here to close the bottle via a seal or a cap . As the sealed bottle slides off conveyor, this process is over and is ready for the next bottle.

B. SCADA for Bottle Filling System

SCADA Integration: - Factory Talk view this SCADA software is used to monitor and control the entire bottle filling system. - The SCADA interface can display real-time information about the status of the system, including the level of liquid in the tanks, the flow rate, and the number of filled bottles. It also provides a user-friendly graphical interface for operators to control the filling process, adjust parameters, and monitor alarms or faults.

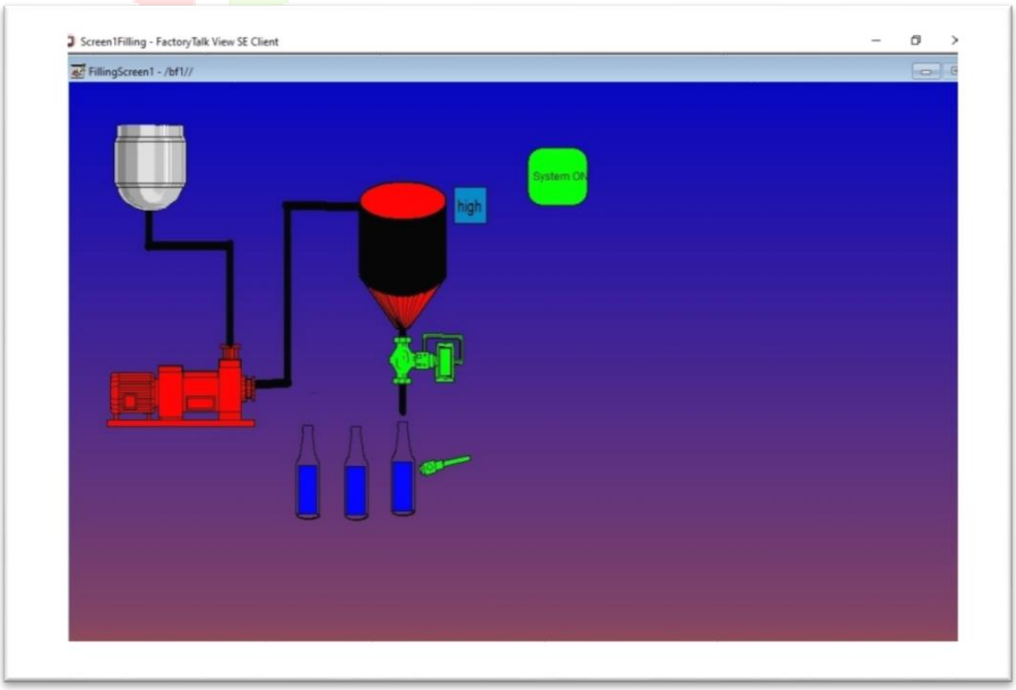

Fig. 5. Developed SCADA for Bottle filling station

Importance of SCADA in our System : –

SCADA (Supervisory Control and Data Acquisition) design plays a critical role in your bottle filling system as it enables real-time monitoring, data acquisition and storage, process control and automation, centralized system management, and enhanced safety and security. By providing real-time monitoring, operators can swiftly detect and respond to any anomalies, reducing downtime and minimizing waste. The data acquisition and storage capabilities enable in-depth analysis of historical trends, facilitating predictive maintenance and continuous process improvement. With comprehensive process control and automation, precise adjustments can be made to optimize filling parameters, ensuring consistent product quality and reducing product losses. The centralized system management ensures streamlined operations, ease of maintenance, and scalability for future expansion. Lastly, the incorporation of robust security measures safeguards against potential attacks or unauthorized access, protecting the integrity of the filling process and ensuring regulatory compliance. Altogether, the SCADA design empowers your bottle filling system with enhanced operational efficiency, reliability, and adaptability in a secure and controlled environment

LITERATURE SURVEY

1. **Manoj M. Nehete, A. P. Tadmalle, Dhiraj Patil (2017),** In this paper **,** The system's order of operation is planned by ladder diagram and integrated programming. PLCs enable various applications in the industry, integrating different handling levels. Components used include horizontal and float level switches, DC motor, solenoid valve, proximity switch, tank, and conveyor. The limitations of this paper was that the manual machines reduce efficiency in production , increasing demand requires capable automated production tools. But the advantages of this system was reducing human efforts, improving economy, and performing tasks beyond human capabilities.Applications range from process robotics to enhancing industrial processes. [1]

2. **Ashwani Kapoor, Vivek Jangir, Jaswant Kumar, Gaurav Tiwari (2014),** This Paper Indicates of being utilizing within the fabricating of a product, one of the foremost trending innovations on which companies are depending on is computerization of the total framework. This robotization is done by utilizing PLC and SCADA in which plc is the equipment and SCADA is computer program, both of these are the heart of robotized framework. PLC is utilized for controlling the yields by changing the inputs and SCADA is utilized for analyzing and observing of the framework.But the system fails to control the problem during faults and errors in the production line, that result to issues in filling liquid products efficiently rather then it has the advantage to computerized the framework, which is utilized since of the tall precision and accuracy . [2]

3. **T. Kalaiselvi, R.Pravenna,, Aakanksha.R, Dhanya.S (2012),** The paper indicates filling and capping the bottles at the same time. The filling and capping operation are synchronized . It also incorporates the user described volume choice menu through which the client can enter the volume to be filled capacity as it were merely required filling. The complete framework is more adaptable and time saving.The filling and capping Operations accomplished utilizing the Programmable Logic Controllers. [3]

4. **Md. Liton Ahmed, Shantonu Kundu, Md. Rafiquzzaman (2017) ,** In this paper, a bottle filling machine is introduced that uses Programmable Logic Controller configured controller in automation industry. The aim of the paper is to design and fabricate a small and a simple filling system using a PLC. A belt conveyor is used for transferring the bottle.A dc pump is installed to tank for controlling the flow of water. The position of bottle is identified by infrared sensor so that pump can be worked at right time. When bottle is beneath the tank, the pump is begun and bottle is filled by water. The limations of this system was as it was designed to utilize a retentive timer instead of an on/off delay timer to reduce the number of rejected bottles. [4]

5. **Abdulrahim Mahrez, Abdulrahim Hilmy, Abduelaziz Alasoad, Adel Elahdi M. Yahya, Khalid Yahya, A. Amer, Hani Attar (2022)**, The paper primarily focuses on the design of a PLC-based system intended for bottle filling and capping applications. However, it does not discuss the utilization of SCADA (Supervisory Control and Data Acquisition) within the system. The literature review section examines existing research in the field, highlighting the advantages associated with

closed-loop control systems employing sensors for enhanced operational efficiency. On the other hand, the authors also acknowledge certain limitations of the proposed system, such as potential control problems during faults or errors, as well as challenges in achieving efficient liquid product filling. The main contribution of the paper lies in the development of a closed-loop control design specifically tailored for bottle filling and capping, utilizing PLC technology as the foundation. This design incorporates the use of sensors to detect bottle position and water level, contributing to overall system efficiency. [5]

6. **D.Baladhandabany, S.Gowtham, T.Kowsikkumar, P.Gomathi (2015),** The purpose of this paper is to explain the methods of filling more than one bottle at a time. A stepper engine is used in a transport system design due to its efficiency . The united digital volume choice is provided to the user at the desired point. In system uses less number of sensors, hence it's cheaper. Filling is controlled by PLC using the ladder logic method. Inside the bottle filling system, the PLC receives the sensor feedback and adjusts the solenoid valve open timelines and controls the conveyor belt. By programming the PLC, the whole framework is being controlled. But the limitations of this system was that, the the maximum reading distance from sensor: 80-90 cm Filling time for 250 ml bottle : 7.81 seconds [6]

III. Experimental Result

1. Flow Rate Calculation:

Flow Rate (Q) = Area (A) × Velocity (V) Eq . (1).

Where A is the cross-sectional area through which the liquid flows and V is the velocity of the liquid.

2. Fill Time Calculation:

Fill Time (T) = Volume (V) / Flow Rate (Q) Eq . (2).

Where V is the desired volume to be filled.

3. Total Volume Calculation :

Total Volume = Flow Rate × Filling Time Eq . (3).

To examine how different flow rates impact the process of filling, six tests were carried out based of a bottle filling system. More specifically, the process was analyzed by the following flow rates: 5.1 ml/s, 4.2 ml/s, 3.1ml/s, 2.1 ml/s, 1.2 ml/s and 0.9 ml/s which directly relate to a variety of industrial filling rate conditions. Similarly, each flow rate was repeated several times on different bottles, whereby the time and the fill amount were recorded for each circumstance. As a result, the filling time depends on the flow rate. The larger the flow measure, such as 5.1 ml/s, the shorter the filling time, as the slower with 0.9 ml/s leads to relatively long filling process. The observed trend can be attributed to the larger volume of liquid being dispensed per unit time at higher flow rates, leading to faster filling.

BOTTLE NUMBER	FLOW RATE (A)(ml/s)	FILLING TIME(B) (s)	Total Volume Filled (A*B) (ml)
1	5.1	5	**25.5**
2	4.2	8	**33.6**
3	3.1	11	**34.1**
4	2.1	16	**33.6**
5	1.2	20	**24**
6	0.9	22	**19.8**

TABLE: Flow Rate Impact on Filling Time and Volume

The findings reveal the significance of optimization of flow rate in bottle filling systems. The choice of an optimal flow rate would enhance productivity, deleaded filling duration and maintain control within volume. Optimizing filling should be coupled with several enhancement pursuits such as the examination of other options like nozzle design and container geometry among others.

CONCLUSION

The research paper, that we have presented demonstrate several key benefits associated with the implementation of PLC control and SCADA in bottle filling systems. These include improved product quality, reduced downtime, increased production throughput, and enhanced operational efficiency. Furthermore, the high level of configurability and flexibility offered by PLCs and SCADA systems allows for customization and adaptation to diverse bottle filling requirements. The implementation of this system has proven to be incredibly useful when it comes to managing sudden production rate increments. The system itself is comprised of several components, including a filling tank and various fluid mixing elements, that operate seamlessly on a pre-configured program. One of the distinct features of this system is the integration of a buzzer for acknowledgment. This acknowledgement feature has proven to be vital in reducing costs and enhancing overall performance. By including an automated system with feedback mechanisms tailored to the particular production workflow, it helps eliminate traditional manual errors, ensuring optimal system efficiency. Additionally, the system's automatic workflow ensures smoother operations, allowing for effective handling of increased production demands

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