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DEVELOPMENT OF PROTOTYPE OF COMPONENT CLENING STATION USING PLC

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ABSTRACT

In the rapidly evolving industrial landscape, the imperative to optimize manufacturing processes for enhanced efficiency, product quality, and cost-effectiveness has never been more pronounced. This ambitious project endeavours to revolutionize component cleaning by introducing a sophisticated PLC-based Component Cleaning Station, incorporating innovative conveyor stations. At its core is a resilient rubber conveyor belt, intricately driven by a robust 12V DC motor, seamlessly controlled by either Delta GOC PLCs. The primary goal is to design, implement, and optimize a PLC-based Component Cleaning Station, incorporating advanced automation and control mechanisms. This includes the meticulous integration of sensors, actuators, and PLC programming to orchestrate a flawless cleaning process. The expected outcomes encompass remarkable improvements in cleaning efficiency, reduced labour costs, elevated product quality, and advanced PLC programming for precision control and real-time monitoring. Positioned as a precursor to the comprehensive exploration of the project, this summary underscores its significance in ushering in a new era of automated component cleaning to meet the evolving needs of the modern industrial sector. Through this initiative, the project aspires to contribute significantly to the paradigm shift towards advanced, automated manufacturing processes, aligning with and addressing the challenges.

Keywords: PLC-Based, Conveyor Stations, Rubber Conveyor Belt, 12V DC Motor, Delta GOC PLC, Automation, Control Mechanisms, Sensors, Actuators, Programming, Cleaning Efficiency, Labor Costs.

I. INTRODUCTION

In the ever-evolving landscape of industrial cleaning practices, Clean-in-Place (CIP) stands out as a revolutionary method that has transformed the way interior surfaces of pipes, vessels, equipment, filters, and fittings are cleaned, all without the need for major disassembly. This automated cleaning methodology utilizes turbulent flow, spray balls, and, in some instances, a fill, soak, and agitate approach to ensure thorough cleaning. The advantages bestowed upon industries adopting CIP are multifield, ranging from minimized cleaning errors and improved employee safety to increased productivity and enhanced product quality. Moreover, CIP contributes to reduced operating costs by lowering water and energy consumption during the cleaning process. The evolution of CIP has been marked by technological advancements, transitioning from simple, manually operated systems to fully automated setups incorporating programmable logic controllers, sensors, valves, heat exchangers, and specially designed spray nozzle systems. The design principles of CIP vary based on factors such as soil load and process geometry, encompassing highly turbulent flow, low-energy spray, and high-energy impinging spray approaches.

While elevated temperature and chemical detergents play a pivotal role in enhancing cleaning effectiveness, the imperative to recycle water has become increasingly pronounced. Addressing this, initiatives like Melbourne Water and City West Water's salinity reduction strategy underscore the importance of reducing Total Dissolved Solids (TDS) in treated water. In this pursuit, the food and beverage industries emerge as significant contributors to TDS loads in effluent streams due to the cleaning chemicals they employ. To tackle this environmental challenge, a two-fold project was conceived. The first objective focused on identifying alternative cleaning chemicals capable of replacing traditional ones in the food and beverage industry, with a specific emphasis on reducing TDS in effluent discharge. Simultaneously, the project aimed to explore technologies for collecting, treating, and reusing cleaning solutions in subsequent cycles, presenting promising avenue for substantial reductions in cleaning chemical usage. This dual-pronged approach aligns with the waste

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hierarchy, emphasizing source-based TDS reduction and substitution to minimize environmental impact and operational costs.

II. METHODOLOGY

Problem Statement

During the manufacturing process of electronic components, it is necessary to clean the components between different production stages in order to remove any contaminants, debris, or residue that may have accumulated. Currently, the cleaning process is done manually which is time-consuming and lacks consistency. The goal of this project is to automate the component cleaning station using a Programmable Logic Controller (PLC) in order to streamline and standardize the cleaning process. Problem Identification

- Assess the current manual cleaning process and identify pain points or inconsistencies that need addressing. This could include things like variability in cleaning results, ergonomic issues, bottlenecks, safety concerns etc.
- Determine the specific component types and contaminants that need to be cleaned. This will influence the selection of appropriate cleaning tools and methods.
- Evaluate factors like throughput needs, space/footprint constraints, budget for the project. These provide boundaries for the design.
- Research existing cleaning station/line designs for ideas and technologies that could apply to this project. Identify opportunities for automation.

Determine requirements for control system (PLC), interfacing cleaning tools, tracking components through stations.

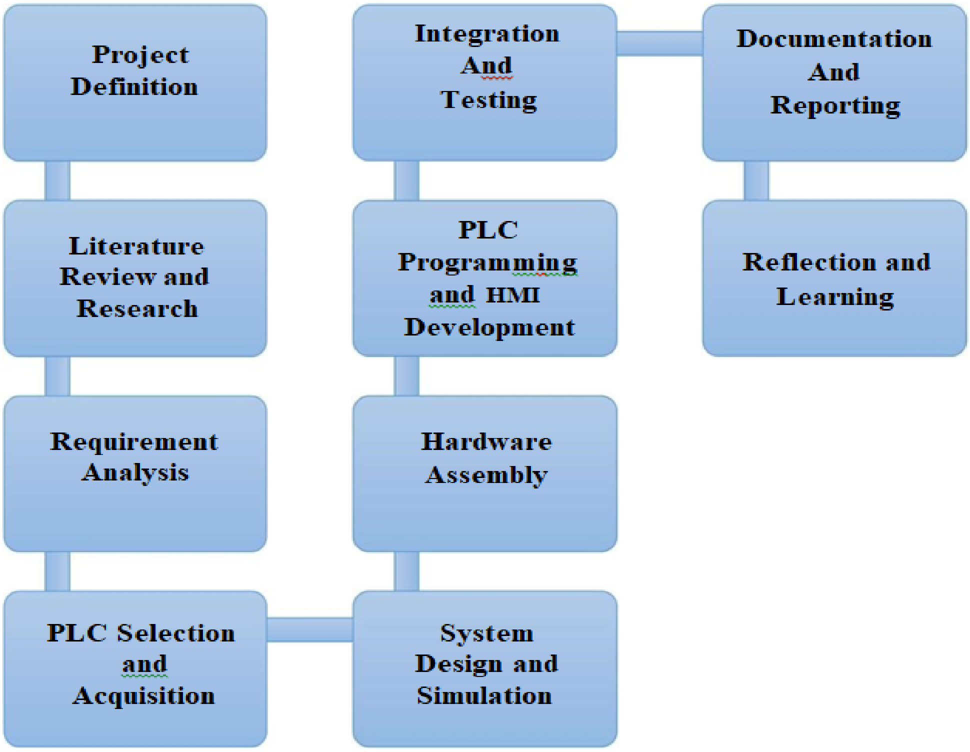

Figure 1: Methodology

III. DESIGNING OF THE COMPONENT CLENING STATION

Normal Signal Pass Station: This station likely acts as a default or standby mode where the signal passes through unaffected. It might serve as an idle state or a bypass when the other stations are not in use.Water Supply Station: This station likely controls the supply of water for whatever process or function it's needed for. It might involve pumps, valves, or other equipment to regulate the flow of water.Wrapping Station: This station is involved in wrapping something, perhaps packaging a product or material. It could involve machinery that wraps, seals, or packages items as part of a production line.Drying Station: This station would be responsible for drying whatever is being processed or manufactured. It might involve heat sources, fans, or other drying mechanisms to remove moisture from materials.

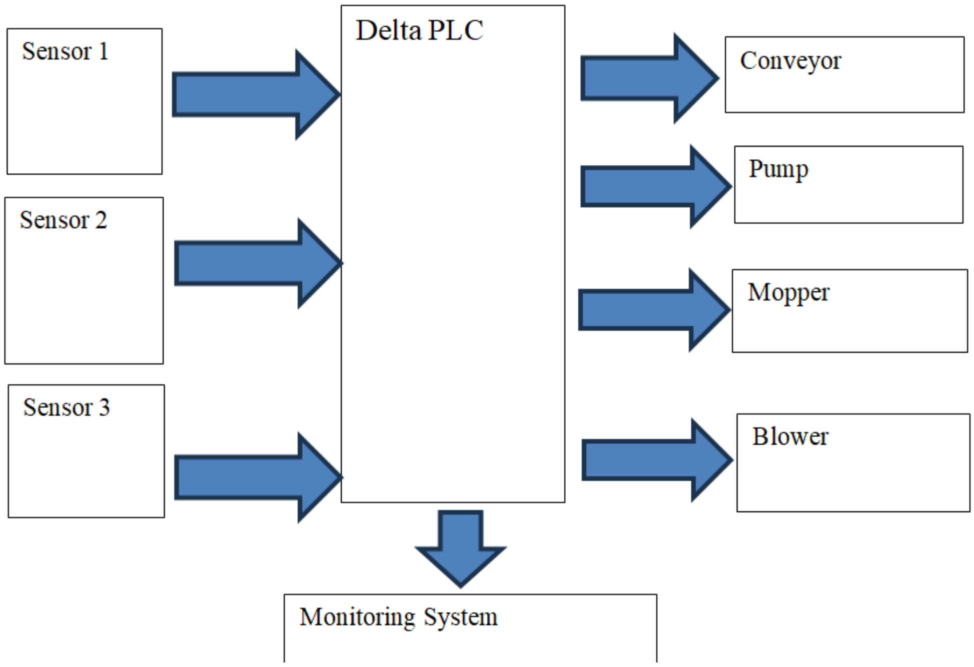

Figure 2: Design

IV. CALCULATION

1. Load Mass (m): 5 kg
2. Acceleration due to Gravity (g): Approximately 9.81 m/s^2
3. Conveyor Pulley Radius (r): You will need to provide the radius of the conveyor pulley or drive roller.

For this calculation, let's assume a hypothetical value of 0.1 meters (10 cm).

Now, let's calculate the force required to move the load:

$F = m \cdot g = 5\,kg \cdot 9.81\,m/s^2 = 49.05\,NF = 5kg \cdot 9.81m/s^2 = 49.05N$ Next, calculate the motor torque required using the formula:

$T = r \cdot F = 0.1\,m \cdot 49.05\,N = 4.905\,NmT = 0.1m \cdot 49.05N = 4.905Nm$

So, to transport a 5 kg load on the conveyor system with a pulley or drive roller radius of 0.1 meters, you would need a 12V DC motor with a torque rating of at least 4.905 Nm to ensure smooth and efficient operation.

Remember to consider a safety margin when selecting the motor to account for variations in load and any potential increases in friction or resistance in the system during operation

V. HARDWARE

DELTA PLC

Figure 3: DELTA PLC

The Delta PLC serves as the central control unit for the component cleaning station, streamlining operations and enhancing efficiency. Through process automation, it orchestrates the sequential operation of cleaning stages, monitors critical parameters, and ensures consistent performance. The PLC's fault detection capabilities provide an added layer of security by promptly identifying and alerting operators to any anomalies or equipment malfunctions. Moreover, its energy-efficient control algorithms optimize resource usage, contributing to cost savings and sustainability. Additionally, the Delta PLC enables data collection and analysis, empowering operators to make informed decisions for process optimization and continuous improvement. Overall, the Delta PLC plays a pivotal role in driving operational excellence and reliability within the component cleaning station.

Figure 4: Relay Board

Relays act as switches in electrical circuits, controlled by the PLC. They enable the PLC to manage high-power devices such as motors and heaters, ensuring safe and efficient operation. By isolating the PLC's low-voltage control signals from the higher voltage or current required by these devices, relays protect the PLC and facilitate precise control of processes in automation systems. Intermediaries, translating the PLC's instructions into actions within the system, thereby enabling precise and reliable control of processes.

PROXIMITY SENSOR

Figure 5: Proximity Sensor

Proximity sensors are utilized for detecting the presence or absence of objects within the system. These sensors operate based on the principle of detecting changes in electromagnetic fields or the interruption of infrared beams caused by nearby objects. Proximity sensors can be employed to monitor various aspects of the cleaning process, such as detecting the presence of components as they enter or exit the cleaning station, or verifying the position of moving parts within the system. By providing real-time feedback to the PLC system, proximity sensors enable precise control and automation of the cleaning process, ensuring that operations proceed smoothly and efficiently. Additionally, they contribute to safety by detecting any anomalies or obstructions that may pose a risk to the equipment or personnel, allowing for prompt intervention and corrective action. Overall, proximity sensors play a crucial role in optimizing the performance and reliability of the component cleaning station.

STEP-DOWN MODULE

The Step-Down Module serves a crucial function in regulating voltage levels to meet the specific requirements of the system. Operating on the principle of electromagnetic induction, the module efficiently steps down the input voltage to a lower level suitable for powering various components within the system. This regulated output voltage ensures that sensitive electronic devices, such as the PLC system, sensors, and control circuitry, receive the correct voltage to operate reliably and efficiently. By providing stable and precise voltage regulation, the Step-Down Module enhances the overall performance and longevity of the cleaning station, contributing to its effectiveness and reliability in operation.

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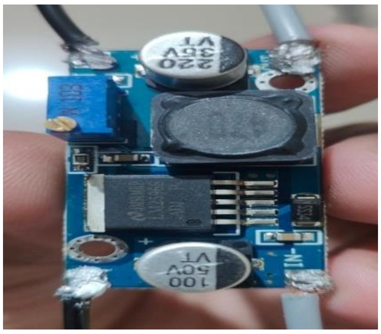

Figure 6: Step-Down Module

VI. LADDER LOGIC

Ladder logic is a graphical programming language commonly used for programming PLCs (Programmable Logic Controllers) like the Delta PLC mentioned in the project. It represents logic functions using graphical symbols, resembling a ladder with horizontal rungs and vertical rails. Each rung in ladder logic represents a specific control function or operation within the PLC program.

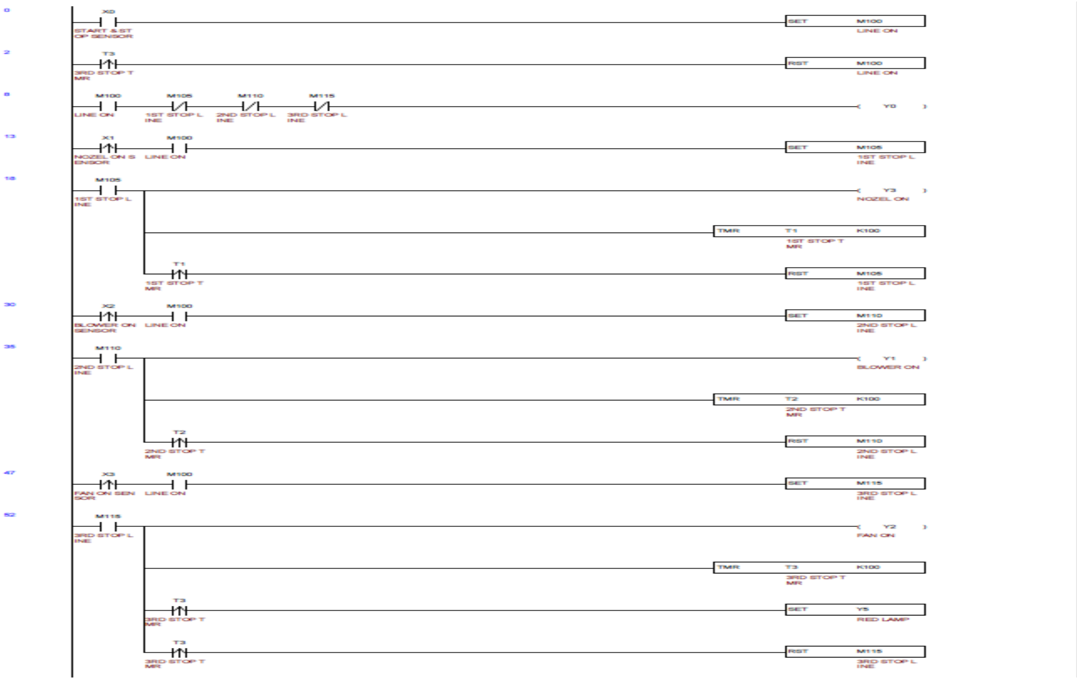

Figure 7: PLC Ladder Logic

For the component cleaning station project, ladder logic can be utilized to program the Delta PLC to control various components such as the conveyor belt, solenoid valves, pumps, motors, fans, and sensors. Here's a simplified explanation of how ladder logic might be used for this project:

Conveyor Belt Control:

A rung of ladder logic can be dedicated to controlling the conveyor belt motor. The rung might include an input contact (representing a start button or sensor detecting component presence) connected in series with an output coil (representing the conveyor belt motor).

When the start button is pressed or a component is detected on the conveyor, the input contact will close, allowing current to flow to the output coil and activate the conveyor belt motor.

Solenoid Valve Control:

Each solenoid valve used in the cleaning process can have its own rung of ladder logic. The rung would include an input contact (representing a condition for the valve to open) connected in series with an output coil (representing the solenoid valve).

When the specified condition is met (e.g., a timer reaches a certain value or a sensor detects a component), the input contact will close, energizing the solenoid valve and allowing fluid flow.

Pump Control:

Similar to solenoid valve control, ladder logic can be used to control the pump motor. An input contact representing a condition for the pump to operate (e.g., a low fluid level sensor) is connected in series with an output coil representing the pump motor.

When the condition is met, the input contact closes, activating the pump motor and circulating fluid through the system.

Motor, Fan, and Sensor Control:

Additional rungs of ladder logic can be used to control other components such as motors, fans, and sensors. Each component is controlled based on specific conditions or inputs detected by the PLC.

For example, a temperature sensor might trigger a fan to turn on when the temperature exceeds a certain threshold, or a proximity sensor might stop a motor if it detects an obstruction in the system.\

Safety Interlocks:

Ladder logic can also incorporate safety interlocks to ensure safe operation of the cleaning station. For instance, emergency stop buttons or safety switches can be connected to input contacts, which, when triggered, immediately deactivate all output coils to stop all moving parts.

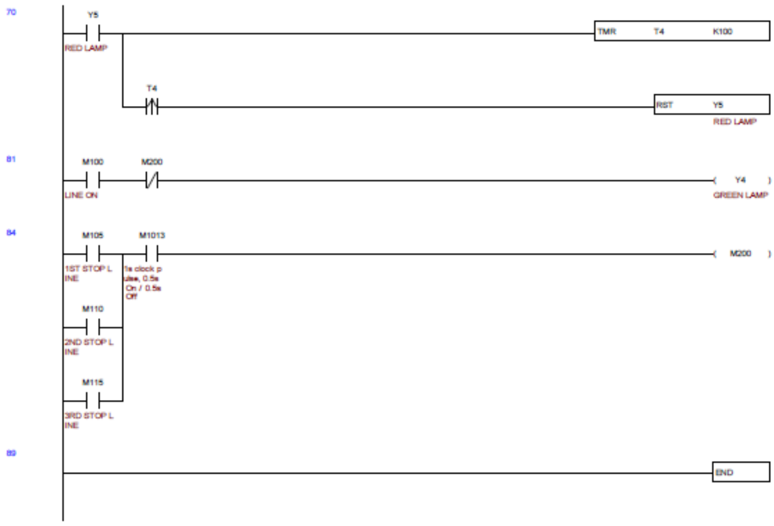

Figure 8: Ladder Logic

VII. CONCLUSION

The PLC-based Component Cleaning Station using conveyor stations represents a transformative project in industrial manufacturing, offering a comprehensive solution to address the challenges associated with manual cleaning practices. This summary provides an overview of the project's key elements and its potential impact on the manufacturing industry.

Project Overview:

The project aims to design, implement, and optimize an automated cleaning system with three integral stations: Water Pump, Mopping, and Blower Motor. It leverages PLC technology, advanced sensors, and precision actuators to enhance efficiency, quality, and cost-effectiveness in component cleaning.

Key Objectives:

The project's objectives encompass system design, PLC programming, sensor integration, actuator implementation, testing, and optimization. It focuses on reducing labour costs, improving cleaning quality, ensuring workplace safety, and promoting sustainability.

Expected Outcomes:

The expected outcomes include enhanced efficiency, improved cleaning quality, cost reduction, resource optimization, scalability, safety enhancement, data-driven decision-making, competitive advantage, and environmental responsibility. The project aims to demonstrate the effective utilization of advanced technologies and provide opportunities for future enhancements.

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Significance:

The project addresses the pressing need for efficient and precise component cleaning in manufacturing. Manual processes are labour-intensive, inconsistent, and costly, making automation a compelling solution. By integrating state-of-the-art automation and control systems, this project aims to set new standards in industrial cleaning practices.

Impact:

The automated cleaning station is expected to have a profound impact on manufacturing operations, leading to increased productivity, higher product quality, and reduced operational costs. It aligns with industry trends towards automation, sustainability, and data-driven decision-making.

Conclusion

In conclusion, the PLC-based Component Cleaning Station project represents a pioneering effort to revolutionize component cleaning in industrial manufacturing. Through meticulous system design, advanced technology utilization, and a commitment to efficiency and quality, this project has the potential to reshape manufacturing processes, offering a competitive advantage and a sustainable future for industries worldwide

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