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Automatic Counting and Packaging System for Arc Welding Rod

Keshav Selvaraj*, Sanjana Raghavan, R. Arikaran and Oviya Arunachalam

Department of Robotics and Automation, PSG College of Technology, Coimbatore, Tamil Nadu, India

Abstract

This paper introduces a novel automated system for counting and packaging, particularly tailored for the welding rod manufacturing industry. The research outlines the design and implementation of this system, emphasizing its capability to accurately count welding rods and efficiently package them utilizing conveyor technology. The integration of key components, including sensors and Programmable Logic Controllers (PLCs), is detailed to ensure precise counting and seamless packaging. The paper highlights the advantages of this system, along with challenges faced during development and a comparative analysis of manual versus automated packaging processes. It provides valuable insights and recommendations for industries considering similar conveyor-based counting and packaging solutions, with a focus on enhancing operational efficiency and cost-effectiveness.

Keywords: Automated system • Counting • Packaging • Welding rod manufacturing • Conveyor system • Sensors • Programmable Logic Controllers (PLC)

Introduction

In today's manufacturing sector, automation is essential. It has transformed production methods across many industries. Automated packaging machines for welding rods are important parts of industrial automation. These machines are designed to package welding rods efficiently. They meet the growing demand in industries such as construction, automotive and aerospace. Welding rods are crucial components in many metalworking processes. They need to be handled carefully and packaged precisely to maintain their structural integrity. Manual packaging methods are labour-intensive and prone to inconsistencies, often resulting in substandard packaging. Automated packaging machines for welding rods address these challenges by providing a reliable, high-speed, and precise packaging solution.

Definition and importance of automatic welding rod packaging machines in industrial settings

With rapid technological advancement, automation has become a key driver of industrial progress. It is significant because it can increase productivity, reduce operational costs, and ensure consistent product quality. Automation reduces human intervention, which minimises errors and improves overall operational efficiency.

The role of automation in improving efficiency and productivity in manufacturing

Automated packaging machines for welding rods play a significant role in improving the efficiency of the packaging process. These machines operate seamlessly to ensure a continuous and uninterrupted flow of production. They also offer exceptional precision in tasks such as measuring, cutting, and packaging welding rods, which raises the overall quality standard of the final product. Additionally, by reducing labour costs and minimising material wastage, these automated systems are highly cost-effective in the long run.

Overview of PLC Systems

Explanation of what PLC is and how it works in industrial automation

Programmable Logic Controllers (PLCs) are specialised computers that are widely used in industrial automation and control systems. Their main job is to control electro-mechanical processes in a precise and reliable way. PLCs do this by receiving signals from sensors, processing the data using a programmed logic, and then sending signals to control actuators and other devices. PLCs are different from general-purpose computers because they are designed to withstand harsh industrial environments. This makes them ideal for use in factories [1].

Components of a PLC system

Central Processing Unit (CPU): The CPU is the brain of the PLC. It is responsible for running the control program and processing data. It reads the input signals and sends the appropriate output signals based on the programmed logic.

Input modules: Input modules receive signals from sensors and other input devices, such as switches and buttons. They convert these physical signals into digital data that the PLC can understand.

Output modules: Output modules control actuators, motors, relays, and other output devices based on the processed data. They convert the PLC's digital data into physical actions in the industrial process.

Programming device: A programming device, usually a computer, is used by engineers to create, edit, and upload control programs to the PLC. Specialized software is used to write the logic that controls how the PLC behaves.

Communication interfaces: Communication interfaces allow PLCs to talk to other devices and systems on an industrial network. This allows data to be transferred between PLCs, Human-Machine Interfaces (HMIs) and Supervisory Control Systems (SCADA).

***Address for Correspondence:** Keshav Selvaraj, Department of Robotics and Automation, PSG College of Technology, Coimbatore, Tamil Nadu, India, E-mail: keshavselva1011@gmail.com*

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Types of PLC systems suitable for welding rod transportation and packaging applications

Modular PLCs: These versatile systems are made up of interchangeable modules that can be customised to meet the specific needs of the application. They offer design flexibility and can be adjusted or expanded as needed, making them a good choice for a variety of operational requirements.

Compact PLCs: These integrated units have fixed input and output terminals, making them well-suited for applications where space is limited. They offer a cost-effective solution for managing smaller-scale automation tasks efficiently.

Rack-mounted PLCs: These PLCs are designed for large industrial systems. They have a lot of processing power and a lot of input/output capabilities. They are ideal for controlling complex automation processes that require a lot of inputs and outputs.

Safety PLCs: These PLCs have advanced safety features and certified safety functions. They are essential for applications where human safety is very important. They make sure that the industrial environment is as safe as possible by following industry safety standards and rules.

Advantages of using PLC in automation processes

Reliability: PLCs are built to withstand a variety of industrial conditions, including temperature fluctuations, humidity, and electrical noise. This ensures that they will operate reliably in even the most challenging environments.

Flexibility: PLCs offer the ability to change the control logic without having to make any physical changes to the system. This makes them very flexible, especially in industries where production processes change often.

Cost-effectiveness: PLCs are a cost-effective solution for automation tasks. They are reliable, easy to program, and have a long lifespan. This makes them a good investment for industrial applications.

Diagnostic capabilities: PLCs have comprehensive diagnostic features that allow engineers to monitor system performance, identify problems, and troubleshoot them quickly. This helps to minimise downtime and improve overall system efficiency.

Design and Components of Automatic Welding Rod Transportation Machine Conclusion

Description of the mechanical and electrical components of the transportation system

Conveyor belts: Conveyor belts are the foundation of the transportation system. They can handle welding rods of all sizes and weights. These modular conveyor systems can be customised to fit different production line layouts. They have rollers and guides to ensure that the rods move precisely and don't get misaligned [2].

Robotic arms: Robotic arms are essential for automating the handling of welding rods. They have special end- effectors, such as grippers or suction cups that can hold and release rods securely. These programmable arms can position the rods precisely, ensuring that they are packaged seamlessly without any damage. Their adaptability and precision make it easy to move the rods around efficiently.

Rollers and guides: Rollers and guides are strategically placed along the conveyor system to help the welding rods move smoothly. By guiding the rods along the designated path, they prevent the rods from going off course and getting jammed. Motorised rollers allow for controlled movement and can be adjusted to accommodate different rod sizes. Guides also help to keep the rods aligned and oriented as they move through the system.

Chutes and hoppers: Chutes and hoppers are essential elements that regulate the flow of welding rods. Chutes have sloped channels that help the rods move smoothly between conveyors or from higher to lower levels. Hoppers are temporary containers that hold the rods before they are released onto the conveyor. They have sensors that make sure there is a steady supply of rods. Chutes and hoppers must be carefully designed to prevent the rods from getting tangled and to ensure a smooth, efficient flow throughout the system.

Sensors and actuators used in the transportation system

Proximity sensors: Proximity sensors are non-contact sensors that can detect the presence or absence of welding rods. Inductive proximity sensors are commonly used to detect metal objects like rods. They are strategically placed along the conveyor path to monitor rod movement. When a rod is detected, the sensor sends a signal to the PLC, which triggers the next steps in the transportation process.

Photoelectric sensors: Photoelectric sensors use light beams to detect the presence, position, and sometimes the colour of welding rods. Through-beam sensors emit a light beam from a transmitter to a receiver. When the beam is interrupted by a rod, the receiver sends a signal to the PLC indicating the rod's position. Retro-reflective sensors reflect light off a reflector, and diffuse sensors detect light reflected directly from the object. Photoelectric sensors provide precise information about rod movement, which helps with accurate positioning within the system.

PLC programming: PLC programming is the process of writing the PLC code that controls the automatic welding rod transportation system. Programming languages such as ladder logic or structured text are used to write the code. The code interprets input signals from sensors and executes corresponding output commands to control motors, robotic arms, and other important actuators. The PLC programming also includes logic for sequencing, error handling, and safety interlocks. This ensures the smooth and safe operation of the system. Well-structured and documented code makes maintenance and troubleshooting easier.

HMI (Human-Machine Interface): The HMI is the interface between users and the automatic system. It provides operators with real-time feedback, so they can monitor the system status, view error messages, and input commands. Modern HMIs have touchscreen displays, which makes them easy to use. Operators can start or stop the system, change settings, and review production statistics on the HMI. Alarm notifications and diagnostic information are prominently displayed, so operators can quickly respond to problems. The HMI improves the user experience and makes system management more efficient.

Emergency stop buttons: Emergency stop buttons are critical safety devices that are placed within easy reach of operators. When activated, they immediately stop all system operations. Emergency stop mechanisms are directly connected to the PLC, so they can respond quickly to emergencies such as equipment malfunctions, jams, or safety concerns for personnel. Proper placement and function of emergency stop buttons are essential for maintaining a safe working environment [3].

Control mechanisms for precise movement and positioning of welding rods

Motors: Electric motors power the conveyor belts, rollers, and other moving parts in the transportation system. Variable Frequency Drives (VFDs) are often used to control the speed of the motors, so that they can be adjusted to meet production needs. The motors are synchronised with the PLC, which gives the system precise control and allows it to adapt to changing workloads efficiently.

Power supply units: Power supply units convert electrical energy from the main power source into the voltage and current that the system needs to run. They provide a steady flow of power to all of the electrical components, which ensures stable and reliable performance. Redundant power supplies may be used to protect the system from failures if the power goes out.

Relays: Relays are electromagnetic switches that control high-power devices such as motors and solenoids. They act as intermediaries between the low-power signals from the PLC and the high-power components, ensuring the safe and effective operation of the system. Relays are also important for isolating the PLC from high-voltage circuits, which protects it from electrical surges.

Switches: Manual switches, such as start/stop buttons and emergency stop switches, allow for control over the system operations. Start buttons start the transportation process, setting the conveyor belts and associated components in motion. Emergency stop switches, on the other hand, immediately stop all system operations when activated, prioritising the safety of personnel and equipment in critical or emergency situations.

Integration of PLC in the System

How PLC is integrated into the transportation and packaging machines

The Programmable Logic Controller (PLC) is integrated into the automatic welding rod transportation and packaging system in several key steps. First, the system requirements are carefully assessed to identify the necessary inputs and outputs. Then, the appropriate PLC hardware, including the Central Processing Unit (CPU), input modules and output modules, is selected based on the system specifications. Finally, the PLC is physically installed and connected to the sensors, actuators, and other essential components of the transportation and packaging machinery.

Programming languages and software used for PLC programming

The operational behaviour of the automated system is determined by PLC programming. Popular PLC programming languages, such as ladder logic, structured text, function block diagrams, and sequential function charts, are used by engineers to create a coherent sequence of operations. Specialised software solutions, such as Siemens STEP 7, Allen-Bradley RSLogix, or Schneider Electric Unity Pro, facilitate the programming process. These software platforms allow engineers to draft, simulate, and debug the control logic before integrating it into the PLC hardware.

Detailed explanation of the PLC code structure and logic for the system

The complex architecture of the PLC code is carefully organised to reflect the functional complexities of the transportation and packaging system. Sensor inputs, such as those from proximity sensors and photoelectric sensors, are closely monitored within the code structure. Logical conditions are systematically formulated to effectively interpret these inputs. Based on the sensor inputs and pre-established conditions, the PLC triggers the appropriate output signals to control motors, robotic arms, conveyors, and other essential actuators within the system. The inclusion of error handling routines and safety interlocks in the code structure ensures the safe and efficient operation of the system. Notably, the structured, modular and well-documented nature of the PLC code facilitates streamlined maintenance and enables efficient troubleshooting procedures [4].

Sensors and Feedback Systems

Role of sensors in detecting welding rod positions and packaging completeness

Sensors play a vital role in the automatic welding rod transportation and packaging system by enabling real-time detection and feedback. Proximity sensors are essential components that identify the presence or absence of welding rods at specific points in the system. Using electromagnetic fields, these sensors can efficiently detect the proximity of metal objects, such as welding rods. Additionally, photoelectric sensors use light beams to precisely determine the position, movement, and even the color attributes of the welding rods. The intricate data collected by these sensors provides accurate feedback to the Programmable Logic Controller (PLC), empowering the system to make informed decisions regarding the transportation and packaging processes of the rods.

Feedback loops and how sensors provide input for PLC control decisions

The inputs from the sensors act as the senses of the automated system. When a welding rod is detected, the sensors send signals to the PLC, conveying crucial information about the rod's precise location, dimensions and quantity. Using this data, the PLC efficiently coordinates the movement, direction and speed of the transportation system. For example, if a sensor detects a rod at a specific point, the PLC can command the conveyor to stop, enabling a robotic arm to grasp the rod for subsequent packaging. The real-time data provided by the sensors allows the system to adapt dynamically to varying conditions along the production line.

Types of sensors used in welding rod transportation and packaging systems

Proximity sensors, including inductive, capacitive and magnetic variants, can proficiently detect the presence or absence of welding rods without requiring physical contact. Strategically positioned at various points along the conveyor, they effectively monitor the movement of the rods throughout the system. Photoelectric sensors encompass various sensor types, such as through-beam, retro-reflective, and diffuse sensors, which utilise light beams to accurately determine the position, dimensions and material characteristics of the welding rods. Known for their versatility, they effectively handle different sizes and materials of rods. Ultrasonic sensors measure the distance between the sensor and the object using sound waves, making them crucial for measuring the stack height of welding rods in hoppers or containers, thereby ensuring optimal rod distribution throughout the system. Load cells are used to measure the weight of welding rods, providing essential feedback for quality control purposes. Their role is critical in ensuring that each package contains the designated number of rods and that the overall weight meets predefined quality standards.

Prototype

Working of the model

The development of an automated system for counting and packaging arc welding rods, designed to function without a hopper, represents advancement in the quest for increased efficiency and accuracy within manufacturing processes. This comprehensive system seamlessly integrates various facets, incorporating mechanical, electrical and control elements to adeptly manage the welding rods as they traverse along a conveyor or production line. Among the mechanical constituents are the conveyor systems for rod transportation, sensors responsible for detecting rod presence and alignment, a counting mechanism to segregate rods into individual units, and a packing station for bundling. On the electrical front, the system relies on sensors, a Programmable Logic Controller (PLC) for decision-making and control, motor drives to power the mechanical components, and a Human Machine Interface (HMI) to facilitate operator interaction.

The core of the operation resides within the control system, which utilizes a ladder logic program within the PLC to meticulously control the workflow. The "Start Button" initiates conveyor operation, while the "Stop Button" provides the means to halt proceedings as necessary. A "Sensor" accurately identifies the presence of welding rods, triggering the counting mechanism to meticulously tally each rod. The "Counting Mechanism" updates the counter, while the "Packing Mechanism" organizes and packages the counted rods. The "Reset Button" affords the ability to reset the counter and predefined limits, such as the "Count Limit" and "Packing Limit," instigate actions when specific conditions are met, ensuring a controlled and dependable process (Figure 1).

This system delivers a substantial enhancement to the efficiency and precision of the welding rod packaging process, effectively reducing the potential for human error and concurrently elevating overall productivity. However, it

Figure 1. Prototype model of the conveyor setup.

remains imperative to rigorously adhere to safety standards and thoughtfully contemplate the specific requirements and quality control measures that are pertinent to the unique manufacturing environment in question.

Safety Measures and Error Handling

Safety mechanisms integrated into the system to prevent accidents

In the setting of an automated system for transporting and packaging welding rods, a range of safety measures are applied to minimise potential risks and ensure the safety of operators. These safety protocols are an essential aspect of the system's design, aiming to lower the likelihood of accidents and injuries during its operation. Emergency stop buttons, serving as a core element of the safety procedures, are strategically positioned within the workspace for operators' quick and convenient access. Upon activation, these buttons act as a fail-safe, prompting an immediate shutdown of the entire system. Consequently, all motors, conveyors, and actuators come to a halt, preventing any further movement of materials or components within the system.

Furthermore, safety interlocks are integrated into the system to impose limitations during critical operations. These interlocks function as control devices, restricting specific actions or movements when particular pre-established conditions are not met. For instance, within the welding system, robotic arms can be programmed to cease movement if a human operator enters a designated safety zone. This precautionary measure ensures that accidental collisions or mishaps between the equipment and the operator are avoided. Creating a secure working environment involves the use of physical barriers like fences or light curtains, effectively outlining and protecting the workspace. These barriers act as a shield, preventing direct access to hazardous areas and limiting interaction between operators and the moving components or machinery. By establishing dedicated and secure workspaces, these physical barriers significantly reduce the risk of accidents and injuries that may arise from the operational movements of the automated system. Overall, these safety measures contribute to an overarching risk management strategy, fostering a secure and well-regulated working environment for operators. This comprehensive approach effectively safeguards them from potential hazards associated with the automated welding rod transportation and packaging system.

Error handling procedures in case of malfunctions or system failures

Automated systems need error handling procedures to deal with different types of system failures and malfunctions. These procedures are carefully designed to identify and fix any problems with the system's normal operation as quickly as possible. The Programmable Logic Controller (PLC) is responsible for running error detection routines. It does this by actively monitoring sensor inputs and system responses to look for any anomalies. When the PLC finds an abnormal condition, it can start predefined error handling procedures. This allows the system to react quickly and appropriately. For example, if a sensor doesn't detect a welding rod within a certain amount of time, the system will send an alert to let someone know about the potential problem. This alert will notify the appropriate maintenance personnel, who can quickly inspect and fix the broken sensor. This keeps the system running smoothly and efficiently [5].

The system also displays error codes and messages on the Human-Machine Interface (HMI). This is an important tool for operators because it allows them to quickly see what type of problem has occurred. Through the HMI, operators can get important information about the specific error, which helps them make informed decisions and take corrective actions quickly. This quick response to error notifications is essential for keeping the system running smoothly and minimising downtime. It also helps to ensure that the automated welding system functions seamlessly and without interruptions.

Emergency shutdown protocols and their implementation through PLC

Emergency shutdown protocols are essential in industrial environments to quickly and efficiently respond to critical situations that could jeopardize system operation and personnel safety. These protocols are carefully designed to address various emergency scenarios, such as power failures, system overloads, and unexpected hardware failures, which can all disrupt system functionality. To enhance system resilience against unforeseen emergencies, redundant systems are integrated to ensure a seamless transition to backup mechanisms if the primary system fails. Additionally, the strategic integration of backup power supplies provides an alternative power source to maintain essential operations during power outages or disruptions. As an added preventive measure, fail-safe mechanisms are implemented to allow the system to automatically activate predefined safety procedures to prevent catastrophic consequences during critical malfunctions.

Rigorous testing is performed on these emergency shutdown protocols to validate their efficacy and reliability, ensuring seamless integration with the PLC logic. Upon activation, these protocols initiate a systematic and controlled shutdown sequence across all system components. By orchestrating a coordinated shutdown process, potential equipment damage is minimised, and system and personnel safety are preserved. This systematic implementation of emergency shutdown protocols serves as a robust protective measure, guaranteeing the overall resilience and operational integrity of the industrial system in the face of unforeseen critical events.

Benefits and Challenges of Implementing Automatic Welding Rod Packaging

Efficiency improvements and cost savings due to automation

Automating the transportation and packaging of welding rods significantly improves manufacturing efficiency. By eliminating interruptions and delays, automation ensures a smooth and uninterrupted workflow. Automated systems can handle large quantities of welding rods, reducing packaging time and increasing production yield. This leads to enhanced productivity and profitability for the manufacturing facility. Automation streamlines logistics operations and optimises material handling and packaging procedures. Automated transportation ensures the swift and accurate movement of welding rods within the production environment. Automated packaging expedites the sealing and labelling of welding rods, facilitating the final stages of the production cycle.

Automation reduces reliance on manual labour for transportation and packaging tasks, thereby minimising human error and cutting operational costs. The precision and consistency of automation contribute to a standardised and uniform packaging process, ensuring the consistent delivery of high-quality products to customers. This improved quality control and standardised output reinforce the manufacturing facility's reputation and credibility within the industry.

Challenges faced during the design, implementation and maintenance phases

Despite the numerous advantages, implementing automatic welding rod transportation and packaging systems comes with challenges. One significant challenge is the initial setup cost, which includes the expenses associated with purchasing and installing the PLC hardware, sensors, actuators, and other components. Additionally, integrating the automatic system into existing manufacturing processes might require modifications to the production line layout, which can be time-consuming and disruptive. Another challenge is the complexity of programming the PLC logic accurately, ensuring seamless coordination between sensors, actuators, and other devices. Moreover, maintaining and troubleshooting the system demands skilled personnel familiar with both PLC programming and the mechanical aspects of the system.

Comparative analysis of manual *vs.* automated packaging processes

Comparing manual and automated packaging processes highlights the benefits of automation. Manual packaging requires a lot of labour and is prone to errors. Workers may have difficulty handling rods of different sizes, which can lead to inaccurate packaging. Additionally, manual operations are often slow, limiting overall production capacity.

On the other hand, automated systems are precise, fast, and reliable. They can skilfully handle rods of different sizes and materials, ensuring consistent and standardized packaging quality. Automated systems significantly reduce the need for human labour, which minimizes the risks associated with repetitive tasks and manual errors.

Future Trends and Innovations in Automatic Welding Rod Packaging

Emerging technologies in the field of industrial automation

The field of industrial automation is constantly changing, driven by emerging technologies that are revolutionizing manufacturing processes. One notable trend is the rise of collaborative robots (cobots). These adaptable robots are designed to work alongside human operators, making them ideal for tasks that require human-robot collaboration.

Another important development is the integration of machine learning algorithms and Artificial Intelligence (AI) into automation systems. This integration enables predictive maintenance, robust quality control, and adaptive learning capabilities within the manufacturing setting. By leveraging AI capabilities, industrial automation systems can quickly adapt to changing production demands and improve operational processes with greater accuracy and efficiency.

Finally, the introduction of IoT (Internet of Things) connectivity is fostering a connected ecosystem within industrial automation. This connectivity allows machines and systems to communicate and exchange data seamlessly in real time, enabling informed decision-making and creating a more streamlined operational structure. By harnessing IoT connectivity, industrial automation systems can achieve improved responsiveness, advanced data analytics, and enhanced system coordination, leading to overall improved efficiency and performance in the manufacturing sector.

Predictions for the future of automatic welding rod packaging machines

Automated packaging systems for welding rods are expected to become even better in the future, thanks to new technologies. Predictive analytics and AI will help these systems to predict when they need maintenance, which will reduce downtime and improve reliability. Advanced sensors, such as 3D vision systems and LiDAR, will help the systems to detect and handle welding rods more accurately, making them more versatile and adaptable to different production needs.

Block chain technology could also transform traceability and quality control in the welding rod supply chain. Block chain can be used to create a secure record of the entire lifecycle of a welding rod, from its manufacture to its use, which can help to ensure the authenticity and quality of products. This could make the welding rod industry more transparent, accountable, and trustworthy.

Integration of artificial intelligence and machine learning in PLC-based systems

AI and machine learning are making automatic welding rod packaging systems more intelligent and efficient. These systems use neural networks and deep learning algorithms to analyses complex data sets, identify patterns, and make decisions in real time. They can also use supervised and unsupervised learning to learn the best packaging strategies. Machine learning algorithms can help to predict when equipment will need maintenance. This is called predictive maintenance analytics. It can help to prevent costly downtime and extend the life of machines. AI can also be used for quality control. AI systems can use computer vision and image processing to inspect welding rods for defects. This helps to ensure that only high-quality products are packaged. AI can also be used to optimise the packaging process. AI systems can analyse historical data and use reinforcement learning to determine the best parameters for the packaging process, such as how much packaging material to use, how fast to move the conveyor belt, and how to configure the packaging machines. This can help to reduce material waste, streamline the production process, and improve resource management.

Conclusion

Summary of key findings from the research

Automatic welding rod transportation and packaging systems driven by programmable logic controllers (PLCs) offer several advantages, including increased efficiency, cost savings, and improved product quality. These systems rely heavily on sophisticated sensors, precise actuators, and carefully crafted PLC programming to streamline transportation and packaging processes. This reduces human involvement and minimizes the risk of errors.

Recommendations

Recommendations for industries considering the implementation of similar systems

Industries considering implementing automatic welding rod packaging systems should invest in training skilled personnel who are knowledgeable in both mechanical engineering and PLC programming. Robust training programs and workshops can significantly improve the workforce's capabilities, ensuring the smooth operation and meticulous maintenance of these systems. Additionally, industries should stay up-to-date on the latest advances in automation technologies, including sensors, Artificial Intelligence (AI) algorithms, and PLC innovations, to continuously improve the performance of their systems.

Personal insights and suggestions for future research in this area

Future research initiatives in this field should focus on exploring the seamless integration of cutting-edge technologies, such as block chain applications, AI-powered predictive maintenance mechanisms, and advanced machine learning algorithms. Comparative analyses of various PLC systems and programming languages can provide valuable insights into optimizing the overall performance of these systems. Additionally, research exploring human-robot collaboration and the development of more secure and user- friendly Human-Machine Interfaces (HMIs) has the potential to further enhance the automation experience in industrial environments.

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Conflict of Interest

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