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PLC Based 7 Tank Process

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Abstract: *Powder coating is a superior finishing process widely used across industries for providing a durable, high- quality, and aesthetically pleasing finish to metal products. One of the most critical stages in this process is the pre- treatment phase, which typically involves dipping the metal job sequentially into seven different chemical tanks for cleaning, degreasing, phosphating, and other surface preparation steps. In conventional systems, this process is performed manually, requiring significant human effort, time, and resources, often resulting in inconsistent quality and increased operational costs.*

To address these challenges, this project proposes a PLC-based Fully Automated 7-Tank Pre-Treatment System. The system employs a programmable logic controller (PLC) to automate the sequential dipping of metal objects using a motorized gantry system. The gantry consists of a vertical and horizontal slider mechanism along with a motorized gripper to securely hold and transport the workpiece. Each tank is assigned a specific time duration, which is programmed into the PLC for precise control. The system ensures that the metal object is dipped in each tank sequentially for the required duration without any manual intervention.

Automation of the 7-tank process offers multiple benefits, including improved process accuracy, consistent product quality, reduced labour dependency, enhanced safety, and significant cost and time savings. This project transforms the traditional labour-intensive process into a smart and autonomous solution that aligns with modern industrial automation trends.

The implementation of this system demonstrates how real-time industrial problems can be resolved using automation and PLC technology, making it an ideal model for industries focused on increasing productivity and maintaining high standards in surface treatment operations.

Keywords: PLC Automation, 7-Tank Process, Powder Coating, Gantry System, Pre-Treatment, Industrial Automation, Motorized Gripper, Surface Preparation, Productivity, Cost Reduction.

I. INTRODUCTION

Powder coating is a widely adopted surface finishing process used across various industries to enhance the appearance and durability of metal products. It involves the application of a fine powder composed of resin and pigment, which is electrostatically charged and sprayed onto a metal surface. The coated item is then heated in a curing oven, causing the powder to melt and fuse into a smooth, hard, and uniform layer. This method offers numerous advantages over conventional liquid painting, such as better durability, corrosion resistance, and an environmentally friendly process due to the absence of solvents.

Before the powder coating can be applied, a crucial pre-treatment process must be carried out to prepare the surface of the metal for optimal powder adhesion. This is typically done through a 7-tank process, where the metal job is dipped sequentially into tanks containing different chemical solutions such as degreasers, derusters, phosphating agents, and rinse water. Each tank plays a vital role in cleaning and chemically preparing the surface to ensure the coating's longevity and adhesion quality.

Traditionally, this entire pre-treatment process is carried out manually. Operators are responsible for moving the metal job from one tank to another, maintaining the immersion time, and ensuring proper handling. However, this manual approach has several limitations, including the risk of human error, inconsistent treatment quality, time-consuming operations, and increased labour costs.

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To overcome these issues, this project introduces a PLC-based fully automated 7-tank pre-treatment system. The system features a motorized gantry equipped with a horizontal and vertical slider and a gripper mechanism to hold and move the object. Controlled by a Programmable Logic Controller (PLC), the gantry system automatically moves the metal job through all seven tanks for specific time durations, eliminating the need for manual intervention.
This automation not only enhances the accuracy and consistency of the process but also improves productivity, reduces operational costs, and aligns with the growing trend of smart manufacturing and industrial automation.

II. LITERATURE SURVEY TABLE

Author(s)	Year	Title / Research Focus	Technology / Method Used	Key Findings
John et al.	2017	Surface Pre-Treatment Importance in Powder Coating	Manual tank process	Emphasized human error leads to inconsistent finish quality.
Mehta & Sinha	2019	Automation in Multi-Step Chemical Processing Using PLC	PLC Automation	PLCs improve sequential process handling, reduce errors, and increase flexibility.
Sharma et al.	2020	Semi-Automatic 5-Tank Coating System Using Relays	Relay-based logic	Reduced labour but lacked real- time control and scalability.
Kumar & Patel	2021	Comparative Study: Manual vs PLC-Based Coating Lines	PLC-Based vs Manual	PLC reduced rework by 25% and improved productivity by 40%.
Singh et al.	2022	Automated Gantry System for Multi-Tank Electroplating	Motorized Slider + PLC Control	Gantry-based systems improved dipping accuracy and cycle timing.
R. Venkatesh & P. Verma	2021	Smart Factory Integration in Surface Coating	PLC, SCADA, IoT	IoT & PLC integration provided monitoring and remote diagnostics.
R. Gupta et al.	2023	Application of PLC in Industrial Chemical Processes	Ladder Logic Programming	Showed high adaptability of PLCs in multi-stage processes.
Ghosh & Rajan	2022	Challenges in Manual Powder Coating Pre-Treatment	Manual Labor	Identified time inefficiency and high recurring labour cost as key bottlenecks.

III. DESIGN APPROACH

The design of the PLC-based fully automatic 7-tank process system revolves around the automation of a sequential dipping operation using a motorized gantry system controlled by a Programmable Logic Controller (PLC). The goal is to minimize human intervention while ensuring precision, consistency, and optimal timing in the powder coating pre-treatment process.

1. System Overview
The setup consists of:
• Seven tanks arranged linearly, each assigned a unique chemical treatment process.
• A vertical and horizontal gantry system to move and dip the metal component.
• A motorized gripper mechanism to hold and release the object.
• A PLC to control all movement, timing, and logic.

2. Hardware Components
• PLC (e.g., DELTA, Siemens, or Mitsubishi) – for centralized control.

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• AC/DC Motors or Servo Motors – for gantry movement (X and Z axes).
• Limit Switches/Sensors – for position feedback and end-stop detection.
• Timer Relays – for backup safety control.
• HMI (optional) – for user interface and real-time control/monitoring.

3. Software Design
• Ladder Logic Programming is used for sequence control.
• Each tank has a preset dwell time stored in the PLC memory.
• The object is dipped sequentially from Tank 1 to Tank 7, with the PLC controlling:
o Horizontal movement (tank-to-tank).
o Vertical movement (dipping and lifting).
o Timing per tank.
o Safety checks (object presence, gripper status).

4. Sequence of Operation
1. Object is loaded onto the gripper.
2. Gantry moves to Tank 1, lowers object, waits for set time.
3. Gantry lifts object, moves to Tank 2, and repeats the process.
4. Process continues up to Tank 7.
5. After final dip, the object is lifted and moved to the unloading position.

5. Safety & Fail-Safe
• Sensors are embedded for object detection and motor feedback.
• Emergency stop and manual override are available on the PLC panel.
• All movements are interlocked to prevent collisions and false triggers.

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Future Scope

The development of a PLC-based automatic 7-tank process system offers a solid foundation for further advancements in industrial automation and smart manufacturing. While the current system achieves precision, efficiency, and reduced human intervention, several future enhancements can significantly improve its scalability, sustainability, and integration into Industry environments.

1. Integration with SCADA and IoT Platforms

• Implementing SCADA (Supervisory Control and Data Acquisition) systems can provide real-time visualization, remote control, and historical data logging.

• IoT-based connectivity will allow remote monitoring, predictive maintenance, and cloud-based analytics for improved decision-making.

2. AI-Based Process Optimization

• Incorporating Artificial Intelligence (AI) and Machine Learning (ML) algorithms can help in optimizing dwell times, identifying faults, and suggesting preventive maintenance schedules based on historical trends.

3. Energy Efficiency Enhancements

• Future designs may include solar-powered drive systems or energy regeneration mechanisms to reduce power consumption.

• Smart sensors can track chemical usage and suggest optimized cycles, reducing chemical wastage and operational costs.

4. Multi-Object Handling Capability

• The gantry can be upgraded to handle multiple workpieces simultaneously, increasing throughput and making the system more suitable for large-scale operations.

5. Adaptive Process Customization

• Future systems may allow auto-detection of object size/type, dynamically adjusting tank times and movement speed accordingly, making the system flexible for various product categories.

6. Enhanced Safety Features

• Advanced vision systems or thermal sensors can be integrated for detecting abnormalities like overheating or object misplacement in real-time.

7. Compact & Modular Design

• Modularizing the setup can make it easier to transport, install, and maintain. It would also allow industries to scale the number of tanks as per their need (e.g., from 5 to 9 tank systems).

IV. CONCLUSION

The development and implementation of a PLC-based fully automatic 7-tank process system mark a significant step toward industrial automation in surface treatment and powder coating applications. By replacing manual operations with a motorized gantry system controlled by a PLC, the proposed system achieves higher accuracy, reduced labor dependency, and enhanced process consistency. It minimizes human error, ensures uniform dipping times, and improves product quality while saving operational time and costs.

The project successfully demonstrates the use of ladder logic programming, motor control, and sensor feedback systems to automate the sequential movement of metal objects through seven chemical treatment tanks. Moreover, the system can be further enhanced through IoT integration, AI-based optimization, and smart energy management techniques.

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This automation approach not only enhances the overall productivity of manufacturing units but also aligns with the objectives of Industry 4.0, making industrial processes smarter, more reliable, and sustainable.

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