PLC-Based Chemical Tank Level Control System

|Pandhare Nalini V.|Ghogare Mansi V.|Jawadwar Mansi S.| Kadam Shradhha M.|Pople Namrata U.|

lecturer, Department of Electronics and Telecommunication Student, Department of Electronics and Telecommunication

Vishweshwarayya Institute of Engineering & Technology, Almala, India

ABSTRACT:

This paper presents a PLC-based chemical tank level control system using the Siemens LOGO! . Two water-level sensors (low and high) continuously monitor the tank, and a 12V DC relay-driven pump maintains liquid within safe limits. Ladder Diagram logic programmed in LOGO! Soft Comfort ensures automatic pump ON/OFF without human intervention, preventing overflow and dry-running. The system was tested over 50 cycles with zero faults, confirming reliable and cost- effective industrial automation.

KEYWORDS PLC; Siemens LOGO!; chemical tank; level control; relay; ladder logic; automation.

I. INTRODUCTION

Chemical storage tanks are critical assets in industries such as water treatment, pharmaceuticals, food processing, and chemical manufacturing. Maintaining the correct liquid level inside these tanks is essential for safe and efficient operation. Excess liquid causes overflow and chemical wastage, while insufficient liquid risks pump damage due to dry running.

Traditional manual monitoring is labour-intensive and error-prone. The emergence of Programmable Logic Controllers (PLCs) has enabled fully automated, reliable, and easily reconfigurable control solutions. This work implements an automated level-control loop using the Siemens LOGO! 12/24 RCE PLC, two conductive water-level sensors, a 12V DC relay, and a centrifugal pump.

The PLC executes a Ladder Diagram program that continuously scans sensor inputs and drives relay outputs, thereby keeping the tank level between a user-defined low limit and high limit without any human intervention.

A. Background

Float-switch and relay-based level controllers provided the earliest form of automation but suffered from poor accuracy, mechanical wear, and inflexibility. Microcontroller platforms (Arduino, PIC) improved flexibility but lack the industrial robustness required in chemical environments. PLC-based systems combine reliability, real-time response, and easy re-programmability.

B. Problem Statement

Many industries still rely on conventional manual monitoring that is insufficient to ensure accuracy, safety, and efficiency. Key issues include:

1. Overflow causing spillage of hazardous chemicals and environmental pollution.
2. Pump damage due to dry running when liquid levels fall too low.
3. Lack of real-time monitoring and automatic corrective action.
4. Limited flexibility and high modification cost in conventional systems.

C. Objectives

1. Design and develop an automated tank level control system using PLC.

2. Continuously monitor liquid level using two sensors (low and high).
3. Maintain liquid level between minimum and maximum limits automatically.
4. Start the pump automatically when liquid falls below the low-level sensor.
5. Stop the pump automatically when liquid reaches the high-level sensor.
6. Prevent overflow conditions and dry running of the pump.
7. Reduce human effort and improve safety in chemical handling.

II. LITERATURE REVIEW

1. Wei et al. (2024) presented a PLC-based industrial liquid level control system that improves automation and accuracy in monitoring tank levels. Their work highlights the importance of PLC in industrial environments for maintaining stable liquid levels and reducing human intervention.
2. Iqbal et al. proposed a PLC-based overflow protection system for tanks, focusing on safety mechanisms. Their study emphasizes the need for reliable control systems in handling hazardous liquids, which is highly relevant for chemical tank applications.

3. Das (2013) developed an automated tank level control system using PLC integrated with SCADA. The study demonstrates how real-time monitoring and visualization improve operational efficiency and control in industrial processes.

4. Hajar et al. (2023) designed a system combining PLC and HMI for automatic control of water level and pressure. Their research shows that integrating monitoring interfaces enhances system usability and performance.

5. Illes et al. introduced a PLC-based tank level control system using wireless sensors. This approach enables remote monitoring and provides flexibility in industrial automation systems.

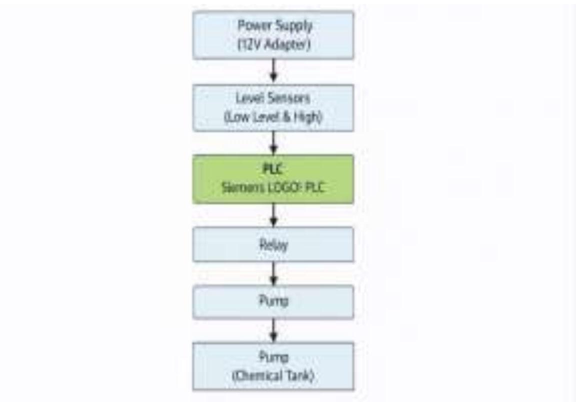
6. Mahmood et al. discussed the application of PID controllers in liquid level systems. Their findings indicate that PID control improves system stability and accuracy, especially in dynamic conditions.

7. Recent studies also explore IoT-based and intelligent control methods, which allow real-time data access and advanced automation. These approaches are increasingly being adopted in modern chemical industries.

A. Existing Technologies

1. Manual Level Control: Prone to human error; unsuitable for hazardous environments.
2. Float Switch-Based: Simple but limited accuracy and mechanical wear issues.
3. Relay-Based Control: Complex wiring, difficult to modify or troubleshoot.
4. Timer-Based Systems: Unreliable as actual liquid level is not measured.
5. Microcontroller-Based: Suitable for academic use; not industrial-grade.
6. SCADA-Based: Advanced but expensive; used in large industries only.
7. PLC-Based (Modern): Most widely used; combines automation, flexibility, reliability.

III. METHODOLOGY



1. **System Planning**

- Identify requirements such as tank capacity, type of chemical, and safety needs.
- Decide the components required for the system.

2. **Component Selection**

- Select PLC as the main controller.
- Choose suitable level sensors (float, ultrasonic, or pressure type).
- Select pump/valve, relay module, and power supply.

3. **System Setup**

- Arrange and connect all components properly.
- Ensure correct wiring between sensors, PLC, and output devices.

4. **PLC Programming**

- Develop control logic using ladder programming in Siemens LOGO! Soft Comfort.
- Set conditions:
  - Low level → Pump ON
  - High level → Pump OFF

5. **Control Operation**

- Sensors continuously monitor the liquid level.
- PLC receives signals and controls the pump automatically.
- Maintains the liquid level within desired limits.

6. **Safety Implementation**

- Add protection against overflow and dry running.
- Ensure safe handling of chemicals.

7. **Testing and Calibration**

- Test system under different conditions.
- Calibrate sensors for accurate readings.

8. **System Evaluation**

- Check performance based on accuracy, response time, and reliability.
- Make improvements if required.

IV. WORKING PRINCIPLE

On power-up, the PLC initialises all I/O and enters its cyclic scan loop:

1. Step 1 – Power ON: 12V adapter energises PLC, sensors, and relay circuit.
2. Step 2 – Level Monitoring: Sensors report to inputs I1 (low) and I2 (high).
3. Step 3 – Low-Level (I1=HIGH): PLC activates Q1, energising relay coil.
4. Step 4 – Relay Closes: Pump receives power and fills the tank.
5. Step 5 – High-Level (I2=HIGH): PLC de-activates Q1, relay opens, pump stops.
6. Step 6 – Loop Repeats: Cycle continues maintaining level between limits.

A latching rung keeps the pump ON after the low-level signal drops until the high-level signal is received, preventing rapid pump cycling.

V. SOFTWARE DESIGN

A. Programming Environment

Siemens LOGO! Soft Comfort provides drag-and-drop LAD/FBD programming with a built-in simulator for offline verification before USB download to the PLC.

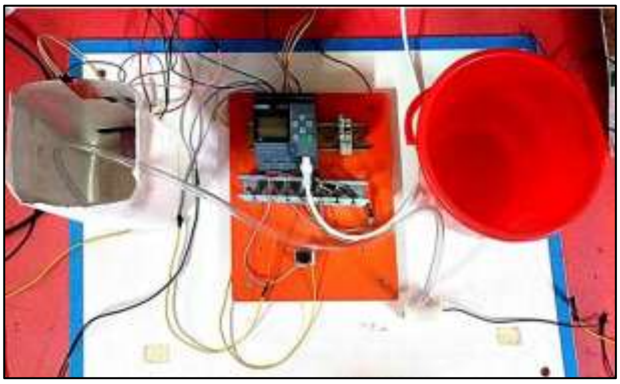
B. Ladder Logic

1. Normally-open I1 in series with normally-closed I2 drives coil Q1.
2. Self-holding (latch) contact Q1 in parallel with I1 keeps pump ON until tank is full.
3. Normally-closed I2 breaks the latch when tank is full, stopping the pump.

VI. IMPLEMENTATION AND RESULTS

The prototype was assembled and tested with water in a transparent acrylic tank.

The PLC was programmed with the ladder logic from Section V and verified in LOGO! Soft Comfort simulation before download.



A. Observed Behaviour

1. Pump activated within one PLC scan cycle (~10 ms) after low-level trigger.
2. Pump deactivated immediately upon high-level activation; no overflow observed.
3. Latching rung prevented pump chatter during level rise between sensors.
4. 50 consecutive ON/OFF cycles in a 2-hour endurance test; zero faults.

B. Performance Summary

Parameter	Value
PLC Scan Cycle Time	~10 ms
Pump Activation Delay	< 15 ms
Pump Stop Delay	< 15 ms
Control Accuracy	±5 mm
Test Duration	2 hr / 50 cycles
Fault Count	0

Table I. Experimental Performance

VII. CONCLUSION

This paper presented the design, implementation, and testing of a PLC-based chemical tank level control system using the Siemens LOGO!. The system successfully automates liquid-level management by monitoring two digital level sensors and controlling a pump through a relay, preventing both overflow and dry-running conditions.

Experimental results demonstrated zero faults over a 2-hour, 50-cycle endurance test with pump delays below 15 ms. The approach offers a cost-effective, reliable alternative to manual systems and provides a strong foundation for future IoT and AI-based integration.

REFERENCES

1. https://drpress.org/ojs/index.php/fcis/article/view/1703
2. https://researcher.manipal.edu/en/publications/overflow-protection-of-level-tanks-using-programmable-logic-contr
3. https://ijcs.net/ijcs/index.php/ijcs/article/view/4127
4. https://ijariie.com/FormDetails.aspx?MenuScriptId=159647
5. https://www.researchgate.net/publication/271258009