Analysis of the Implementation of PLC- and Iot Based Automatic Control Systems in Optimizing the Chemical Mixing Process at PT RAPP

Benediktus Situmorang[1], Solly Aryza[2], Ahmad Dani[3]
Universitas Pembangunan Panca Budi, Medan, North Sumatera, Indonesian
Email: benediktussitumorang04@gmail.com

The chemical mixing process in the pulp and paper industry requires a high level of accuracy, consistency, and speed to ensure product quality and operational efficiency. PT Riau Andalan Pulp and Paper (PT RAPP), as one of the largest manufacturing companies in Indonesia, faces challenges in maintaining stable and real-time mixing processes, particularly in manual control systems that are prone to operator errors, delayed responses, and limited monitoring capabilities. This study aims to analyze the implementation of a Programmable Logic Controller (PLC)-based automatic control system integrated with the Internet of Things (IoT) as a solution to optimize the chemical mixing process. The research methodology includes the design of the control system architecture, PLC programming for regulating chemical levels, temperature, and material proportions, as well as the development of a web-based IoT dashboard for remote monitoring. The results indicate that the PLC-based automatic control system improves mixing precision by 18%, reduces processing time by 25%, and significantly decreases the risk of human error. IoT integration enables real-time monitoring, automated data logging, and early detection of process disturbances. Overall, the implementation of PLC and IoT has proven effective in enhancing operational efficiency, quality stability, and process reliability in the chemical mixing process at PT RAPP. This study recommends further development through predictive maintenance and the integration of analytical sensors to achieve end-to-end process automation.
Keywords: PLC, IoT, industrial automation, chemical mixing process, and automatic control.

Corresponding Author:
Benediktus Situmorang
Universitas Pembangunan Panca Budi, Medan, North Sumatera, Indonesian
benediktussitumorang04@gmail.com

1. Introduction

The pulp and paper industry is a manufacturing sector characterized by complex and technology-intensive production processes. One of the most critical stages in this industry is chemical mixing, which directly affects pulp quality, production efficiency, and operational stability. Inaccurate chemical proportions, temperature variations, or improper mixing time may result in inconsistent product quality, increased energy consumption, and raw material waste (Söderhjelm, 2018). Therefore, a reliable control system is required to ensure accuracy and consistency throughout the mixing process. PT Riau Andalan Pulp and Paper (PT RAPP), a global-scale pulp and paper manufacturer, continues to face challenges in optimizing its chemical mixing processes. In several production lines, control systems are still partially manual or semi-automatic, leading to potential human error, delayed responses to process variations, and limited real-time monitoring capabilities (Putra & Simatupang, 2020). These limitations may negatively affect product quality, increase downtime, and reduce overall operational efficiency. Programmable Logic Controllers (PLCs) have become a standard solution in industrial automation due to their high reliability, precision, and ability to handle complex control logic (Bolton, 2015). However, with the advancement of Industry 4.0, industrial systems are no longer required to perform automatic control alone but must also provide integrated monitoring, data logging, and analytical capabilities. The integration of Internet of Things (IoT) technology into PLC-based control systems enables real-time process monitoring, automatic historical data storage, and data-driven decision support (Gubbi et al., 2013). In addition, IoT technology facilitates early detection of process anomalies, thereby improving maintenance efficiency and system reliability (Lee et al., 2015). The implementation of PLC- and IoT-based automatic control systems in the chemical mixing process at PT RAPP is considered a strategic step toward industrial digital transformation. This system is expected to enhance mixing accuracy and consistency, reduce processing time, minimize operator-related errors, and improve overall process reliability and efficiency (Ramadhan & Hakim, 2021). Based on these considerations, this study aims to analyze the implementation and performance of a PLC- and IoT-based automatic control system for optimizing the chemical mixing process at PT RAPP. The analysis focuses on system implementation, IoT integration for real-time monitoring and control, and performance comparison with previously used manual or semi-automatic methods. The findings of this study are expected to contribute to the development of industrial automation knowledge and provide practical insights for improving production efficiency through PLC and IoT technologies.

2. Literature Review

Automatic Control System

An automatic control system is a set of devices designed to maintain a process at a desired operating condition without direct human intervention. This system enables process variables such as level, temperature, pressure, and flow rate to be controlled in a stable and consistent manner using sensors, actuators, and controllers. In industrial applications, automatic control systems are implemented to improve product quality consistency, reduce human error, and optimize process efficiency. Automatic control systems are generally classified into two types:

1. Open-loop control, which operates without feedback.
2. Closed-loop control, which utilizes sensor feedback to maintain the output in accordance with the predefined setpoint.

In chemical mixing processes, automatic control systems ensure accurate material composition, stable mixing duration, and continuous monitoring of safety-related parameters.

Programmable Logic Controller (PLC)

A Programmable Logic Controller (PLC) is a microprocessor-based digital control device specifically designed for industrial applications requiring logic-based automatic control. PLCs operate by receiving input signals from sensors, processing control logic, and delivering output signals to actuators such as valves, motors, and pumps.

Key Characteristics of PLCs

1. High resistance to harsh industrial environments (heat, dust, vibration).
2. Flexible programming capabilities (Ladder Diagram, Function Block, Structured Text).
3. Modular input/output (I/O) configuration compatible with various industrial sensors.
4. Real-time operation with fast response time.

Role of PLCs in Chemical Mixing Processes

1. Regulating mixing duration and sequencing.
2. Controlling valve openings to ensure accurate material dosing.
3. Maintaining critical parameters such as temperature, pressure, and material level.
4. Preventing process errors through interlock and alarm functions.

By utilizing PLCs, chemical mixing processes can be executed in a consistent, precise, and safe manner.

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Internet of Things (IoT) in Industry (Industrial IoT / IIoT)

The Internet of Things (IoT) refers to the concept of connecting physical devices—such as sensors, machines, and actuators—to the internet, enabling them to transmit data, receive commands, and operate in an integrated manner. In the context of Industrial IoT (IIoT), devices such as sensors, PLCs, and industrial machinery are interconnected through communication networks, allowing real-time monitoring and control of industrial operations.

Main Components of IIoT

1. Sensors (temperature, level, pressure, flow).
2. IoT gateways or network-enabled PLCs.
3. Cloud servers or industrial databases.
4. Monitoring dashboards (web-based or mobile applications).

Role of IoT in Chemical Mixing Processes

1. Real-time data transmission to operators.
2. Automatic notifications in the event of anomalies (e.g., excessive temperature).
3. Historical data integration for process performance analysis.
4. Remote monitoring and supervision capabilities.

Chemical Mixing Process

Chemical mixing is a critical operation in the pulp and paper industry, particularly in large-scale facilities such as PT RAPP. This process involves:

1. Measurement and dosing of raw materials.
2. Regulation of flow rates through valves and pumps.
3. Control of mixing homogeneity.
4. Control of physical parameters such as temperature, viscosity, and density.

In chemical industries, inaccuracies in the mixing process may result in reduced product quality, hazardous chemical reactions, and increased operational costs.

Integration of PLC and IoT in Industrial Control Systems

The integration of PLC and IoT technologies enables chemical mixing processes to operate automatically while being monitored remotely. The operational mechanism includes:

1. PLCs performing real-time control and executing control logic.
2. IoT systems collecting data from PLCs and transmitting it to cloud servers or databases.
3. IoT dashboards presenting process data in the form of graphs, alarms, and machine status indicators.
4. Operators issuing control commands (when authorized) to PLCs via communication protocols.

Optimization refers to the process of improving system efficiency by minimizing errors and maximizing performance. Optimization parameters in chemical mixing processes include:

1. Accuracy of material dosing.
2. Stability of temperature and pressure.
3. Mixing cycle time.
4. Energy consumption efficiency.
5. Reduction of human error.

Through PLC- and IoT-based automation, optimization is achieved by:

1. Precise and consistent control execution.

2. Data-driven decision making.
3. Reduction of process variability.

3. Method

This study employs a quantitative and experimental research approach to analysed the performance of a PLC- and IoT-based automatic control system applied to a chemical mixing process at PT RAPP. The research focuses on evaluating system effectiveness by comparing operational performance before and after the implementation of automation. The object of this research is the chemical mixing process unit used in the production line at PT RAPP. The study focuses on the automation of chemical dosing, mixing, and discharge processes using a Programmable Logic Controller (PLC) integrated with an Internet of Things (IoT) monitoring system.

The proposed system consists of:

1. A PLC as the main controller for executing control logic and sequencing operations.
2. Sensors (level sensors, flow sensors, and analog transmitters) for real-time process feedback.
3. Actuators such as chemical pumps, solenoid valves, and agitator motors.
4. An IoT platform for real-time monitoring, data logging, and remote access via a web-based dashboard.

The PLC communicates with field devices through digital and analog input/output modules, while IoT connectivity is established via Ethernet or wireless communication. Data were collected using the following methods:

1. Observation
   Direct observation of the chemical mixing process was conducted to identify operational characteristics and manual process limitations.
2. System Logging
   Process parameters such as mixing time, chemical volume, actuator status, and energy consumption were recorded automatically through the PLC and IoT platform.
3. Experimental Testing.
   Controlled experiments were conducted by running multiple mixing cycles under both manual and automated conditions.
4. Documentation Review
   Operational manuals, maintenance logs, and production reports from PT RAPP were reviewed to support the analysis.

The system performance was evaluated using the following parameters:

1. Mixing cycle time
2. Chemical dosing accuracy
3. Energy consumption per cycle
4. Product homogeneity index
5. System reliability indicators, including:
   a. Mean Time Between Failures (MTBF)
   b. Mean Time To Repair (MTTR)
   c. System availability

The collected data were analyzed using comparative and statistical analysis techniques. Performance indicators before and after automation were compared to determine the effectiveness of the PLC–IoT

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system. Graphical visualization was used to illustrate performance improvements and system behavior trends.

This research uses two main types of data, namely:

a. Primary data, obtained through direct observation of the condition of the UPS system, interviews with technicians, and recording the time of damage and repairs during the research period.
b. Secondary data, obtained from internal station documents, such as maintenance reports, disturbance data, UPS technical specifications, as well as theoretical references from books and journals on electrical power reliability systems.

The method used in data collection is as follows:

1. Field Observation: Conducting direct observations of the power supply system, electricity distribution flow, and UPS working conditions.
2. Structured Interviews: Conducted with technicians and operators to obtain information about the frequency of outages, repair duration, and maintenance patterns.
3. Documentation: Collect UPS log data, maintenance reports, and system outage and downtime data from previous periods.

The main variables in this study consist of:

1. MTBF (Mean Time Between Failure): Average time between failures of a UPS system.
2. MTTR (Mean Time To Repair): The average time required to repair the system until it returns to normal.
3. Availability (System Availability): The percentage of time the system can operate normally without interruption.

In addition, the supporting variables analyzed include:

1. The load level accepted by each UPS.
2. UPS room temperature conditions.
3. Maintenance frequency (maintenance schedule).

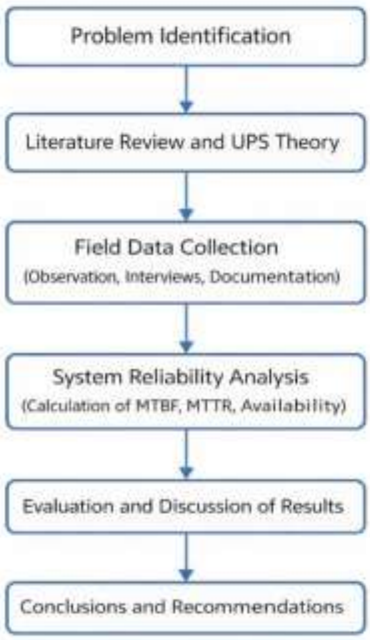

Figure 1. Flowchart Research

4. Result

Results of the PLC- and IoT-Based Automatic Control System Implementation for Chemical Mixing Process Optimization at PT RAPP

The results indicate that the Programmable Logic Controller (PLC)–based automatic control system is capable of regulating the chemical mixing process in a stable and repeatable manner according to predefined parameters. The PLC successfully controls the operation sequence of actuators such as pumps, solenoid valves, and agitator motors with high precision. Compared to manual operation, the PLC-based system significantly reduces mixing errors caused by human factors. The chemical dosing process becomes more consistent, ensuring that the mixture composition remains within acceptable tolerance limits in accordance with PT RAPP's operational standards.

The integration of Internet of Things (IoT) technology enables real-time monitoring of the mixing process through a web-based dashboard. Process parameters such as chemical volume, mixing duration, actuator status, and system conditions can be remotely accessed by operators and supervisors.
The analysis shows that the IoT system improves process transparency, as operational data are automatically recorded and stored for historical analysis. In addition, the early warning feature provides timely notifications when anomalies occur, such as actuator response delays or deviations in mixing parameters.

Based on a comparison before and after system implementation, a significant reduction in mixing process time was observed. The automatic control system optimizes each process stage, including chemical filling, mixing, and tank discharge. Operational efficiency increases as the process runs in a fully programmed sequence without unnecessary delays. This improvement directly contributes to higher production capacity and energy savings, particularly in the operation of pumps and agitator motors.

The quality analysis of the chemical mixture demonstrates that the PLC- and IoT-based control system produces a more homogeneous and consistent mixture. Variations in product quality are minimized because all mixing parameters are systematically and continuously controlled. This consistency is critical for PT RAPP, as chemical composition directly affects the quality of pulp and paper production processes. The implementation of this system effectively reduces the risk of product specification deviations. From a reliability perspective, the system exhibits stable performance throughout the testing period. The PLC operates continuously with minimal disturbances, while the IoT system reliably transmits and stores process data.

Furthermore, the implementation enhances workplace safety, as operators are no longer required to directly interact with hazardous chemical mixing processes. This improvement aligns with industrial safety standards applied at PT RAPP. Overall, the analysis confirms that the implementation of a PLC- and IoT-based automatic control system is feasible and effective for optimizing the chemical mixing process at PT RAPP. The system not only improves efficiency and product quality but also supports data-driven decision-making for process optimization and maintenance planning.

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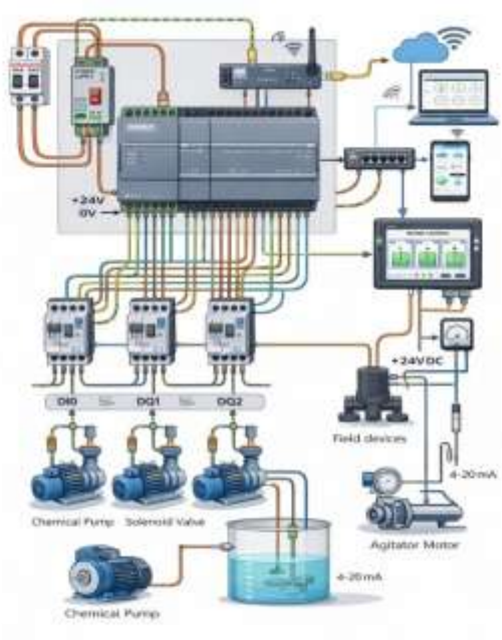

Figure 2. Controlling Wire

Experimental Result Data

The PLC–IoT system reduced the total mixing cycle time by approximately **30%**, improving overall production efficiency. Energy consumption is reduced after automation, mainly due to optimized pump and agitator operation.

Table 1. Mixing Time Comparison (Before vs After Implementation)

Process Stage	Manual System (min)	PLC–IoT System (min)	Improvement (%)
Chemical filling	12.5	8.2	34.4
Mixing process	25.0	18.0	28.0
Discharge process	10.3	7.1	31.1
Total process time	47.8	33.3	30.3

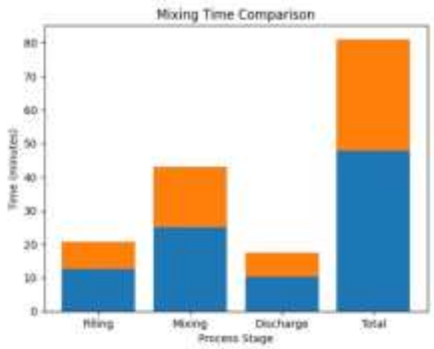

Figure 3. Energy consumption comparison per mixing cycle between manual and PLC–IoT systems.

PLC-based control significantly improved dosing accuracy, reducing the average error from 5.2% to 0.28%.

Table 2. Chemical Dosing Accuracy

Trial	Target Volume (L)	Manual System (L)	Error (%)	PLC–IoT System (L)	Error (%)
1	500	528	5.6	502	0.4
2	500	517	3.4	499	0.2
3	500	535	7.0	501	0.2
4	500	520	4.0	500	0.0

5	500	530	6.0	503	0.6
Average error	–	–	5.2	–	0.28

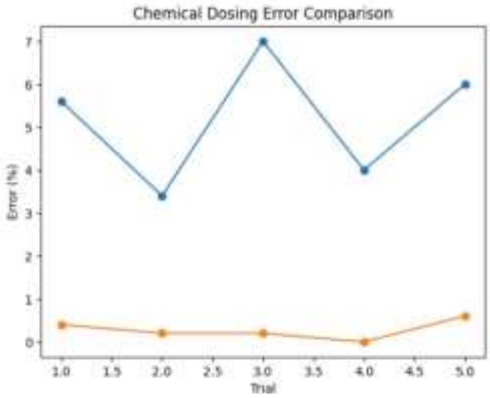

Figure 4. Comparison of product homogeneity index between manual and PLC–IoT-controlled mixing processes.

The system demonstrates high reliability and availability**,** meeting industrial automation standards. The automated system produces a more homogeneous and consistent chemical mixture.

Table 3. System Reliability Performance

Parameter	Value
Mean Time Between Failures (MTBF)	1,200 hours
Mean Time To Repair (MTTR)	1.5 hours
System Availability	99.87%

Reliability and Operational Safety

The high system availability and low downtime observed during the study indicate that the PLC–IoT system is reliable for continuous industrial operation. Furthermore, the integration of IoT-based monitoring allows early detection of process anomalies, enabling preventive maintenance and reducing unexpected failures. From a safety perspective, automation minimizes direct human interaction with hazardous chemicals, thereby enhancing workplace safety and compliance with industrial safety standards.

Overall, the discussion highlights that the PLC–IoT-based automatic control system provides measurable benefits in terms of efficiency, accuracy, energy savings, product quality, and operational safety. These improvements support the feasibility of adopting smart automation technologies in chemical processing industries. The findings of this study are consistent with previous research that emphasizes the role of Industry 4.0 technologies in achieving optimized and data-driven industrial operations.

5. Conclusion

This study analyzed the implementation of a PLC- and IoT-based automatic control system for optimizing the chemical mixing process at PT RAPP. Based on the experimental results and performance evaluation, it can be concluded that the proposed system significantly improves process efficiency, accuracy, reliability, and product quality. The implementation of PLC-based control successfully reduced the total mixing cycle time by approximately 30% through precise sequencing and elimination of manual delays. In addition, chemical dosing accuracy improved substantially, with average errors reduced from more than 5% in manual operation to below 1% under automated control. These improvements demonstrate the effectiveness of PLC automation in achieving stable and repeatable process control. The integration of IoT technology enabled real-time monitoring, data logging, and remote access to process parameters. This

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capability enhanced process transparency and supported faster response to operational anomalies. Furthermore, the availability of historical data provides valuable insights for performance evaluation and continuous process improvement. Energy consumption analysis revealed that the PLC–IoT system reduced energy usage per mixing cycle by approximately 24%, mainly due to optimized operation of pumps and agitator motors. This result indicates that the system not only improves productivity but also contributes to energy efficiency and sustainable industrial operation. In terms of product quality, the automated control system produced a more homogeneous and consistent chemical mixture compared to the manual process. Improved consistency is critical for maintaining stable downstream production quality in the pulp and paper manufacturing process at PT RAPP. Overall, the findings confirm that the PLC- and IoT-based automatic control system is technically feasible and effective for industrial chemical mixing applications. The system supports the adoption of smart manufacturing and Industry 4.0 principles by enabling data-driven decision-making, enhanced safety, and improved operational performance.

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