International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 05 May 2025
Page No: 2621 - 2626
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0388

Real-Time Industrial Process Monitoring and Safety Enhancement Using PLC and SCADA

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Abstract
As per the change in industrial automation to make it more digitalized and advanced to improve production, various technologies have been introduced, one of the key methods to improve production is the reduction of faults. In this paper, you will get to know how faults can be monitored by using SCADA screens, where we can collect the output data of the PLC to generate signals on the SCADA screens as per requirement. This will automate the process and also calculate fault time and display it on the SCADA screens, so we can calculate up time and down time based on that observation, which will help to enhance production by monitoring and reducing the fault. also, it consists safety enhancement technique by installation of camera to capture human presence in overhead areas of factory to start or stop the production process as per sensing human presence for their safety. this whole research will help you to achieve real time monitoring in the overhead areas easily to detect and reduce the fault with safety enhancement.

Keywords: *SCADA, PLC, Safety camera, Industrial Automation, Real-time Monitoring, Safety Systems, Production Time, Down Time, fault calculation.*

1. Introduction

In modern industrial environments, real-time monitoring and safety mechanisms are essential for maximizing operational efficiency and minimizing risk. This research focuses on upgrading traditional HMI-based systems with a SCADA-integrated platform, enabling centralized, zone-wise, and shift-wise fault tracking across an industrial setup. In addition to enhancing visibility and fault diagnostics, the proposed system integrates AI-based safety cameras to detect human presence in hazardous areas, such as overhead conveyors, thereby reducing the likelihood of workplace accidents. The developed framework supports improved fault quantification, buffer time analysis, and decision-making processes, ultimately contributing to better productivity and proactive maintenance strategies. In contemporary industrial setups, timely access to operational data and effective safety systems plays a critical role in maintaining productivity and worker safety. Traditional Human-Machine Interface (HMI) systems, though functional, often lack centralized monitoring capabilities and are restricted to limited zones. These limitations can result in delayed fault detection, increased downtime, and suboptimal response times. To address these issues, this project explores the transition from an HMI-based infrastructure to a centralized Supervisory Control and Data Acquisition (SCADA) system. The upgraded framework supports real-time monitoring of all shop floor zones, facilitates efficient fault logging on an hourly and shift-wise basis, and enables improved analysis through data visualization. Furthermore, safety has been significantly enhanced through the incorporation of cameras that identify human presence in restricted overhead areas. The system automatically halts conveyors upon detecting potential hazards, thereby preventing accidents and improving workplace safety. By integrating automation, intelligent safety mechanisms, and robust monitoring systems, the project demonstrates a scalable approach to industrial performance enhancement and risk mitigation.

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2. Problem Statement

2.1. Inconsistent Count Data Monitoring

The count data monitoring system in the previous setup was inconsistent, leading to frequent errors in tracking the number of operations or processed items. This inconsistency directly affected production accuracy and performance evaluation.

2.2. Lack of Dedicated SCADA Screens for Overhead Monitoring

There were no dedicated SCADA screens for comprehensive monitoring of the overhead system. This resulted in poor visibility into crucial operational parameters, including:

2.2.1. Faults Occurring in Real Time

- **Previous Issue:** No dedicated screens were available to display real-time faults.
- **Importance:** Real-time fault detection is essential to minimize downtime and immediately alert operators for quick intervention. Without timely information, faults go unnoticed, leading to extended disruptions in the production line and delayed maintenance response.

2.2.2. Current Mode of Operation (Auto/Manual)

- **Previous Issue:** No screens were available to indicate the system's operational mode.
- **Importance:** Knowing whether the system is running in automatic or manual mode is crucial for both troubleshooting and productivity analysis. If the system is unknowingly left in manual mode, automation efficiency is compromised, and operator workload increases unnecessarily.

2.2.3. Fault Wait Time Tracking

- **Previous Issue:** No dedicated SCADA screen was available for displaying fault wait time.
- **Importance:** Fault wait time tracking enables calculation of how long the system stays idle due to unresolved issues. Without this metric, it becomes impossible to analyse MTTR (Mean Time to Repair) accurately, making it harder to identify weak points in the maintenance process or bottlenecks in fault resolution.

2.3. Status of Empty Dollies

- **Previous Issue:** As shown in fig 1 Data for empty dollies was often incorrect or not monitored.
- **Importance:** Tracking empty dollies is important for ensuring a continuous supply of components or materials. If data is incorrect, it may trigger unnecessary stoppages due to assumptions that no dollies are available, even when they or vice versa—creating confusion and inefficiencies (Figure 1)

Figure 1 Status of Empty Dollies

2.4. Presence of Dollies in Designated Zones

- **Previous Issue:** As shown in fig 2 Presence detection data was either unavailable or inaccurate.
- **Importance:** Confirming that dollies are in the correct zones helps maintain flow within the production line. Inaccurate or missing data may lead to incorrect process initiation, missed pickups, or blocked areas, which all contribute to reduced productivity and logistical errors. (Figure 2)

Figure 2 Presence of Dollies in Designated Zones

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2.5.RFID Status

- **Previous Issue:** As shown in fig 3 RFID tag detection status was often incorrect or not reflected in
- **Importance:** RFID-based tracking is used to validate material movement, dolly identity, or workflow sequence. Incorrect RFID data may cause wrong items to enter the process line, misrouting of components, or even halt the process entirely if validations fail leading to significant losses in time and quality. (Figure 3)

Figure 3 RFID Status

Since proper real-time monitoring was not available, and the existing system was often displaying incorrect or outdated data, the Mean Time to Repair (MTTR) for faults and breakdowns increased significantly. This not only delayed corrective action but also reduced overall operational efficiency.

3. Methodology

To resolve the identified problem statements such as inconsistent count monitoring, absence of SCADA-based visualization, lack of dolly and RFID status tracking, and incorrect fault data, the proposed methodology has been structured to enhance both monitoring and safety. The process begins with a detailed study of the existing system, focusing on the current PLC configuration, limitations in data collection, and the lack of any centralized SCADA monitoring interface. This helps identify the key weaknesses in the system that affect real-time visibility and data accuracy. The detailed steps are as follows: (Figure 4)

3.1.Study of Previous System

The process begins with an in-depth analysis of the existing system, including its PLC logic, HMI setup, hardware structure, and communication patterns. This step helps identify the current limitations, such as inconsistent data monitoring, absence of fault tracking, and lack of safety mechanisms.

3.2.Analysing Problems

After understanding the previous system, the specific issues are analysed. These include missing or inaccurate HMI screens, inconsistent PLC count data, and no real-time feedback or monitoring for faults, dolly statuses, or RFID validations. This step forms the foundation for targeted improvements.

3.3.PLC Logic Correction

Based on the identified issues, the PLC logic is updated. The corrections aim to improve accuracy in data tracking (e.g., fault occurrence, dolly presence), ensure timely signal generation for SCADA visualization, and integrate logic for automation status (manual/auto mode). This step ensures the backend logic is reliable for real-time system performance.

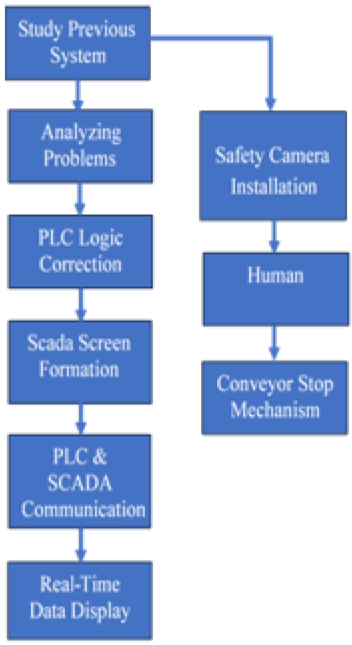

Figure 4 Methodology

3.4.SCADA Screen Formation

New SCADA screens are developed to visualize the critical data points that were previously unmonitored or misrepresented. These include:

- Real-time fault alerts

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- Auto/Manual status indicators
- Dolly empty/present detection
- RFID status
- Fault wait time tracking

Each screen is designed to provide clear and accessible information to the operator, enhancing decision-making and operational awareness.

3.5.PLC and SCADA Communication

Seamless communication between the PLC and SCADA system is established using industry-standard protocols such as Modbus. This ensures the accurate transmission of real-time data from the PLC to the SCADA interface, which is crucial for visualization and timely alerts.

3.6.Real-Time Data Display

With proper communication and logic setup, real-time data is now displayed on the SCADA screens. Operators can monitor system status, respond to faults immediately, and make informed decisions based on actual system conditions, which minimizes downtime and enhances overall efficiency.

3.7.Parallel Safety Enhancement Track

3.7.1. Safety Camera Installation

Simultaneously, camera system is installed in overhead or restricted factory zones where human presence could pose a safety hazard. This system is designed to detect human movement or presence using motion recognition or Human detection algorithms.

3.7.2. Human Detection

The camera continuously scans the designated area. Upon detecting a human in the zone, it sends a signal to the PLC. This signal acts as a trigger for halting the operation to prevent accidents.

3.7.3. Conveyor Stop Mechanism

The signal from the camera is processed by the PLC, which initiates a conveyor stop mechanism. This ensures the production line pauses immediately upon detecting a safety risk, thereby preventing potential injuries or accidents.

4. Results and Discussion

After implementing the proposed methodology, the new SCADA screens were successfully developed and integrated into the system to address the monitoring gaps identified in the previous setup. These screens now provide real-time visibility into several critical parameters that were previously unmonitored or inaccurately displayed. The newly designed SCADA interface includes separate visualizations for fault occurrence, auto/manual operation mode, dolly presence in designated zones, empty dolly detection, RFID scan status, and fault wait time tracking. Each of these screens plays a vital role in improving operator awareness and system responsiveness. (Figure 4)

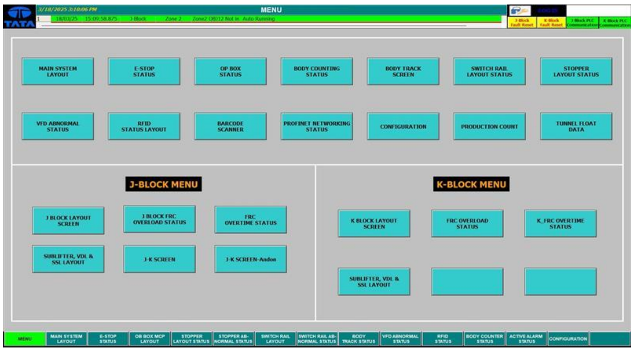

Figure 5 Result

Fig 4 is the main screen of the new SCADA system, which displays various buttons. Clicking on the indicated buttons opens the respective screens, providing detailed visuals and insights (Figure 5) is the Andon screen that displays the current ongoing status in the shop on a single interface. It also provides shop-wise data for better monitoring. Andon helps in real-time issue tracking, quick response, and improving overall efficiency

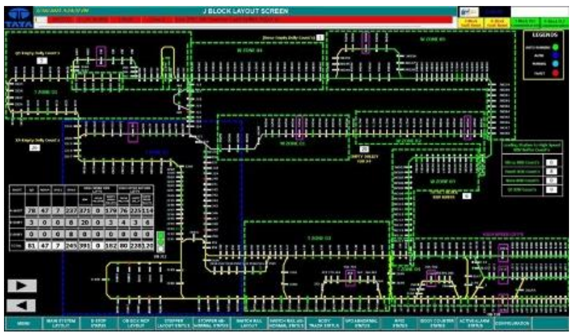

Figure 5 Andon Screen

(Figure 6) is the main screen that collects overall zone-wise and shift-wise fault time data, providing real-time, quantified insights for efficient monitoring.

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Figure 6 Zone-Wise and Shift-Wise Fault Time Data

After the main screen, multiple sub-screens are available, each displaying data related to specific elements involved in the conveyor process. These screens help monitor the status of each element individually, ensuring better visibility and control.

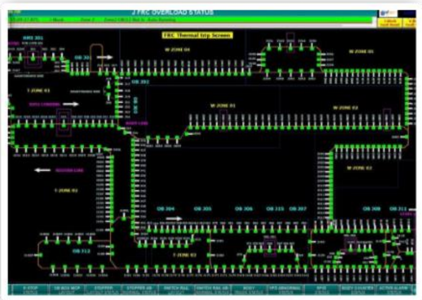

Figure 7 Main Screen

FRC Time Over: Figure 8 is used to indicate when a fault is not resolved within one minute, highlighted by a red indication block

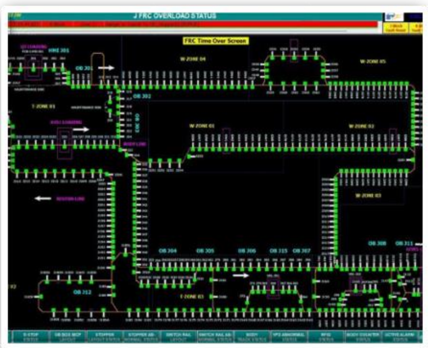

Figure 8 FRC Time Over

Stopper Status: (Figure 9) Shows the real-time working status of the stopper mechanism.

Figure 9 Stopper Status

Switch Rail Status: (Figure 10) Indicates the operational status of the switch rail on the line.

Figure 10 Switch Rail Status

Sub Lifter FRC Status: (Figure 11) Provides visual tracking of dolly movement across zones and offers zone-wise accurate dolly count.

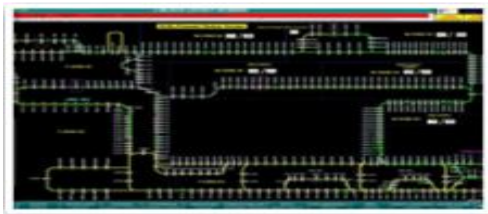

Figure 11 Sub Lifter FRC Status

Auto / Manual Status: (Figure 12) Displays whether the system is running in Auto or Manual mode, controlled via the OB box to switch modes as required.

RFID Status: (Figure 13) Offers detailed RFID-related information including RFID read status, error notifications, communication status, and tag detection.

Figure 13 RFID Status

Safety Status: Fig 14 Detects emergency button activation and displays hazard-related information.

Figure 14 Safety Status

Together, these sub-screens deliver real-time, accurate data that enhance automation, improve monitoring, and ensure efficient performance. For instance, the dolly status screens now clearly indicate whether a dolly is present or empty, helping manage logistics efficiently. The RFID status screen confirms tag scans, ensuring traceability and reducing manual verification efforts. Fault tracking has been made easier with a real-time fault display and fault wait timer, which allows operators to assess system performance and downtime more accurately. Compared to the previous system, where such data was either unavailable or unreliable, the upgraded SCADA system has significantly improved operational monitoring, reduced fault response time, and contributed to a more efficient and safe production environment.

Conclusion

This research demonstrated how PLC and SCADA integration, along with AI-driven safety systems, can significantly upgrade industrial monitoring and protection. The solution improved fault visibility, reduced reaction time, and proactively prevented accidents. By centralizing data, enhancing fault diagnostics, and proactively detecting safety threats, the system significantly boosts operational efficiency. The results validate the shift from reactive systems to predictive, intelligent automation. Moving forward, Future work will aim at cloud integration for remote access, using IoT-based analytics, and expanding AI surveillance to other critical points on the shop floor. Integration with cloud-based dashboards and expansion of AI monitoring to other areas of the plant will be explored.

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