IoT Enabled Real Time Load Height Monitoring and Control System Using PLC and HMI for Smart Industrial Solutions

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Abstrak

This paper presents a real-time IoT-enabled system for monitoring and controlling load height, integrating Programmable Logic Controllers with Human-Machine Interfaces, personal computers, and smartphones. Specifically designed for dynamic load height measurement, the system ensures precision and safety in industrial applications where accurate load control is critical. The research follows the System Development Life Cycle methodology for systematic design, implementation, and evaluation. The integration of IoT technology facilitates remote monitoring and control, offering users real-time data access through a cloud-based interface. The PLC processes sensor inputs to measure load height, and control signals are sent to adjust the system as necessary. The Haiwell C7S HMI provides a user-friendly interface for monitoring, controlling, and configuring parameters. Data is transmitted wirelessly to a central monitoring station, enabling remote supervision and decision-making. Key findings show that the system achieves a transmission delay of under 2 seconds, ensuring efficient real-time performance. Experimental results indicate the system provides accurate measurements and effective control actions. Additionally, the system is highly scalable, making it applicable across various industries such as warehousing, logistics, and manufacturing. This paper highlights the benefits of integrating PLC, IoT, and HMI technologies in creating a smart, automated load management system, contributing to improved productivity and operational oversight.

Kata kunci: *Internet of Things, Real Time Monitoring, Load Height Control, Programmable Logic Controller, Human-Machine Interface*

1. INTRODUCTION

In modern industrial environments, automation and precise control systems are essential for maintaining operational efficiency and ensuring safety. Among various processes, the monitoring and controlling of load height is a critical task, especially in industries such as warehousing, manufacturing, and logistics. Accurate monitoring of load height is vital for avoiding overloading, ensuring safety in transportation, and maintaining smooth production workflows. Traditional methods of load height management often involve manual measurement and adjustment, which are not only time-consuming but also prone to errors. As industries move towards smarter solutions, integrating automated systems with real-time monitoring capabilities has become a significant focus of research and development [1]–[3]. Programmable Logic Controllers (PLC) have long been used in industrial automation for their robustness and reliability in controlling complex processes [4]. PLCs provide flexible programming capabilities and can handle a wide range of input/output (I/O) configurations, making them suitable for monitoring and controlling tasks. However, in recent years, the integration of Internet of Things (IoT) with PLCs has enhanced the functionality of these systems, enabling remote monitoring and control through wireless communication [5], [6]. The IoT-based systems allow for real-time data transmission to cloud platforms [7], where it can be accessed remotely by operators or integrated into larger supervisory control systems interface (HMI) technology also plays a crucial role in improving the usability of such systems [8]. An HMI allows operators to visualize the data generated by the PLC, interact with the system, and make adjustments as needed. The Haiwell C7S HMI, specifically, offers a user-friendly interface with real-time data visualization, enabling operators to monitor load height effectively and control the system from a central control point.

The integration of IoT and HMI technologies in load height monitoring and control systems offers transformative advantages, enabling real-time feedback that enhances accuracy and reduces human errors. IoT implementation facilitates remote access, empowering operators to monitor and control load height from any location with internet connectivity [9]. This capability minimizes downtime, improves decision-making, and boosts overall productivity. Research has highlighted the scalability and adaptability of IoT-enhanced PLC systems across diverse industrial applications, showcasing their potential to revolutionize monitoring and control systems. Despite these advancements, several challenges persist in modern industrial environments, particularly in the context of real-time monitoring and remote control.

Many existing load monitoring systems are confined to local control and lack IoT integration, restricting the ability of operators to access real-time data remotely. This limitation impedes the adoption of smart manufacturing practices that rely on connectivity and automation. Additionally, conventional systems often fail to support seamless access across multiple platforms, such as PCs, smartphones, or tablets. This lack of compatibility reduces operational flexibility, inhibiting timely and effective decision-making in critical scenarios.

Outdated communication protocols further exacerbate these issues, as legacy systems rely on slower and less reliable methods that are not optimized for modern IoT frameworks. These methods are unsuitable for industrial environments that demand high-speed data transmission and real-time synchronization across multiple devices. Furthermore, traditional systems depend heavily on manual intervention, leading to delays in responding to critical events, such as when load height thresholds are reached. This reliance on human operators reduces overall system efficiency and increases the risk of errors.

Another significant challenge lies in the rigidity of current solutions, which often lack the flexibility to scale or integrate with enterprise-level systems such as ERP or MES [10]. This lack of scalability and interoperability hinders industries from achieving comprehensive operational digitization and optimizing workflows. Addressing these challenges is crucial for developing smarter, more efficient industrial solutions that align with the principles of Industry 4.0 [11]. By addressing these gaps, this research provides a practical solution that enhances industrial automation, improves accessibility, and aligns with the principles of Industry 4.0.

This paper proposes at monitoring and controlling system using PLC and IoT technologies, integrated with the Haiwell C7S HMI. The system is designed to ensure accurate and automated height measurement of loads, providing a smart solution for industries that require continuous monitoring and adjustment of load levels. The following sections will discuss the system architecture, implementation, and the experimental results that validate the effectiveness of the proposed solution.

. This research introduces significant advantages over previous research in several key areas, specifically by utilizing industry-grade devices that are designed to meet the demanding conditions of modern industrial environments. Unlike earlier solutions that may have focused on using more affordable but less robust platforms such as Arduino or Raspberry Pi, this research leverages a PLC system that is engineered to withstand high levels of vibration and extreme temperatures, making it more suitable for industrial applications. The selected hardware, Haiwell C7S HMI and the PLC, provides benefits such as ease of programming and design, with intuitive user interfaces that reduce development time and complexity. This is in contrast to platforms like Arduino or Raspberry Pi, which often require more manual coding and circuit design. Additionally, the durability and long lifespan of the equipment ensure that the system can function reliably in harsh industrial settings over extended periods, thus reducing maintenance costs and downtime. Another notable advantage of this research is the system's ability to integrate seamlessly with both smartphones and PCs. This integration supports remote monitoring and control, enhancing the flexibility and convenience for operators, which is critical in modern IoT-based industrial applications. The remote access feature provides real-time insights and control capabilities from virtually anywhere, improving overall operational efficiency.

However, while this study introduces advanced features and addresses the limitations of earlier research, there is a trade-off in terms of cost. The PLC and HMI devices used in this system are significantly more expensive than microcontroller-based alternatives such as Arduino or Raspberry Pi. This higher initial investment may be seen as a disadvantage, particularly for small-scale implementations or educational purposes. Despite this, the long-term benefits of using robust, industrystandard equipment, such as increased reliability and reduced maintenance, are likely to outweigh the higher upfront costs in industrial applications. This research aims to balance these factors, delivering a monitoring and control system that is highly reliable, scalable, and suitable for industrial deployment, while acknowledging the higher cost as a necessary trade-off for these benefits.

2. RESEARCH METHODS

The research develops an IoT-enabled real-time load height monitoring and control system, integrating a Programmable Logic Controller (PLC) and a Human-Machine Interface (HMI) to address industrial automation and remote monitoring needs. Using the System Development Life Cycle (SDLC) model, the methodology ensures a structured, efficient, and scalable development process. The system employs IoT technologies, including the MQTT protocol and cloud platforms like HaiwellCloud, to enable seamless real-time data synchronization across PCs and smartphones, enhancing operational flexibility and cross-platform accessibility. Key features include a modern communication adapter (RS232 to RS422) and lightweight protocols for fast, reliable data transmission, as well as automated processes, such as threshold alarms and remote counter resets, to minimize manual intervention. Designed for scalability, the system supports integration with enterprise resource planning (ERP) and manufacturing execution systems (MES), facilitating comprehensive operational digitization and advancing industrial IoT adoption.

2.1 System Architecture and Communication Flow

The system architecture and communication flow are presented comprehensively to detail the interaction among its core components, as illustrated in Figure 1, which outlines the Communication Protocol Layout. The communication framework between the programmable Logic Controller (PLC) and the Human Machine Interface (HMI) is established using a serial communication adapter, transitioning from RS232 to RS422, ensuring robust and reliable data exchange within the system [12]. For connectivity across diverse platforms, including personal computers and smartphones, the system utilizes the Message Queuing Telemetry Transport (MQTT) protocol, which is specifically selected for its lightweight design, efficiency, and capability to facilitate real-time data exchange, making it particularly suitable for Internet of Things (IoT) applications. To provide seamless access for users, the system incorporates versatile options tailored for different platforms. Smartphone users can engage with the system through the HaiwellCloud application, a mobile platform designed to enable remote monitoring and control functionalities. Simultaneously, personal computer users can access the system through the HaiwellCloud web portal, available at www.cloud.haiwell.com. This cross-platform accessibility ensures a user-friendly and consistent interface, enabling effective and efficient remote operations regardless of the device being used.

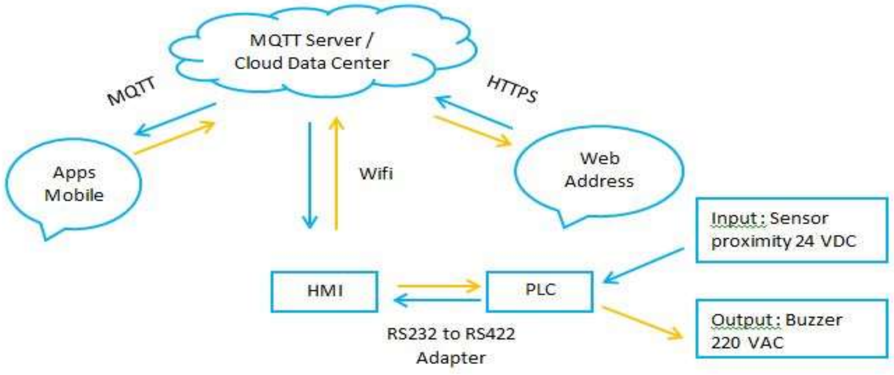


Figure 1. Communication Protocol Layout

2.2 Operational Workflow and Real-Time Monitoring

The operational workflow of the system, as visualized in Figure 2, outlines the core functionality and steps essential for real-time monitoring and control in industrial applications. The process begins with input signal acquisition, where two proximity sensors mounted on the load conveyor detect and classify items based on their size, such as small or large. These sensors transmit data to the programmable logic controller (PLC), which processes the information in real time. The processed data is then forwarded to the human-machine interface (HMI), providing a real-time visual display that allows operators to monitor the system locally. Simultaneously, the HMI uploads this data to a cloud platform, enabling remote access through smartphones and PCs.

The workflow also incorporates a threshold-based alert and reset mechanism, where the PLC activates a buzzer alarm upon reaching a predefined item count, signaling the operator. At this point, the system requires a counter reset, which can be performed remotely via the HMI, smartphone, or PC. This comprehensive workflow ensures efficient operation, real-time monitoring, and remote control, effectively addressing critical challenges in industrial applications.

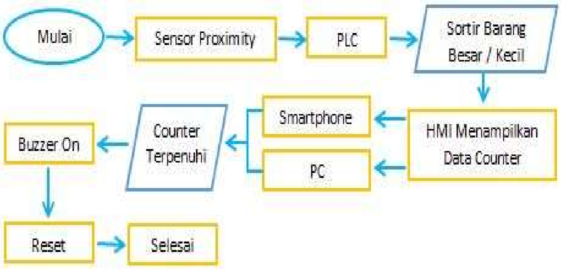


Figure 2. Flowchart of Operational Workflow and Real-Time Monitoring

2.3 Development Stages Using the SDLC Methodology

The research utilizes the System Development Life Cycle (SDLC) model to structure the development and implementation of the proposed system, ensuring a systematic and iterative approach while fostering collaboration among developers, designers, and analysts [13]. The methodology begins with the planning phase, which identifies the core problem of enabling real-time remote monitoring and control of industrial processes without requiring physical proximity to machinery. Specific objectives include achieving multi-platform accessibility, ensuring system reliability, and integrating IoT technologies.

In the analysis phase, a comprehensive literature review is conducted to explore existing solutions and identify potential innovations. Functional requirements are defined to address industrial needs, emphasizing system strengths, weaknesses, and areas for improvement. During the design phase, a prototype system is developed using carefully selected hardware and software components. The human-machine interface (HMI) is designed using HaiwellScada software to provide intuitive interaction, while programmable logic controller (PLC) programming is implemented using GX-Works 2 to ensure seamless communication with other components. Hardware components, such as the Haiwell C7S-W IoT Cloud HMI and PLC, are assembled and integrated. Simulations are performed to validate the system's functionality and accuracy, ensuring reliability before transitioning to real-world deployment.

The implementation and testing phase involves deploying the system in a controlled industrial environment to evaluate its functionality and adaptability under various conditions. Key performance indicators, including data transmission speed, system response time, and accuracy, are measured. Real-time testing validates the MQTT-based communication framework and cloud-enabled accessibility, confirming the system's ability to meet operational requirements effectively.

2.4 System Components and Features

In this research, the Haiwell C7S-W IoT Cloud HMI with a 7-inch display serves as the core component of the system, offering advanced features tailored to industrial applications. This HMI supports remote access and control through a smartphone application, enabling real-time monitoring and interaction. It also provides real-time alarms delivered via the mobile application, allowing for prompt user intervention when critical events occur. The device connects seamlessly to databases such as enterprise resource planning (ERP) and manufacturing execution systems (MES), facilitating comprehensive integration with broader industrial operations. Furthermore, its support for a wide range of third-party protocols ensures compatibility with diverse industrial equipment, including programmable logic controllers (PLCs), inverters, and other instruments. These features not only align the system with modern industrial standards but also provide scalability for future enhancements. Figure 3 illustrates the Design of the Equipment, highlighting the system's physical components, including: (1) Electrical Panel Box, (2) Power Lamp, (3) Buzzer Alarm, (4) Haiwell HMI, (5) Large Proximity Sensor, and (6) Small Proximity Sensor.

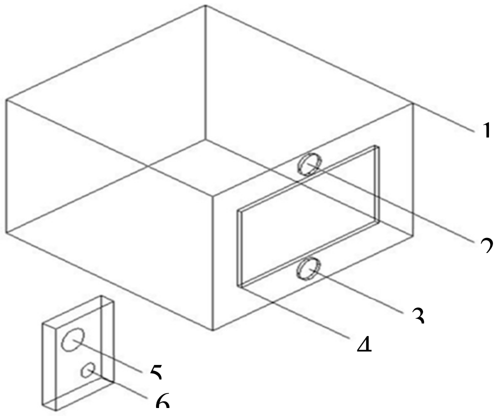
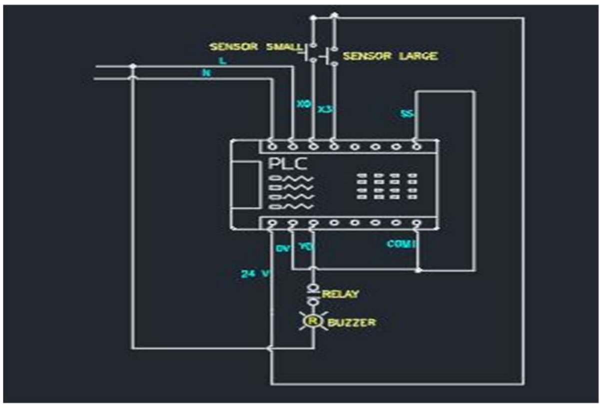


Figure 3 Design of the Equipment

3. RESULTS AND DISCUSSION

3.1 Prototype Development

This research employed a Mitsubishi FX1N-24MR compact PLC, programmed using GX-Works2 software, to develop an IoT-enabled monitoring and control system. The wiring diagram and I/O addressing in Figure 4 , illustrates the connection between the PLC and peripheral components such as proximity sensors and a buzzer alarm. The system's operational workflow begins by setting a target count, for example, 10 items. Proximity sensors then detect passing items, categorizing them based on size. The small sensor activates for smaller items, while both the small and large sensors activate for larger items.



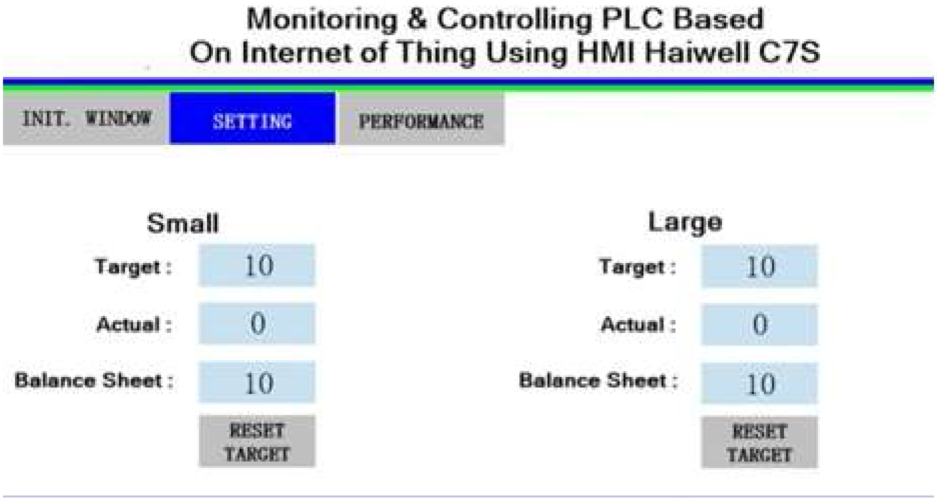
No.	Address	Function	No.	Address	Function
1	X0	Sensor Proximity Small	12	D14	Balance Large
2	X3	Sensor Proximity Large	13	D20	Realtime Large
3	D100	Target Small	14	D2	Time Product
4	D102	Actual Small	15	D22	Actual Percentage Large
5	D104	Balance Large	16	D24	Balance Percentage Large
6	D110	Realtime Small	17	M800	Always On
7	D112	Time Product Small	18	M0	Reset Target Small
8	D122	Actual Percentage Small	19	M8103	1 Sec Clock Pulse (flicker)
9	D124	Balance Percentage Small	20	M10	Reset Large
10	D10	Target Large	21	Y0	Buzzer
11	D12	Actual Large			

Figure 4. PLC Wiring Diagram and I/O Addressing Integration of Sensors and Alarm System

The detected data is stored in the actual small or actual large counters, while any deficit is recorded in the balance counter. Once the target for either small or large items is met, the buzzer alarm is triggered, prompting the operator to reset the target, which resets the count to zero.

Figure 5 Device Overview Compact and Functional Design

For system interfacing, an IoT Cloud HMI Haiwell C7S-W with a 7-inch display was utilized, designed using Haiwell Cloud SCADA Designer software. The interface consists of three primary displays: an initial display serving as the opening screen with the system title, creator's identity, menu buttons, time, and date; a setting display acting as the main screen to configure targets, display actual and balance data, and reset targets, as depicted in Figure 6; and a performance display visualizing system performance through two pie charts—one for small items and one for large items—representing actual and balance data as percentages, as shown in Figure 7.



Monitoring & Controlling PLC Based
On Internet of Thing Using HMI Haiwell C7S

Small
Target : 10
Actual : 0
Balance Sheet : 10

Large
Target : 10
Actual : 0
Balance Sheet : 10

Figure 6 Setting Display on HMI and Web Target Configuration and Real Time Data Monitoring

The performance display also incorporates an adjustable timer for controlling pie chart update intervals. Figure 7 illustrate the interface design process, which emphasizes usability and real-time monitoring capabilities. The performance display provides a clear and intuitive visualization of operational efficiency, enabling operators to monitor progress effectively. By integrating advanced IoT features and visualization tools, the system ensures efficient operation, real-time data tracking, and streamlined control of industrial processes.

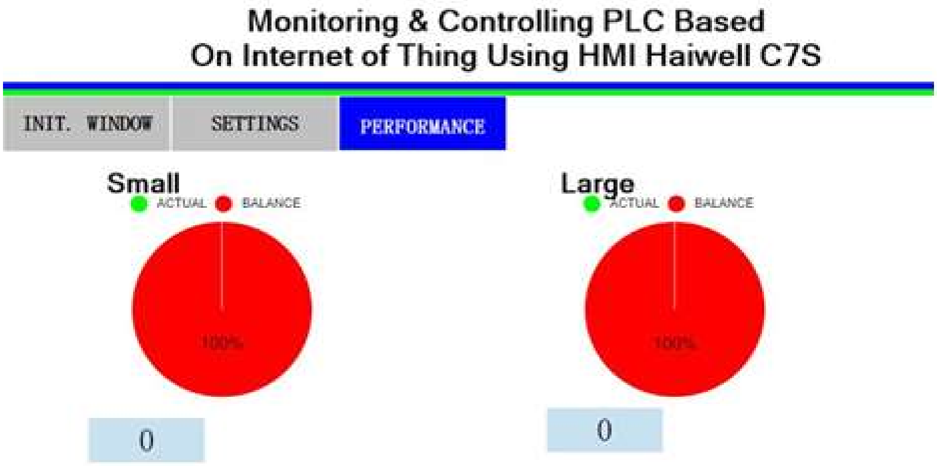


Figure 7 Performance Display on HMI and Web Visualizing Operational Metrics with Pie Charts

The prototype utilizes the Omron E2E-X2F1 inductive proximity sensor, specifically designed to detect metallic objects within a maximum range of 2 mm. To evaluate its performance, particularly the data transmission speed from the Human-Machine Interface (HMI) to mobile applications or web platforms, experiments were conducted under varying internet speeds of 2.58 Mbps, 6.56 Mbps, and 5.56 Mbps, Table 1 and Figure 8.

The testing results demonstrated consistent performance across the different network conditions, with the fastest data transmission time recorded at 0.66 seconds in all scenarios. At an internet speed of 2.58 Mbps, the slowest recorded was 1.58 seconds, while at 6.56 Mbps, the maximum delay decreased to 1.12 seconds. Under a speed of 5.56 Mbps, the longest delay returned to 1.58 seconds. These findings indicate that the system achieves near real-time data transfer, with variations in delay influenced by internet speed.

Table 1. the data transmission speed from the Human-Machine Interface (HMI) to mobile applications or web platforms

No.	Internet Speeds of 2.58 Mbps		Internet Speeds of 6.56 Mbps		Internet Speeds of 5.56 Mbps	
	Transmission Speed to Mobile Apps (sec)	Transmission Speed to web platform (sec)	Transmission Speed to Mobile Apps (sec)	Transmission Speed to web platform (sec)	Transmission Speed to Mobile Apps (sec)	Transmission Speed to web platform (sec)
1	1,13	1,13	1,12	1,12	1,06	1,06
2	1,58	1,58	0,86	0,86	1,06	1,06
3	1,00	1,00	1,06	1,06	1,18	1,18
4	0,66	0,66	0,66	0,66	1,58	1,58
5	1,58	1,58	0,98	0,98	1,45	1,45
6	0,66	0,66	0,86	0,86	0,66	0,66
7	0,94	0,94	1,05	1,05	0,73	0,73
8	1,19	1,19	0,92	0,92	0,92	0,92
9	1,13	1,13	0,73	0,73	0,99	0,99
10	0,86	0,86	0,80	0,80	0,80	0,80

The system demonstrated effective real-time data transmission performance, with the fastest delay time recorded at 0.66 seconds and the slowest delay at 1.58 seconds. This variation in delay is influenced by internet speed, which plays a critical role in ensuring efficient data communication. The proximity sensor performed within its specified accuracy limits, successfully detecting objects at a maximum distance of 2 mm. This confirms the sensor's reliability in short-range object detection tasks, aligning with its design specifications.

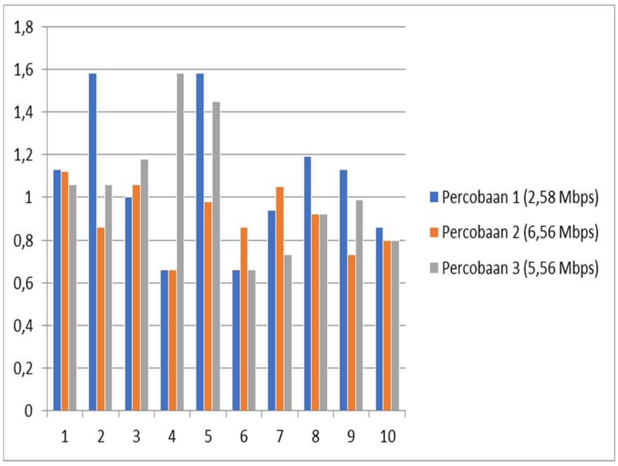


Figure 9 Data Transmission Speed Evaluation Between HMI and Mobile/Web Platforms Under Varying Internet Speeds

Integration between multiple devices, including Human-Machine Interface (HMI), PC, and smartphone, functioned seamlessly. Data synchronization and communication between these platforms occurred without any observable issues, ensuring smooth operational performance and inter-device compatibility. Regarding object size detection, the small sensor demonstrated its capability to identify items with dimensions of 6 cm, 8 cm, and 9 cm. In contrast, the large sensor effectively detected larger objects measuring 13 cm and 15 cm. These results indicate that the system can accurately differentiate and classify objects based on their size, providing versatility for various applications.

Table 2 Object Classification Based on Heights Detected by Sensors

No.	Object Height (cm)	Small	Large
1	6	Detected	-
2	8	Detected	-
3	9	Detected	-
4	13	-	Detected
5	15	-	Detected

Overall, the prototype showcases reliable functionality, with the proximity sensor accurately detecting objects within its specified range and the HMI achieving seamless communication with mobile and web platforms. This performance highlights the system's potential for effective real-time monitoring and control in industrial applications.

4. CONCLUSION

Data transmission operates in near real-time, with delays ranging from 0.66 to 1.58 seconds depending on internet speed. The proximity sensors function accurately within their detection range, identifying objects at a maximum distance of 2 mm. Device integration between the HMI, PC, and smartphones is seamless and reliable. The small sensor detects objects measuring 6 cm, 8 cm, and 9 cm, while the large sensor identifies objects of 13 cm and 15 cm. By combining IoT technologies with PLC and HMI systems, this research addresses the pressing need for efficient and accessible solutions in industrial automation. The adoption of the SDLC methodology ensures a well-structured development process, while the integration of MQTT-based communication and cloud platforms guarantees reliability and usability. Extensive testing under diverse conditions demonstrates the system's potential to enhance operational efficiency and scalability, making it a robust solution for modern smart industrial environments.

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