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Review on Technologies used for PLC Remote Controlling and Monitoring Applications

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ABSTRACT: The industrial landscape is rapidly evolving, and the demand for more flexible, efficient, and scalable automation solutions is growing. The need for automation solutions that are more adaptable, effective, and scalable is rising as the industrial landscape changes quickly. One of the most important ways to satisfy these expectations is by integrating wireless technologies like Bluetooth, ZigBee, and others with PLCs. The ability to provide remote monitoring and control is one of the main reasons for automating PLCs using wireless technology. In order to oversee and troubleshoot operations using traditional PLC systems, operators must be physically present in the control room or factory floor. By enabling operators to monitor and operate PLCs from a distance, wireless technologies such as Bluetooth, ZigBee, and GSM overcome this restriction, speeding up response times to any problems and increasing system dependability overall. Because they provide real-time access and management of control systems that were previously reliant on wired connections, these wireless technologies are important enablers in the field of industrial automation. These technologies' improved flexibility and simplicity of integration have transformed the automation sector and increased operational efficiency across a range of industrial applications. This analysis examines the benefits and appropriate uses of Bluetooth, ZigBee, and GSM with PLC automation technology. Wireless communication technologies in PLC-based control systems will play an ever more crucial role in the future of smart manufacturing and process control as the need for more sophisticated and affordable industrial automation solutions grows.

KEYWORDS: PLC, Automation, wireless integration, remote monitoring, Wi-Fi, Bluetooth, GSM, zigbee

I. INTRODUCTION

Programmable Logic Controller (PLC) systems may now be remotely monitored and controlled, which is essential for increasing productivity, decreasing downtime, and streamlining processes in contemporary industrial automation. Conventional PLC systems exchange data over wired communication networks like Ethernet, RS-232, or RS-485. However, particularly in big industrial systems, these wired solutions may be expensive, complicated, and challenging to scale. Because of this, wireless communication technologies like Bluetooth, Zigbee, and GSM have become good substitutes for incorporating inexpensive remote connection into PLC systems. Without requiring significant changes to the infrastructure, these wireless technologies provide for flexible, scalable, and affordable industrial automation. The Global System for Mobile Communications, or GSM, is one of the most commonly used wireless technologies for remote control and monitoring. Industrial systems may be accessible from almost any location with network coverage because to GSM's ability to provide long-distance communication over cellular networks. Because of this, GSM is especially well-suited for use in remote locations where conventional wired networks are not feasible. By integrating GSM modules, PLCs may provide constant communication by sending and receiving real-time data and control instructions via SMS or internet-based protocols like 4G LTE and GPRS (General Packet Radio Service). In contrast, Zigbee is a low-power, short-range wireless communication standard intended for home and business automation. It is ideal for applications that need dependable, low-latency data sharing across several devices in a network and runs on the IEEE 802.15.4 standard. Zigbee's capacity to create mesh networks improves communication coverage and robustness, making it a great choice for industrial settings. Zigbee integration with PLC systems enables energy-efficient automation, remote monitoring, and smooth data collection. Another interesting option for PLC communication is Bluetooth technology, especially in settings requiring high-speed, short-range wireless connectivity. PLCs may now remotely link to neighboring control systems, tablets, or mobile devices for real-time monitoring and diagnostics thanks to innovations like Bluetooth Low Energy (BLE). When operators require immediate, secure access to PLC data without requiring complicated network configurations, Bluetooth is useful. Furthermore, Bluetooth-enabled PLC connectivity helps speed up system configuration and troubleshooting, which lowers maintenance

requirements. Notwithstanding their benefits, there are drawbacks to integrating GSM, Zigbee, and Bluetooth with PLCs. Notwithstanding their benefits, there are drawbacks to integrating GSM, Zigbee, and Bluetooth with PLCs, including issues with latency, data security, and compatibility with current industrial protocols. Cellular congestion can cause delays in GSM networks, while Bluetooth and Zigbee have a shorter range than conventional cable alternatives. It takes strong data encryption, well-designed network setups, and compatibility with industrial protocols like Modbus, MQTT, and OPC UA to guarantee smooth communication between PLCs and these wireless modules. To achieve dependable and secure wireless PLC communication, these obstacles must be overcome. The viability and efficiency of incorporating Bluetooth, Zigbee, and GSM technologies into PLC systems for remote control and monitoring are examined in this research. It looks at the advantages, difficulties, and different implementation tactics of each wireless technology. This study intends to shed light on how these inexpensive wireless solutions may boost industrial automation, increase accessibility, and lower infrastructure costs while guaranteeing dependable system performance by examining real-world applications and case studies.

II. LITERATURE REVIEW

In order to improve automation through remote monitoring and control, the integration of wireless communication technologies like GSM, Zigbee, and Bluetooth into Programmable Logic Controller (PLC) systems has been thoroughly researched. The important contributions made by different authors in this field are examined in this overview of the literature.

Smith and Brown (2020) explored the application of ESP8266 in wireless control systems for industrial automation, highlighting its reliability, cost-effectiveness, and ease of integration. The study demonstrates how the ESP8266 Wi-Fi module enables real-time monitoring and remote control of industrial processes, reducing the need for wired connections and enhancing system flexibility. By leveraging wireless communication, the system improves efficiency in industrial operations by allowing seamless data transmission between sensors, controllers, and cloud-based platforms. The authors emphasize the benefits of low power consumption, scalability, and interoperability with IoT-based automation frameworks. However, challenges such as network security, interference, and latency are discussed as potential limitations. This research contributes to the growing adoption of wireless industrial control systems, reinforcing the role of IoT and smart automation in enhancing operational efficiency and remote accessibility in modern industries [1].

Lee et al. (2019) examined the integration of Wi-Fi modules in Programmable Logic Controller (PLC) systems to enhance remote monitoring and industrial automation. The study highlights the advantages of wireless communication in reducing wiring costs, improving system flexibility, and enabling real-time data access. By incorporating Wi-Fi connectivity, PLC systems can transmit data to cloud platforms, allowing operators to monitor and control industrial processes remotely. This approach enhances scalability, mobility, and ease of maintenance compared to traditional wired systems. However, the study also discusses challenges such as network security, interference, and latency, which must be addressed for reliable industrial applications. This research contributes to the ongoing evolution of smart manufacturing and Industry 4.0, showcasing how wireless PLC integration can optimize industrial efficiency and support more adaptable, interconnected automation systems [2].

Gonzalez and Martinez (2021) proposed a low-cost wireless PLC interface using the ESP8266 module, emphasizing affordability, ease of use, and flexibility in industrial automation. The study demonstrates how the ESP8266 enables wireless communication between PLCs and remote monitoring systems, reducing the need for extensive wiring and lowering installation costs. The proposed solution allows for real-time data exchange, remote access, and control of industrial processes, making automation more accessible, especially for small and medium-sized enterprises. The authors highlight key advantages such as low power consumption, scalability, and simple integration with existing PLC-based infrastructures. However, potential challenges related to network security, latency, and signal interference are discussed. This research contributes to the growing adoption of wireless industrial automation, showcasing how cost-effective solutions can enhance efficiency, flexibility, and connectivity in modern manufacturing and control systems [3].

Ahmed et al. (2020) explored the integration of wireless IoT modules, such as ESP8266, in industrial automation, emphasizing their role in remote monitoring and control. The study highlights how IoT-enabled systems enhance real-

time data collection, process automation, and operational efficiency by reducing dependency on wired networks. By leveraging wireless communication, industries can remotely monitor equipment status, optimize resource utilization, and improve decision-making through cloud-based analytics. The authors discuss key benefits such as cost-effectiveness, scalability, and ease of deployment, making IoT solutions particularly valuable for modern Industry 4.0 applications. However, challenges related to network security, latency, and data reliability are also considered. This research contributes to the advancement of smart manufacturing, demonstrating how wireless IoT integration can enhance flexibility, efficiency, and real-time control in industrial environments [4].

Zhang (2018) explored the feasibility of using Wi-Fi communication for remote PLC control, highlighting its potential to enhance system accessibility and flexibility in industrial automation. The study demonstrates how integrating Wi-Fi-enabled PLCs allows operators to monitor and control industrial processes remotely, reducing reliance on traditional wired connections. By enabling real-time data transmission and remote troubleshooting, this approach improves operational efficiency and reduces maintenance costs. The research also discusses key advantages, such as scalability, ease of implementation, and compatibility with cloud-based monitoring systems. However, challenges related to network security, latency, and signal reliability are acknowledged. This study contributes to the development of wireless industrial automation, showcasing how Wi-Fi-based PLC control can optimize industrial operations and support the growing demand for smart, interconnected manufacturing systems [5].

Patel and Singh (2021) proposed a cost-effective industrial automation system that integrates ESP8266 with ULN2008, aiming to provide an affordable and efficient solution for industrial control. The study highlights how the ESP8266 Wi-Fi module enables wireless communication and remote monitoring, while the ULN2008 relay driver facilitates the control of industrial actuators and machinery. This combination enhances system flexibility, reduces wiring costs, and improves automation capabilities in small and medium-sized industries. The authors emphasize key advantages such as low power consumption, scalability, and easy integration with existing industrial infrastructures. However, the research also acknowledges challenges related to network security, response time, and system stability in wireless environments. This study contributes to the growing field of IoT-based industrial automation, showcasing how affordable wireless solutions can enhance efficiency, remote access, and smart manufacturing [6].

Kim and Park (2019) explored real-time monitoring of PLC systems using wireless networks, focusing on Wi-Fi-enabled data transmission to improve system responsiveness and efficiency in industrial automation. The study highlights how wireless communication allows for continuous data collection, remote access, and real-time decision-making, reducing the limitations of traditional wired monitoring systems. By integrating Wi-Fi with PLCs, industries can enhance operational flexibility, reduce maintenance costs, and enable predictive maintenance through real-time analytics. The authors discuss key advantages such as low latency, scalability, and seamless integration with cloud-based platforms, while also addressing potential challenges related to network security, interference, and data transmission reliability. This research contributes to the advancement of smart manufacturing and Industry 4.0, demonstrating how real-time wireless monitoring can optimize industrial processes and improve overall system performance [7].

Torres et al. (2020) explored the implementation of wireless communication in legacy PLC systems, demonstrating how wireless modules can modernize existing industrial automation setups. The study highlights how integrating Wi-Fi and IoT-based communication with older PLCs enhances remote monitoring, control, and data transmission, reducing dependence on extensive wiring. By upgrading traditional systems with wireless connectivity, industries can improve operational flexibility, scalability, and real-time decision-making without requiring a complete system overhaul. The authors discuss key benefits such as cost-effectiveness, reduced maintenance efforts, and seamless integration with cloud platforms, while also addressing challenges like network security, latency, and compatibility with legacy hardware. This research contributes to the advancement of smart manufacturing, showcasing how wireless communication can extend the life and efficiency of older PLC systems, aligning them with modern Industry 4.0 standards [8].

Choudhury and Sharma (2021) explored the IoT-based remote control of industrial processes, emphasizing the role of IoT devices like ESP8266 in enabling real-time monitoring and automation. The study highlights how wireless communication enhances industrial operations by allowing operators to remotely control machinery, monitor system performance, and optimize resource utilization through cloud-based platforms. By integrating ESP8266 with industrial

control systems, the proposed solution improves efficiency, scalability, and cost-effectiveness, reducing the need for complex wiring and manual intervention. The authors discuss key benefits such as low power consumption, seamless connectivity, and enhanced system responsiveness, while also addressing challenges like network security, data latency, and reliability in industrial environments. This research contributes to the advancement of smart manufacturing and Industry 4.0, demonstrating how IoT-driven automation can enhance operational flexibility and decision-making in modern industries [9].

Wang et al. (2018) explored the use of wireless sensor networks (WSNs) for industrial automation, highlighting their role in enhancing monitoring, control, and data collection in industrial environments. The study emphasizes how wireless sensors can provide real-time information on various industrial parameters, such as temperature, pressure, and humidity, without the need for extensive wiring, thus reducing installation and maintenance costs. The authors discuss the advantages of flexibility, scalability, and ease of deployment, allowing industries to quickly adapt to changing conditions and optimize their processes. Additionally, the paper covers the challenges of data reliability, network security, and interference in wireless sensor systems. This research contributes to the growing field of smart manufacturing, demonstrating how WSNs can enable more efficient, adaptable, and cost-effective industrial automation by improving data accessibility and real-time decision-making capabilities [10].

Bedi et al. (2018) reviewed the application of the Internet of Things (IoT) in electric power and energy systems, focusing on how IoT technologies can enhance the monitoring, control, and optimization of energy infrastructure. The study highlights the integration of smart sensors, devices, and communication networks to enable real-time data collection, energy management, and predictive maintenance. The authors discuss how IoT applications can improve grid efficiency, reduce energy consumption, and support renewable energy integration by enabling intelligent decision-making and dynamic control. Challenges such as data security, interoperability, and the need for robust communication networks are also addressed. This research contributes to the understanding of IoT's transformative impact on the energy sector, showing how it can lead to more efficient, sustainable, and reliable power systems [11].

B. Ramamurthy, S. Bhargavi, and R. Shashikumar (2010) developed a GSM-based remote monitoring and control system for industrial processes, addressing the limitations of traditional wired monitoring methods. The system integrates sensors, a microcontroller, and a GSM module to enable real-time data collection and remote control of parameters such as temperature, pressure, and humidity. By using SMS or GPRS for data transmission, the system allows operators to monitor industrial conditions and send control commands remotely, enhancing efficiency and safety. The study demonstrates the advantages of wireless communication in industrial automation, including reduced installation costs and improved flexibility. However, limitations such as low data bandwidth and security vulnerabilities in SMS-based communication highlight the need for more advanced technologies. This research serves as an early step toward modern industrial Internet of Things (IIoT) systems, which now incorporate cloud computing, AI-driven analytics, and advanced wireless protocols like LoRaWAN and 5G for improved performance and reliability [12].

T. Georgieva, N. Bencheva, P. Daskalov, H. Yahoui, and S. Khemmarath (2022) discussed the importance of capacity development through the implementation of Programmable Logic Controller (PLC) training to support the transition towards Industry 4.0. The study emphasizes that as industries adopt smart manufacturing, automation, and IoT-based solutions, there is a growing need for skilled professionals proficient in PLC programming and industrial automation. The authors highlight how specialized training programs enhance workforce competence, ensuring smoother integration of cyber-physical systems, real-time data processing, and AI-driven automation in industrial settings. The research also addresses the challenges in PLC education, such as the need for modern training infrastructure, updated curricula, and hands-on experience with advanced automation technologies. This study underscores the crucial role of education and skill development in driving industrial transformation, aligning with global trends where technical training and Industry 4.0 adoption go hand in hand [13].

Chen Qiang and Chen Ming (2018) explored the application of Programmable Logic Controller (PLC) technology in electrical engineering automation control, highlighting its significance in improving efficiency, reliability, and automation in industrial processes. The study discusses how PLCs, as programmable and flexible control devices, enhance automation by enabling real-time monitoring, fault detection, and precise control of electrical systems. The authors emphasize the advantages of PLC-based systems over traditional relay-based controls, including higher adaptability, ease of programming, and improved system stability. The paper also touches upon the integration of PLCs

with modern automation technologies, such as sensors, communication networks, and intelligent control systems, to optimize industrial operations. This research contributes to the growing body of knowledge on automation in electrical engineering, reinforcing the role of PLCs as a fundamental component in smart manufacturing and Industry 4.0 initiatives [14].

Liu Jia and Liu Jia (2016) examined the application of Programmable Logic Controller (PLC) technology in electrical engineering and automation control, emphasizing its role in enhancing industrial automation. The study highlights how PLCs provide efficient, reliable, and flexible control solutions for electrical systems by enabling real-time monitoring, fault diagnosis, and automated decision-making. The authors discuss the advantages of PLCs over traditional control methods, such as higher stability, ease of programming, and seamless integration with sensors and industrial networks. Additionally, the paper explores how PLC technology supports intelligent automation by improving system responsiveness and reducing manual intervention. This research contributes to the broader understanding of PLC-based automation, reinforcing its importance in modern industrial control systems and Industry 4.0 advancements [15].

P. Singh and S. Saikia (2016) proposed an Arduino-based smart irrigation system that integrates multiple sensors, including a water flow sensor, soil moisture sensor, and temperature sensor, along with the ESP8266 WiFi module for remote monitoring and control. The study highlights the importance of precision irrigation in optimizing water usage, reducing wastage, and improving agricultural productivity. The system operates by continuously monitoring soil moisture levels, temperature, and water flow, ensuring that irrigation is automated based on real-time environmental conditions. The use of WiFi connectivity allows farmers to remotely access data and control the irrigation system via a web-based interface, enhancing efficiency and convenience. The research demonstrates how low-cost, IoT-enabled solutions can contribute to smart agriculture, promoting sustainable water management and resource efficiency. This study serves as a foundation for further advancements in IoT-driven precision farming, where automation and real-time data analytics play a crucial role in modern agricultural practices [16].

Saraswati Saha and Anupam Majumdar (2017) presented a data center temperature monitoring system using an ESP8266-based Wireless Sensor Network (WSN) integrated with a cloud-based dashboard and real-time alert system. The study emphasizes the importance of maintaining optimal temperature conditions in data centers to prevent equipment overheating, reduce energy consumption, and enhance system reliability. The proposed system continuously monitors temperature levels using wireless sensors and transmits the data to the cloud, where it is displayed on a real-time dashboard. Additionally, an automated alert system notifies administrators when temperature thresholds are exceeded, allowing for quick intervention and preventive maintenance. The research highlights the advantages of IoT-based monitoring, including remote access, real-time decision-making, and improved energy efficiency. This study contributes to the growing field of smart infrastructure management, showcasing how wireless sensor networks and cloud computing can enhance the efficiency and reliability of data center operations [17].

S. D. Sharma and R. S. Kasana (2011) explored the research issues and challenges of mobile database systems, emphasizing the complexities introduced by mobility, limited resources, and dynamic network conditions. The study highlights key challenges such as data consistency, transaction management, query processing, security, and energy efficiency in mobile environments. Since mobile devices frequently experience network disconnections, bandwidth limitations, and power constraints, ensuring reliable data access, synchronization, and seamless transactions remains a significant research concern. The paper also discusses strategies for efficient data replication, adaptive query optimization, and secure mobile database access to enhance system performance. This research contributes to the ongoing advancements in mobile computing and cloud-based database management, providing insights into how modern technologies like edge computing, 5G, and AI-driven data management can help address these challenges and improve the reliability of mobile database systems [18].

Eung Soo Kim and Min Sung Kim (2006) presented the design and fabrication of a security and home automation system, aiming to integrate security features with home automation for enhanced convenience and safety. The system combines various technologies, such as sensors, controllers, and communication networks, to enable remote monitoring and control of home security features like alarms, surveillance cameras, and entry systems. The study emphasizes the importance of automated responses to security breaches, as well as the integration of home appliances for energy management and convenience. The proposed system allows homeowners to monitor and control various aspects of their home, including lighting, temperature, and security settings, through a centralized interface. This research contributes

to the development of smart home technologies, illustrating the potential of automation to improve safety, efficiency, and user experience in residential settings [21].

Intelligent Automation with the Use of GSM and Zigbee: This study suggests a smart automation solution for wireless network automation that makes use of Zigbee-based controllers. The use of GSM and Zigbee technologies to create effective and adaptable automation solutions that can be used with PLC systems in industrial settings is covered in the research.

A Thorough Analysis of Automation Systems for Smart Homes: The authors offer a thorough analysis of the state of smart home automation systems today, pointing out areas that require more study and advancement. The article provides insights relevant to PLC system integration while highlighting the elements, uses, and difficulties of smart home automation systems.

Internet of Things: Technologies That Make It Possible: This page covers a number of IoT supporting technologies, such as long-range wireless alternatives like GSM and short-range wireless communications like Bluetooth, Zigbee, and Wi-Fi. The conversation offers a fundamental comprehension of the functions of these technologies in Internet of Things applications, pertinent to their incorporation into PLC systems for automation.

A Review of the Literature on Smart Home Automation: The article offers a thorough overview of the developments and difficulties in the industry by discussing numerous intelligent home automation systems and technologies from a variety of feature viewpoints. The information is useful for comprehending how wireless technologies are used in PLC-based automation systems.

III. REVIEW OF TECHNOLOGIES USED

Bluetooth in Industrial Automation

Bluetooth technology is now widely used for low-power, short-range communication in industrial applications. It is especially beneficial for sensor, actuator, and device connection in limited spaces. Amin et al. (2017) say that Bluetooth offers flexibility and cost-effectiveness, especially in small-scale industrial systems where devices need wireless communication with low power consumption. They also emphasize its success in the supervision and management of production lines via mobile devices (Amin, M., et al., 2017). Yet, limited coverage and susceptibility to interference in dense industrial settings can be a challenge (Zhao et al., 2018).

ZigBee in Industrial Networks

ZigBee is commonly known for its low-power, low-data-rate wireless communication and is commonly employed in industrial automation for smart grids and monitoring systems. Chin et al. (2015) discuss the application of ZigBee in industrial wireless sensor networks, claiming that its low energy usage and self-healing mesh network features make it perfect for IoT-based industrial applications (Chin, W., et al., 2015). ZigBee's capability to form extensive networks with little interference has been the major contributing factor in its usage for process automation, asset tracking, and environmental monitoring (Vasquez et al., 2016).

GSM Remote Monitoring and Control

GSM (Global System for Mobile Communications) provides a good solution for remote monitoring and control of industrial systems, particularly in geographically scattered areas. Saha et al. (2016) suggest that GSM-based systems can be implemented in industrial environments for real-time data acquisition and automatic control via SMS and calls (Saha, M., et al., 2016). The reliability and scalability of GSM have made it the go-to choice for pump control, agricultural automation, and water treatment systems (Singh et al., 2018). Although it has been used very extensively, the relatively low data transfer rates of GSM and the fact that it relies on mobile networks make its use in high-bandwidth applications less suitable.

LoRa in Industrial IoT

LoRa (Long Range) technology is being considered for its potential to deliver long-range, low-power communication in industrial IoT applications. Kumar et al. (2020) emphasize the potential of LoRa in industrial asset tracking, predictive maintenance, and environmental monitoring because of its up to 15 km open-range capability (Kumar, V., et

al., 2020). LoRa's low power consumption makes it possible to have long battery life, which is essential in remote industrial settings with poor power infrastructure. Nevertheless, the limitations are that there is a requirement for stable gateway installations and restricted bandwidth, which can impact data-intensive applications (Liu et al., 2019)

PLC Control Systems in Automation

PLC control systems have been the central pillar of industrial automation for years with high reliability and flexibility in process control. Kumar and Sharma (2015) assert that PLCs are crucial in automating production processes, providing real-time control of machinery, sensors, and actuators (Kumar, R., & Sharma, A., 2015). Their strength and ease of programming qualify PLCs as perfect for industries from automotive to food processing. The coupling of PLCs with wireless communication technologies such as ZigBee and GSM also increases their capability in remote monitoring and control applications (Bargoti et al., 2017).

Bluetooth Low Energy (BLE) for Industrial IoT.

Raj and Suresh (2019) articulate the increasing function of Bluetooth Low Energy (BLE) in the industrial Internet of Things (IoT), particularly its application to energy-saving sectors such as warehouse management and forecasting maintenance systems (Raj, D., & Suresh, N., 2019). BLE supporting numerous connected devices with low power consumption is one of the factors that make it superior to older Bluetooth, particularly in sensor-infused industrial systems. Its interconnection with Programmable Logic Controllers (PLCs) improves data monitoring in real-time, responding faster in the production line.

Hybrid Integration of PLCs and Wireless Technologies

Zhang et al. (2018) investigate the use of hybrid systems that integrate PLCs with ZigBee and GSM, generating versatile and scalable industrial automation solutions. In their view, the integration enhances the scalability and flexibility of control systems through the facilitation of remote communication and simplicity in wiring (Zhang, Y., et al., 2018). In addition, PLCs serve as a center of control while wireless communication protocols are responsible for real-time data transmission.

Wireless Sensor Networks in Industry

Arshad et al. (2017) discusses the application of wireless sensor networks (WSNs) in industry automation, viz., ZigBee and LoRa technologies employed for predictive maintenance and performance tracking (Arshad, A., et al., 2017). The WSNs have facilitated industries to minimize downtime and maximize usage by offering real-time information related to machine wellness.

GSM and PLC in Industrial Monitoring Systems

Zhu and Liu (2016) discuss the integration of GSM with PLCs for use in remote industrial monitoring systems, especially energy management and fault detection (Zhu, W., & Liu, F., 2016). They illustrate that the integration provides real-time status and control operations through mobile phones or internet-based applications. The authors provide some case studies in which GSM-PLC systems were successfully implemented in power plants and water treatment plants.

LoRa and ZigBee in Smart Factory Systems

Vasquez et al. (2016) explore the integration of LoRa and ZigBee technologies in the development of smart factory spaces. Their study reveals that LoRa's long-range nature is supplemented by ZigBee's low power usage and mesh network ability, which gives a solid solution for controlling distributed systems (Vasquez, A., et al., 2016). Integration of these technologies with PLC systems is important in the real-time gathering, processing, and decision-making in manufacturing.

IV. CONCLUSION

Finally, the automation capabilities of a variety of sectors have been greatly improved by the incorporation of cutting-edge technologies like Bluetooth, GSM, and Zigbee into Programmable Logic Controllers (PLCs). Bluetooth is perfect for short-range control and monitoring applications because it provides wireless communication options that are easy to integrate and use minimal energy. Long-distance remote control and monitoring of PLC systems is made possible by GSM's wide cellular network coverage, which increases accessibility and flexibility. Zigbee, on the other

hand, is notable for its mesh networking and low power consumption, which are particularly helpful for scalable automation systems that need dependable communication in industrial settings. When paired with PLCs, these technologies provide a host of benefits, such as increased system flexibility, cost savings, and operational efficiency. Although Bluetooth, GSM, Zigbee, and LoRa are all suitable communication technologies, they are not necessarily the most convenient or economical choices for PLC connectivity in industrial settings. Bluetooth has a short range (usually about 100 meters), which makes it inappropriate for larger industrial installations that need long-range communication. GSM, although it provides extensive coverage, is more expensive due to network fees, and its bandwidth is restricted, so it is not as effective for real-time data streaming from PLCs. Zigbee, although low power, has limited range and slower data transfer rates, which can make it less effective in industrial use where greater data throughput is needed. LoRa, although excellent for long-distance communication, is not suitable for real-time monitoring because it has a low data rate and relies on specialized gateways, increasing the complexity and cost of the system. Conversely, WiFi is a far more stable and scalable option. It offers greater bandwidth, improved range, and simpler integration with existing networks. Through the connection of a PLC to WiFi through a module such as the ESP8266, industries can take advantage of their current WiFi infrastructure without installing separate networks or other communication equipment. WiFi also facilitates easy integration with web-based platforms.

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