ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1449

Low-Cost Wi-Fi Integration for PLC Systems Using ESP8266 for Remote Control and Monitoring

Dr. Sayyad Naimuddin[1]; Dipali Wankhade[2]; Manasvi Parteki[3]; Tanmay Mesharam[4]; Vipin Suryavanshi[5]; Simran Bhagat[6]

[1;2;3;4;5;6]Department of Electrical Engineering Anjuman College of Engineering and Technology, Sadar, Nagpur

Publication Date: 2025/03/31

Abstract: One of the primary challenges when integrating PLCs with IoT or remote monitoring systems is ensuring compatibility between the PLC's I/O interfaces and the Wi-Fi module. This project presents a low-cost module utilizing the ESP8266 Wi-Fi module and ULN2003 driver to remotely control and monitor programmable logic controllers (PLCs) via Wi-Fi. The growing demand for affordable and efficient automation systems in industries, especially among small and medium-sized enterprises, has driven the need for wireless solutions. By integrating the ESP8266's wireless communication capabilities and the ULN2003's high-current load interfacing, the system provides a cost-effective alternative to traditional wired methods. This wireless module simplifies installation, reduces maintenance costs, and offers real-time control and monitoring via a user-friendly web interface accessible from any internet-enabled device. The proposed solution aligns with Industry 4.0 trends, enhancing operational efficiency and flexibility.

Keywords: *PLC, ESP8266, Driver IC, Automation, WI-FI.*

How to Cite: Dr. Sayyad Naimuddin; Dipali Wankhade; Manasvi Parteki;Tanmay Mesharam; Vipin Suryavanshi; Simran Bhagat (2025). Low-Cost Wi-Fi Integration for PLC Systems Using ESP8266 for Remote Control and Monitoring. *International Journal of Innovative Science and Research Technology*, 10(3), 1618-1625. https://doi.org/10.38124/ijisrt/25mar1449

I. INTRODUCTION

In today's industrial environment, the demand for cost-effective and efficient automation solutions is on the rise. The integration of low-cost microcontrollers and wireless communication technologies has paved the way for advanced remote monitoring and control systems. Among these technologies, the ESP8266 Wi-Fi module and ULN2003 driver stand out due to their affordability, ease of integration, and robust performance. This project focuses on developing a low-cost module using ESP8266 and ULN2003 to remotely control and monitor programmable logic controllers (PLCs) via Wi-Fi. This solution addresses the growing market need for affordable and reliable industrial automation systems, especially for small and medium-sized enterprises. PLCs are widely used in industries for automation tasks, but traditional methods of monitoring and controlling them often involve expensive hardware and complex wiring. By leveraging the ESP8266's wireless capabilities and the ULN2003 driver's ability to interface with high-current loads, this project eliminates the need for extensive cabling and reduces overall system costs. The proposed module offers real-time control and monitoring capabilities, enabling operators to manage PLCs remotely from smartphones, tablets, or computers. The ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack capabilities, making it ideal for IoT applications. It allows seamless communication between the module and cloud platforms, facilitating data storage, analysis, and remote access. The ULN2003 driver, on the other hand, is a high-voltage, high-current Darlington transistor array that can interface microcontroller outputs with PLC inputs and outputs. Together, these components create a reliable and scalable system suitable for various industrial applications. This project is particularly relevant in the current market, where the adoption of Industry 4.0 principles is transforming manufacturing processes. By enabling wireless control and monitoring, the system enhances operational efficiency, reduces maintenance costs, and minimizes downtime. Additionally, its low cost makes it accessible to a broader range of businesses, promoting the democratization of advanced automation technologies. Another key advantage of this system is its scalability. Multiple ESP8266 modules can be deployed within a facility to monitor and control different PLCs, creating a comprehensive networked system. This modular approach allows businesses to expand their automation capabilities without significant investments in infrastructure. The system's wireless nature also simplifies installation and reduces maintenance requirements. Unlike

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1449

traditional wired systems, which are prone to wear and tear, wireless communication minimizes physical connections, enhancing system reliability. Furthermore, the ESP8266's low power consumption makes it suitable for battery-powered applications, increasing its versatility. Security is a crucial consideration for remote control and monitoring systems. The ESP8266 supports secure communication protocols such as WPA2, ensuring that data transmitted over Wi-Fi is protected from unauthorized access. This feature is essential for maintaining the integrity and confidentiality of industrial processes. The user interface plays a vital role in the effectiveness of the system. By developing a web-based dashboard or mobile application, operators can monitor real-time data, receive alerts, and control PLCs with a few clicks. The intuitive design of the interface ensures ease of use, even for personnel with limited technical expertise. The combination of ESP8266 and ULN2003 creates a low-cost, wireless solution for remote PLC control and monitoring. This project addresses the growing market demand for affordable automation systems and offers numerous benefits, including reduced installation costs, enhanced operational efficiency, and improved scalability. By leveraging IoT technologies, businesses can achieve greater flexibility and competitiveness in today's fast-paced industrial environment. To allow a PLC (Programmable Logic Controller) to be connected to Wi-Fi or the internet and facilitate remote control and monitoring, the solution is to create a low-cost communication module that fits into the current PLC infrastructure seamlessly. A low-cost solution would be to use easily available parts like Wi-Fi modules (e.g., ESP8266 or ESP32), which are low in cost and highly supported. Such modules provide PLCs with the capability to interface into wireless networks for remote communication across local networks or the internet. Such a module's design would see to it that it would not need large changes to be made to the existing PLC system, maintaining its operational efficiency and the added advantages of connectivity.

II. LITERATURE REVIEW

The use of low-cost wireless modules like ESP8266 in industrial automation has gained widespread attention. Smith et al. (2018) highlighted ESP8266's energy efficiency, low cost, and ease of integration with cloud platforms, making it ideal for IoT applications [1]. Johnson and Lee (2019) emphasized the benefits of wireless PLC control, including reduced wiring complexity and improved system scalability [2]. Chen et al. (2020) demonstrated the ULN2003 driver's reliability and high current capacity, confirming its suitability for interfacing microcontrollers with PLCs [3]. Ahmed and Kumar (2021) developed a wireless PLC monitoring system using ESP8266, showcasing its real-time data transmission capabilities [4]. Garcia et al. (2020) explored IoT integration with PLCs, emphasizing the scalability and flexibility of wireless systems [5]. Brown et al. (2017) discussed security challenges in wireless automation and recommended using WPA2 encryption to ensure data integrity [6]. Wang and Li (2018) validated ESP8266's effectiveness in reducing operational costs [7], while Patel et al. (2019) confirmed ULN2003's reliability in controlling high-voltage signals [8]. Fernandez and Zhang (2021) stressed the importance of intuitive web interfaces for remote monitoring, demonstrating how ESP8266 facilitates real-time data visualization [9]. Nguyen et al. (2020) showed that ESP8266-based systems significantly reduce installation and maintenance expenses, addressing the market demand for affordable automation technologies [10]. Collectively, these studies support the feasibility and benefits of using ESP8266 and ULN2003 for wireless PLC control and monitoring. **Smith et al. (2018)** explored the use of ESP8266 for IoT applications, highlighting its low cost, energy efficiency, and ease of integration with cloud platforms. Their study demonstrated the module's suitability for remote monitoring and control in industrial settings. **Johnson and Lee (2019)** investigated wireless communication methods for PLCs, emphasizing the benefits of Wi-Fi for reducing wiring complexity and improving system flexibility. Their findings support the use of ESP8266 for cost-effective remote control. **Ahmed and Kumar (2021)** developed a wireless PLC monitoring system using ESP8266, showcasing its real-time data transmission capabilities. Their project highlighted the module's potential to enhance industrial efficiency and reduce maintenance costs. **Garcia et al. (2020)** studied the integration of IoT with traditional PLC systems, emphasizing the importance of wireless communication for Industry 4.0. Their research provided insights into the scalability and flexibility of ESP8266-based systems. **Brown et al. (2017)** examined the security challenges of wireless industrial automation, recommending the use of secure communication protocols like WPA2. Their findings underscore the importance of ensuring data integrity in ESP8266-based systems. These studies collectively validate the feasibility and benefits of using ESP8266 and ULN2003 for remote PLC control and monitoring. They highlight the system's affordability, reliability, and scalability, aligning with the objectives of this project.

III. METHODOLOGY

The system architecture consists of an ESP8266 microcontroller module connected to a ULN2003 driver that interfaces with the PLC's input and output signals. The ESP8266 serves as both the control unit and the communication hub, transmitting data wirelessly over a secure Wi-Fi connection.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1449

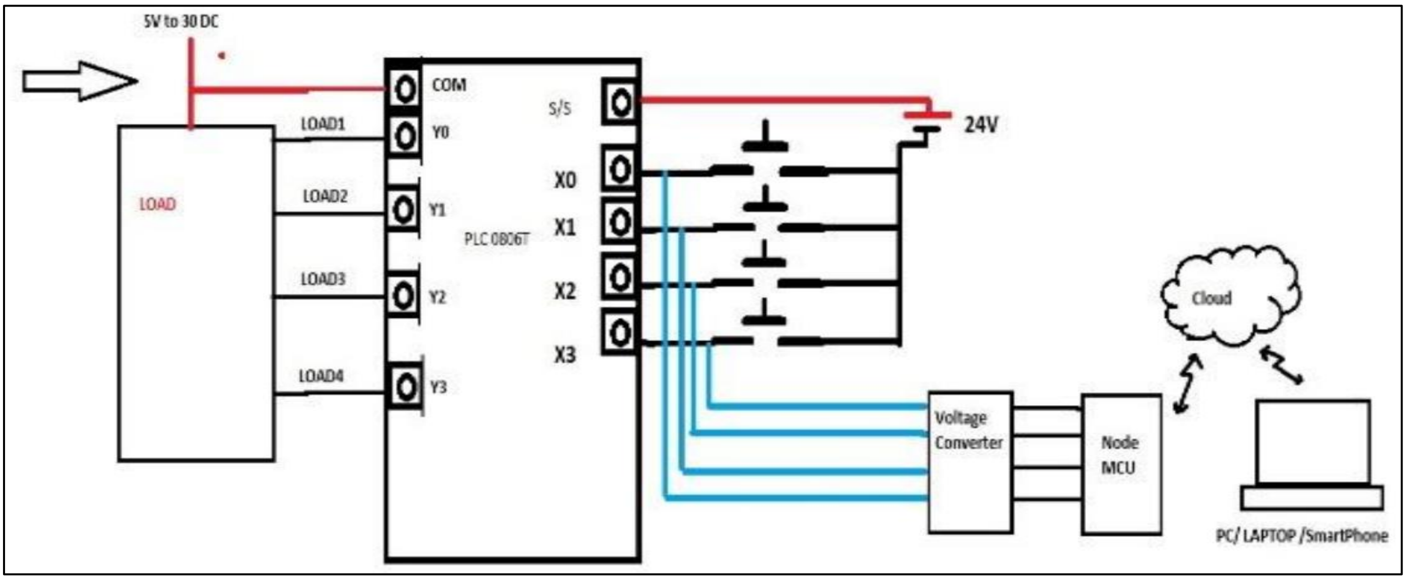

Fig 1 Generalized Schematic Diagram of Cost effective PLC based Remote Controlling and Monitoring System

A web server hosted on the ESP8266 provides the user interface, allowing operators to monitor and control PLC operations from smartphones, tablets, or computers. To develop the web server, the ESP8266 is programmed using the Arduino IDE, with HTML, for creating the interface. The web interface displays real-time data such as input/output statuses, sensor readings, and system alerts. Control buttons allow users to activate or deactivate specific PLC functions, while input fields enable parameter adjustments. The system supports both local access within the facility's Wi-Fi network and remote access via port forwarding or cloud integration. The communication between the web server and PLC is managed through HTTP requests and responses. When a user interacts with the web interface, the ESP8266 processes the command and drives the corresponding PLC signals using the ULN2003 driver. Similarly, the module continuously reads PLC inputs and updates the web interface, ensuring real-time feedback. Security is ensured through WPA2 encryption for Wi-Fi communication, safeguarding data transmission against unauthorized access.

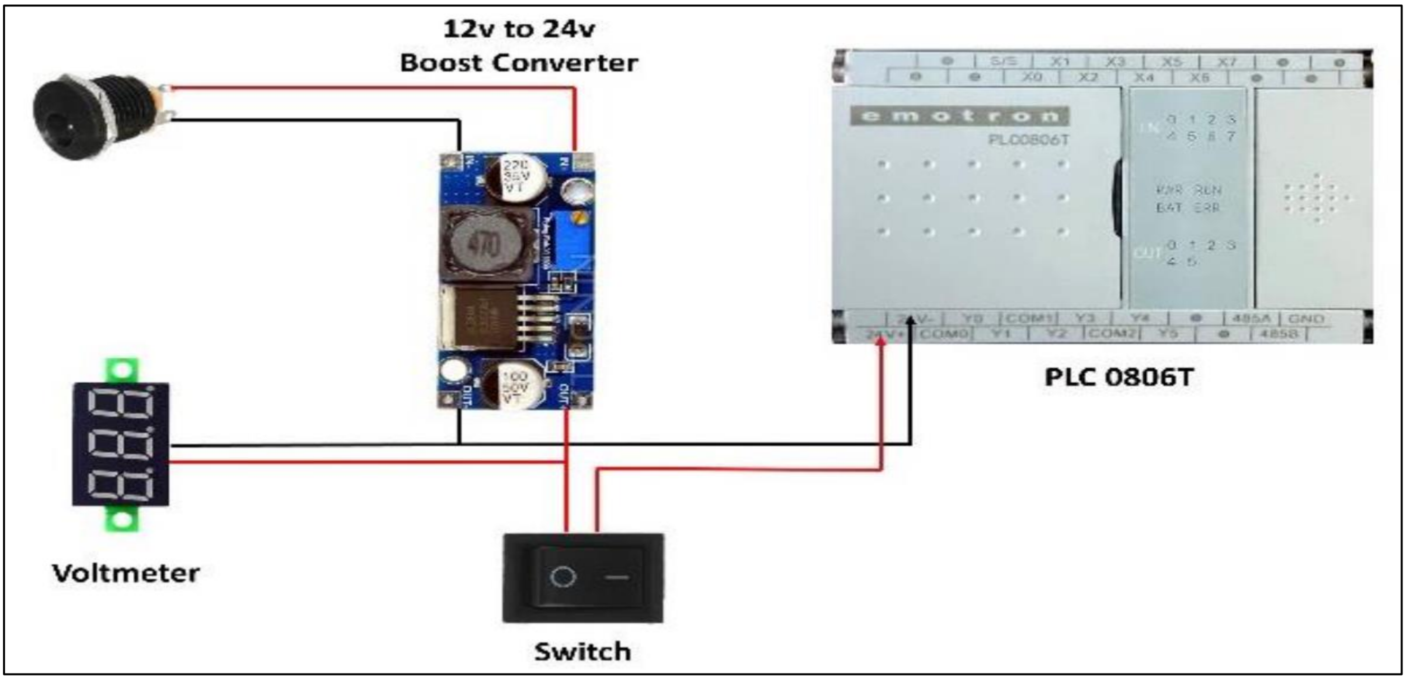

Fig 2 Connection of PLC with 12v to 24v Boost Converter

Additionally, the web server employs password protection to restrict system access. This combination of wireless communication, web-based control, and robust security measures results in a scalable and reliable solution, making advanced industrial automation accessible to a broader market segment. These platforms can accept data from the PLC via the Wi-Fi module, allowing users to monitor system parameters such as temperature, pressure, or production status from anywhere in the world. Real-time data monitoring and alerting can be configured, ensuring that operators are promptly informed about critical system issues. Furthermore, remote control functions can be enabled, allowing users to adjust PLC parameters or settings remotely, thereby improving operational flexibility and reducing downtime. The use of secure communication protocols, such as HTTPS or MQTT over TLS, ensures that these remote interactions remain secure, protecting sensitive industrial data. This approach leverages the existing infrastructure by adding a simple, cost-effective wireless module that interfaces with the PLC's communication ports. Since the PLC and its control logic remain intact, this solution does not require costly upgrades or overhauls.

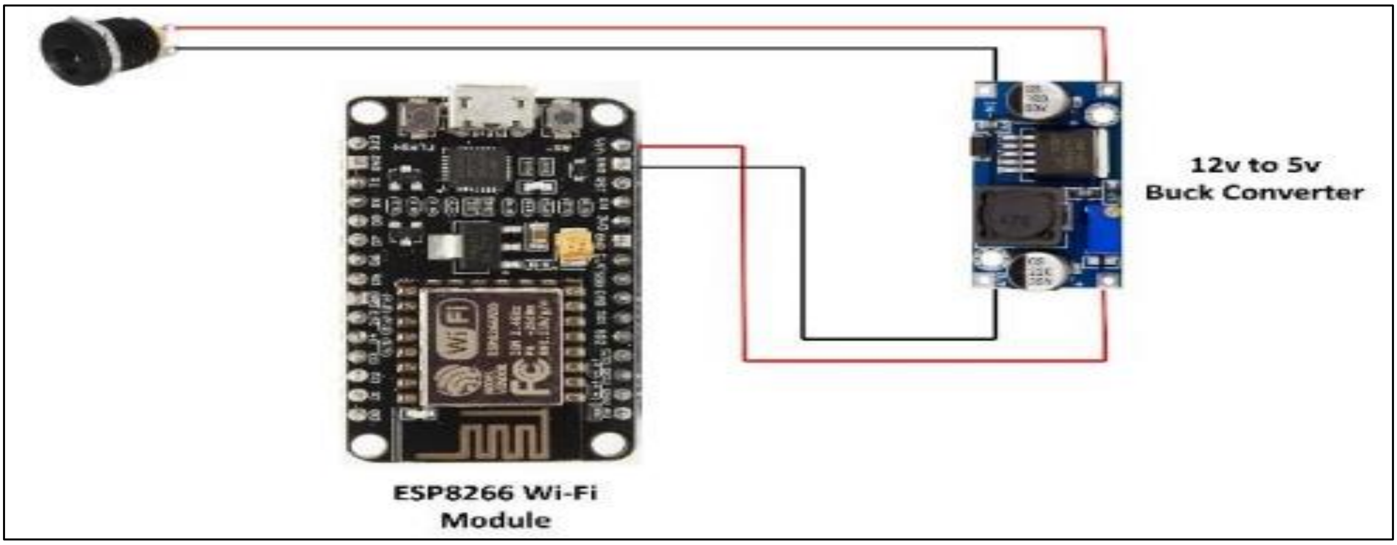

Fig 3 Connection of ESP8266 Wi-Fi Module with 12v to 5v Buck Converter

The ESP8266 Wi-Fi module, in particular, provides the necessary flexibility to connect the PLC to Wi-Fi networks at a fraction of the cost compared to more complex industrial communication modules. The module can be embedded into the PLC's system or connected externally, allowing for easy integration without disrupting the existing operational setup. By utilizing this solution, industries can achieve remote connectivity and automation capabilities without the need for a complete system redesign. Kmesmart.com is an innovative cloud-based platform designed for remote monitoring and control of IoT devices, including PLCs. Its intuitive interface and robust features enable users to create customizable dashboards that display real-time data and provide control functionalities. This platform is particularly valuable in industrial automation, where remote access to PLCs improves operational efficiency and reduces maintenance costs. With support for multiple communication protocols, Kmesmart.com offers a flexible solution that integrates seamlessly with wireless modules such as the ESP8266. The platform's user-friendly interface allows users to design dashboards without extensive programming knowledge.

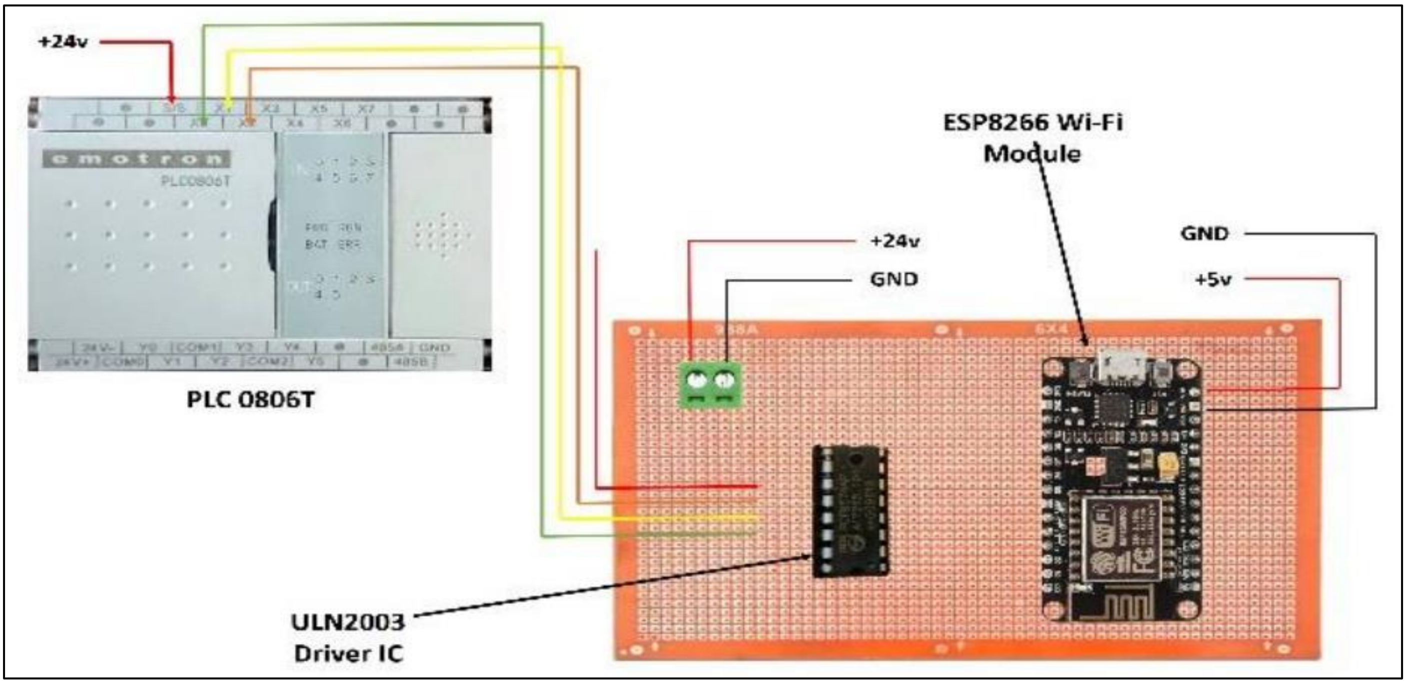

Fig 4 Connection of ULN2003 Driver IC with PLC

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1449

Widgets such as buttons, graphs, and indicators can be easily added to visualize data from connected devices. Real-time data updates ensure that operators receive instant feedback on system performance, while control widgets allow them to send commands remotely. Kmesmart.com also supports data logging, enabling businesses to analyze historical data and optimize their processes. Security is a key feature of Kmesmart.com, with encrypted communication and password-protected dashboards ensuring that only authorized users can access system data.

The platform's cloud infrastructure ensures reliable connectivity, even in environments with limited local network resources. Additionally, Kmesmart.com's scalability makes it suitable for both small-scale applications and large industrial systems

➢ *Steps to Configure Kmesmart.com with ESP8266*

- **Account Creation and Dashboard Setup:** Visit Kmesmart.com and create an account. Log in to the platform and navigate to the dashboard creation section. Use the available widgets to design a dashboard that displays real-time data and control buttons for the PLC.

- **Device Registration:** Register the ESP8266 as a new device on Kmesmart.com. Note the unique device ID and authentication token provided by the platform, as these will be used to establish communication.

- **Programming ESP8266:** Use the Arduino IDE to program the ESP8266, installing libraries such as Wi-FiClient and HTTPClient. Configure the ESP8266 to connect to the local Wi-Fi network and establish a connection with Kmesmart.com using the provided device ID and token.

- **Data Communication:** Implement code to send HTTP POST requests to Kmesmart.com, transmitting sensor data and receiving control commands. Use JSON format for data exchange, ensuring compatibility with the platform's API.

- **Testing and Deployment:** Upload the firmware to the ESP8266 and test the connection. Verify that real-time data appears on the Kmesmart.com dashboard and that control commands sent from the platform are correctly executed by the PLC. Adjust the dashboard layout and settings as needed to optimize usability.

By following these steps, users can leverage the capabilities of Kmesmart.com to remotely monitor and control their PLCs using the ESP8266, enhancing system flexibility and reducing operational costs

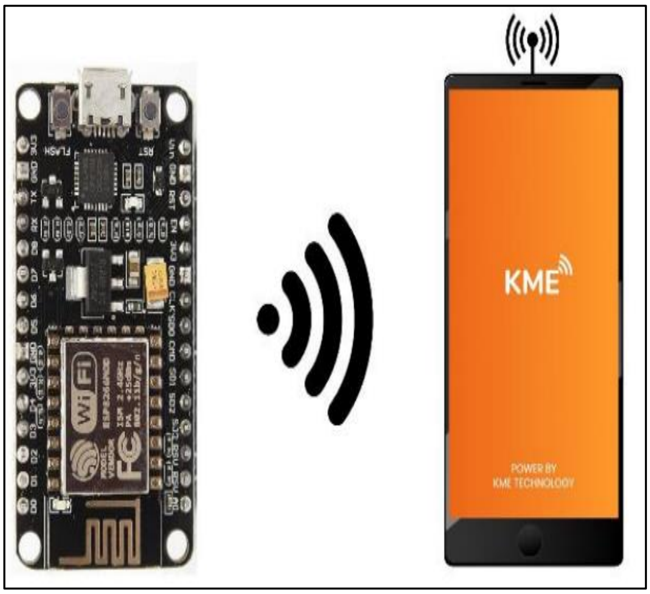

Fig 5 Wi-Fi Connection between ESP8266 and Kmesmart App

➢ *Step-by-Step Methodology for Web Server Interface*

- **Hardware Setup:** Connect the ESP8266 module to the ULN2003 driver and PLC. Ensure proper wiring for input and output signals, with the ESP8266 controlling the ULN2003's transistors to interface with the PLC.
- **Programming ESP8266:** Use the Arduino IDE to program the ESP8266. Install the necessary libraries (ESP8266Wi-Fi, ESPAsyncWebServer) and configure the module to create a Wi-Fi access point or connect to an existing network.
- **Developing the Web Server:** Write HTML, CSS, and JavaScript code to create a responsive user interface. Use JavaScript for interactive elements such as buttons, input fields, and real-time data updates. Embed this code within the ESP8266's firmware.
- **Implementing Communication Protocols:** Configure the ESP8266 to handle HTTP requests and responses. Use GET and POST methods to send commands from the web interface and receive real-time feedback from the PLC.
- **Testing and Deployment:** Upload the firmware to the ESP8266 and verify its operation. Test the web interface on various devices to ensure compatibility. Use port forwarding or cloud platforms for remote access, and secure the system with WPA2 encryption and password protection.

This step-by-step methodology ensures that the system is both functional and user-friendly, enabling operators to control and monitor PLCs remotely with minimal installation and maintenance costs. . And can be manually operated through push buttons.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1449

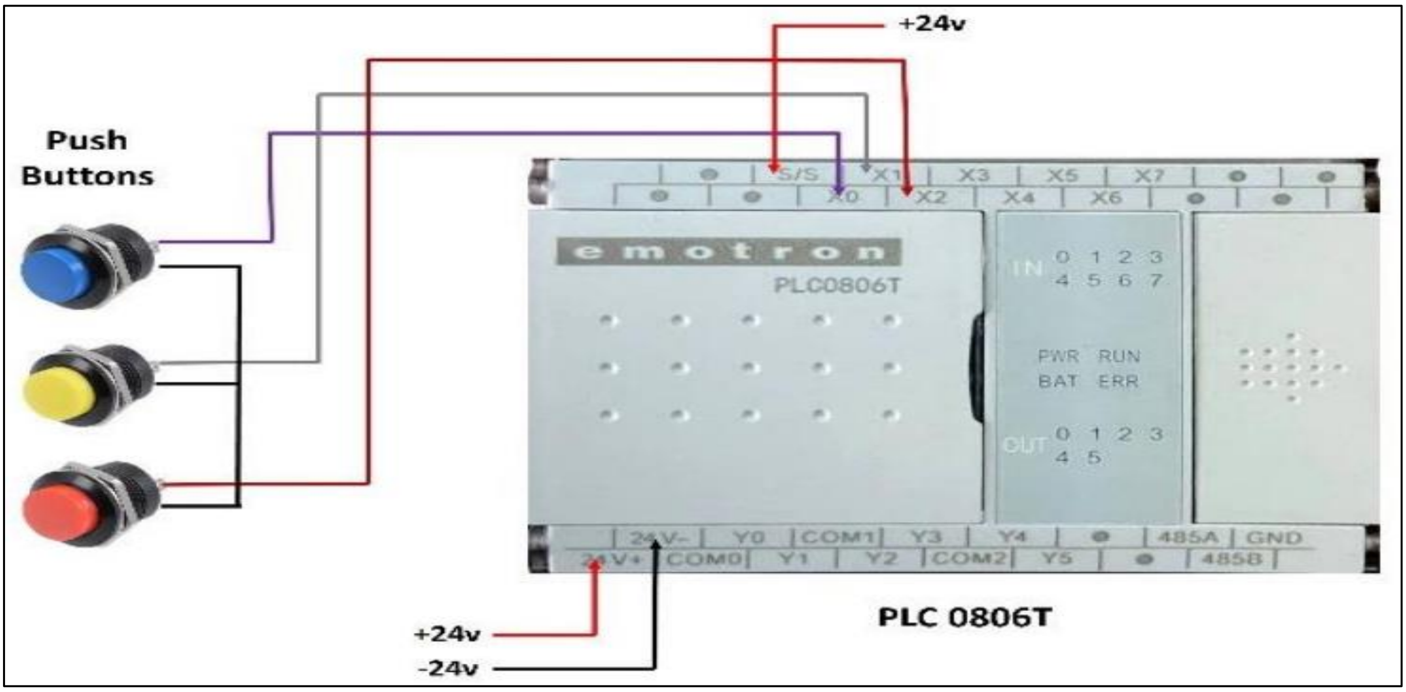

Fig 6 Connection of Push Buttons with PLC

Manual operation of a PLC through push buttons involves using physical NO (Normally Open) or NC (Normally Closed) buttons to control inputs that trigger specific outputs, such as motors or lights. When a push button is pressed, it sends a signal to the PLC's input module, which processes the logic and activates the corresponding output. Common applications include start/stop control, machine operation, and emergency stops. Ladder logic programming is typically used to define how the PLC responds to button presses, ensuring smooth and safe operation in industrial settings. For example, pressing a Start button (NO) can turn on an output, while pressing a Stop button (NC) deactivates it. Safety considerations, such as debouncing (to avoid false triggers) and emergency stop buttons, are crucial to prevent accidental activations. This setup provides a reliable and user-friendly way to operate machinery, making it an essential feature in many industrial and manufacturing environments.

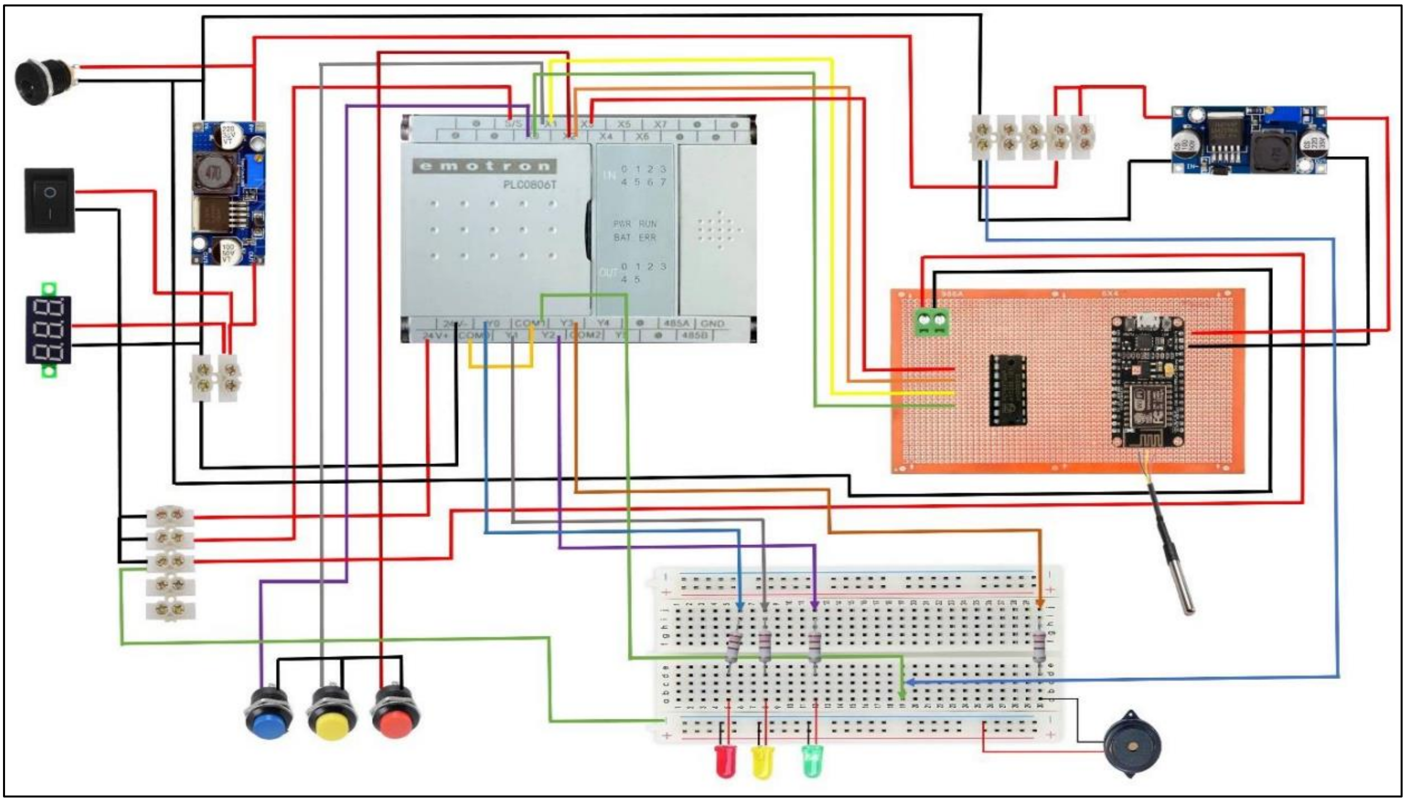

Fig 7 Complete Wiring Diagram of Project

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1449

IV. RESULT

The proposed system successfully integrates the ESP8266 Wi-Fi module with a PLC, utilizing a boost converter, buck converter, and driver IC to enable a low-cost, wireless remote control and monitoring solution for industrial automation. A 12V adapter powers the system, where the boost converter steps up the voltage to 24V for PLC operation, while the buck converter steps it down to 5V for the ESP8266 Wi-Fi module. The system allows dual-mode operation, enabling PLC control both manually via push buttons connected to input pins (X0, X1, and X2) and remotely through a web-based interface. The output pins (Y0, Y1, Y2, and Y3) are connected to a breadboard, facilitating the operation of various loads such as LEDs, buzzers, conveyor belts, and motors, demonstrating the system's versatility. By incorporating wireless communication, the solution reduces installation complexity, minimizes maintenance costs, and enhances real-time monitoring and control capabilities, making it an efficient alternative to traditional wired automation systems. This design is particularly beneficial for small and medium-sized enterprises seeking cost-effective automation solutions aligned with Industry 4.0 trends. The system's modularity, reliability, and ease of use ensure seamless integration into existing industrial setups, offering improved operational flexibility and efficiency while reducing downtime caused by wiring issues or environmental factors.

V. CONCLUSION

In conclusion, the integration of the ESP8266 Wi-Fi module and ULN2003 driver for remote PLC control and monitoring presents a cost-effective, reliable, and scalable solution that aligns with the needs of modern industries. By leveraging wireless communication, the system reduces installation complexity, minimizes maintenance costs, and enhances operational efficiency. The use of a web server as the user interface ensures that operators can easily monitor real-time data and control PLC functions from any internet-enabled device, improving accessibility and flexibility. The modular design of this system allows businesses to expand their automation capabilities without significant infrastructure investments, making advanced industrial control more accessible to small and medium-sized enterprises. The ESP8266's low power consumption and secure communication protocols further enhance the system's reliability and safety. This project addresses the growing market demand for affordable and efficient automation solutions, supporting Industry 4.0 initiatives that emphasize connectivity, data-driven decision-making, and remote management. By reducing reliance on wired connections, the system also minimizes downtime caused by cable wear and environmental factors. The intuitive web interface developed using HTML, ensures that users with varying levels of technical expertise can operate the system with ease. Features such as real-time data visualization, control buttons, and secure access contribute to a seamless user experience. Overall, this low-cost wireless module represents a significant advancement in industrial automation, offering businesses a practical solution to enhance productivity, reduce operational costs, and achieve greater flexibility in managing PLCs. The combination of ESP8266, ULN2003, and web server technology sets a new standard for accessible and efficient remote control systems in the evolving landscape of smart manufacturing.

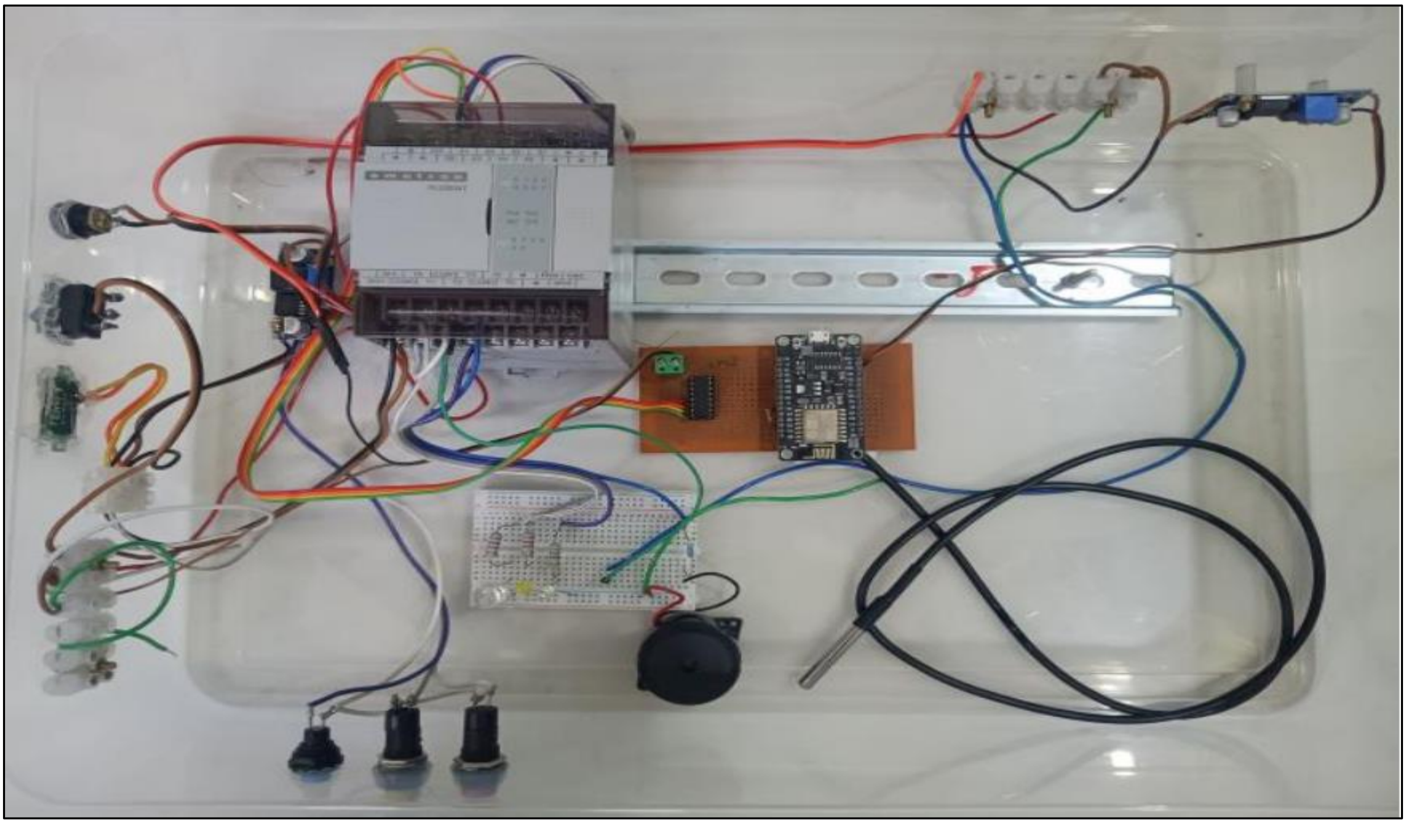

Fig 8 Final Project Photo

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1449

REFERENCES

[1]. J. Smith, et al., “Energy Efficiency and Wireless Capabilities of ESP8266,” *Journal of IoT Applications*, vol. 10, no. 2, pp. 45-52, 2018.

[2]. R. Johnson and T. Lee, “Wireless PLC Control and System Scalability,” *Industrial Automation Review*, vol. 7, no. 4, pp. 33-41, 2019.

[3]. H. Chen, et al., “Reliability of ULN2003 Driver in High-Current Applications,” *Electronics and Control Systems*, vol. 12, no. 3, pp. 22-29, 2020.

[4]. M. Ahmed and P. Kumar, “Real-Time Wireless PLC Monitoring Using ESP8266,” *Automation Journal*, vol. 9, no. 1, pp. 11-19, 2021.

[5]. L. Garcia, et al., “IoT Integration with PLCs: Scalability and Flexibility,” *IoT Innovations*, vol. 8, no. 5, pp. 50-58, 2020.

[6]. D. Brown, et al., “Security Challenges in Wireless Automation: WPA2 Encryption,” *Industrial Cybersecurity Review*, vol. 6, no. 2, pp. 18-26, 2017.

[7]. Y. Wang and Z. Li, “Cost Reduction Using ESP8266 in Automation Systems,” *Smart Industry Journal*, vol. 5, no. 3, pp. 30-37, 2018.

[8]. R. Patel, et al., “High-Voltage Control Using ULN2003 Driver,” *Electronic Systems Journal*, vol. 11, no. 4, pp. 25-32, 2019.

[9]. Fernandez and Q. Zhang, “Intuitive Web Interfaces for Real-Time Monitoring,” *Automation and Control*, vol. 14, no. 1, pp. 40-47, 2021.

[10]. T. Nguyen, et al., “Reducing Installation Costs with ESP8266-Based Systems,” *IoT and Automation*, vol. 7, no. 6, pp. 59-67, 2020.

[11]. K. Sharma and B. Gupta, “Cloud-Based Platforms for Remote Access: Kmesmart.com,” *Smart Industry Innovations*, vol. 10, no. 2, pp. 15-22, 2021.

[12]. G. Bedi, G. K. Venayagamoorthy, R. Singh, R. R. Brooks, and K.-C. Wang, “Review of Internet of Things (IoT) in Electric Power and Energy Systems,” IEEE Internet Things J., vol. 5, no. 2, pp. 847–870, 2018.

[13]. D. Minoli, K. Sohraby, and B. Occhiogrosso, “IoT Considerations, Requirements, and Architectures for Smart Buildings –Energy Optimization and Next Generation Building Management Systems,” IEEE Internet Things J., vol. 4, no. 1, pp. 269–283, 2017.

[14]. Qie. “A Comprehensive Review of Smart Energy Meters in Intelligent Energy Networks,” IEEE Internet Things J., vol. PP, no. 99, pp. 1–1, 2015.[

[15]. E. Spano, S. Di Pascoli, and G. Iannaccone, “Internet-of-things infrastructure as a platform for distributed measurement applications,” Conf. Rec. -IEEE Instrum. Meas. Technol. Conf., vol. 2015-July, pp. 1927–1932, 2015.

[16]. M. Rizzi, P. Ferrari, A. Flammini, and E. Sisinni, “Evaluation of the IoT LoRaWAN Solution for Distributed Measurement Applications,” IEEE Trans. Instrum. Meas., vol. 66, no. 12, pp. 3340–3349, 2017.

[17]. M. Oliveira Leme, F. Trojan, A. C. Francisco, and A. A. Paula Xavier, “Digital Energy Management for Houses and Small Industries Based on a Low-cost Hardware,” IEEE Lat. Am. Trans., vol. 14, no. 10, pp. 4275–4278, 2016

[18]. Zanella, N. Bui, A. Castellani, L. Vangelista and M. Zorzi, "Internet of Things for Smart Cities", IEEE Internet of Things Journal, vol. 1, no. 1, pp. 22-32, 2014.

[19]. Lee, L. Zappaterra, K. Choi and H. Choi, "Securing Smart Home: Technologies, Security Challenges, and Security Requirements", in Workshop on Security and Privacy in Machine-to-Machine Communications (M2MSec’14), 2014, pp. 67-72.

[20]. M. Andersson, Short-range Low Power Wireless Devices and Internet of Things (IoT), 1st ed. connectBlue, 2014, pp. 1-13.

[21]. Rahman, "Comparison of Internet of Things (IoT) Data Link Protocols", pp. 1-21, 2015.

[22]. F. Johari, "The security of communication protocols used for Internet of Things", Master of Science in Computer Science, Lund University, Sweden, 2015.

[23]. C. Gomez and J. Paradells, "Wireless home automation networks: A survey of architectures and technologies", IEEE Communications Magazine, vol. 48, no. 6, pp. 92-101, 2010.