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Smart EV Charging Station Monitoring System using ESP32 and IoT

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Abstract - The rapid growth of electric vehicles has increased the demand for smart and reliable charging systems. This project presents a Smart EV Charging Station Monitoring System using ESP32 and Internet of Things (IoT) technology. The system is designed to monitor important charging parameters such as voltage, current, power consumption, energy usage, and temperature in real time. A PZEM-004T module is used for measuring electrical parameters, while a DS18B20 temperature sensor is used to detect abnormal temperature conditions during charging. The collected data is displayed locally on an LCD screen and also uploaded to the ThingSpeak cloud platform through Wi-Fi for remote monitoring and visualization. A relay-based protection mechanism is included to automatically disconnect the charging load whenever unsafe conditions are detected. The proposed system provides a simple, cost-effective, and efficient solution for improving monitoring, safety, and overall performance of EV charging stations.

Keywords - Electric Vehicle (EV), ESP32, Internet of Things (IoT), Real-Time Monitoring, Smart Charging System.

I. INTRODUCTION

Electric vehicles (EVs) are becoming increasingly popular because they help reduce air pollution and decrease the use of fossil fuels. As the number of EV users continues to grow, the demand for reliable and efficient charging stations is also increasing rapidly. EV charging stations are now being installed in homes, offices, parking areas, and public locations to support the growing adoption of electric vehicles. However, many traditional charging systems still lack smart monitoring and safety features, which can affect charging performance and user safety

With the rapid expansion of EV infrastructure, the need for proper monitoring and protection systems has become more important. However, many traditional charging systems still lack smart monitoring and safety features, which can affect charging performance, energy efficiency, and user safety. In several existing systems, important charging parameters such as voltage, current, power consumption, and temperature are not continuously monitored, making it difficult to identify abnormal charging conditions in real time. Many EV charging stations are currently unable to continuously monitor important charging parameters such as voltage, current, power, and energy consumption in real time. Due to the lack of proper monitoring, unsafe conditions such as overheating, overloading, and power fluctuations may occur during charging operations. In addition, many conventional charging systems do not provide remote monitoring or automatic protection features, which can reduce charging efficiency and create safety risks for both users and charging equipment. Therefore, there is a need to develop a cost-effective smart monitoring system that can provide safe, efficient, and remotely accessible operation for EV charging stations.

To overcome these problems, this project proposes a Smart EV Charging Station Monitoring System using ESP32 and Internet of Things (IoT) technology. The system uses a PZEM-004T module to measure electrical parameters and a DS18B20 temperature sensor to monitor temperature conditions. The ESP32 microcontroller collects the data and uploads it to the ThingSpeak cloud platform through Wi-Fi for remote monitoring and visualization. A relay-based protection mechanism is also included to automatically disconnect the charging load whenever abnormal conditions are detected, improving overall safety and system reliability.

II. LITERATURE SURVEY

Several researchers have worked on smart monitoring and safety systems for electric vehicle charging stations using IoT technology. Gupta and Singh (2021) proposed an IoT-based EV charging monitoring system that used sensors and cloud integration for real-time data monitoring. Their system improved remote accessibility and monitoring efficiency, but it did not include an automatic protection mechanism for handling unsafe charging conditions. Kumar et al. (2022) developed an ESP32-based energy monitoring system capable of measuring voltage, current, and power consumption in real time. Although the system provided accurate energy monitoring, temperature-based safety control was not included in their work.

Ahmed and Khan (2021) presented a cloud-enabled smart EV charging framework that allowed users to monitor charging data remotely through internet connectivity. The system improved user accessibility and charging management, but the implementation

(2020) focused on energy management techniques for EV charging stations to improve charging efficiency and reduce unnecessary power usage. However, their research mainly concentrated on power optimization and provided limited safety features for practical charging applications.

In another study, researchers introduced temperature monitoring systems to prevent overheating during EV charging operations. Many existing systems use IoT platforms and cloud-based monitoring for data visualization and analysis, but several of them either increase the overall cost or lack integrated protection features such as automatic relay cutoff during abnormal conditions. Based on these observations, the proposed system combines real-time electrical monitoring, temperature sensing, cloud integration, and automatic safety control using ESP32 and IoT technology to provide a simple, cost-effective, and reliable solution for EV charging station applications.

III. OBJECTIVES OF THE PROPOSED SYSTEM

1. To design and develop a smart EV charging station monitoring system using the ESP32 microcontroller and IoT technology.
2. To monitor important charging parameters such as voltage, current, power consumption, energy usage, and temperature in real time.
3. To transmit charging data to the ThingSpeak cloud platform for remote monitoring and visualization through Wi-Fi connectivity.
4. To implement an automatic safety mechanism using a relay module to disconnect the charging load during abnormal conditions such as overheating or overloading..

IV. SYSTEM ARCHITECTURE

The proposed EV charging station monitoring system is developed using ESP32 as the main controller along with energy and temperature sensing modules. A PZEM-004T energy meter is used to measure important electrical parameters such as voltage, current, power, and total energy consumption during the charging process. In addition, a DS18B20 temperature sensor continuously monitors the temperature of the charging setup to ensure safe operation and detect abnormal conditions. The ESP32 microcontroller processes the collected sensor data and displays the real-time charging parameters on a 16×2 I2C LCD for local monitoring. The system is designed to provide continuous monitoring, improved safety, and efficient management of EV charging operations.

For remote monitoring, the ESP32 sends the collected sensor data to the ThingSpeak IoT cloud platform using Wi-Fi connectivity, allowing users to access and view real-time charging information from anywhere. In addition, a relay-based protection system is implemented to ensure safety by automatically disconnecting the load whenever abnormal conditions such as overheating or overcurrent are detected. This helps in improving system reliability and protecting the charging setup from potential damage.

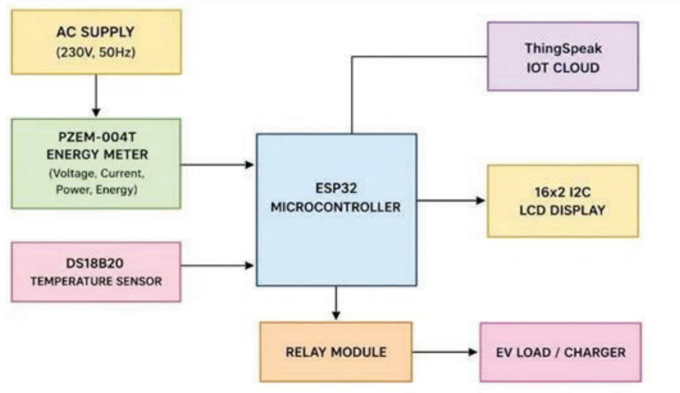

Fig. 1. Block diagram of the proposed EV charging station monitoring system

This architecture provides a simple, low-cost, and efficient solution for real-time monitoring of EV charging stations. It also improves safety by continuously tracking key parameters and helping in early detection of abnormal conditions.

V. MATHEMATICAL MODELING OF THE PROPOSED SYSTEM

A. Power Calculation

$$P=V\times I$$

The instantaneous power drawn by the EV charging unit is determined as the product of supply voltage and load current. In the proposed system, these electrical parameters are acquired continuously using the PZEM-004T energy monitoring module. The ESP32 controller processes the incoming measurements in real time to estimate the active power consumed during charging. This analysis is useful for observing load variations and maintaining system operation within permissible electrical limits.

B. Energy Consumption

$$E = P\times t$$

The total energy consumed during EV charging is calculated using the relation $E = P \times t$, where Erepresents energy, Pdenotes power, and
$t$indicates charging time. The ESP32 continuously monitors

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voltage and current values using the PZEM-004T sensor module and calculates the power consumed during charging. Based on the charging duration, the system estimates the total energy usage in real time. The collected data is sent to the IoT cloud platform for monitoring and analysis.

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C. Temperature- Based Cutoff Control

$$T > T_{max} \Rightarrow \text{Relay OFF}$$

The system continuously monitors temperature using the DS18B20 sensor to ensure safe operation of the EV charging station. It compares the real-time temperature with a predefined safe threshold

VI. HARDWARE IMPLEMENTATION

The hardware implementation of the proposed EV charging In addition, IoT cloud integration helps in long-term data storage and performance analysis of the EV charging system. It allows users to track energy consumption patterns, identify irregularities, and evaluate system efficiency over time. This makes the proposed system more intelligent, user-friendly, and suitable for modern smart EV charging infrastructure.station monitoring system is developed using the ESP32 microcontroller as the central processing unit. The ESP32 is selected because it supports built-in Wi-Fi connectivity, low power consumption, and efficient processing capabilities, which makes it suitable for IoT-based applications. It acts as the main controller that collects data from different sensors, processes it in real time, and manages the overall operation of the charging system.

The system uses a PZEM-004T energy monitoring module to measure important electrical parameters such as voltage, current, power, and total energy consumption during the EV charging process. These values are continuously monitored and sent to the ESP32, which processes the data for analysis and displays real-time information. This helps in understanding the load behavior and ensures that the charging system operates within safe electrical limits.

For temperature monitoring, a DS18B20 sensor is integrated into the system. It continuously measures the temperature of the charging setup and provides real-time feedback to the ESP32. This is important for detecting overheating conditions, which may occur during long-duration charging or high-load operation. By monitoring temperature continuously, the system ensures better safety and prevents possible damage to components.

A 16×2 I2C LCD display is used for local monitoring of the system. It displays real-time values such as voltage, current, power, energy consumption, and temperature in a simple and readable format. This allows users to easily observe the charging status without depending only on internet connectivity or cloud access.

In addition to monitoring, the system also includes a 5V relay module as a safety protection mechanism. The relay works as an automatic switch that controls the charging load. Whenever abnormal conditions such as overtemperature, overcurrent, or unsafe operating conditions are detected, the ESP32 immediately triggers the relay to disconnect the load. This ensures protection of both the EV battery and the charging station hardware, making the system more reliable, safe, and suitable for real-time EV charging applications.

VII. IOT CLOUD INTEGRATION

The IoT cloud integration in the proposed EV charging station monitoring system is implemented using the ThingSpeak platform. The ESP32 microcontroller plays a key role in collecting real-time data from different sensors such as voltage, current, power, energy, and temperature. This data is then transmitted to the cloud through Wi-Fi connectivity, allowing seamless communication between the hardware system and the online platform.

Once the data is uploaded to ThingSpeak, it is displayed in the form of graphs and charts, which makes it easier to analyze and understand the charging behavior over time. Users can access this information remotely from any location using an internet-enabled device such as a smartphone or laptop. This feature improves the overall usability of the system by providing real-time monitoring without the need for physical presence at the charging station.

VIII. SAFETY PROTECTION MECHANISM

The safety protection mechanism in the proposed EV charging station monitoring system is designed to ensure secure and reliable operation during the charging process. The system continuously monitors important parameters such as current, voltage, and temperature using sensors connected to the ESP32 microcontroller. This real-time monitoring helps in detecting any abnormal conditions that may affect the safety of the charging station or the connected EV.

One of the key safety features is overcurrent protection. If the current exceeds a predefined safe limit, the system immediately identifies it as an abnormal condition. In such a case, the ESP32 sends a signal to the relay module to disconnect the charging load, preventing any possible damage to the battery, wiring, or charging equipment. This helps in maintaining safe electrical operation at all times.

Another important safety feature is temperature-based protection. The DS18B20 sensor continuously measures the temperature of the charging setup. If the temperature rises beyond the safe threshold value, it indicates a risk of overheating. In this situation, the system automatically turns OFF the relay, stopping the charging process to avoid thermal damage or fire hazards.

Overall, the safety protection mechanism ensures that the EV

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charging station operates in a controlled and secure environment. By combining real-time monitoring and automatic cutoff features, the system enhances user safety, protects hardware components, and improves the reliability of the entire charging process.

In addition to electrical and temperature-based protection, the system also includes automatic load control based on abnormal operating conditions. The ESP32 continuously evaluates sensor data in real time, and if any parameter goes beyond the safe operating range, it instantly takes corrective action. This ensures that the system does not remain in an unsafe state for even a short duration, thereby improving overall reliability.

The relay module acts as the main switching device for protection. It works as an automatic cutoff switch that disconnects the EV charging supply whenever unsafe conditions are detected. Since the relay is controlled directly by the ESP32, the response time is very fast, which helps in preventing further damage to the charging system and connected vehicle. This fast response mechanism is important for real-world EV charging applications where safety is critical.

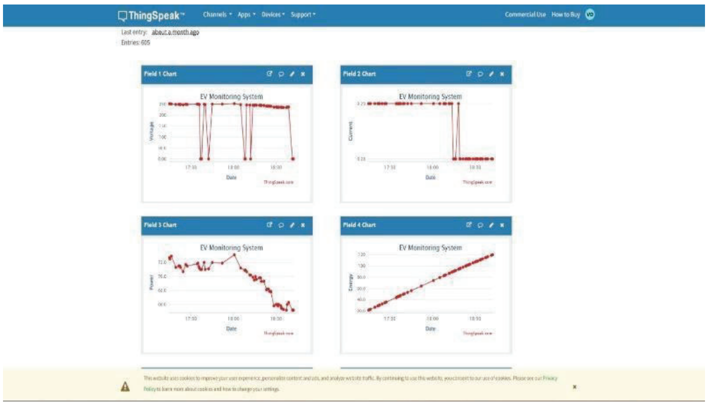
Overall, these protection features make the EV charging station more reliable and safe for users. The combination of real-time monitoring, quick response action, and automatic shutdown capability ensures that both the charging infrastructure and the EV battery remain protected under all operating conditions.

IX. EXPECTED RESULTS AND FUTURE SCOPE

The proposed EV charging station monitoring system is expected to provide accurate and real-time monitoring of key parameters such as voltage, current, power, energy consumption, and temperature. These values will be displayed on both the LCD screen and the ThingSpeak cloud platform, enabling users to monitor the charging process locally as well as remotely. The system is also expected to improve overall visibility and control of the charging operation, making it more efficient and user-friendly.

It is further expected that the system will successfully detect abnormal conditions such as overheating and overcurrent in real time. In such cases, the relay will automatically disconnect the charging load, ensuring quick response and improved safety. This will help in protecting both the EV battery and the charging infrastructure from potential damage, thereby increasing system reliability.

The future scope of this project includes the integration of advanced technologies such as machine learning for predictive maintenance and intelligent fault detection. The system can also be enhanced with mobile application support for real-time notifications, remote control, and better user interaction. Additionally, it can be expanded to support multiple EV charging points and fast-charging systems with efficient load management techniques. Integration with smart grid systems can further optimize energy usage and improve power distribution efficiency.



X. CONCLUSION

The proposed EV charging station monitoring system provides an effective and practical solution for real-time monitoring and safety management of charging stations by integrating modern IoT technology with embedded hardware. Using the ESP32 microcontroller along with sensors like PZEM-004T and DS18B20, the system continuously monitors key electrical and environmental parameters such as voltage, current, power, energy consumption, and temperature. This real-time monitoring ensures better control, improved understanding, and efficient management of the EV charging process. It also helps in maintaining safe operating conditions by quickly detecting any abnormal variations in system behavior.

The integration of IoT technology through the ThingSpeak cloud platform further enhances the system by enabling remote access to live charging data from anywhere. This allows users to conveniently monitor system performance without being physically present at the charging station and also supports better analysis of energy usage patterns over time. Additionally, the system includes an automatic safety mechanism using a relay module, which immediately disconnects the load during

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abnormal conditions such as overheating or overcurrent. This not only improves safety but also protects both the EV and the charging infrastructure from potential damage, making the system more reliable, efficient, and suitable for real-world applications.

In conclusion, the proposed system serves as a smart, efficient, and scalable solution for modern EV charging infrastructure, providing reliable real-time monitoring and safety control. It effectively integrates IoT-based cloud connectivity with sensor-driven data acquisition to ensure continuous supervision of critical charging parameters such as voltage, current, power, energy, and temperature. This improves overall system transparency, operational efficiency, and user convenience.
Furthermore, the system is designed in a way that it can be easily expanded and upgraded to meet future technological requirements. With advancements in smart grid technology and intelligent transportation systems, this solution can be integrated with more advanced features such as automated energy management, predictive maintenance, and mobile-based control systems. Such improvements can further enhance its performance, reliability, and adaptability in large-scale EV charging networks.

Overall, this project provides a strong foundation for future towards the growth of sustainable and intelligent transportation infrastructure.

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