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Smart EV Charging Station Monitoring and User Feedback System

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Abstract

The efficiency and reliability of electric vehicle (EV) charging stations are pivotal for user satisfaction and broader EV adoption. This research introduces a system that monitors essential parameters of EV charging stations, such as temperature, voltage, and current, using advanced sensors and the ESP32 microcontroller. The collected data is transmitted through the Bylnk platform, for real-time monitoring and analysis. To enhance the user experience, a mobile application has been developed, allowing users to review these critical details and receive notifications. The app provides a detailed overview of each charging station's performance, helping users identify the best stations based on historical data and user reviews. By offering insights into the operational status and efficiency of charging stations, the system aids users in making informed decisions about where to charge their vehicles. This integration of real-time monitoring with user-friendly mobile access improves user convenience and optimizes the EV charging infrastructure management.

Keywords: ESP 32, Voltage Sensor, Current Sensor, Temperature Sensor, Bylnk

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1. Introduction

With this surge in EV adoption comes the need for robust charging infrastructure, making these charging stations paramount. These systems incorporate a range of sensors, including temperature, voltage, and current sensors, to ensure optimal performance and safety during the charging process.

At the heart of this technology is a sophisticated mobile application that empowers users to review real-time data from these sensors. The effectiveness of electrical vehicle (EV) charging station monitoring systems hinges on several key factors: charging time, power capacity, and cost-effectiveness [2]. Through this application, EV owners can access detailed insights into the charging process, including temperature readings, voltage levels, and current flow. Such comprehensive information not only enhances the user experience but also instills confidence in the reliability of the charging infrastructure. Additionally, the study explores multistage charging, fast-charging solutions, and the broader impact of EV adoption on India's development [3].

To enhance the user experience and ensure the reliability of charging infrastructure, optimized charging strategies have also significantly decreased fossil fuel generation [4]. The user interface of the mobile application offers a detailed view of each charging station, enabling users to make informed decisions about where to charge their vehicles. By analyzing the data provided, users can identify the best charging stations based on factors such as efficiency, safety, and user satisfaction [16]. This level of transparency not only improves the overall charging experience but also fosters trust and loyalty among EV owners.

Furthermore, this technology is not just about convenience; it's about shaping the future of transportation. By promoting the use of electric vehicles and facilitating seamless charging experiences, these monitoring systems play a crucial role in reducing carbon emissions and mitigating the environmental impact of traditional transportation methods.

In summary, electrical vehicle charging station monitoring systems [17], coupled with user-friendly mobile applications, represent a significant step towards building a sustainable and efficient transportation ecosystem. By utilizing the power of data and technology, we are paving the way for a greener and smarter future [10].

1.1 Objectives

- To provide real-time monitoring of electrical vehicle charging stations.
- To ensure optimal performance and safety during the charging process.
- To empower users with detailed insights into temperature, voltage, and current levels.
- To enhance the overall user experience of EV owners.
- To enable users to make informed decisions about where to charge their vehicles.

2. Literature Review

The paper examines present and upcoming trends in EV battery charging methods, encompassing both traditional and innovative approaches with detailed comparative assessments. It delves into various tiers of EV charging infrastructure, emphasizing advanced designs such as rapid charging, intelligent charging, wireless solutions, and battery exchange systems. It underscores the incorporation of renewable energy sources and the application of optimized energy management algorithms. The research scrutinizes operational processes, advantages, obstacles, and effectiveness across diverse charging methodologies and configurations. Additionally, it investigates the influence of these technologies on EV adoption in India, taking into account governmental policies while proposing intelligent EV charging stations [1].

The study provides a quantitative assessment of various technologies and methodologies, focusing on efficiency, charging time, power capacity, and cost-effectiveness. It compares AC and DC charging stations and examines technological challenges, power conversion stages, and international standards. The review identifies trends and suggests future research directions, emphasizing high efficiency, wireless charging, wide band-gap technology, and renewable energy integration [2].

The study discusses technologies and strategies to address these challenges, highlights Indian government policies, and emphasizes the importance of reliable and efficient electrical transportation. The research explores multistage charging, fast-charging solutions, and the broader impact of EV adoption on India's development. It stresses integrating renewable energy sources and policy analysis to enhance EV infrastructure [3].

The study examines the impact of EV charging on power system expansion planning using a co-optimization model for generation and transmission. It evaluates EV penetration rates and charging strategies in the Chilean power grid context, highlighting increased solar power capacity investments and reduced fossil fuel generation. The study suggests intelligent charging can significantly influence power system expansion plans and calls for future research on diverse EV types and charging patterns [4].

The research on optimal locations for EV charging stations considers EV load modeling, uncertainty handling, and V2G strategy. It examines the impact on distribution networks, investor attitudes, and EV user behavior. The study uses optimization techniques to determine suitable locations, assesses environmental and economic effects, and synthesizes insights to enhance EV infrastructure planning [5].

The study analyzes EV infrastructure deployment challenges, focusing on charging power levels, methods, and grid impacts. It discusses conductive and wireless charging, highlighting the need for standardization. The study proposes smart charging to mitigate grid impacts and provides insights into current and future EV infrastructure trends [6].

The research includes battery swap stations, wireless power transfer, and conductive charging. The study examines regulatory standards, and optimization techniques for charging station placement, and identifies research gaps. It focuses on the technological and standard aspects of EV infrastructure [7].

The authors discusses fast-charging techniques, genetic algorithms for size estimation, and forecasts future trends. The study highlights multilevel converters and renewable energy integration for reduced grid impact [8].

The research paper tackles issues surrounding EV charging infrastructure through the introduction of a rapid-charging DC-DC converter and control algorithm designed specifically for a solar PV-driven charging station. It validates the converter's performance using simulations and standard compliance. The study highlights the converter's efficiency, low THD, and integration with renewable energy for grid stability [9].

The study incorporates passenger electric vehicles and public buses into an urban energy framework, investigating charging tactics and their adaptability. It simulates the generation of local electricity and heat, storage options, and imports to attain carbon neutrality. The study compares inflexible and intelligent charging strategies, highlights V2G technology benefits, and assesses synergies between public transport electrification and solar PV infrastructure [10].

The study conducts a comparative analysis of commercial and prototype electric vehicles (EVs) focusing on range, battery size, charger power, and charging time. Data was collected from existing commercial models and prototype designs through manufacturer specifications, technical documents, and real-world performance tests. Analytical methods, including statistical analysis and performance benchmarking, were employed to evaluate and compare the efficiency and effectiveness of different charging systems. The study aimed to identify key factors that influence charging infrastructure performance and propose enhancements to support the growing EV market and improve the user experience [11].

The proposed model integrates solar power into EV charging stations, supporting semi-fast and fast charging. The methodology includes designing a versatile charging system for residential use, applicable to individual homes and apartment buildings. Solar photovoltaic panels were incorporated into the design, with simulations conducted to optimize energy conversion and storage. Field tests were performed to assess system efficiency, reliability, and adaptability in various residential settings. Data on energy output, charging times, and user feedback were collected and analyzed to refine the model and ensure its practicality and sustainability [12].

The study focuses on designing circuits for fast DC charging stations essential for developing EV infrastructure. The methodology involves creating circuit prototypes and using simulation software to evaluate their performance under different conditions. Key technical requirements, such as voltage regulation, current control, and safety features, were addressed. Experimental setups were used to test the prototypes' efficiency, stability, and compliance with industry standards. Data collected from these tests was analyzed to optimize the design, ensuring effective and reliable implementation of fast DC charging stations [13].

The study focuses on advancing intelligent DC fast charging stations that autonomously monitor themselves, addressing critical needs in long-distance travel and high-traffic locations. The methodology includes designing a prototype charging station with integrated sensors and monitoring systems. These systems track various parameters, such as charging speed, energy consumption, and operational status. The software was developed to manage and analyze the data collected, providing real-time feedback and alerts. The charging station prototype was tested under various conditions to ensure its reliability and efficiency. Data from these tests was used to refine the design and enhance performance [14].

The study reviews the integration of solar photovoltaic (PV) systems with EV charging stations, emphasizing carbon footprint reduction. The methodology involves conducting a comprehensive literature review of existing PV-integrated charging stations and case studies to identify best practices and challenges. Simulation models were developed to evaluate the performance of these systems under different environmental conditions. Data on PV capacity, intermittency, and energy output were analyzed to assess the feasibility and effectiveness of integrating solar power into charging stations. The findings were used to propose solutions to overcome the identified challenges [15].

The paper explores the creation and advancement of decentralized charging stations for renewable energy, integrating RFID for user identification and microcontrollers for streamlined management. The approach includes constructing prototype stations that harness solar and wind power. Field tests were carried out to assess station performance, dependability, and user approval. Data on energy generation, usage trends, and operational efficiency were gathered and studied. The goal was to refine the incorporation of renewable sources into charging infrastructure, promoting sustainability and user convenience [16].

The research compares coordinated EV charging methods with uncoordinated ones, focusing on peak load reduction and energy efficiency. The methodology involves collecting large datasets from existing charging stations and using data-driven analysis techniques. The models were tested under various scenarios to compare peak load conditions and overall energy consumption. Data from these simulations was analyzed to identify the benefits of coordinated charging strategies, providing insights into improving grid stability and efficiency [17].

The study involves designing the converter and developing a prototype for testing. Simulations were conducted to evaluate the converter's performance under various conditions, including different load scenarios and battery states. Field tests were performed to validate the simulation results and assess the practical application of the charge-sharing scheme. Data on efficiency, reliability, and user experience were collected and analyzed to refine the design and enhance the system's effectiveness [18].

The planning method integrates photovoltaic power generation with EV charging networks to optimize layout and capacity. The methodology involves modeling EV types, charging behaviors, and PV generation patterns. Optimization algorithms were developed and applied to plan the placement and capacity of charging stations, considering transportation and power network integration. Simulations were conducted to test the models and validate their effectiveness in different scenarios. Data from these simulations was analyzed to identify optimal strategies for integrating PV power into EV charging networks, enhancing efficiency and sustainability [19].

The methodology involves developing load models that incorporate wireless charging data and conducting simulations to predict the impact on peak load and power system capacity. Real-world data was collected from existing wireless charging systems and used to validate the models. The study also includes scenario analysis to explore different deployment strategies and their effects on load management. Data from these analyses was used to propose solutions for reducing peak load and improving the overall efficiency of the power system [20].

3. Proposed Methodology

A proposed method for an advanced electric vehicle (EV) charging station monitoring system involves integrating sensors and smart technology to enhance user experience and safety. The system employs an ESP32 controller, which is a powerful and cost-effective microcontroller with built-in Wi-Fi and Bluetooth capabilities. This controller act as the heart of the monitoring system, gathering data from various sensors and transmitting it to a mobile application.

Key sensors include temperature, voltage, and current sensors. The temperature sensor ensures that the solar PV-based charging station [9] operates within safe thermal limits, preventing overheating and potential damage to both the station and the vehicle. Voltage and current sensors monitor the electrical parameters to ensure efficient and safe charging, alerting users and operators of any irregularities. Figure 1 shows the proposed flowchart.

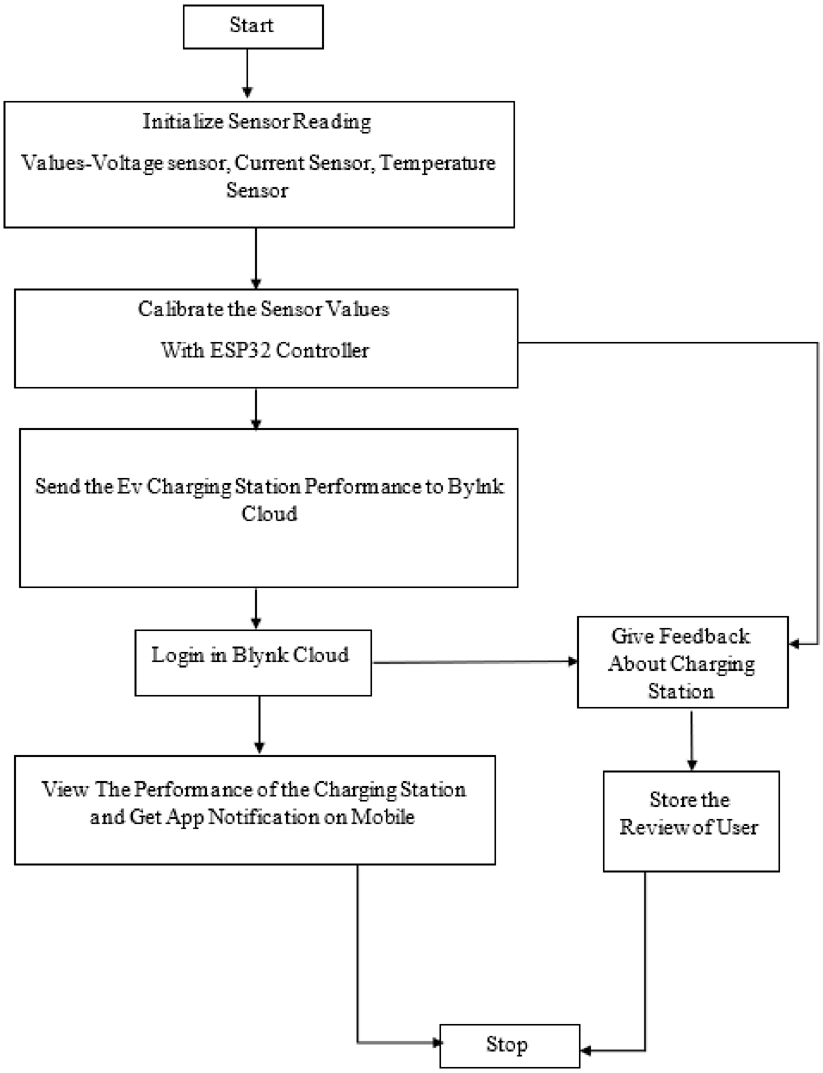

Figure 1. Proposed Flowchart

The system also incorporates GPS technology to provide the exact location of each charging station. This allows users to easily find nearby stations and view real-time data on their operational status. All collected data is transmitted through the ESP32 to a cloud server, where it is processed and made accessible through a mobile application.

The mobile application displays detailed information about each charging station, including temperature, voltage, and current readings, along with user reviews and ratings. This information helps users make informed decisions about where to charge their vehicles, considering both the safety and performance of the stations.

By providing real-time monitoring and detailed analytics [19], this system ensures a safer and more efficient charging process. Users can rely on accurate data to select the best charging station, enhancing their overall experience and promoting the adoption of electric vehicles [18]. Figure 2 shows the proposed block diagram.

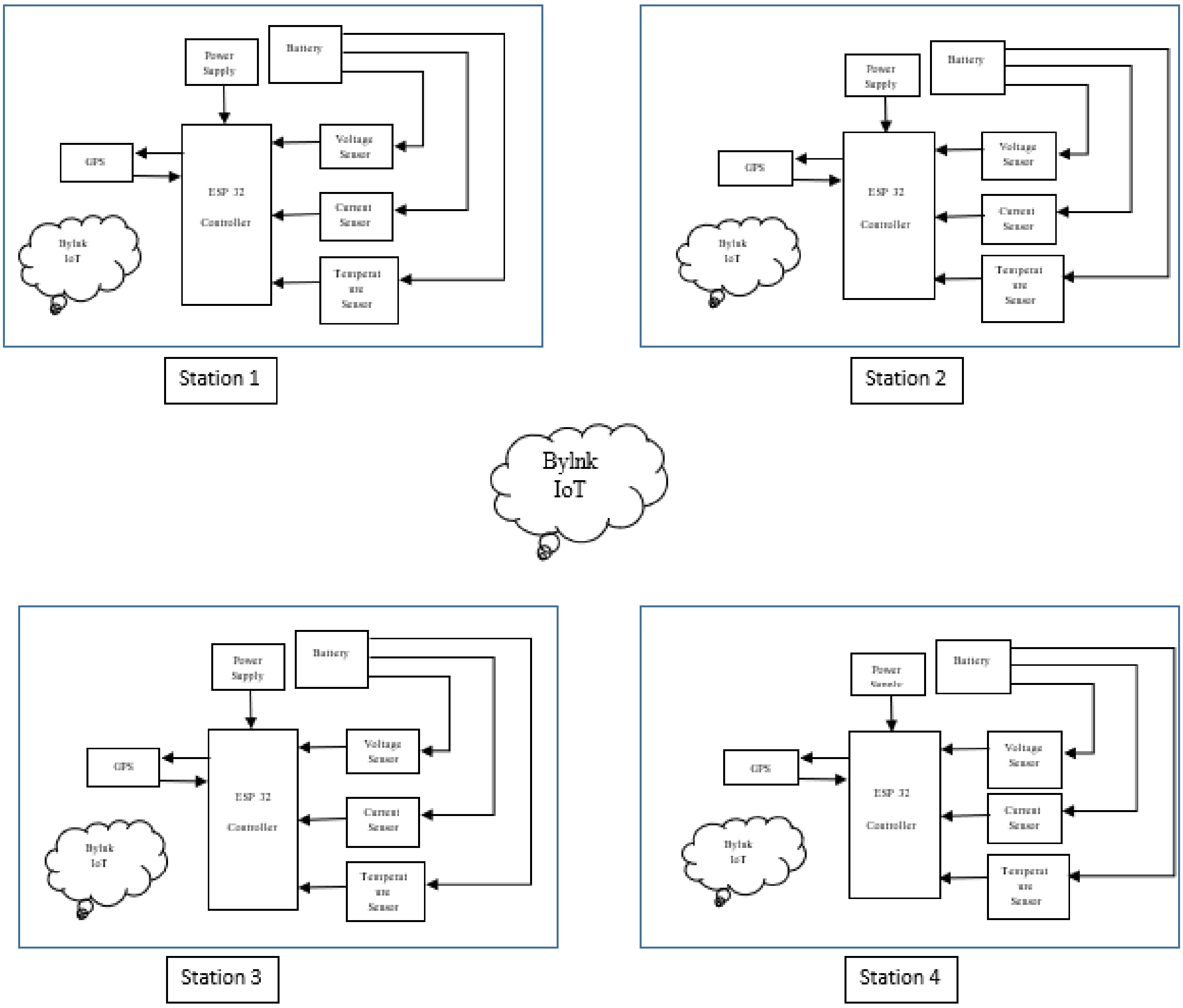

Figure 2. Proposed Block Diagram

3.1 Working Principle

The sensors integrated into the proposed module gather data such as temperature, humidity, and other relevant metrics from each charging station. This information is then relayed to the cloud through the controller. The modules gather information from every charging station, store it, and send it to the cloud. Using real-time data and presentation, users can access information regarding charging station efficiency and available slots using the

Blynk app. The position of the charging station and the data integrated with the Google map will be aided by the additional GPS sensors.

3.2 Hardware Components

The Table .1 shows the hardware components used and its specification.

Table 1. Hardware Components

S. No	Hardware Name	Specification	Quantity
1	Power Supply Circuit	Capacitor: 470uf Resistor: 4.7k Step down transformer: Transformer has 240V primary winding and center tapped secondary winding. Input - 220V/240V AC, Output - 0-12V AC	1
2	ESP 32 Controller	Single or dual-core 32-bit LX6 microprocessor with clock frequency up to 240 MHz and up to 600 DMIPS 320 KB of RAM, 448 KB of ROM and 16 KB of RTC SRAM Wi-Fi: 802.11 b/g/n with speeds up to 150 Mbps Bluetooth: v4.2 BR/EDR and BLE 34 × programmable GPIOs and various peripheral interfaces	1
3	GPS (NEO-6M GPS module)	Baud Rate: Adjustable from 1200 to 115200 bps Power Supply Voltage: 3.4V – 4.5V	1
4	LCD	Operating Voltage: 4.7V to 5.3V Operating Current 1mA (without backlight) Can display (16x2) 32 Alphanumeric Characters Custom Characters Support Works in both 8-bit and 4-bit Mode	1
5	Voltage Sensor (ZMPT101B)	Input Voltage: 0 to 25V Voltage Detection Range: 0.02445 to 25 Analog Voltage Resolution: 0.00489V Needs no external components Easy to use with Microcontrollers Small, cheap and easily available Dimensions: 4 × 3 × 2 cm	1

6	Temperature Sensor (DHT22)	Operating Voltage: 3.5V to 5.5V Operating current: 0.3mA (measuring) 60uA (standby) Output: Serial data Temperature Range: 0°C to 50°C Humidity Range: 20% to 90% Resolution: Temperature and Humidity both are 16-bit Accuracy: ±1°C and ±1%	1
7	Current Sensor (ACS712)	Suitable for <5A current sensing applications. Sensitivity: 200mV/A. 1 MHz bandwidth with response time <550 ns. Low noise: 8 mA (rms) at 1 MHz	1
8	Battery (lead acid battery)	Voltage Per Unit: 12 V Nominal Capacity: 150Ah at a 10-hour rate to EOD of 1.8V per cell at 25°C Maximum Discharge Current: 1500A (5 sec) Recommended Max Charging Current: 45A End of discharge voltage: Varies from 10.5V to 10.8	1

3.3 Software Description

A. Development Environment: Because of its comprehensive support for a variety of Arduino boards and its user-friendly interface, the Arduino IDE was chosen as the main development environment. Code authoring, code compilation, and code uploading to the microcontroller are made easier with the help of the IDE.

B. Algorithm Development: The C programming language was used to create the coding. The reason for selecting the C language is its extensive usage in embedded devices and its effectiveness. The coding was made to manage many types of digital input and output functions, which are necessary for sensors, actuators, and the Arduino controller to communicate with one another.

C. Communication Protocol: The MQTT protocol was used for the communication layer. MQTT is a lightweight messaging protocol that is perfect for Internet of Things applications since it is optimized for high-latency or unstable networks. It uses a publish-subscribe approach that improves the scalability and flexibility of the system by severing the connection between the message producer (publisher) and the message consumer (subscriber).

D. System Architecture: In the proposed system architecture, the Arduino controller functions as a pivotal link connecting various Internet of Things (IoT) devices. Through the MQTT protocol and broker, each device can efficiently exchange messages within the network. The MQTT broker acts as an intermediary, managing message distribution and ensuring seamless communication across devices. The Arduino controller plays a central role by subscribing to relevant topics on the MQTT broker, allowing it to receive real-time data from connected IoT devices. Upon receiving data, the controller interprets this information using programmed logic, determining appropriate actions based on the interpreted data. This architecture enables a distributed and scalable IoT ecosystem where the Arduino controller serves as a cohesive hub, establishing communication and executing operational decisions in response to data received from the sensors.

4. Result and Discussion

The Figure 3 presents the hardware prototype of the smart EV charging station monitoring and user feedback system, showcasing the synchronized functionality of various components. Voltage, current, and temperature sensors ensure precise monitoring of essential parameters, maintaining optimal charging conditions for electric vehicles. The ESP32 controller regulates the system's operations, efficiently managing data acquisition, processing, and transmission. Through the integration with Blynk, a versatile IoT platform, users gain real-time insights and control over the charging process, facilitating informed decision-making and enhancing the overall user experience. This holistic approach not only ensures the safety and efficiency of electric vehicle charging but also empowers users with actionable feedback, fostering a seamless transition towards sustainable transportation solutions.

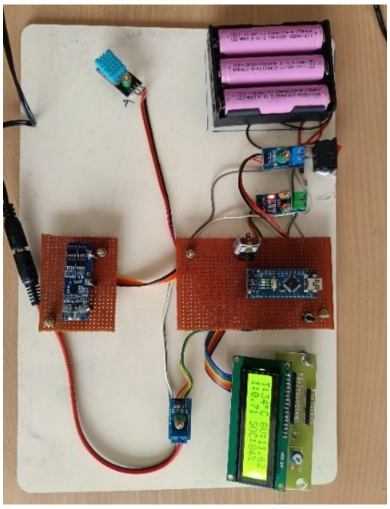

Figure 3. Hardware Prototype of the Proposed

Figure 4 . Display Sensor Readings in Mobile App

The Figure 4 displays the Blynk mobile application interface, showcasing a comprehensive array of data readings and user engagement features. The primary metrics visible include voltage, temperature, and current readings, providing users with real-time insights into the operational status of the Smart EV Charging Station. This multifunctional display empowers users to monitor crucial parameters, ensuring optimal performance and safety. Additionally, the inclusion of user reviews fosters a participatory environment, allowing individuals to share their experiences and feedback. The project title, "Smart EV Charging

Station Monitoring and User Feedback System," briefly encapsulates the application's purpose and functionality, emphasizing its role in enhancing both operational efficiency and user satisfaction within the electric vehicle charging ecosystem.

5. Conclusion

In conclusion, the proposed advanced EV charging station monitoring system integrates sensors and smart technology for enhanced safety and user experience. Utilizing an ESP32 controller as its core, the system collects data from temperature, voltage, and current sensors to ensure safe charging operations, preventing overheating and damage. GPS technology enables real-time location tracking of charging stations, improving accessibility. Data is transmitted to a cloud server for processing and made accessible through a mobile application, providing users with detailed station information, including reviews and ratings. This empowers users to make informed decisions, promoting electric vehicle adoption. By offering real-time monitoring and comprehensive analytics, the system ensures a safer, more efficient charging process, contributing to sustainability efforts.

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