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IoT-Based E-Vehicle Wireless Charging Station

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Abstract: *The increasing adoption of Electric Vehicles (EVs) has created a strong demand for advanced, safe, and user-friendly charging solutions. Conventional plug-in charging methods require physical connectors, which may result in inconvenience, mechanical wear, electrical hazards, and maintenance issues. To overcome these limitations, this project proposes a Smart IoT-Based EV Wireless Charging Station that enables contactless power transfer using wireless charging technology based on electromagnetic induction.*

The proposed system consists of a wireless power transmitter embedded in the charging station and a receiver coil mounted on the EV. When the vehicle is properly aligned over the charging pad, electrical energy is transferred wirelessly to charge the EV battery. An ESP32 microcontroller is used for system control, monitoring, and communication. Charging parameters such as voltage, current, temperature, and charging status are continuously monitored and displayed locally on an LCD screen.

The system is integrated with an IoT platform that allows users and administrators to remotely monitor charging status in real time through a web or mobile dashboard. Alerts are generated when abnormal conditions such as overheating, misalignment, or overcurrent are detected. The proposed system is cost-effective, safe, efficient, and suitable for smart city and future EV infrastructure applications.

Keywords*:* EV Wireless Charging, Inductive Power Transfer, IoT, Smart Charging Station, Contactless Charging, ESP32

I. INTRODUCTION

Electric Vehicles (EVs) are becoming increasingly popular due to their environmental benefits, energy efficiency, and reduced dependence on fossil fuels. However, one of the major challenges faced by EV users is the availability and convenience of charging infrastructure. Traditional wired charging systems require physical connectors, which can be inconvenient, especially in outdoor environments, and may pose safety risks due to exposure to moisture and wear over time.Wireless charging technology offers a modern solution by enabling contactless energy transfer between the charging station and the vehicle. This technology eliminates the need for cables and connectors, reducing maintenance requirements and improving user convenience.With the advancement of Internet of Things (IoT) technology, EV charging stations can be made smarter by enabling real-time monitoring, remote access, fault detection, and energy management. IoT integration allows charging data to be accessed from anywhere, improving system transparency and operational efficiency.This project presents a Smart IoT-Based EV Wireless Charging Station that combines wireless power transfer and IoT technology to provide a safe, efficient, and user-friendly EV charging solution. The system is designed mainly for educational, demonstration, and prototype-level applications.

II. LITERATURE REVIEW

Several researchers have explored wireless charging systems and IoT integration for EV applications:

• Zhang et al. (2021) proposed an inductive wireless power transfer system for EVs, focusing on coil alignment and efficiency improvement. However, the system lacked remote monitoring features.

• Patel and Mehta (2022) developed an IoT-based EV charging station for wired charging. Although effective, it did not address the inconvenience of physical connectors.

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• Alam et al. (2023) introduced a smart wireless charging prototype using resonant inductive coupling, but the system was expensive and complex.
• Singh et al. (2020) designed a low-power wireless charging system for electric scooters but did not include safety alerts or cloud integration.

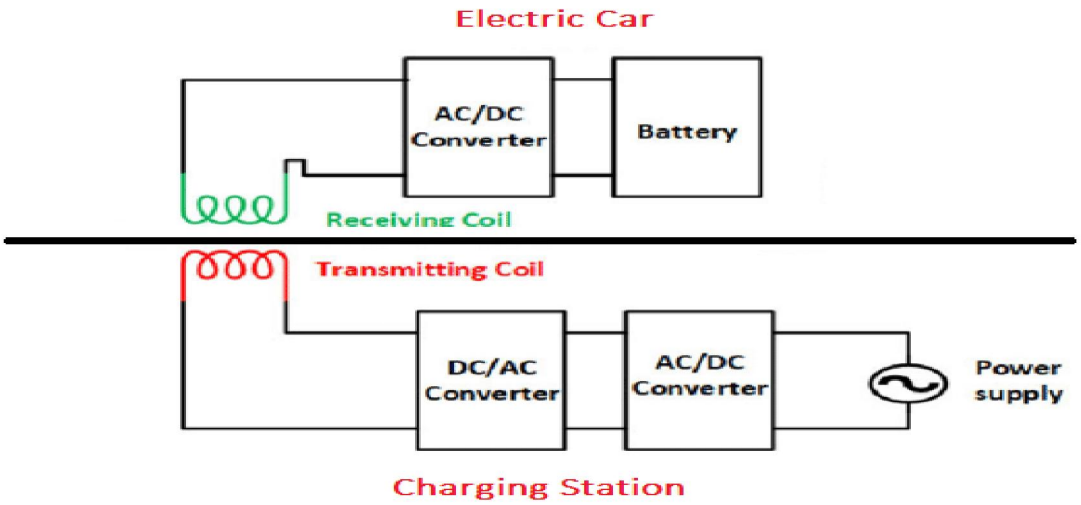
From the review, it is observed that existing systems either lack IoT-based monitoring or are costly and complex. Hence, a low-cost, IoT-enabled wireless EV charging station is needed.

III. PROBLEM STATEMENTS

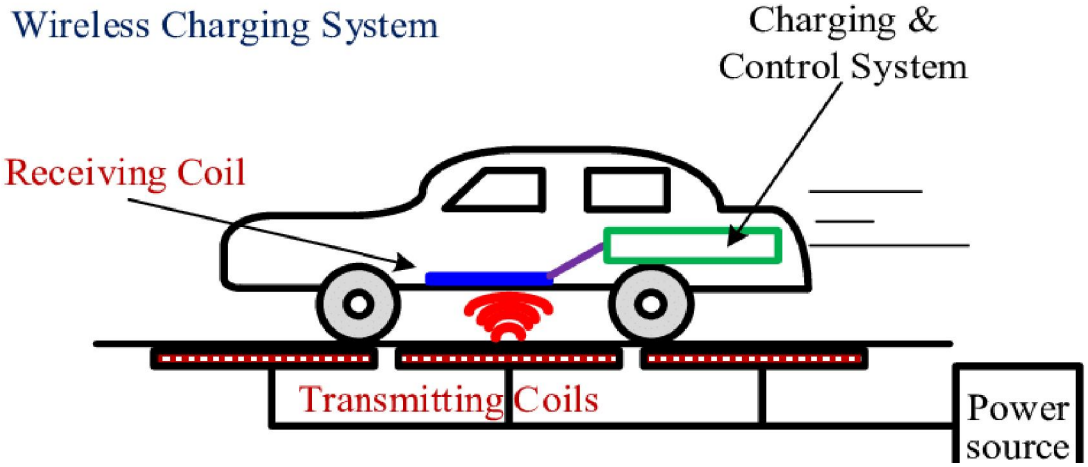
Most existing EV charging systems rely on wired connections, which can be inconvenient, unsafe, and prone to mechanical damage. Manual handling of cables is required, and charging connectors may fail due to environmental exposure. Additionally, many charging stations do not provide real-time monitoring or fault alerts.

Therefore, there is a need for a smart, wireless, and IoT-enabled EV charging system that allows contactless charging, remote monitoring, and alert generation to improve safety, efficiency, and user convenience.

IV. SYSTEM ARCHITECTURE



V. DESIGN OF THE PROJECT



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VI. DESIGN AND IMPLEMENTATION CONSTRAINTS

There are three major components of the proposed system: sensing unit (hardware), processing and communication unit, and user interface.

6.1 External Interface Requirements

User Interfaces:
• LCD display showing charging status, voltage, current, and temperature
• Web/mobile IoT dashboard for remote monitoring
Hardware Interfaces:
• ESP32 interfaced with sensors and wireless charging module
• Transmitter and receiver coils
Software Interfaces:
• Arduino IDE
• Open-source libraries
Communication Interfaces:
• Wi-Fi communication for IoT connectivity

6.2 Other Non-Functional Requirements

Performance Requirements:
• Near real-time charging data updates
Safety Requirements:
• Overcurrent and overtemperature protection
Security Requirements:
• Basic Wi-Fi authentication
Software Quality Attributes:
• Reliability: Stable operation under proper alignment
• Availability: Continuous operation with power and internet

6.3 Software and Hardware Requirements

Software Requirements:
• Arduino IDE
• ESP32 Board Package
• IoT Cloud Platform
• Wi-Fi Library
Hardware Requirements:
• ESP32 Microcontroller
• Wireless Charging Module
• Transmitter & Receiver Coils
• Voltage, Current, Temperature Sensors
• LCD Display
• Power Supply

VII. TEST CASES

Test Case	Description	Expected Result
TC1	Proper vehicle alignment	Charging starts
TC2	Vehicle misalignment	Charging stops
TC3	Overtemperature	Alert generated
TC4	Internet disconnection	Local display continues

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Requirement Gathering and Analysis

In this phase, the basic requirements of the IoT-Based EV Wireless Charging Station are identified. The system is designed to enable wireless power transfer for charging electric vehicles without physical connectors. The need for safe and efficient charging, real-time monitoring of charging parameters such as voltage, current, temperature, and charging status is analyzed. Requirements for local display, remote monitoring through the internet, and alert generation in case of abnormal conditions are considered to ensure that the system is safe, reliable, cost-effective, and easy to use.

System Design

During the system design phase, the overall architecture of the EV wireless charging system is planned. The ESP32 microcontroller is used for data processing, control, and Wi-Fi communication. A wireless charging module with transmitter and receiver coils is used for contactless power transfer. Sensors are integrated to measure voltage, current, and temperature during charging. An LCD display is included for local visualization of charging status. The system is designed to ensure efficient power transfer, proper alignment detection, and smooth data flow between hardware components and the IoT platform.

Implementation

In the implementation phase, all hardware components are assembled and interconnected according to the system design. The transmitter and receiver coils, ESP32 controller, sensors, LCD display, and power supply are properly configured. The system software is developed using the Arduino IDE, and programs are written to control wireless charging, read sensor data, display values, and transmit data to the IoT cloud platform. All components are integrated and tested together to function as a single, reliable system.

Deployment

After successful implementation and testing, the EV wireless charging system is deployed at the required location. The system is tested under real operating conditions to verify wireless charging functionality, safety mechanisms, and IoT connectivity. Once verified, the system is made ready for actual use by users or for demonstration purposes.

Maintenance

Regular maintenance is required to ensure reliable operation of the EV wireless charging station. Sensors are periodically checked for accuracy, and coil alignment is verified to maintain charging efficiency. Software updates are performed when necessary to improve system performance and security. Minor faults or issues are identified and corrected promptly to ensure continuous and safe operation of the system.

Cost Estimation

Phases	Cost / Hour (₹)	Hours	Cost Estimation (₹)
Requirement Gathering	200	7	1400
System Design	200	9	1800
Code Planning	200	7	1400
Code Development	200	14	2800
Hardware Integration	200	9	1800
Testing and Debugging	200	8	1600
Documentation and Report	200	6	1200
Total Cost			₹13,000

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Risk Identification:

The Smart IoT-Based EV Wireless Charging Station involves several potential risks that may affect its development, performance, and reliability. One of the major risks is coil misalignment, where improper positioning of the electric vehicle over the charging pad may result in inefficient or interrupted power transfer. This can reduce charging efficiency or stop the charging process completely.

Another significant risk is power loss or fluctuation, which may occur due to unstable power supply or inefficiencies in wireless power transfer. This can affect charging speed and system reliability. Connectivity issues also pose a risk, as the system relies on Wi-Fi or internet connectivity to transmit charging data to the IoT platform. Network interruptions may result in delayed updates or loss of remote monitoring functionality.

Additionally, overheating of the transmitter or receiver coils is a critical risk. Excessive heat generation during charging may damage components and reduce system safety. Improper monitoring of temperature can lead to system failure and safety concerns.

ID	Risk Description	Probability	Impact
1	Coil misalignment	Medium	High
2	Power loss	Medium	Medium
3	Network failure	Low	Medium
4	Overheating	Low	High

Table: Risk Analysis

VIII. OVERVIEW OF RISK MITIGATION, MONITORING, MANAGEMENT

The Risk Mitigation, Monitoring, and Management (RMMM) process is applied to identify and control potential risks associated with the Smart IoT-Based EV Wireless Charging Station. One of the major risks identified is wireless power transfer inefficiency due to coil misalignment, which can affect charging performance and system safety. This risk belongs to the operational environment category and originates from improper vehicle positioning over the charging pad. The probability of occurrence is medium, while the impact is high, as misalignment can interrupt charging or reduce efficiency.To mitigate this risk, alignment indicators and real-time monitoring of power transfer parameters are implemented. The system continuously monitors voltage, current, and efficiency levels to detect misalignment conditions. This risk is managed through automatic charging control and alert notifications, ensuring safe and reliable system operation. Regular monitoring and preventive strategies help minimize the impact of this risk and maintain consistent charging performance.

Software Requirement Specification:

System Implementation Software Required:

- Arduino IDE – Used for writing, compiling, and uploading code to the ESP32
- ESP32 Board Package – Required to program and manage ESP32 hardware
- Wireless Charging Control Libraries – For controlling power transfer and charging logic
- FreeRTOS – For multitasking and parallel task execution
- IoT Cloud Platform (Thinger.io) – For remote charging data visualization and monitoring
- Telegram Bot API – For sending charging alerts and system notifications
- Wi-Fi Library – For wireless network connectivity

Product Scope:

The Smart IoT-Based EV Wireless Charging Station is designed to enable contactless charging of electric vehicles using wireless power transfer technology. The system monitors essential charging parameters such as voltage, current, temperature, power transfer efficiency, and charging status using sensor-based technology. The collected data is

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processed by the ESP32 microcontroller and displayed locally on an LCD screen, allowing users to observe the charging status instantly.

In addition to local monitoring, the system uploads charging data to an IoT cloud platform, enabling remote access for users, administrators, or service providers from any location with internet connectivity. The software also supports alert notifications through Telegram when abnormal conditions such as overheating, power loss, or misalignment are detected.

The product supports multitasking using the ESP32's dual-core FreeRTOS environment, ensuring smooth and simultaneous operation of wireless charging control, sensor data acquisition, local display updates, cloud communication, and alert handling. This makes the system efficient, reliable, and suitable for smart EV charging infrastructure and educational demonstrations.

IX. RESULT

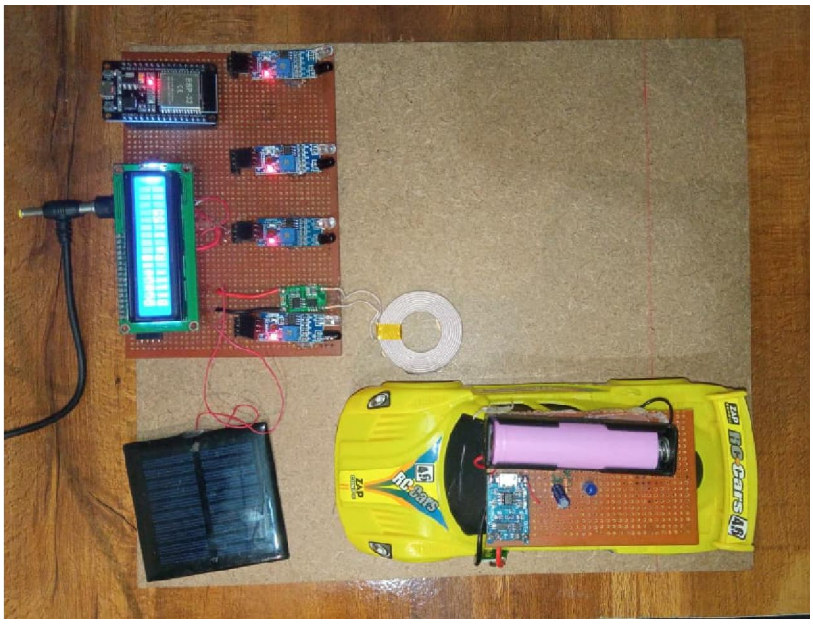

Image: ESP32 Microcontroller

Image: LCD Display

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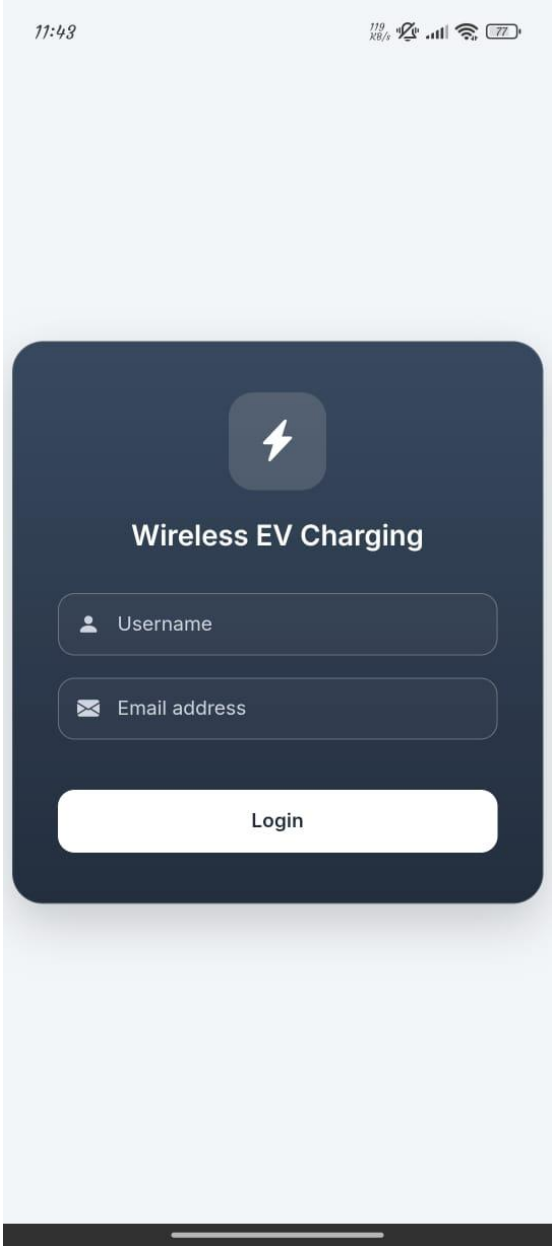

Image: Login Page

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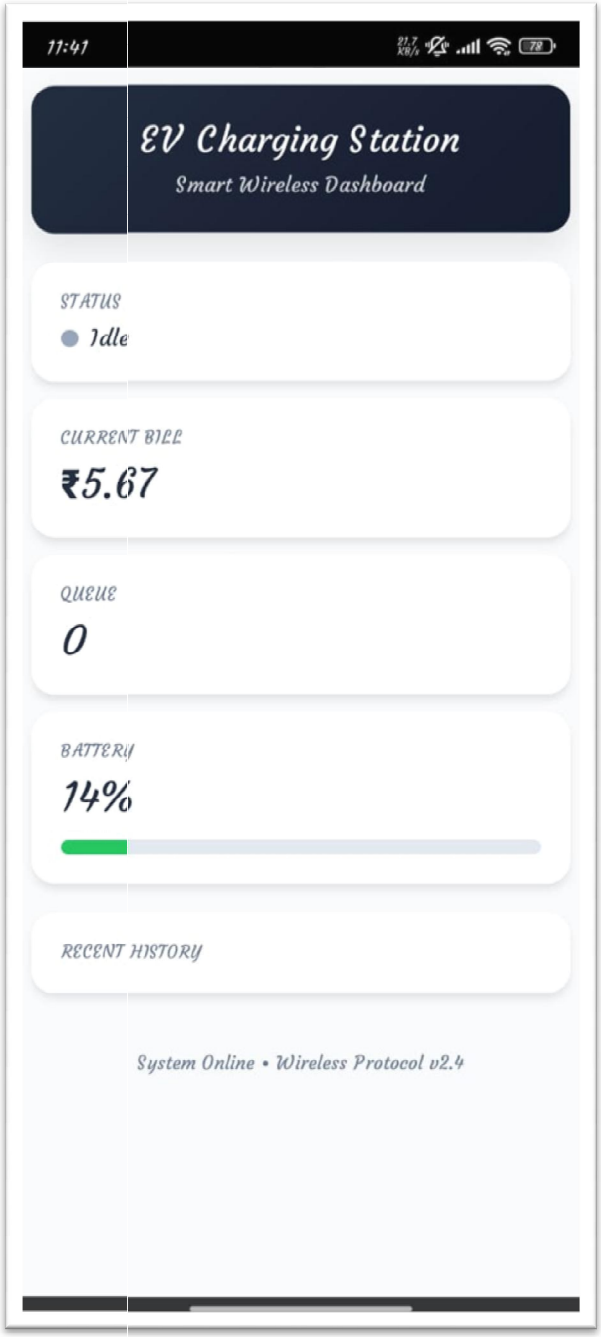

Image: Dashboard

X. CONCLUSION

The Smart IoT-Based EV Wireless Charging Station successfully demonstrates an effective solution for contactless and intelligent charging of electric vehicles. By using the ESP32 microcontroller and wireless power transfer technology, the system enables safe and efficient energy transfer without the need for physical connectors. The system provides

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real-time monitoring of charging parameters such as voltage, current, temperature, and charging status, along with local display and remote access through an IoT cloud platform.

The integration of Telegram-based alert notifications ensures timely information regarding charging progress and abnormal conditions, thereby improving system safety and user awareness. The project highlights the practical application of embedded systems, IoT technology, wireless power transfer, and real-time multitasking using FreeRTOS in modern EV charging infrastructure. Overall, the proposed system proves to be a low-cost, reliable, and user-friendly solution suitable for educational, demonstration, and prototype-level applications, showcasing the potential of smart technologies in advancing sustainable transportation and future EV charging systems.

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