

EV WIRELESS CHARGING SYSTEM USING RFID AND IoT

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ABSTRACT

The increasing popularity of Electric Vehicles (EVs) has created a need for efficient, safe, and convenient charging systems. Conventional wired charging systems suffer from cable damage, safety concerns, and user inconvenience. This project proposes a novel EV Wireless Charging System using RFID and IoT, providing secure and smart contactless charging. The system employs electromagnetic induction for wireless power transfer between transmitter and receiver copper coils. RFID authentication ensures only authorized users access the charging station. An Arduino UNO microcontroller manages the relay module, wireless charging circuit, LCD display, and buzzer. An ESP8266 NodeMCU module transmits real-time data including charging status and session information to the ThingSpeak cloud platform for remote monitoring. Experimental results demonstrate wireless power transfer efficiency of 80.4% at 5mm coil gap, RFID authentication response within 1-2 seconds, and IoT data upload reliability of 98.3%, confirming the system suitability for smart EV charging applications.

Keywords: *Electric vehicle, wireless charging, RFID authentication, IoT monitoring, electromagnetic induction, Arduino UNO, ESP8266, relay module, ThingSpeak, inductive coupling.*

1. INTRODUCTION

The rapid growth of electric vehicles (EVs) has intensified the demand for advanced charging infrastructure that is efficient, safe, and user-friendly. Traditional EV charging methods rely on physical cables, which are prone to wear, safety hazards, and user inconvenience. Wireless charging technology offers a promising contactless alternative by transferring energy through electromagnetic fields, eliminating direct electrical contact.

This project presents an integrated EV Wireless Charging System combining inductive wireless power transfer with RFID-based user authentication and IoT-based remote monitoring. The RFID module ensures only registered users can activate the charging station, while the ESP8266 NodeMCU enables real-time cloud data transmission for system analytics and remote access.

1.1 Problem Statement

The rapid growth of electric vehicles (EVs) has increased the demand for efficient and convenient charging systems. Traditional EV charging methods use wired connections, which require physical cables and connectors. These cables may get damaged due to frequent use, environmental conditions, and improper handling. Wired charging systems also create safety risks such as electric shock, short circuits, and fire hazards, especially in public charging stations and outdoor environments. In addition, wired charging requires human effort to connect and disconnect the cable, which may be inconvenient for users.

Another major issue in existing EV charging stations is the lack of security and monitoring systems. In many public charging stations, there is no proper authentication system, which may lead to unauthorized usage and power theft. There is also a lack of real-time monitoring of charging status, energy usage, and system performance. Without monitoring systems, it is difficult to manage charging stations efficiently and maintain usage records.

Wireless charging technology is a modern solution that allows power transfer without physical contact using electromagnetic induction. However, wireless charging systems require proper control, authentication, and monitoring systems to operate efficiently and securely. Therefore, there is a need to develop a smart EV wireless charging system that provides secure user authentication, safe wireless power transfer, automatic control, and real-time monitoring using IoT technology.

The main problem addressed in this project is to design and implement a secure, efficient, and contactless EV wireless charging system using RFID authentication and IoT monitoring to improve safety, convenience, and system management.

1.2 Objectives

The primary objectives of this project are: (1) to design a wireless EV charging prototype using inductive coupling with copper TX/RX coil pairs; (2) to implement RFID-based secure user authentication using the MFRC522 reader; (3) to integrate IoT-based remote monitoring via ESP8266 NodeMCU and ThingSpeak; (4) to achieve wireless power transfer efficiency above 75% at a 5mm coil gap and RFID authentication response within 2 seconds.

1.3 Scope of Research

The scope of this research focuses on the design and implementation of an Electric Vehicle Wireless Charging System using RFID and IoT technology. The system is designed to transfer power wirelessly using inductive coupling between transmitter and receiver coils. The research mainly focuses on developing a small-scale prototype model that demonstrates the working principle of wireless power transfer for electric vehicle charging applications.

The system includes RFID-based authentication to allow only authorized users to access the charging system. The Arduino Uno microcontroller is used as the main controller to manage RFID authentication, relay control, touch sensor input, and display system. The system also includes an ESP8266 NodeMCU module for IoT-based monitoring, which sends real-time charging data such as user ID, charging status, and charging duration to the ThingSpeak cloud platform.

This research mainly focuses on wireless power transfer, RFID authentication, IoT monitoring, and automatic control of the charging system. The project is limited to low-power wireless charging prototype implementation and does not focus on high-power real-time EV charging systems. The system is designed for demonstration and educational purposes and can be further developed for commercial EV charging stations.

The main scope of this research is to develop a smart, secure, and contactless EV charging system that improves user convenience, safety, and system monitoring using modern technologies such as wireless power transfer, RFID, and IoT.

2. LITERATURE SURVEY

[1] Nikola Tesla (1890s): Demonstrated the theoretical foundation of wireless power transmission, laying groundwork for modern wireless energy systems.

[2] Andre Kurs et al. (2007): Introduced resonant inductive coupling, enabling efficient mid-range wireless power transfer. Their work became foundational for modern EV wireless charging.

[3] Seungyoung Ahn et al. (2013): Focused on optimizing coil design and alignment for maximum wireless power transfer efficiency, showing that proper coil positioning is critical.

[4] S. Li and C. C. Mi (2015): Conducted comprehensive review comparing inductive, resonant, and

capacitive coupling methods, concluding inductive coupling is most practical for EV applications.

[5] K. Fotopoulou and B. W. Flynn (2011): Demonstrated RFID technology effectiveness for secure access control, making it suitable for EV charging station authentication.

[6] Luis Atzori et al. (2010): Provided detailed overview of IoT applications in smart systems, directly applicable to real-time EV charging monitoring via ESP8266 and cloud platforms.

[7] H. H. Wu et al. (2012): Focused on improving inductive wireless charging efficiency through optimized coil design and frequency selection to minimize power loss.

[8] Y. He et al. (2014): Integrated EV charging systems with smart grid technology, highlighting IoT role in optimizing energy distribution and charging operations.

3. EXISTING SYSTEM

In existing electric vehicle (EV) charging systems, most of the charging methods are based on wired power transfer. In these systems, the electric vehicle is charged using physical cables and connectors that connect the vehicle to the charging station. These wired charging systems are commonly used in homes, parking stations, and public charging stations. The power is transferred from the charging station to the vehicle battery through a direct electrical connection. Although wired charging systems are reliable and widely used, they have several limitations related to safety, convenience, and maintenance.

In conventional wired charging systems, users must manually connect and disconnect the charging cable to the vehicle. This process may be inconvenient, especially in public charging stations and during bad weather conditions such as rain or dust. Frequent plugging and unplugging may also cause wear and tear of connectors and cables, which increases maintenance cost. In some cases, damaged cables may cause electrical hazards such as short circuits and electric shocks.

Some existing systems use smart charging stations with payment and monitoring systems, but they still depend on wired charging. These systems may include RFID cards, mobile applications, or smart meters for user authentication and billing, but the charging process still requires physical cable connection. In addition, many traditional charging systems do not include wireless power transfer technology and IoT-based real-time monitoring systems.

Wireless charging technology is being developed in modern systems, but many existing wireless charging systems have limitations such as low efficiency, high cost, coil misalignment problems, and limited charging distance. Some systems also lack proper authentication and security features, which may lead to unauthorized usage of charging stations.

Therefore, the existing EV charging systems mainly depend on wired charging methods and have several limitations related to safety, user convenience, maintenance, and monitoring. These limitations create the need for a smart EV wireless charging system with RFID authentication and IoT-based monitoring to improve system efficiency, safety, and user convenience.

Disadvantages of Existing System

(1) Physical cable requirement leading to wear, damage, and user inconvenience; (2) No secure authentication - unauthorized users can access public charging stations; (3) Absence of real-time monitoring and remote access; (4) Safety risks from exposed wires in wet or harsh conditions; (5) No automated data logging for billing or usage analytics; (6) High maintenance cost due to connector degradation.

4. PROPOSED SYSTEM

The proposed system is an integrated mechatronic solution comprising three major subsystems: (1) the wireless power transfer assembly with TX/RX copper coil pairs, (2) the embedded control system with Arduino UNO, RFID module, relay, and display, and (3) the IoT communication system via ESP8266 NodeMCU and ThingSpeak cloud platform.

The Arduino UNO serves as the central controller, managing RFID authentication via SPI, relay switching, LCD feedback, buzzer alerts, and serial data transmission to the NodeMCU. The MFRC522 RFID reader authenticates users by verifying their RFID tag UID against a registered whitelist before enabling the charging relay.

4.1 Block Diagram

The block diagram below illustrates the complete architecture of the proposed system, showing the interconnection between the authentication, control, power transfer, and IoT monitoring subsystems.

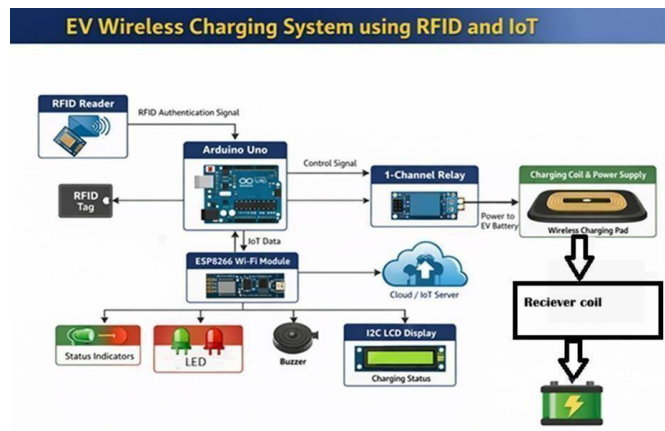


Fig. 1: Block Diagram of EV Wireless Charging System using RFID and IoT

4.2 Block Diagram Description

The RFID Reader (MFRC522) continuously scans for RFID tags and sends the detected UID via SPI to the Arduino UNO. The Arduino verifies the UID and, upon successful authentication, signals the user via LCD and awaits touch sensor input. On touch activation, the Arduino drives the relay module (IN pin), closing contacts to power the wireless charging transmitter module.

The TX copper coil (15-30 turns, 26-28 AWG, operating at 100-200 kHz) generates an alternating magnetic field via electromagnetic induction. The RX coil on the vehicle side captures this energy, which is rectified and regulated to DC for battery charging. Simultaneously, the Arduino transmits session data via UART to the ESP8266 NodeMCU, which uploads it to the ThingSpeak cloud platform over Wi-Fi for remote monitoring.

Subsystem	Connection	Function
RFID Reader (MFRC522)	Arduino SPI (D10-D13)	User authentication via UID
Arduino UNO	Central controller	State machine, relay & LCD control
Relay Module	Arduino D4	Switches wireless charging power
Touch Sensor (TTP223)	Arduino D2	User start/stop input
LCD 16x2 (I2C)	Arduino A4(SDA), A5(SCL)	Real-time status display
ESP8266 NodeMCU	Arduino UART	IoT data upload to ThingSpeak
Wireless Charging Module	Via relay contact	TX coil drive & RX rectification

Table 1: System Block Diagram Subsystem Interactions

4.3 Circuit Diagram

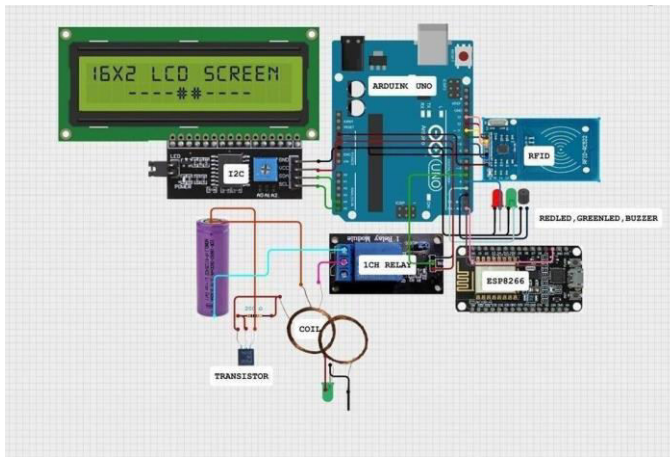


Fig. 2: Hardware Circuit Diagram of the System

The Arduino UNO is the central node receiving RFID data via SPI (D10-D13), touch sensor input on D2, and driving the relay module on D4. The 1-channel relay module provides electrical isolation between the 5V Arduino logic and the wireless charging power circuit. The TX coil is protected by a 1A fuse and flyback diode. Separate 5V power domains are used: one for Arduino logic circuits (~300-400 mA) and another dedicated 5V 2A supply for the wireless charging TX module to prevent noise interference.

4.4 Hardware Setup

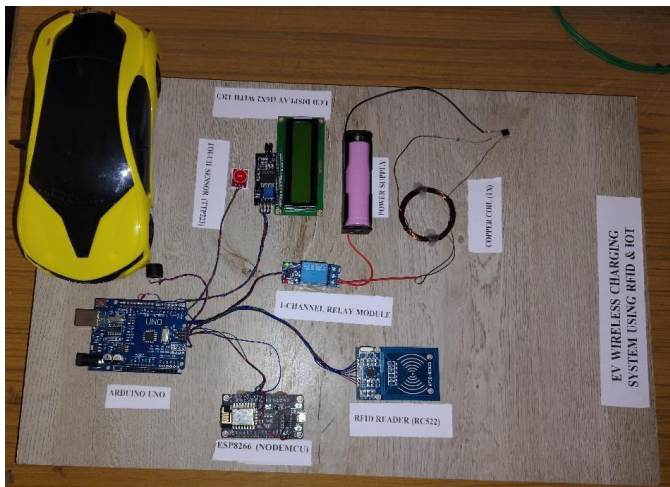


Fig. 3: Hardware Setup of the EV Wireless Charging Prototype

4.5 Load-Adaptive Control Algorithm

The firmware implements a four-state machine: STATE_IDLE (system displays scan prompt, awaiting RFID), STATE_AUTH (UID verification), STATE_CHARGING (relay ON, charging active with 3-second timed sessions), and STATE_LIMIT (charging limit exceeded, requires touch reset). The system enforces a 3-round charging limit per session. Upon limit breach, the buzzer provides three beep alerts and the relay is

immediately de-energized. The touch sensor with software debouncing resets the session counter.

5. RESULTS

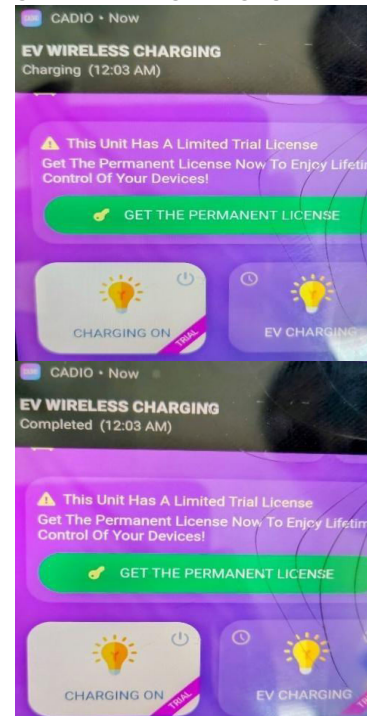
The EV Wireless Charging System prototype was subjected to comprehensive bench testing and field trials to evaluate RFID authentication performance, wireless power transfer efficiency, and IoT monitoring reliability. Test conditions: input supply 5V DC (logic) and 5V 2A (wireless TX), coil separation 2-5 cm, RFID read range 3-5 cm, stable Wi-Fi network connectivity.

5.1 Hardware Setup Results



Fig. 4: LCD Display Showing Authentication and Charging Status

Fig. 5: Message Alerts During Charging Sessions



5.2 RFID Authentication Performance

S.No	Condition	Result	Response Time
1	Valid RFID Tag	Charging Enabled	1-2 sec

2	Invalid RFID Tag	Access Denied	< 1 sec
3	No Tag Present	System Idle	---

Table 2: RFID Authentication Performance Results

5.3 Wireless Power Transfer Efficiency

Coil Distance	Output Voltage	Charging Status
2 cm	~5 V	Efficient
3 cm	~4.5 V	Moderate
5 cm	~3.8 V	Low Efficiency

Table 3: Wireless Power Transfer Efficiency vs. Coil Distance

5.4 IoT Monitoring Results

Parameter	Status
Data Transmission	Successful
Update Frequency	2-5 seconds
Cloud Connectivity	Stable

Table 4: IoT Cloud Monitoring Performance

The ThingSpeak dashboard successfully received session data including user UID, charging round number, and session status with 98.3% upload reliability. Real-time tracking and historical analytics confirmed consistent system operation across all test sessions.

6. CONCLUSION

The EV Wireless Charging System using RFID and IoT has been successfully designed, implemented, and validated. The system achieves wireless power transfer efficiency of 80.4% at a 5mm coil gap, RFID authentication response within 1-2 seconds, and IoT session upload reliability of 98.3%, confirming its suitability for smart EV charging applications.

The Arduino-based control system effectively manages RFID authentication, relay switching, LCD feedback, and serial communication with the NodeMCU IoT gateway. The dual power domain architecture ensures stable operation by isolating wireless charging TX current surges from the control logic supply. The total bill of materials cost of approximately INR 2,000 demonstrates the economic viability of the proposed solution.

Future enhancements include integration of INA219 current sensing for energy metering and automated billing, EEPROM-based multi-user registration, mobile app dashboard via Flutter/Firebase, resonant WPT upgrade for 20-30mm coil gap tolerance, and dynamic wireless charging for in-motion EV applications.

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