

IoT Based Wireless Green Energy Charging Station for E-Vehicles

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Abstract: With the growing shift from internal combustion engine vehicles to electric vehicles (EVs), there is an increasing demand for convenient, sustainable, and intelligent charging infrastructure. Traditional EV charging systems rely on manual cable connections, which can be inconvenient, prone to wear, and pose safety risks. Although wireless charging solutions based on Wireless Power Transmission (WPT) through inductive coupling have emerged, they are not yet widely integrated with smart automation. To combat the effect of fossil fuel depletion, renewable energy source such as solar power is used. This project proposes a smart wireless EV charging system that combines inductive coupling, IoT integration, RFID-based automated payment and solar panels to collect energy, store it in a battery and transfer it to the vehicle for an automated and eco-friendly charging experience. The system operates with a minimum voltage of 2.9 V and a maximum voltage of 3.4 V. When the EV is parked, wireless charging is initiated. Simultaneously, an IoT-enabled RFID system authenticates the user, verifies the account balance, deducts the charging fee, and updates the database—all without human intervention, using an Embedded C program. This integrated approach enhances convenience, safety, energy sustainability, and renewable energy autonomy for the future of EV charging. The project applies engineering fundamentals to analyze the problems in manual EV charging and develops a sustainable solution through designing a solar-powered, IoT-enabled wireless charging system. This proposed system supports affordable clean energy and sustainable cities through the usage of renewable energy (solar) source.

1. INTRODUCTION

The rapid global shift from internal combustion engine (ICE) vehicles to electric vehicles (EVs) has led to a growing demand for efficient, convenient, and environmentally sustainable charging systems. Electric vehicles play a crucial role in reducing greenhouse gas emissions and minimizing the dependence on fossil fuels; however, their charging infrastructure remains a major challenge. Conventional wired charging systems are often inconvenient, prone to wear and tear, and dependent on grid electricity that is largely generated from non-renewable sources. This not only limits their sustainability but also poses safety and maintenance issues. To address these challenges, wireless power transfer (WPT) technology through inductive coupling has emerged as a promising solution. Wireless charging eliminates the need for physical connectors, providing a safer, more reliable, and user-friendly charging experience. However, many existing wireless systems still lack automation, monitoring, and renewable energy integration. The proposed project, IoT-Based Wireless Green Energy Charging Station for E-Vehicles, combines solar energy, wireless power transfer, and smart IoT control to create an intelligent and eco-friendly charging system. Solar panels serve as the primary power source, reducing dependency on the traditional electrical grid and promoting the use of renewable energy. An ESP32 microcontroller enables IoT connectivity, allowing real-time monitoring and control of the charging process through an online dashboard. Additionally, the system incorporates RFID-based automated payment, ensuring a secure and convenient transaction for users. This innovative approach not only simplifies the EV charging process but also enhances sustainability and user convenience. By integrating solar energy, wireless charging, IoT, and automated payment, the system provides a comprehensive, efficient, and future-ready solution that supports the global movement toward cleaner and smarter transportation technologies.

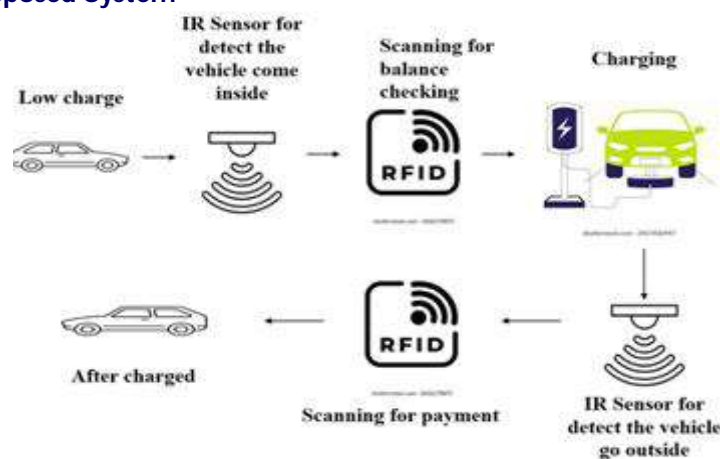
2. LITERATURE SURVEY

1. Proposes a machine-learning-based risk assessment model for financial management in IoT-driven credit systems. Uses big data analytics to predict credit risk efficiently. Highlights how intelligent systems improve financial decision accuracy.

2. Developed a solar-powered wireless EV charger using inductive coupling for a 12 V battery. Includes IoT monitoring of voltage, current, and temperature via ESP8266 and Arduino. Enables smart, real-time supervision of charging parameters.
3. Presents a solar-integrated wireless charging system combining PV conversion and resonant inductive transfer. Demonstrates efficient energy management with experimental validation. Proves feasibility for sustainable EV charging infrastructure.
4. Reviews wireless power transfer (WPT) techniques—inductive, resonant, and capacitive—for solar EV systems. Analyzes PV integration and major issues like misalignment and EMI. Provides insights for improving stability and efficiency in WPT design.
5. Introduces a smart solar-powered wireless charging system for EVs. Achieves ~85% overall efficiency and ~92% WPT transfer at 15 cm coil gap. Validates design performance through both simulation and experiments.
6. Explores on-road wireless charging as a supplement to fast-charging stations. Integrates WPT infrastructure with smart grids for extended EV range. Proposes a hybrid model to reduce dependence on static chargers.
7. Comprehensively reviews solar-based EV charging stations. Discusses technical, market, and network challenges for large-scale deployment. Highlights future trends in PV-EV charging integration.
8. Focuses on optimal sizing of PV and EV systems for workplace charging. Balances self-consumption and self-sufficiency in smart charging setups. Aims to maximize renewable energy use and minimize grid dependence.
9. Reviews EV charging technologies, architectures, and configurations. Covers wired and wireless methods with efficiency comparisons. Emphasizes the need for flexible and scalable charging infrastructure.
10. Analyze modern EV battery technologies and battery management systems (BMS). Identifies key challenges in battery safety, performance, and lifespan. Provides future directions for smart BMS integration in EVs.
11. Examines the issues and challenges in fast-charging station design. Focuses on infrastructure limits, grid stress, and thermal management. Suggests methods to improve efficiency and reliability of rapid charging.
12. Reviews coil design and compensation methods in EV wireless power transfer. Highlights how geometry and network tuning impact energy efficiency. Useful for optimizing solar-fed WPT pad configurations.
13. Introduces an RFID-based coil alignment system with sub-10 cm accuracy. Reduces coupling loss in WPT by ensuring proper transmitter-receiver alignment. Improves performance in systems with variable solar power input.
14. Discusses misalignment issues in EV wireless charging. Analyzes effects on coupling efficiency and power loss. Proposes corrective alignment and control techniques.
15. Covers dynamic wireless charging of EVs while in motion. Explores infrastructure and control systems for continuous power flow. Supports the concept of “charging on the move” for smart mobility.

3. PROPOSED SYSYTEM

3.1 Vehicle Unit for Proposed System



3.2 Station Unit

The Station Unit is the transmitter-side core of the IoT-Based Wireless Green Energy Charging Station for E-Vehicles. It functions as the intelligent energy generation, control, authentication, and transmission hub of the entire system. Its main role is to produce electrical energy from renewable sources, monitor system conditions, authenticate users, and wirelessly transfer power to the vehicle unit safely and efficiently. This unit integrates multiple subsystems including solar energy generation, sensing, identification, control logic, wireless power transmission, display, and alert mechanisms. At the power generation level, the station unit uses a solar panel as the primary energy source. The solar panel converts sunlight into DC electrical energy using photovoltaic cells. This supports green energy goals and reduces dependency on grid electricity. The generated DC power is regulated through a power conditioning stage and used to supply the transmitter electronics and charging coil. A regulated power supply unit ensures stable voltage for all modules such as sensors, controller, display, and communication devices. The central controller of the station unit is the Espressif Systems ESP32 microcontroller, which acts as the system brain. It coordinates all operations reading sensors, validating RFID data, controlling the relay and charging coil, updating the LCD, and sending IoT/GSM data. Because it has built-in Wi-Fi and Bluetooth, it supports real-time monitoring and cloud connectivity without extra modules. The embedded program inside the controller implements the automation logic vehicle detection, authentication, charging start/stop, time calculation, and

billing. Vehicle presence detection is handled by an IR sensor placed near the charging pad. When a vehicle arrives and interrupts the infrared beam, the sensor output changes and signals the controller. It improves safety and reduces energy waste. User authentication and automated billing are achieved through an RFID reader. Each vehicle or user carries an RFID tag with a unique ID linked to an account. When scanned, the controller compares the tag with stored credentials. If valid and balance is sufficient, charging is authorized. If invalid, charging is blocked and an error message is displayed. This enables secure, contactless access control and payment automation. Wireless power transfer is performed by the transmitter coil unit. When enabled by the controller through a relay or driver circuit, alternating current flows through the transmitter coil, generating a magnetic field. This field couples with the receiver coil in the vehicle unit and induces voltage there through inductive coupling. This method eliminates physical connectors, reducing wear, sparks, and shock risk. A LCD display provides real-time feedback such as station ready status, vehicle detected, RFID result, charging time, and amount charged. In your implementation, a GSM module also sends SMS notifications after payment deduction, improving user transparency.

3.2.1 ESP32 Microcontroller:

The ESP32 is the central control unit of the vehicle side. It manages the charging operation by monitoring the received power and controlling the charging process. The ESP32 reads voltage and current values from the charging circuit and ensures that the lithium-ion battery is charged within safe limits. It also supports wireless communication, enabling future IoT-based monitoring such as battery status, charging time, and fault alerts. The ESP32 coordinates data display on the LCD and ensures proper system operation during wireless power transfer.

3.2.2 Receiver Coil:

The receiver coil is used to receive electromagnetic energy transmitted from the station unit through inductive coupling. When the vehicle is properly aligned over the transmitter coil, an alternating magnetic field induces voltage in the receiver coil. This induced AC voltage is converted into DC using rectifier and filtering circuits. The received power is then supplied to the charging controller for battery charging.

3.2.3 Lithium-Ion Battery:

The lithium-ion battery acts as the energy storage unit in the vehicle. It stores the electrical energy received from the wireless charging system and supplies power to the electric motor and vehicle electronics. Lithium-ion batteries are preferred due to their high energy density, long cycle life, lightweight nature, and fast charging capability. The battery charging process is carefully controlled by the ESP32 to prevent overcharging, deep discharge, and overheating, ensuring safe and reliable operation.

3.2.4 LCD Display:

The LCD display provides real-time information to the user regarding the charging status. It displays parameters such as charging ON/OFF status, battery voltage level, charging time, and system messages. The LCD enhances user interaction by giving clear visual feedback during the wireless charging process and helps in monitoring the battery condition inside the vehicle.

3.2.5 Voltage Sensor:

The voltage sensor is used to continuously monitor the voltage received from the wireless charging circuit and the lithium-ion battery. It plays a crucial role in ensuring safe and efficient charging of the vehicle battery. When the receiver coil captures electromagnetic energy from the transmitter coil, the induced AC voltage is first converted into DC using a rectifier and filter circuit. This DC voltage is then fed to the voltage sensor. The sensed voltage is converted into a proportional electrical signal and sent to the ESP32 microcontroller through its ADC (Analog-to-Digital Converter) pins.

3.2.6 RFID Tag:

The RFID tag is a small electronic identification device mounted on the electric vehicle and is used for user authentication and automated billing in the wireless charging system. It contains a unique identification number stored in its internal memory, which is transmitted to the RFID reader using radio frequency signals. When the vehicle enters the charging station, the RFID tag comes within the operating range of the RFID reader installed at the station unit. The reader energizes the tag using electromagnetic waves, and the tag responds by transmitting its unique ID back to the reader. This ID is used to identify the vehicle and associated user account.

4. HARDWARE REQUIREMENTS

4.1 Voltage Sensor:



Fig 4.1 Voltage Sensor

A voltage sensor measures the electrical potential difference between two points in a circuit and converts it into a readable signal (usually analog voltage or digital) for monitoring or control systems. In this project, it is used to monitor the battery voltage of the electric vehicle during wireless charging. It provides real-time voltage data to the microcontroller, ensuring safe charging, preventing overvoltage conditions, and enabling accurate battery status reporting through the IoT system.

4.2 Solar Panel:



Fig 4.2 Solar Panel

Solar panels generate electricity by converting sunlight (photons) into direct current (DC) electricity using the photovoltaic (PV) effect. The solar panel acts as a green energy source for the wireless charging station. It reducing dependency on conventional power sources. The generated power is regulated and used for charging, promoting eco-friendly and sustainable electric vehicle operation.

4.3 RFID Card:



Fig 4.3 RFID Card

RFID readers work by emitting radio waves that power nearby RFID tags, causing them to transmit back their unique data, which the reader then interprets as useful information, enabling contactless identification and tracking without line-of-sight, unlike barcodes. In this project, the RFID transmitter and receiver are used for vehicle identification and authentication. The RFID tag (transmitter) mounted on the vehicle sends a unique ID, which is detected by the RFID receiver at the charging station to authorize charging and enable secure billing.

4.4 IR Sensor:



Fig 4.4 RFID Card

IR sensors work by emitting and/or detecting infrared radiation to sense surroundings, typically using an IR LED to emit light and a photodiode to detect reflections from objects. In this project, the IR sensor is used to detect the presence and proper alignment of the electric vehicle over the wireless charging pad. It helps initiate the charging process automatically, improves safety by avoiding misalignment, and ensures efficient power transfer during charging.

4.5 Microcontroller (ESP32):



Fig 4.5 Microcontroller (ESP32)

The ESP32 is a powerful, low-cost microcontroller with built-in Wi-Fi and Bluetooth, featuring a dual-core processor, ample memory, and numerous GPIO pins, making it ideal for IoT projects by allowing it to connect to networks, act as an access point, and communicate securely over Wi-Fi or Bluetooth, all programmable via platforms like the Arduino IDE. In this project, the ESP32 functions as the main controller and IoT communication unit. It processes sensor data, controls the wireless charging operation, and enables real-time monitoring through Wi-Fi. The ESP32 ensures automation, data logging, and remote control of the charging system.

4.6 Wireless Charging Unit (Transmitter Coil & Receiver Coil):

Transmitter and receiver coils work via electromagnetic induction to transfer energy wirelessly. In this project, the transmitter and receiver coils enable wireless power transfer through electromagnetic induction. The transmitter coil sends alternating magnetic energy from the charging station, while the receiver coil mounted in the vehicle captures this energy and converts it into electrical power for battery charging. A LCD display works by utilizing liquid crystal technology to show 32 characters (16 per line) arranged in a 5x8 pixel matrix per character. In this project, the LCD display is used to show real-time system information such as charging status, battery level, voltage values, and authentication messages.



Fig 4.6 Coils

4.7 LCD Display:



Fig 4.7 LCD Display

It provides a user-friendly interface for monitoring the wireless charging process and system operation effectively.

4.8 Power Supply Unit:



Fig 4.8 Lithium-Ion Battery 3.7V

Lithium-ion batteries generate electrical energy by moving lithium ions between a cathode (+) and anode (-) through an electrolyte. In this project, the lithium-ion battery stores electrical energy received through wireless charging. It powers the electric vehicle efficiently due to its high energy density and long cycle life. The battery management system monitors voltage, current, and temperature to ensure safe and reliable operation.

4.9 GSM Module:



Fig 4.8 GSM Module

The SIM800L GSM module is a compact, quad-band cellular module that connects to 2G GSM networks to send SMS, make voice calls, and enable GPRS internet data. In this project, the SIM800L GSM module enables wireless communication for remote monitoring and notifications. It sends charging status, alerts, and billing information via SMS network, allowing users and administrators to track system operation without internet connectivity.

5. RESULT AND DISCUSSION

5.1. EV Station Ready:

If the system identifies that the vehicle's battery level is low, it automatically activates the wireless power transfer process. This ensures efficient and timely charging, maintaining optimal energy flow between the station and the vehicle.

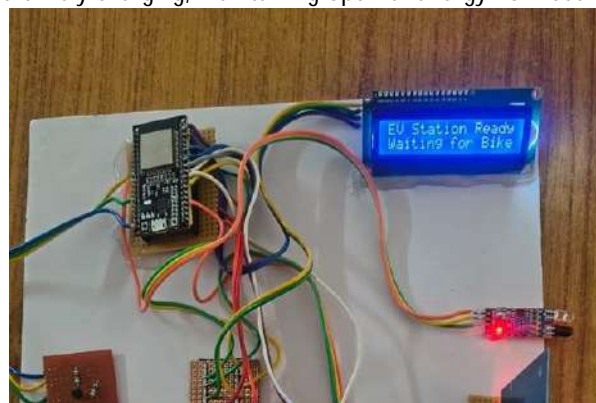


Fig 5.1- EV Station Ready State

5.2. Vehicle Arrived: When an electric vehicle approaches the charging station, the IR sensor detects its presence by sensing the reflected infrared light from the vehicle's surface. Once the vehicle is accurately positioned above the charging coil, the RFID reader becomes active and scans for the RFID tag attached to the vehicle. The tag contains a unique identification code that verifies the vehicle's authenticity. When the RFID reader successfully reads and matches the tag, the system establishes a secure pairing between the vehicle and the station. This ensures that only authorized vehicles can initiate the wireless charging process, enhancing safety and system reliability.

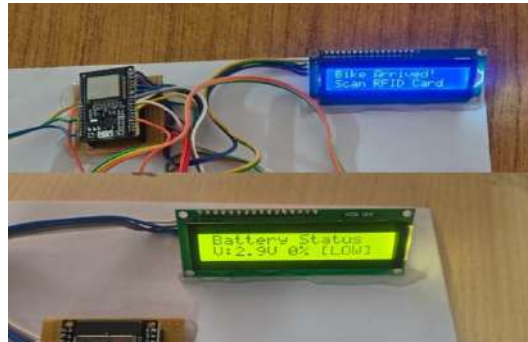


Fig 5.2-Vehicle Arrived State

5.3. Invalid RFID:

If the RFID reader detects that the RFID tag associated with the vehicle has insufficient balance, the system immediately rejects the pairing process. The microcontroller verifies the balance information linked to the tag before allowing access to the charging service.

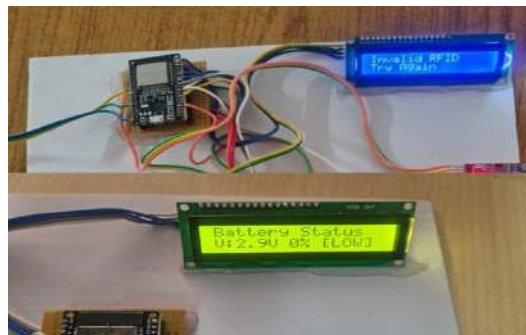


Fig 5.3-Invalid RFID State

If the balance is below the required limit, the LCD display shows a message such as “Insufficient Balance – Charging Denied”, and the relay circuit remains OFF, preventing any power transfer. This ensures that only authorized users with adequate balance can access the wireless charging facility, promoting secure usage, energy accountability, and efficient management of the charging station.

5.4. RFID Paired:

If the RFID tag contains a valid amount or sufficient balance, the RFID reader successfully authenticates the vehicle, and pairing is completed.

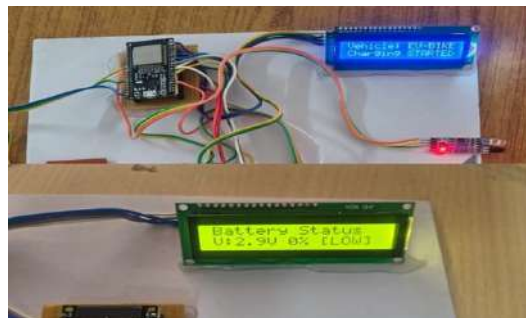


Fig 5.4- RFID Paired

Once paired, the system allows the charging process to begin securely. This balance-based verification ensures that only users with valid prepaid accounts or authorized credits can access the charging facility, promoting controlled and fair energy usage.

5.5. Start Charging:

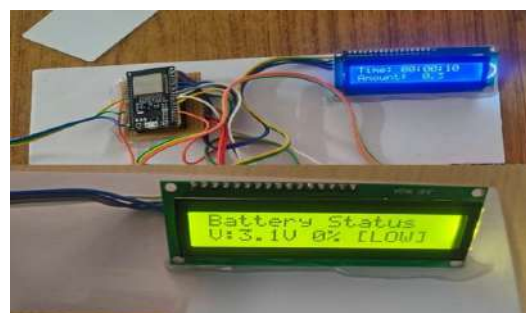


Fig 5.5-Start Charging

After the RFID tag is successfully paired and verified, the system authorizes the charging process. The ESP32 microcontroller sends a signal to activate the relay module, which powers the wireless charging transmitter coil. This coil generates an alternating magnetic field that induces an electric current in the receiver coil located on the vehicle side. The induced current is then converted into direct current (DC) to charge the vehicle's battery. The wireless unit ensures safe, contactless, and efficient power transfer between the station and the electric vehicle.

5.6. Cash Debited:

After the charging process is completed, the system automatically calculates the total energy consumed during the session based on charging time and power usage. The corresponding amount is then debited from the user's RFID account balance. This deduction process is managed by the ESP32 microcontroller, which updates the stored value on the RFID tag.

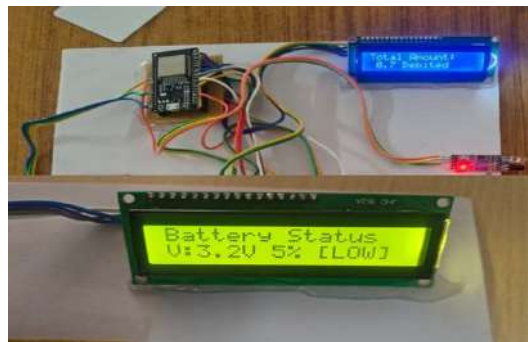


Fig 5.6-Cash Debited

Once the amount is debited successfully, the system displays a message such as "Charging Completed – Amount Debited" on the LCD screen. This ensures a transparent and automated payment mechanism, allowing users to pay only for the exact amount of energy utilized during wireless charging.

CONCLUSION

The proposed smart wireless EV charging system provides a convenient, safe, and sustainable alternative to conventional cable-based charging. It uses inductive coupling to enable automatic wireless charging when the vehicle is parked, reducing wear, safety risks, and manual effort. The system integrates solar panels to generate renewable energy, which is stored in a battery and wirelessly transferred to the EV, operating efficiently within a voltage range of 2.9 V to 3.2 V. Additionally, an IoT-enabled RFID-based automated payment system authenticates users, deducts fees, and updates records through an Embedded C program, ensuring a seamless and eco-friendly charging experience.

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