

Wireless Charging System & User Identification using AI for Electric Vehicle

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ABSTRACT

The increasing adoption of electric vehicles (EVs) has created a growing need for charging systems that are **automated, secure, convenient, and capable of managing multiple charging slots**. Conventional plug-in charging systems require manual cable connection and generally provide limited integration of user authentication, automatic vehicle detection, and centralized slot monitoring. This paper presents an **Wireless Charging System & User Identification using AI for Electric Vehicles**, developed as a two-slot prototype for automated EV charging management. The proposed system integrates **Arduino Nano controllers, MFRC522 RFID readers, infrared (IR) sensors, servo motors, relay modules, 16×2 LCD displays, and wireless transmitter–receiver coils**. RFID technology is used to identify and authenticate users before charging access is provided. IR sensors detect vehicle arrival, slot entry, charging position, and vehicle exit, while servo motors automatically control the main entrance and individual slot gates. After successful RFID authentication and correct vehicle positioning, the corresponding relay activates the wireless charging transmitter. Each slot provides its own LCD for displaying authentication status, charging initiation, charging progress, and completion messages, while a master controller displays the availability status of both charging slots. The system incorporates an **AI-assisted charging-management framework** intended to support future charging-demand prediction, dynamic load balancing, charging optimization, battery-health monitoring, and predictive maintenance. The present prototype primarily implements sensor-based and rule-based control, providing the required hardware and data-acquisition foundation for future AI/ML integration. Functional testing demonstrates the coordinated operation of vehicle detection, RFID authentication, automatic gate control, wireless charging activation, charging-progress indication, charging completion, and slot-status monitoring. The proposed system provides a scalable foundation for the development of **secure, automated, wireless, and intelligent EV charging infrastructure**.

Keywords: Electric Vehicle (EV), Wireless Power Transfer (WPT), Wireless EV Charging, RFID Authentication, Arduino Nano, MFRC522, IR Sensors, Servo Motor, Relay Module, Smart Charging, Artificial Intelligence (AI), User Identification, Automated Charging, Charging Slot Management, AI-Assisted Energy Management.

I. INTRODUCTION

The rapid development and adoption of **electric vehicles (EVs)** has created a growing demand for reliable,

convenient, secure, and intelligent charging infrastructure. EVs offer an alternative to conventional internal-combustion-engine vehicles and can contribute to the reduction of transportation-related emissions and fossil-fuel dependency. However, the availability, accessibility, and efficient management of charging infrastructure remain important challenges for widespread EV adoption. Conventional charging stations generally require the user to manually connect a charging cable to the vehicle, which can reduce convenience and introduce limitations related to cable handling, connector wear, and user interaction.

Wireless Power Transfer (WPT) provides an alternative approach in which electrical energy is transferred from a transmitting coil to a receiving coil without a direct electrical connection. In an EV charging application, the transmitter can be installed at the charging position while the receiver is mounted on the vehicle. When the vehicle is correctly positioned above the transmitter, energy can be transferred wirelessly. This approach can improve user convenience and provides opportunities for automated charging systems. However, practical wireless EV charging requires appropriate control of vehicle positioning, power transfer, safety, alignment, and charging conditions.

Another important requirement of a modern EV charging station is **user identification and access control**. In public, institutional, commercial, and residential charging environments, unauthorized users should be prevented from accessing the charging facility. Radio Frequency Identification (RFID) provides a contactless method of identifying users through a unique card identifier. In the proposed system, an MFRC522 RFID reader is used to authenticate the user before charging access is granted. This provides an additional security layer and allows charging sessions to be associated with authorized users.

For a charging station containing multiple charging slots, efficient slot management is also necessary. The system should identify whether a charging slot is available or occupied and should provide this information to the user before the vehicle enters the charging area. In addition, automatic vehicle detection can reduce manual intervention. Therefore, the proposed system uses **infrared (IR) sensors** to detect vehicle arrival, slot entry, charging position, and vehicle exit. **Servo motors** are used to operate the main entrance and individual slot gates automatically.

The proposed work develops a **two-slot wireless EV charging prototype** using Arduino Nano controllers. Each charging slot has an independent control section consisting of IR sensors, an RFID reader, a servo-controlled gate, a relay-controlled wireless transmitter, and an LCD display. A master Arduino Nano monitors the overall charging station and provides the availability status of both slots through a main LCD. After successful RFID authentication and confirmation of the vehicle's charging position, the corresponding relay activates the wireless charging transmitter. Charging progress is displayed locally on the respective slot LCD.

The system also introduces an **AI-assisted charging-management framework**. Artificial Intelligence can potentially analyze charging demand, slot occupancy, charging history, energy consumption, and battery-related information to improve charging decisions. Possible applications include charging-demand prediction, dynamic load balancing between two slots, charging-time optimization, battery-health estimation, and predictive maintenance. In the present prototype, the primary control functions are implemented using sensor-based and rule-based embedded logic. Thus, the prototype provides the sensing, control, authentication, and data-acquisition foundation required for future implementation of advanced AI/ML algorithms.

The major contribution of this work is the integration of **wireless charging, RFID-based user identification, automatic vehicle detection, automatic gate control, two-slot management, local**

charging monitoring, and centralized slot-status indication within a single embedded prototype. The proposed architecture is intended to demonstrate how these technologies can work together to provide a more automated and secure EV charging experience.

The main objectives of the proposed system are:

1. To develop a **two-slot wireless EV charging prototype**.
2. To implement **RFID-based user identification and authentication**.
3. To automatically detect vehicle movement using **IR sensors**.
4. To control the main entrance and charging-slot gates using **servo motors**.
5. To activate wireless charging only after the required vehicle and authentication conditions are satisfied.
6. To display charging status and progress on dedicated **16×2 LCD displays**.
7. To provide centralized monitoring of Slot 1 and Slot 2 availability.
8. To establish a platform for future **AI-assisted charging optimization and intelligent load management**.

II. LITERATURE REVIEW

The development of intelligent electric vehicle (EV) charging infrastructure has attracted significant research attention due to the increasing adoption of EVs and the need for convenient, efficient, and secure charging methods. Existing research has primarily focused on wireless power transfer, charging control, user authentication, vehicle positioning, smart charging, and intelligent energy management. The following literature provides the technical background for the proposed two-slot EV charging system.

A. Wireless Power Transfer for Electric Vehicles

Li and Mi presented a comprehensive review of wireless power transfer (WPT) technologies for EV applications. Their work discussed the fundamental principles of inductive wireless power transfer, system configurations, compensation techniques, power-transfer efficiency, and challenges associated with EV charging. The study established WPT as a promising alternative to conventional conductive charging because it can improve charging convenience and reduce dependence on physical connectors.

Covic and Boys investigated modern inductive power-transfer systems for transportation applications. Their work highlighted important factors such as magnetic coupling, alignment between transmitting and receiving coils, compensation circuits, power electronics, and system efficiency. These factors are particularly important in stationary EV charging because incorrect vehicle positioning can reduce the effectiveness of wireless energy transfer.

The proposed project applies the basic concept of stationary wireless power transfer by using a transmitter coil at each charging slot and a corresponding receiver coil on the EV prototype. IR sensors are additionally used to confirm that the vehicle has reached the intended charging position before the transmitter is activated.

B. Wireless Charging Standards and Alignment

The development of standards has been an important step toward practical wireless EV charging. SAE J2954 specifies criteria for interoperability, electromagnetic compatibility, electromagnetic-field exposure, minimum performance, safety, and testing for wireless power transfer of light-duty plug-in/electric vehicles. The current standard addresses stationary wireless charging and supports public as well as private charging applications.

Recent work related to SAE J2954 has also investigated vehicle-to-ground-assembly alignment methodologies. Accurate alignment is important because the relative position of the vehicle receiver and ground transmitter directly affects wireless power transfer.

In the proposed prototype, accurate commercial-grade alignment technology is not implemented. Instead, IR7 and IR9 are used as simplified charging-position detection sensors for Slot 1 and Slot 2, respectively. This provides a low-cost method of ensuring that charging is enabled only when the vehicle reaches the designated charging position.

C. RFID-Based User Identification

RFID technology is widely used for contactless identification and access-control applications. An RFID-based charging system can associate a charging session with an authorized user and prevent unauthorized access to the charging infrastructure.

In the proposed system, MFRC522 RFID readers are used at both charging slots. When a vehicle reaches the RFID detection area, the user presents an RFID card. The controller reads the card identifier and compares it with the authorized identifier stored in the system. A valid card results in access being granted, whereas an invalid card keeps the slot gate closed.

This approach provides an additional security layer to the charging system without requiring physical keys or manual authorization.

D. Smart Charging and Coordinated EV Charging

Smart charging has been investigated as a method of coordinating EV charging with electrical-grid requirements, aggregator objectives, and user requirements. Wang *et al.* reviewed smart EV charging from an algorithmic perspective and classified charging strategies according to grid-oriented, aggregator-oriented, and customer-oriented objectives. Their work highlighted applications such as load flattening, voltage regulation, frequency regulation, charging-cost reduction, and management of uncertainty in EV arrival, departure, and charging demand.

Nimalsari *et al.* reviewed distributed charging-control algorithms and discussed centralized, decentralized, and hierarchical approaches for coordinating multiple EVs. Their study emphasized the importance of charging coordination as EV penetration increases and identified uncertainty in EV behavior and charging demand as important challenges.

These studies provide the conceptual basis for the two-slot management approach used in this work. The proposed system monitors the operating condition of Slot 1 and Slot 2 and communicates their status to a master controller. The architecture can subsequently be extended to implement intelligent load balancing when both slots require charging simultaneously.

E. Artificial Intelligence in EV Charging Management

Artificial intelligence and machine-learning techniques are increasingly being investigated for EV charging scheduling and optimization. For example, actor-critic learning has been proposed for online EV charging scheduling under uncertain vehicle arrival, departure, and charging-demand information. Such approaches demonstrate the potential of learning-based algorithms for reducing charging costs and managing peak charging loads.

The proposed project adopts an **AI-assisted architecture** rather than claiming a fully trained AI model in the present prototype. The embedded system collects information such as slot occupancy, vehicle detection, charging progress, and charging-session status. These data can form the basis for future machine-learning models for charging-demand prediction, dynamic load balancing, charging-time optimization, battery-health estimation, and predictive maintenance.

F. Research Gap

The literature demonstrates substantial development in individual areas of EV wireless charging, smart charging, vehicle alignment, and intelligent charging algorithms. However, there is a practical need for low-cost prototype architectures that integrate several functions at the station level.

The proposed work addresses this integration by combining:

1. **Wireless charging** using transmitter and receiver coils.
2. **RFID-based user identification** for charging authorization.
3. **IR-based vehicle detection** at multiple positions.
4. **Automatic servo-controlled gates** for vehicle access.
5. **Two independent charging slots**.
6. **Individual LCD monitoring** for each slot.
7. **Centralized slot-availability monitoring** through a master controller.
8. **Relay-based automatic charging activation and deactivation**.
9. An **AI-assisted framework** for future intelligent charging management.

The major research opportunity is therefore not the invention of each individual technology, but their **integration into a coordinated two-slot wireless EV charging architecture with user identification and a pathway toward AI-based charging optimization**.

III. BACKGROUND AND WORKING PRINCIPLES

A. Background

The rapid adoption of Electric Vehicles (EVs) has increased the demand for charging systems that are convenient, secure, automated, and efficient. Conventional EV charging generally requires a physical cable to connect the vehicle to the charging station. Although this method is widely used, manual cable handling can reduce convenience and requires user interaction. **Wireless Power Transfer (WPT)** provides an alternative method in which electrical energy is transferred from a transmitting coil to a receiving coil without a direct conductive connection.

The proposed project, “**Wireless Charging System & User Identification using AI for Electric Vehicles,**” combines wireless charging with RFID-based user identification, automatic vehicle detection, servo-controlled gates, and two-slot charging management. Arduino Nano controllers are used to coordinate the different hardware components. RFID technology provides user authentication, IR sensors detect vehicle movement and charging position, relay modules control wireless charging, and LCD displays provide information to the user.

The proposed system also provides an **AI-assisted charging-management framework**. The collected information regarding slot occupancy, charging progress, charging duration, and charging requirements can be used for future AI/ML-based charging optimization, load balancing, demand prediction, battery-health monitoring, and predictive maintenance.

B. Working Principle

The working principle of the proposed system is based on the sequential operation of **vehicle detection, user authentication, vehicle positioning, wireless charging, charging monitoring, and vehicle exit detection**.

1. System Initialization

When the power supply is switched ON, the Arduino Nano controllers initialize the connected sensors, RFID readers, servo motors, relay modules, and LCD displays.

The initial displays are:

- **Main Gate LCD:** AI EV CHARGING
- **Main Gate LCD:** S1: AVL S2: AVL
- **Slot 1 LCD:** WELCOME / SCAN RFID
- **Slot 2 LCD:** WELCOME / SCAN RFID

The system then enters standby mode and waits for a vehicle.

2. Vehicle Detection at Main Gate

When an EV reaches the entrance, **IR1** detects the vehicle. The master Arduino activates the main gate servo motor, which rotates from approximately 0° to 90° and opens the gate.

After the vehicle crosses the entrance, **IR2** detects the vehicle. The master controller then commands the servo to return from approximately 90° to 0°, closing the main gate automatically.

3. Charging Slot Selection

After entering the charging station, the driver checks the Main Gate LCD to determine which slot is available.

Examples include:

- S1: AVL S2: CHG → Slot 1 available and Slot 2 occupied.
- S1: CHG S2: AVL → Slot 1 occupied and Slot 2 available.
- S1: AVL S2: AVL → Both slots available.
- S1: CHG S2: CHG → Both slots occupied.

The driver proceeds toward an available slot.

4. RFID Authentication

When the vehicle reaches **Slot 1**, **IR3** detects the vehicle near RFID Reader 1. The Slot 1 LCD displays “SCAN RFID.” The user presents the RFID card to the MFRC522 reader.

The Arduino verifies the RFID UID.

- **Valid card:** RFID VERIFIED / ACCESS GRANTED
- **Invalid card:** ACCESS DENIED / INVALID CARD

For a valid card, the Slot 1 servo gate opens. For an invalid card, the gate remains closed.

The same process is performed for Slot 2 using **IR5 and RFID Reader 2**.

5. Vehicle Entry Confirmation

After successful RFID authentication, the respective slot gate opens and the vehicle enters the charging area.

- **IR4** confirms vehicle entry into Slot 1.
- **IR6** confirms vehicle entry into Slot 2.

After entry is confirmed, the corresponding slot gate is closed automatically.

6. Charging Position Detection

Correct vehicle positioning is important for wireless power transfer. Therefore, separate IR sensors are used to confirm the charging position.

- **IR7** detects the correct charging position for Slot 1.
- **IR9** detects the correct charging position for Slot 2.

Charging is permitted only after the corresponding sensor confirms that the vehicle is positioned over the charging area.

7. Wireless Charging Activation

After successful authentication, vehicle entry, and charging-position confirmation, the corresponding relay is switched ON.

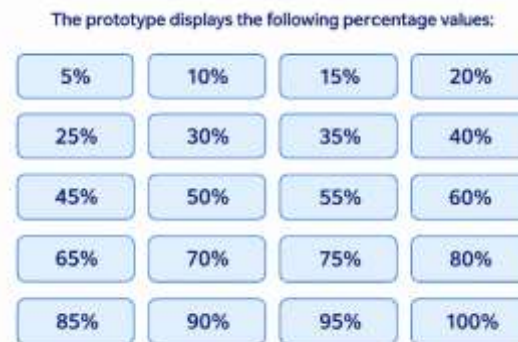
The operation is:

Vehicle positioned → Relay ON → Wireless transmitter activated → Electromagnetic energy transfer → Receiver coil receives energy → EV battery charging.

The transmitter coil generates an electromagnetic field, and the receiver coil mounted on the EV receives the transferred energy. The charging circuit then supplies the required electrical energy to the battery.

8. Charging Progress Monitoring

During charging, the respective LCD provides charging-progress information.



This provides the user with continuous information about the charging process.

Note: In the present prototype, these percentages represent a programmed charging-progress sequence and should not be described as actual battery SOC unless a battery-management system or SOC measurement is integrated.

9. Charging Completion

When the charging sequence reaches 100%, the controller switches the corresponding relay OFF. This stops the power supply to the wireless transmitter.

The LCD displays:

“CHARGING COMPLETE”

followed by:

“THANKS / VISIT AGAIN.”

The charging slot is then prepared for the vehicle-exit process.

10. Vehicle Exit Detection

When the vehicle leaves the charging slot:

- **IR8** detects the exit of the Slot 1 vehicle.
- **IR10** detects the exit of the Slot 2 vehicle.

After detecting the vehicle exit, the corresponding slot status changes to **Available (AVL)**. The updated status is transmitted to the master controller.

11. Centralized Slot Monitoring

The master controller continuously receives the operating status of both charging slots. It updates the Main Gate LCD according to the current condition.

For example:

Before Slot 1 charging:

S1: AVL S2: AVL

During Slot 1 charging:

S1: CHG S2: AVL

After Slot 1 vehicle exits:

S1: AVL S2: AVL

This provides a simple centralized indication of charging-slot availability.

12. AI-Assisted Charging Management

The proposed AI-assisted layer can use charging-station data to improve the efficiency of the charging process. Possible AI functions include:

- **Charging-demand prediction:** Predicting when charging demand is likely to increase.
- **Load balancing:** Distributing available charging power between Slot 1 and Slot 2 when both are occupied.
- **Charging optimization:** Selecting appropriate charging conditions based on available power and charging requirements.
- **Battery-health monitoring:** Analyzing battery voltage, current, temperature, and charging history when BMS data are available.
- **Predictive maintenance:** Identifying abnormal sensor, relay, or charging behavior.
- **Energy optimization:** Reducing unnecessary wireless transmitter operation.

In the current prototype, the main charging sequence is implemented using **embedded sensor-based and rule-based control**. The hardware and collected operating data provide the foundation for integrating a trained AI/ML model in future development.

13. Overall Working Sequence

The complete operation can therefore be summarized as:

1. Power supply is switched ON.
2. Arduino Nano controllers initialize the system.
3. Main LCD displays Slot 1 and Slot 2 availability.
4. IR1 detects the approaching EV.
5. Main gate servo opens.
6. IR2 detects vehicle crossing.
7. Main gate servo closes.
8. Driver selects an available charging slot.
9. IR3 or IR5 detects the vehicle.
10. RFID card is scanned.
11. User authorization is verified.
12. Valid RFID allows the respective slot gate to open.
13. IR4 or IR6 confirms vehicle entry.
14. IR7 or IR9 confirms correct charging position.
15. Corresponding relay switches ON.
16. Wireless charging begins.
17. LCD displays charging progress from 5% to 100%.
18. At 100%, charging is completed.
19. Relay switches OFF.
20. LCD displays “Charging Complete” and “Thanks Visit Again.”
21. IR8 or IR10 detects vehicle exit.

22. The corresponding slot becomes available.

23. Master controller updates the Main Gate LCD.

Thus, the proposed working principle integrates **automatic vehicle detection, RFID user identification, wireless power transfer, automatic gate control, charging monitoring, and two-slot management** into a single EV charging system, while providing a foundation for future AI-based intelligent charging optimization.

IV. METHODOLOGY

The proposed **Wireless Charging System & User Identification using AI for Electric Vehicles** is developed as a two-slot automated EV charging prototype. The methodology combines vehicle detection, RFID-based user identification, automatic gate control, wireless power transfer, charging monitoring, and centralized slot management. The system is divided into **main-gate control, two independent charging-slot controllers, wireless charging units, and an AI-assisted management layer**.

A. System Architecture

The proposed system consists of three Arduino Nano controllers:

1. **Master Controller (Nano 3)** – controls the main entrance and monitors the availability of both charging slots.
2. **Slot 1 Controller (Nano 1)** – controls RFID authentication, vehicle detection, gate operation, charging and display for Slot 1.
3. **Slot 2 Controller (Nano 2)** – performs the corresponding functions for Slot 2.

The master controller communicates with the two slot controllers to obtain their operating status and display the availability of the charging slots on the main LCD.

B. Vehicle Detection

IR sensors are used at different locations of the charging station to identify vehicle movement.

- **IR1 and IR2** are used at the main entrance.
- **IR3 and IR4** are used for Slot 1 entry.
- **IR5 and IR6** are used for Slot 2 entry.
- **IR7** detects the charging position in Slot 1.
- **IR9** detects the charging position in Slot 2.
- **IR8 and IR10** detect vehicle exit from Slot 1 and Slot 2, respectively.

The sensor signals are processed by the respective Arduino Nano controllers to determine the vehicle's location and operating state.

C. RFID-Based User Identification

MFRC522 RFID readers are used for user identification in both charging slots. When a vehicle reaches a slot, the corresponding IR sensor activates the RFID authentication stage.

The RFID card UID is read and compared with the authorized UID stored in the Arduino program.

The authentication process is:

Vehicle Detection → RFID Card Scan → UID Verification → Access Granted/Denied

If the UID is valid, the corresponding slot gate is opened. If the UID is invalid, the charging slot remains inaccessible.

This method provides an additional security layer and prevents unauthorized users from using the charging facility.

D. Automatic Gate Control

Servo motors are used for automatic control of the main entrance and charging-slot gates.

At the main entrance, IR1 detects the approaching vehicle and the master controller opens the gate. After IR2 detects that the vehicle has crossed the entrance, the gate closes.

For the charging slots, successful RFID authentication causes the respective servo to open. After the vehicle enters and the corresponding entry IR sensor detects it, the slot gate is closed.

This provides automatic vehicle access without requiring manual gate operation.

E. Charging Position Detection

Wireless charging requires suitable alignment between the transmitter and receiver coils. To ensure that the vehicle reaches the intended charging area, dedicated IR sensors are used.

For Slot 1, **IR7** confirms that the vehicle is positioned over the charging area. For Slot 2, **IR9** performs the same function.

Charging activation is therefore permitted only after the vehicle has been authenticated, entered the slot, and reached the defined charging position.

F. Wireless Charging Control

Each charging slot contains a wireless transmitter coil and a corresponding receiver coil.

The charging sequence is:

Vehicle positioned → Position confirmed → Relay ON → Transmitter activated → Wireless energy transfer → EV charging

The relay module acts as an electrically controlled switch for the wireless transmitter supply.

When the charging process reaches its completion condition, the controller switches the relay OFF and terminates wireless power transfer.

G. Charging Progress Monitoring

The charging process is displayed on the individual slot LCD.

The prototype uses a programmed charging-progress sequence:

5% → 10% → 15% → 20% → 25% → 30% → 35% → 40% → 45% → 50% → 55% → 60% → 65% → 70% → 75% → 80% → 85% → 90% → 95% → 100%

The LCD also displays:

- Welcome message.
- RFID authentication status.
- Charging-start message.
- Charging progress.
- Charging completion.
- “Thanks / Visit Again.”

The displayed percentage represents the prototype's programmed charging-progress indication and is not a direct battery SOC measurement unless battery/BMS feedback is incorporated.

H. Two-Slot Management

The two charging slots operate independently while their status is monitored centrally.

The slot controllers provide status information such as:

- Available.
- Vehicle detected.
- RFID authentication.
- Charging.

- Charging completed.
- Vehicle exiting.

The master controller processes these status messages and updates the Main Gate LCD.

For example:

S1: AVL S2: AVL

indicates that both slots are available, whereas:

S1: CHG S2: AVL

indicates that Slot 1 is charging and Slot 2 is available.

I. AI-Assisted Charging Management

The proposed methodology includes an AI-assisted layer for improving charging management. Operating information from the charging slots can be collected and used as input data for an AI/ML model.

Potential inputs include:

- Slot occupancy.
- Charging status.
- Charging duration.
- Charging progress.
- Energy demand.
- Number of active charging slots.

The AI layer can subsequently be used for:

1. **Charging-demand prediction** – estimating future charging requirements.
2. **Load balancing** – distributing available power when both slots are occupied.
3. **Charging optimization** – determining suitable charging schedules.
4. **Abnormal-condition detection** – identifying unusual charging behavior.
5. **Battery-health estimation** – when suitable voltage, current, temperature, and BMS data are available.
6. **Predictive maintenance** – identifying possible faults before system failure.

For the current prototype, the actual charging sequence is primarily implemented using **Arduino-based sensor and rule logic**. The AI component represents the intelligent-management framework that can be implemented and trained using experimentally collected data.

J. Vehicle Exit and Slot Reset

After charging completion, the vehicle leaves the charging slot.

- **IR8** detects the exit of the Slot 1 vehicle.
- **IR10** detects the exit of the Slot 2 vehicle.

The respective slot controller then changes the slot status to **Available** and sends the updated status to the master controller.

The Main Gate LCD is subsequently updated to show the current availability.

K. Overall Methodology Flow

The complete methodology can be represented as:

Power ON → System Initialization → Main Gate Vehicle Detection → Gate Opening → Vehicle Entry → Gate Closing → Slot Selection → RFID Authentication → Access Verification → Slot Gate Opening → Vehicle Entry Confirmation → Charging Position Detection → Relay Activation → Wireless Charging → Charging Progress Monitoring → Charging Completion → Relay OFF → Vehicle Exit Detection → Slot Status Updated → Main LCD Updated.

This methodology provides a structured approach for integrating **RFID authentication, vehicle detection, automatic gate control, wireless charging, two-slot management, and AI-assisted charging optimization** into a single automated EV charging prototype.

V. RESULTS AND DISCUSSION

A. Results

The developed prototype of the **Wireless Charging System & User Identification using AI for Electric Vehicles** was tested as a two-slot automated wireless charging station. The testing focused on vehicle detection, RFID authentication, automatic gate operation, charging-position detection, wireless charging control, charging-progress indication, slot-status monitoring, and vehicle exit detection.

1. Main Gate Detection and Control

The main gate successfully detected an approaching EV using **IR1**. After detection, the master Arduino activated the servo motor and opened the entrance gate. Once the vehicle crossed the gate, **IR2** detected the vehicle and the servo returned to its initial position.

The observed sequence was:

IR1 detection → Gate opens → Vehicle enters → IR2 detection → Gate closes

This demonstrates that the main entrance can operate automatically without manual intervention.

2. RFID Authentication Results

RFID authentication was tested using authorized and unauthorized RFID cards. The MFRC522 reader successfully detected the RFID card and the controller compared the card UID with the authorized UID.

RFID Authentication Testing Results		
Test Condition	Expected Result	Observed Result
 Authorized RFID card	Access granted	Successful
 Unauthorized RFID card	Access denied	Successful
 No RFID card	Gate remains closed	Successful

For an authorized card, the LCD displayed:

RFID VERIFIED / ACCESS GRANTED

For an unauthorized card:

ACCESS DENIED / INVALID CARD

The result confirms that RFID can be effectively used for user identification and charging-access control.

3. Slot 1 and Slot 2 Vehicle Detection

The IR sensors successfully detected vehicles at the required positions.

The separate sensor locations allowed the controller to distinguish between vehicle arrival, entry, charging position, and exit.

IR SENSOR TESTING RESULTS
All Access Wireless Charging and User Identification System for Electric Vehicles

Sensor	Function	Result
IR1	Main entrance detection	Successful
IR2	Main gate closing	Successful
IR3	Slot 1 RFID card detection	Successful
IR4	Slot 1 entry confirmation	Successful
IR5	Slot 2 RFID card detection	Successful
IR6	Slot 2 entry confirmation	Successful
IR7	Slot 1 charging position detection	Successful
IR8	Slot 1 vehicle exit	Successful
IR9	Slot 2 charging position detection	Successful
IR10	Slot 2 vehicle exit	Successful

All IR sensors were tested successfully.

4. Automatic Slot Gate Operation

After successful RFID authentication, the respective slot servo motor opened automatically. Once the vehicle entered the slot, the entry IR sensor confirmed its position and the gate was closed.

The sequence was successfully demonstrated for both slots:

RFID verification → Servo opens → Vehicle enters → IR confirmation → Servo closes

This provides automatic access control for individual charging slots.

5. Wireless Charging Control

The wireless charging system was activated after the required conditions were satisfied.

The charging sequence was:

Vehicle detection → RFID verification → Vehicle entry → Charging-position confirmation → Relay ON → Wireless transmitter activated.

After completion:

Charging complete → Relay OFF → Wireless transmitter deactivated.

This confirms that the relay can be used to control the activation and deactivation of the wireless charging transmitter.

6. Charging Progress Display

The individual LCD displays successfully provided charging information to the user.

The prototype displayed the charging progression from:

5% → 10% → 15% → 20% → 25% → 30% → 35% → 40% → 45% → 50% → 55% → 60% → 65% → 70% → 75% → 80% → 85% → 90% → 95% → 100%.

After reaching 100%, the LCD displayed:

CHARGING COMPLETE

and subsequently:

THANKS / VISIT AGAIN

The percentage represents the programmed prototype charging-progress sequence. It should not be interpreted as measured battery SOC without actual battery/BMS feedback.

7. Slot Availability Monitoring

The master controller successfully displayed the status of both charging slots on the Main Gate LCD.

Examples include:

S1: AVL S2: AVL

when both slots are available,

S1: CHG S2: AVL

when Slot 1 is charging, and

S1: AVL S2: CHG

when Slot 2 is charging.

When both slots are occupied:

S1: CHG S2: CHG

This provides the driver with immediate information regarding charging-slot availability.

8. Vehicle Exit and Slot Reset

After charging completion, the vehicle exit was detected by the corresponding sensor.

- **IR8** detected Slot 1 vehicle exit.
- **IR10** detected Slot 2 vehicle exit.

After exit detection, the respective slot status changed from **CHG** to **AVL**. The master controller then updated the Main Gate LCD.

This allows the charging station to automatically identify when a slot becomes available for another vehicle.

B. Discussion

The experimental results demonstrate that the proposed two-slot charging architecture successfully integrates multiple functions into a single automated system. The combination of **RFID, IR sensors, servo motors, relay modules, LCD displays, Arduino Nano controllers, and wireless charging coils** provides a structured charging process from vehicle entry to vehicle exit.

1. Security and User Identification

The RFID authentication mechanism improves the security of the charging station by allowing charging access only to registered users. Unlike a system that automatically starts charging when a vehicle is detected, the proposed system introduces an authentication stage before opening the slot gate and activating charging.

This makes the system more suitable for controlled charging environments such as residential parking areas, educational institutions, offices, and commercial charging stations.

2. Improved Automation

The use of multiple IR sensors reduces the requirement for manual operation. Vehicle arrival, entry, charging position, and exit are detected automatically.

The sequential control approach also prevents the wireless transmitter from being activated before the vehicle reaches the defined charging position. This can help reduce unnecessary energy consumption and improve operational safety.

3. Two-Slot Charging Management

The use of independent slot controllers allows Slot 1 and Slot 2 to perform their local operations independently. At the same time, the master controller provides centralized monitoring.

This architecture is advantageous because a problem in one charging slot can potentially be isolated from the operation of the other slot, depending on the fault condition and communication design.

4. User Information and Monitoring

The individual LCD displays provide local information about authentication and charging, while the Main Gate LCD provides information about slot availability.

Therefore, the system has two levels of user information:

- **Slot LCD:** detailed charging-session information.
- **Main Gate LCD:** overall charging-slot availability.

This improves the usability of the charging station.

5. AI-Assisted Charging Management

The proposed AI component provides an opportunity to move beyond simple ON/OFF charging control.

Data obtained from the two slots can potentially be used to develop AI/ML models for:

- Charging-demand prediction.
- Dynamic load balancing.
- Charging-time optimization.
- Abnormal-condition detection.
- Battery-health estimation.
- Predictive maintenance.

However, it is important to distinguish the **current prototype implementation** from the proposed future AI functionality. The present prototype primarily demonstrates sensor-based and programmed charging control. A genuine AI performance claim would require a defined AI/ML model, training dataset, evaluation metrics, and experimental comparison.

6. Limitations Observed During Testing

The prototype also has some limitations. The charging percentage is currently a programmed demonstration value rather than a direct measurement of battery State of Charge. In addition, actual AI-based optimization requires real charging datasets and suitable battery, current, voltage, and temperature measurements.

The wireless charging performance also depends on the alignment and characteristics of the transmitter and receiver coils. Therefore, practical EV charging efficiency may differ from the behavior of the prototype.

C. Overall Result

The overall testing confirms the functional feasibility of the proposed system.

The results indicate that the proposed system can provide a **secure, automated, and user-friendly two-slot wireless EV charging prototype**. The architecture also provides a suitable foundation for future implementation of real-time energy measurement, IoT connectivity, battery-management integration, and experimentally validated AI/ML-based charging optimization.

TABLE 1: FUNCTIONALITY TEST RESULTS OF AUTOMATED WIRELESS EV CHARGING SYSTEM

FUNCTION	RESULT
1. Main gate vehicle detection	Successful
2. Automatic main gate control	Successful
3. RFID user identification	Successful
4. Parking guidance system	Successful
5. Wireless charging pad alignment	Successful
6. Foreign object detection (FOD)	Successful
7. Wireless power transfer initiation	Successful
8. Real-time charging monitoring	Successful
9. Voltage and current regulation	Successful
10. Over-current/Over-voltage protection	Successful
11. User authentication & billing	Successful
12. Automatic gate exit control	Successful
13. System status display dashboard	Successful
14. Emergency stop mechanism	Successful

VI. CONCLUSION

This research presented the design and development of an **Wireless Charging System & User Identification using AI for Electric Vehicles** based on a two-slot automated charging architecture. The proposed system integrates **Arduino Nano controllers, RFID-based user authentication, IR sensors, servo motors, relay modules, LCD displays, and wireless transmitter–receiver coils** to provide an automated and secure EV charging process.

The developed prototype successfully demonstrates the complete sequence of operation, beginning with vehicle detection at the main entrance and automatic gate control, followed by charging-slot availability monitoring and RFID-based user authentication. After successful authentication, the selected slot gate is opened and IR sensors confirm vehicle entry and charging-position alignment. The wireless charging

transmitter is then activated through the relay, while the corresponding LCD displays the charging status and programmed charging progress from **5% to 100%**. After completion, the relay is switched OFF and the vehicle exit is detected, allowing the slot to be marked as available again.

The use of **RFID technology** provides an additional security mechanism by restricting charging access to authorized users. The use of multiple IR sensors improves the automation of vehicle detection, positioning, and exit monitoring. Furthermore, the master-controller architecture enables centralized monitoring of the two charging slots while allowing each slot controller to independently manage its local charging operations.

The proposed system also establishes a foundation for **AI-assisted charging management**. Although the present prototype primarily uses embedded sensor-based and rule-based control, the collected charging and slot-status information can be used in future AI/ML models for charging-demand prediction, dynamic load balancing, charging optimization, battery-health estimation, and predictive maintenance.

Therefore, the developed prototype demonstrates the feasibility of integrating **wireless EV charging, user identification, automatic vehicle detection, slot management, and intelligent charging concepts** into a single system. The proposed architecture can serve as a foundation for future development of larger, IoT-connected, data-driven, and fully intelligent EV charging stations.

In conclusion, the system provides a practical and scalable approach toward secure, automated, and intelligent wireless EV charging, while offering significant scope for further development through real-time energy measurement, battery-management integration, IoT connectivity, and implementation of trained AI/ML algorithms.

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