International Journal of Scientific Research and Engineering Development-– Volume 9 Issue 2, Mar-Apr 2026
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Design and Implementation of Smart Solar Energy Based Charging Station for EV Application

Mr. Shubham A. Harane*, Miss. Rishika K. Maskar**, Miss. Punam S. Ambule***, Mr. Ayan S. Ahmed****, Mr. Yash S. Girmekar*****, Miss. Kasturi R. Premalwar******

*(Professor, Department of Electrical Engineering, Kavikulguru Institute of Technology and Science, Ramtek
(Shubham.harne@rediffmail.com)
** (Student, Department of Electrical Engineering, Kavikulguru Institute of Technology and Science, Ramtek
(rishikamaskar28@gmail.com)
*** (Student, Department of Electrical Engineering, Kavikulguru Institute of Technology and Science, Ramtek
(punamambule5@gmail.com)
**** (Student, Department of Electrical Engineering, Kavikulguru Institute of Technology and Science, Ramtek
(ayanahmed.19032004@gmail.com)
***** (Student, Department of Electrical Engineering, Kavikulguru Institute of Technology and Science, Ramtek
(girmekaryash@gmail.com)
****** (Student, Department of Electrical Engineering, Kavikulguru Institute of Technology and Science, Ramtek
(kasturipremalwar@gmail.com)

--************************----------------------------------

Abstract:

This project presents the design and implementation of smart solar energy-based charging station for EV application. Electric vehicles (EVs) are increasing in popularity globally, offering a greener and more energy-efficient alternative to traditional cars. It addresses the need for sustainable and decentralized charging infrastructure by integrating a photovoltaic (PV) system, battery energy storage, and a microcontroller-based management system. The station harnesses solar energy to provide clean power, reducing reliance on the conventional grid and lowering the Carbon Footprint. Our research aims to develop an RFID-Based system designed to automate EV charging with minimal user input. This system integrates RFID readers, tags, A microcontroller, and a relay module to efficiently manage and monitor charging sessions. An IoT platform supports real- time monitoring and remote control, while a secure payment mechanism handles transactions seamlessly. RFID tags identify vehicles for charging initiation, and the relay module prevents overcharging by disconnecting power after a set time.

Keywords —— **Solar panel, Battery, Charge controller, Relay switching, RFID card, Internet of things, ESP32 Node MCU, Electric vehicle.**

--************************----------------------------------

I. INTRODUCTION

The worldwide transition to sustainable energy solutions requires novel strategies for generating, storing, and using energy. The increasing demand for Electric Vehicles (EVs) has accelerated the need for efficient and sustainable EV charging infrastructure. It aims to familiarize EV users with innovative payment technology, enhancing accessibility and usability. The proposal suggests an app that offers diverse services such as locating, booking, and paying for charging, along with battery swapping and delivery options for emergencies. Using the Google Maps API, it provides precise station details and nearby attractions sourced from multiple databases,

ensuring comprehensive user assistance. The authors developed a system featuring an RFID module for electric vehicle charging, including options such as emergency cutoff and repayment policies. Users can see RFID setups, with clear LED indicators for charging status. The module displays the remaining charging time and user balance, promising a convenient experience for electric vehicle owners.

The main objective of the paper is to provide power from solar PV cell to the charging station in which the vehicle can be charged through the rechargeable battery and also with the help of IOT, the availability status of the charging station can be monitored frequently at any moment.

II. DESIGN METHODOLOGY

This section provides an overview of the methodical design and implementation methodology of the proposed electric car charging system that incorporates RFID technology and the integration of the Internet of Things. This paper presents a complete analysis of the system architecture, focusing on key components such as the block diagram, flowchart, circuit diagram, and pin connections. These components are thoroughly discussed to provide a full understanding of the system's structure and functionality.

A. Block Diagram

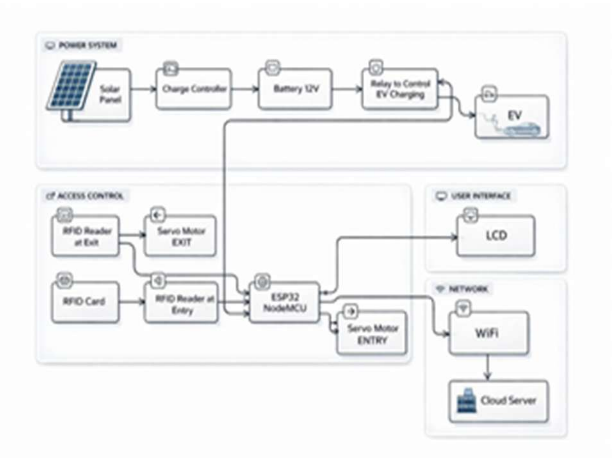

Fig 1. Block Diagram

The block diagram represents a smart solar-powered Electric Vehicle (EV) charging station with RFID-based access control. The entire system is controlled by an ESP32 Node MCU, which manages the power system, access control, and communication. In the power system, the solar panel captures energy from the sun and sends it to a charge controller, which regulates the power and safely charges a 12V battery while preventing overcharging. The stored energy in the battery is supplied to the EV through a relay that acts as an electronic switch controlled by the ESP32. The power flow follows the path: Solar Panel → Charge Controller → Battery → Relay → Electric Vehicle.

The access control system ensures that only authorized users can use the charging station. An RFID reader at the entry scans the user's RFID card and sends the card ID to the ESP32. If the card is authorized, the ESP32 activates a servo motor to open the entry gate. A similar setup with another RFID reader and servo motor is used at the exit to allow the vehicle to leave after charging. The system also includes an LCD display that provides information to the user, such as "Please present your card," "Access granted," or "Charging in progress." Additionally, the ESP32 uses its built-in Wi-Fi to connect to a cloud server, allowing the system to store and monitor data like user access details, charging time, and energy usage for logging and monitoring purposes.

B. Circuit Diagram and Connection Diagram

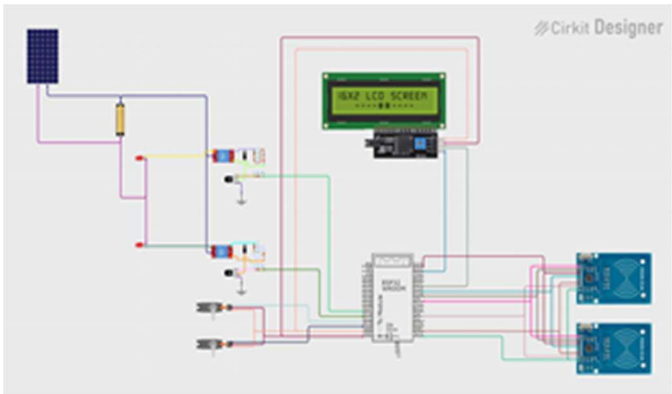

Fig 2. Circuit Diagram and Connection Diagram

The circuit diagram shown in Fig. 2 provides a clear depiction of the physical interconnections of the system's hardware components. The text illustrates the interplay of many elements, including the RFID reader, microcontroller, relay module, LCD display, and Node MCU. The diagram functions as a visual depiction of the tangible linkages that provide uninterrupted communication and command. The communication between the RFID reader and the ESP 32 is established via the Serial Peripheral Interface (SPI) protocol, whilst the relay module is connected to the ESP 32 by dedicated digital input/output (I/O) pins. The liquid crystal display (LCD) employs the Inter-Integrated Circuit (I2C) protocol for communication.

C. Flow Chart

The flowchart describes the working of a solar powered smart EV charging station with RFID authentication and IoT monitoring. The process starts when the solar panel generates electrical energy, which is regulated by a charge controller and stored in a battery for later use. The system is then powered using a microcontroller such as ESP32 or Node MCU, which controls the entire charging process. When a vehicle arrives at the charging station, the driver scans an RFID card for identification. The system checks whether the RFID card is authorized. If the card is not authorized, access is denied. If the card is valid, the entry gate opens and the system checks whether a charging slot is available. If no slot is available, the system displays a "No Slot Available" message. If a slot is available, the vehicle parks in the charging slot and charging starts. The system monitors the charging process until the charging time is completed. After charging is finished, the vehicle exits the station with RFID verification, and the slot status is updated on the IoT platform to show that the slot is free. Finally, the process ends.

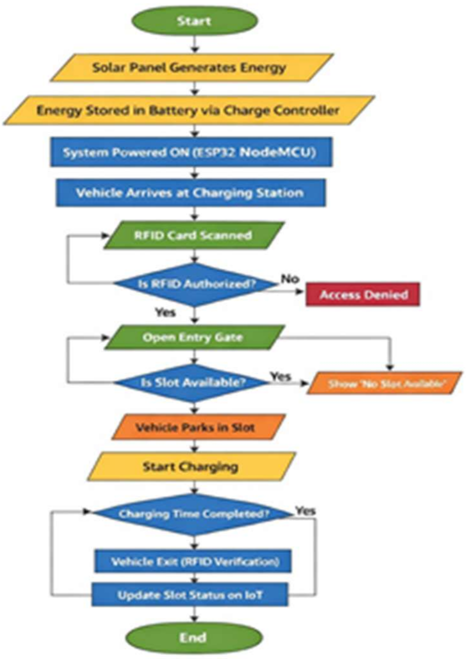

Fig 3. Flow Chart

III. HARDWARE AND SOFTWARE

A. Control and Processing Unit

- **Master Controller (ESP32):** The system utilizes an ESP32 as the primary processing hub. Its dual-core architecture allows for simultaneous management of the Wi-Fi stack and real-time sensor polling. It acts as the gateway for data logging and manages the logic for the entry/exit gates.
- **Vehicle Monitoring Node (ESP8266):** To maintain a modular design, an ESP8266 is dedicated to the vehicle side. It interfaces with the car's battery management indicators to measure parameters like voltage and current, transmitting this data wirelessly to the master controller.

B. Sensing and Actuation

- **Authentication and Detection:** An RFID module provides a secure interface for user identification. Complementing this, Infrared (IR) sensors are positioned at the station boundaries to detect the physical presence of a vehicle, triggering the automation sequence.
- **Mechanical Control:** High-torque Servo Motors are employed for the gate mechanism. Unlike standard motors, these provide the precise 0° to 90° rotation required for barrier arms, controlled via Pulse Width Modulation (PWM) from the ESP32.

C. Energy Harvesting System

- **Solar Photovoltaic Array:** A solar panel serves as the primary DC power source. This energy is routed through a charge controller to provide a stable voltage for both the EV battery and the system's internal electronics.

D. Firmware Development

The firmware for both ESP32 and ESP8266 was developed using the C++ based Arduino Framework.

E. Communication Protocol

Data exchange between the vehicle node (ESP8266) and the charging hub (ESP32) is handled via UDP or HTTP Local Web Server. This allows the station to "read" the car's parameters in real time without requiring a constant internet connection, ensuring reliability in remote locations.

F. Logic Flow

1. Idle State: The system polls the IR sensor and RFID sensors.
2. Validation: Upon valid RFID tag detection and IR "Object Present" signal, the ESP32 commands the entry servo to rotate.
3. Monitoring: ESP8266 initiates a handshake with the ESP32 to begin transmitting charging parameters.
4. Completion: Once the charging is finished or the user disconnects, the exit sequence is triggered.

IV. RESULTS

A. Hardware Prototype Overview

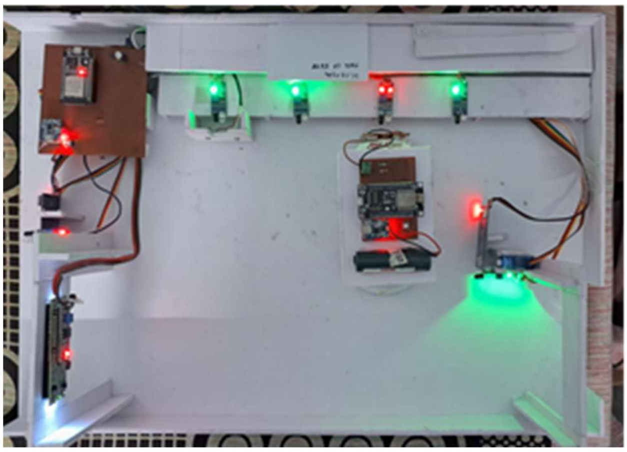

Fig 4. Hardware Prototype

This figure 4 illustrates the physical integration of the smart charging station. You can see the ESP32 master node on the left and the ESP8266 mobile node (simulating the car) in the center.

B. System Logic and User Interface

Fig 5. Display Output (Slot Availability)

Figure 5 represents the parking mangement system where,

"E" (Empty): The IR sensor beam is uninterrupted.

"O" (Occupied): The vehicle has broken the IR beam, and the system has updated the status for the user. This data can be pushed to a mobile app via the ESP32's Wi-Fi.

Fig 6. User Authentication and Balance Check

When an RFID tag is scanned, the ESP32 queries its internal database (or a cloud database) to identify the vehicle. This demonstrates the **Security Layer**. The display shows the initial balance, ensuring the user has sufficient credits before the charging relay is activated.

Fig 7. Users Charging Time (in minutes)

Fig 8. Time Based Billing

Figure 6 & 7 demonstrates the automated billing algorithm. he system calculates the duration the vehicle remained at the station.

Based on a predefined tariff (e.g., Rs 10 per minute), the system calculates the final charge (Charge: Rs 10.00) and automatically updates the remaining balance (Bal: Rs 490.00).

C. System Performance Analysis

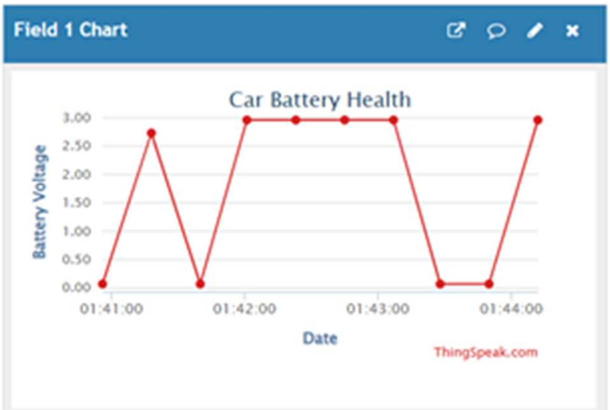

Fig 9. Graph of Battery Voltage

The voltage graph shows a stable plateau at approximately \$3.0V during active charging intervals. The sharp drops to \$0V indicate moments where the vehicle was disconnected or the sensor was reset. The consistent recovery to the \$3.0V level demonstrates the reliability of the power delivery system and the accuracy of the ESP8266's analog-to-digital conversion (ADC) sensing.

D. Custom Web Dashboard and User Interface

Fig. 10. Web dashboard and user interface

While Thing Speak provides back-end data logging, a custom **Smart Parking Dashboard** was developed to serve as the front-end interface for station operators and users.

- **Real-time Slot Management:** The dashboard provides a visual representation of the four charging bays. Occupied slots are highlighted in red, while available slots are shown in green.
- **Solar Energy Monitoring:** A critical feature shown at the top of the UI is the **"Solar Voltage"** indicator. This allows for real-time tracking of the renewable energy being harvested to power the station.
- **Financial Transactions:** The UI includes functional modules for **"Recharge Card"** and **"Check Balance."** This demonstrates the integration of the hardware RFID reader with a software-based database, allowing users to manage their credits digitally.

V. FUTURE SCOPES

The future scope of a smart solar EV charging station is highly promising, with improvements like AI-based energy management for efficient power use and demand prediction. Advanced solar panels and better battery storage can ensure continuous charging, while vehicle-to-grid (V2G) technology can enhance energy efficiency. The system can be upgraded with fast charging, support for multiple vehicles, and IoT-based real-time monitoring and control. Integration with smart grids and renewable networks will increase sustainability, and adding advanced security features like biometric authentication along with RFID will improve safety, making the system more efficient and future-ready.

VI. CONCLUSION

The smart solar EV charging station project provides an effective and environmentally friendly solution for charging electric vehicles using renewable energy. By combining solar power with technologies like RFID authentication, online booking, and real-time monitoring, the system ensures convenience, efficiency, and reliability. It reduces dependence on conventional electricity and supports sustainable development. Overall, this project highlights the potential of integrating smart technology with clean energy to meet future transportation needs while minimizing environmental impact.

VII. REFERANCES

1] MD Mehedi Hassain, Injamul Haque Jamil, Md..Mahmudul Hoque, Md.Jahid Hasan, "Electric Vehicle Charging System Using RFID And IOT For Enhanced Experience".(IEEE),February 2025, DOI:10.1109/MENA COMM62946.2025.10911013

[2] Swati Dasi, Swarupa Rani Bondalapati, "IOT Based Intelligent Energy Manegement For EV Charging Station".(IAENG), Volume 51, Issue 11, November 2024, Pages 1853-1861.

[3] Ms. Rutuja Rajole, Mrs. Geetanjali Khot, Mr. Gajanan Udas, IOT Based Electric vehicle Charging System",(IRJET), Volume:10, Issue:03, March 2023.

[4] Younes Ledamaouli, Adila EI Megh Raoui, And Ahmed Chebak, " Solar Charging Station For Electric Vehicles With IOT Solution For Monitoring Energy Production."(CCIS), January 2023,DOI:10.1007/978-3-03/-20490-6_6.

[5]J.Surendiran,Ms.R.Reenadevi,R.G.Vidhya,S.S.Siva Sankar,B.P.Peadeep Kumar,N.Balaji," IOT-Based Advanced Electric Vehicle Charging Infrastructure".(CCIP), 2022 IEEE DOI:10.1109/CCIP57447.2022.10058649.

