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Portable EV Charging Station with Advanced IoT Connectivity

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Abstract: *The increasing adoption of electric vehicles (EVs) is driving the need for accessible and cost-effective charging infrastructure. One of the significant challenges in this transition is the high initial investment and infrastructure requirements for traditional charging stations. To address these challenges, this project presents the design and implementation of a Portable EV Charging Station with Advanced IoT Connectivity. The proposed system utilizes a microcontroller (ATmega328p) to manage key functions, including power measurement, billing, and real-time monitoring of the charging process. Equipped with current and voltage sensors, the system accurately measures the power delivered to the EV and calculates the associated billing amount. Users can interact with the system through a keypad and LCD display, setting parameters such as charging time or billing amount. The system also integrates a Wi-Fi module (ESP8266) for remote monitoring and control via a webpage, allowing users to track charging sessions in real-time from anywhere. The use of a relay and cutoff device ensures safety by disconnecting the power supply once the set conditions are met. The design is compact, cost-effective, and scalable, making it ideal for deployment in residential areas, commercial spaces, and public places. By offering a portable and user-friendly solution, this project aims to expand the availability of EV charging stations, ultimately supporting the widespread adoption of electric vehicles and contributing to the transition toward sustainable transportation.*

Keywords: Portable EV Charging Station, IoT Connectivity, Microcontroller, Power Measurement, Remote Monitoring

I. INTRODUCTION

The global shift towards electric vehicles (EVs) is an essential step in reducing greenhouse gas emissions, minimizing reliance on non-renewable fossil fuels, and promoting sustainable transportation. The adoption of electric vehicles has been gaining momentum worldwide, largely due to government incentives, environmental concerns, and technological advancements. However, one of the significant barriers to widespread EV adoption remains the limited availability of charging infrastructure, which results in range anxiety and operational challenges for EV users. While conventional vehicles can refuel in a matter of minutes, electric vehicles typically require several hours to recharge, further emphasizing the need for easily accessible, efficient, and user-friendly charging solutions.

The current EV charging infrastructure, which primarily consists of fixed charging stations, requires significant investment and space. These stations are typically installed in public areas, residential zones, and commercial centers, but they are often insufficient in number and sometimes inconveniently located, leading to an inadequate charging network. The high initial cost of installation, maintenance, and infrastructure expansion is a significant deterrent to small businesses or homeowners who wish to offer charging services. Therefore, there is a clear demand for low-cost, portable charging stations that can be deployed in various locations, including areas that may not currently have easy access to EV charging infrastructure. A portable solution would allow businesses to provide charging services without incurring high capital expenditures while ensuring that EV users can access reliable charging points more conveniently.

In this context, this project aims to design and develop a Portable EV Charging Station with Advanced IoT Connectivity, providing a practical, compact, and cost-effective solution to improve the accessibility and convenience of EV charging. The proposed system uses a microcontroller at its core, with sensors to monitor key charging parameters such as voltage and current. The microcontroller not only controls the power supply to the EV but also calculates the energy consumed and the associated cost. By integrating IoT capabilities, the system enables remote monitoring and control via a web-based interface, allowing users to check charging status, adjust settings, and view real-time data, even when they are not physically present at the charging point.

A critical feature of the system is its use of a current sensor (ACS712) and voltage sensors to accurately measure the power delivered during the charging process. These sensors relay data to the microcontroller, which processes the information and manages the power delivery accordingly. Users can input their preferred charging settings through a keypad, with parameters such as time limits or billing amounts displayed on an LCD screen. Additionally, once the set limit is reached, the system utilizes a cutoff device to safely disconnect the power, preventing overcharging or unauthorized usage. This added layer of control ensures the safety and efficiency of the charging process, reducing the risk of electrical faults or overloads.

This system leverages a Wi-Fi module (ESP8266) to provide connectivity for remote monitoring and control, offering significant convenience for both users and operators. The webpage interface serves as a real-time dashboard, providing users with insights into their ongoing charging sessions, including the total energy consumed, the total cost, and the status of the charging process. This cloud-based monitoring feature aligns with the growing trend of smart technologies in the IoT space, making the system more flexible and easier to integrate with other smart services. Additionally, the use of buzzer alerts ensures that users receive immediate audio feedback on the system's status, such as when the charging is complete or if any errors occur.

This design focuses not only on functionality but also on cost-effectiveness and scalability. The compact nature of the system allows for its deployment in a variety of locations, from small businesses like shops and cafes to larger commercial areas. By reducing the financial barriers to entry for establishing charging stations, this project aims to democratize the availability of EV charging services, thereby fostering a more inclusive and robust EV ecosystem. With the integration of advanced monitoring and control features, the system enhances user experience, boosts the reliability of charging stations, and accelerates the adoption of electric vehicles.

The proposed Portable EV Charging Station with Advanced IoT Connectivity is a versatile and innovative solution that can bridge the gap between the rising demand for electric vehicle charging and the lack of widespread infrastructure. By offering a portable, user-friendly, and smart alternative, this project aims to contribute significantly to the growth of the electric vehicle market, promote sustainable energy practices, and facilitate the global transition towards eco-friendly transportation. The ease of installation, low cost, and advanced features make this system an attractive option for businesses, residential areas, and other public locations seeking to cater to the needs of EV users.

PROBLEM STATEMENT

The limited availability of affordable and accessible EV charging stations hinders the widespread adoption of electric vehicles. This project aims to address this challenge by designing a portable, cost-effective EV charging station with advanced IoT connectivity to enhance charging infrastructure accessibility.

OBJECTIVE OF THE STUDY

- To design a cost-effective, portable EV charging station for increased accessibility.
- To integrate IoT connectivity for remote monitoring and control of the charging process.
- To implement a billing system that calculates power consumption and charging costs.
- To ensure compatibility with various EV chargers through a 230V AC output.
- To enhance user experience with real-time data display and alert notifications.

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II. LITERATURE SURVEY

1. **Development of an IoT System with Smart Charging Current Control for Electric Vehicles** (Ruben A. Sousa, IEEE, 2018): This paper explores the development and testing of an IoT-based system for monitoring and controlling electric vehicle charging. It focuses on synchronizing the vehicle's data with an online server for real-time monitoring and management.

2. **Multifunctional Single-Phase EV On-Board Charger With a New V2V Charging Assistance Capability** (Seyedfoad Taghizadeh, IEEE, 2018): This study discusses an innovative EV charger design capable of Vehicle-to-Vehicle (V2V) charging, which allows an EV to charge another EV in emergency situations, thus eliminating the need for additional portable chargers in case of battery depletion.

3. **A Study on Trends and Developments in Electric Vehicle Charging Technologies** (S. Hemavati, ScienceDirect, 2022): This paper presents an in-depth analysis of advanced EV charging technologies, including fast charging, smart charging, wireless charging, and battery swapping, highlighting the ongoing developments in these fields.

4. **Smart Emergency EV-to-EV Portable Battery Charger** (Mahadi Mosayebi, MDPI, 2022): The study presents an emergency EV-to-EV portable battery charger, designed for roadside emergencies, where one EV can charge another. The charger can share up to 15% of stored energy while considering the state of charge (SOC) of the battery.

5. **Review of Electric Vehicle Charging Technologies and Standards** (Sithara S.G. Acharige, IEEE Access, 2023): This paper reviews various EV charging technologies and their standards, focusing on how the charging infrastructure influences the performance of electric vehicle batteries and the need for standardized solutions to enhance EV adoption.

6. **Charging Infrastructure for Commercial Electric Vehicles** (Basam Al.Hanahi, IEEE Access, 2024): This paper highlights the challenges associated with the charging infrastructure for commercial electric vehicles (EVs), focusing on the complexities of scaling charging systems for large fleets and the specific needs of the commercial transportation sector.

7. **Automatic Electric Vehicle Charging Station** (Shalom Richard Pakhare, SJET, 2024): This research discusses a system that uses a Raspberry Pi as the primary controller for an automatic EV charging station. The system communicates with the vehicle's management system to negotiate charging speed and battery capacity, with a user interface displayed on an LCD.

8. **A User-Friendly IoT-Enabled Smart Charging Station** (Busam Sumanjali, IEEE, 2024): This paper introduces a user-friendly, IoT-enabled smart charging station, focusing on improving the charging experience through enhanced connectivity and automation, offering users real-time updates and better management of the charging process.

III. WORKING OF PROPOSED SYSTEM

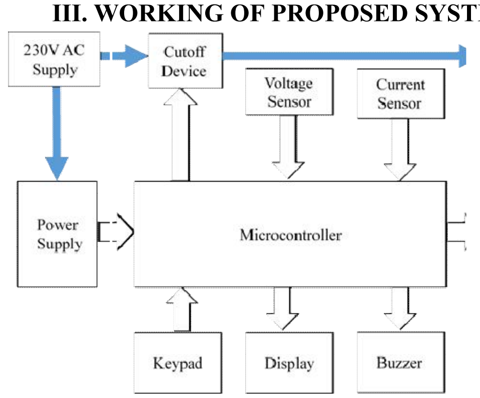

Fig.1 System Block Diagram

The working of the proposed Portable EV Charging Station with Advanced IoT Connectivity is designed to offer a cost-effective, compact, and efficient charging solution that can be easily deployed in various locations. The system utilizes a microcontroller-based architecture to manage the charging process, monitor power usage, and provide real-time feedback to both the user and the operator.

Power Supply and Conversion:
The system is powered by a 230V AC supply, which is the main input for the charging process. This AC power is converted to the necessary DC voltage using a step-down transformer and voltage regulators (7805 and AMS1117). The DC power is then used to power the control circuits, including the microcontroller (ATMEGA328p), Wi-Fi module, keypad, and display.

Measurement of Power Delivered:
The voltage sensor and current sensor (ACS712) are used to measure the voltage and current supplied to the electric vehicle during the charging process. The voltage sensor measures the incoming voltage, while the current sensor monitors the current flowing through the charging circuit. These sensors send the corresponding data to the microcontroller.

Power Calculation and Billing:
The microcontroller (ATMEGA328p) processes the data from the sensors and calculates the power being delivered to the EV. Based on the measured current and voltage, the microcontroller calculates the energy consumption and determines the billing amount. The charging cost is displayed on the LCD screen for user reference. The user can adjust the charging parameters (e.g., billing amount, charging time) via the 3x4 matrix keypad, which is interfaced with the microcontroller.

Control of Charging Process:
The microcontroller uses the relay and cutoff device to control the flow of power to the charging station. Once the set billing amount or charging time is reached, the microcontroller sends a signal to the cutoff device, which disconnects the power supply, ensuring that the charging session is safely terminated. This prevents overcharging and ensures that the system operates within safe parameters.

IoT Integration for Remote Monitoring:
A critical feature of the proposed system is the integration of a Wi-Fi module (ESP8266), which enables remote monitoring of the charging process through an online interface. The system continuously sends real-time data (such as current, voltage, power consumption, and billing status) to a webpage, which can be accessed remotely by users or system administrators. This feature allows users to track their charging sessions, adjust settings, and receive alerts without being physically present at the charging station.

User Alerts and Feedback:
The system provides audible alerts through a buzzer. The buzzer sounds in various scenarios, such as when the charging is complete, when the system is malfunctioning, or when the set billing amount or time limit has been reached. This ensures that the user is always informed about the status of the charging process.

System Interface and User Interaction:
The keypad serves as the primary interface for users to input their preferences. It allows users to set the desired charging time, billing amount, or other parameters. Once the input is made, the microcontroller processes this information and adjusts the charging behavior accordingly. The LCD display provides feedback to the user, showing real-time data like voltage, current, total consumption, and the calculated billing amount.

Safety and Efficiency:
The system ensures safe operation through features like automatic cutoff of power when the charging limit is reached, protection against overloads, and real-time monitoring. By using accurate voltage and current sensing, the system can regulate the charging process efficiently, ensuring that energy is delivered optimally to the vehicle's battery.

The working of the proposed Portable EV Charging Station with Advanced IoT Connectivity involves the integration of various components such as sensors, a microcontroller, a Wi-Fi module, and user interfaces. It efficiently manages the charging process, enables real-time monitoring, and offers a convenient, user-friendly solution for EV charging that is adaptable to a wide range of environments.

IV. DISCUSSION AND SUMMARY

The proposed Portable EV Charging Station with Advanced IoT Connectivity aims to provide an affordable, portable, and efficient solution to address the increasing need for electric vehicle (EV) charging infrastructure. By incorporating

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advanced features such as IoT connectivity and real-time monitoring, the system enhances the user experience and promotes wider EV adoption.

Hardware Overview:

- **Microcontroller (ATMEGA328p)**: The central processing unit of the system, responsible for managing sensor data, controlling the charging process, and communicating with other components.
- **Voltage and Current Sensors (ACS712)**: These sensors accurately measure the voltage and current flowing during the charging process and relay the information to the microcontroller for power calculation and control.
- **Relay and Cutoff Device**: The relay is used to control the power flow to the charging point, ensuring that charging stops once the preset limits (billing or time) are reached.
- **Wi-Fi Module (ESP8266)**: This module facilitates remote monitoring and control of the charging process via a web interface, allowing users to access real-time data on their charging sessions.
- **LCD Display and Keypad**: The LCD displays relevant information such as voltage, current, and billing details. The keypad allows users to input settings like charging time and billing limits.
- **Power Supply and Transformers**: Power supply components ensure that the system receives a stable DC voltage, converting 230V AC to the required DC voltages for the control circuit.

Software Overview:

- **Embedded Programming (Microcontroller)**: The core software running on the microcontroller is responsible for reading sensor data, calculating the power consumption, and controlling the charging process based on user inputs. It also communicates with the Wi-Fi module to upload real-time data to the webpage.
- **IoT Platform (Web Interface)**: The system uses an online platform to display real-time data such as voltage, current, power consumption, and billing amount. Users can also remotely monitor and control their charging sessions through this interface, providing flexibility and convenience.
- **Control Logic**: The software ensures that when the user input conditions (like billing amount or time) are met, the relay cuts off the power, preventing overcharging and ensuring the safe operation of the system.

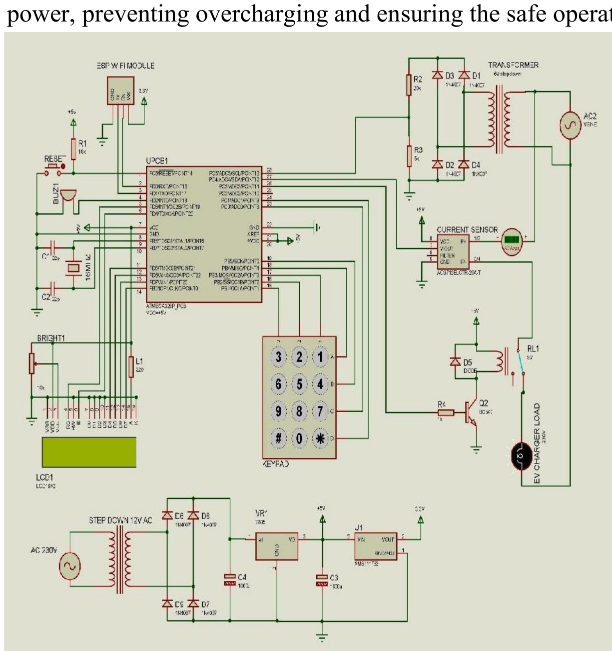

Fig.2 Circuit Diagram

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This system efficiently integrates hardware components like sensors, microcontroller, relay, and Wi-Fi module, combined with software that manages the charging process, real-time monitoring, and user interaction. The use of IoT connectivity improves user convenience, allowing them to manage charging sessions remotely. The system's portability and affordability make it suitable for various environments, contributing to the expansion of EV charging infrastructure and supporting the transition to sustainable transportation. The project demonstrates the potential of compact, IoT-enabled charging solutions in addressing the challenges faced by electric vehicle users in accessing reliable and efficient charging points.

V. RESULT

The implementation of the Portable EV Charging Station with Advanced IoT Connectivity successfully demonstrated the functionality of a compact and user-friendly electric vehicle charging system. The system was able to deliver a stable 230V AC output compatible with standard EV chargers, confirming its effectiveness in practical charging scenarios.

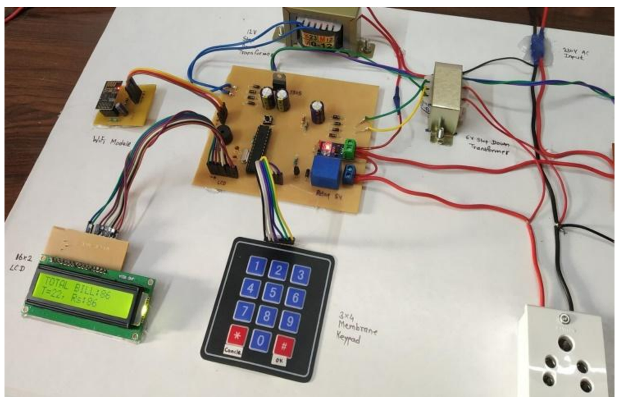

Fig.3 Hardware Interface

Key results observed:

- **Accurate Measurement**: The integrated voltage and current sensors (ACS712 and step-down transformer) provided real-time and accurate data on power usage, enabling precise billing calculations.
- **Efficient Control**: The ATmega328P microcontroller efficiently managed the entire operation — from accepting user input to controlling power delivery and cutoff based on set parameters (charging time or cost).
- **IoT Monitoring**: With the ESP8266 Wi-Fi module, live data such as charging voltage, current, energy consumed, and cost was successfully uploaded to a webpage, allowing users to monitor the session remotely.
- **User Interface**: The 3x4 matrix keypad allowed users to enter charging preferences (time or billing amount), and the 16x2 LCD displayed all necessary information in real-time, ensuring a smooth user experience.
- **Safety Features**: The relay-based cutoff device accurately terminated the power supply after reaching user-defined limits, preventing overcharging and enhancing safety.
- **Audible Alert**: The buzzer functioned properly, alerting users when charging was complete or when any abnormal condition occurred.

Overall, the prototype fulfilled its intended objectives and proved to be a cost-effective, scalable, and portable solution for establishing small-scale EV charging points, especially for local shop owners or in remote areas with limited infrastructure.

VI. FUTURE SCOPE

The proposed portable EV charging station can be enhanced further by integrating solar power compatibility to make it fully sustainable and grid-independent. Future improvements may include mobile app integration for better user control, RFID authentication for secure access, and fast charging support to reduce charging time. Additionally, implementing dynamic pricing based on load conditions and enabling multi-vehicle support can make the system more versatile and suitable for commercial deployment.

VII. CONCLUSION

The development of the Portable EV Charging Station with Advanced IoT Connectivity offers a practical, affordable, and scalable solution to address the growing demand for electric vehicle infrastructure. By combining key components such as a microcontroller, current and voltage sensors, relay-based power control, and Wi-Fi-enabled IoT integration, the system allows users to monitor, control, and manage EV charging efficiently. Its user-friendly interface, accurate billing, and remote access capabilities make it suitable for deployment in small businesses, residential areas, and remote locations. Overall, this project contributes significantly toward supporting sustainable transportation by promoting wider accessibility to EV charging facilities.

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