Smart Wireless Charging System for Electric Vehicles with Sensor – Based Control and Monitoring

[1]J. Balaji, [2] N. Subhathra Devi, [3]S. Kirubakaran

*1Assistant professor, *2Assistant professor, *3UG Scholar

Department of Electronics and Communication Engineering, RAAK College of Engineering and Technology, Puducherry, India

ABSTRACT

The growing adoption of electric vehicles (EVs) has necessitated the development of efficient, safe, and user – friendly charging system. Traditional plug-in charging method are limited by mechanical wear, safety concerns in wet environments and user inconvenience to overcome these challenges, this project presents a wireless charging station for Electric Vehicles that employs Inductive Power Transfer (IPT) technology integrated with Arduino-based monitoring and control. The system is designed with two major section A charging station consisting of a wireless power transmitter, relay module and IR sensor for vehicle detection, Arduino Uno, 16x2 LCD display, voltage and current sensor, and a relay-controlled DC motor simulating real-time charging behavior. The IR sensor automatically activates the transmitter when a vehicle is detected, ensuring energy efficiency and system safety. The receiver coil captures the induced electromagnetic field, rectifies it to DC and provides controlled power to the vehicle battery while continuously monitoring voltage and current levels. Data from sensors are displayed on the LCD for real-time status updates. This system eliminates the need for physical connectors, reducing the risk of electric shock, corrosion or mechanical failure. The Arduino ensures precise control of charging parameters, while the design is scalable for integration into smart city infrastructure. Future extensions can include IOT- based remote monitoring, AI-driven load optimization and solar-powered charging to enhance sustainability. Overall, this project demonstrates a low-cost, intelligent and practical approach for implementing wireless EV charging station suited for academic, urban and industrial applications.

Keywords:

Wireless Power Transfer (WPT), Electric Vehicle (EV) charging, Resonant inductive coupling, Sensor-Based inductive coupling, Sensor-Based monitoring, Arduino-Based control.

I.INTRODUCTION

Electric vehicles (EVs) have emerged as a sustainable alternative to conventional internal combustion engine vehicles, significantly reducing greenhouse gas emissions and dependence on fossil fuels. However, one of the major bottlenecks in EV adoption is the availability of efficient and convenient charging infrastructure. Traditional wired charging station Require manual connection, which introduces user inconvenience, exposure to weather conditions, and potential safety hazards such as electric shock or short circuits. To address these issues, wireless power transfer (WPT) technology has gained immense interest for contactless energy delivery between a stationary power source and an onboard receiver in EVs. The principle of inductive coupling forms the foundation of this system, where energy is transferred via magnetic field between two coils separated by an air gap. This method ensures electrical isolation, operational safety, and ease of use.

In this paper, a wireless EV charging prototype has been developed using an Arduino UNO microcontroller to manage sensor data, control relays, and display charging parameters on an LCD, the charging station consists of an AC-powered transmitter coil, a relay unit, and an IR sensor to detect vehicle presence. Once a vehicle is detected, the transmitter activates automatically, initiating power transfer. The vehicle-side receiver coil captures this electromagnetic energy, converts it to DC using a rectifier circuit, and supplies it to the simulated battery system. Voltage and current sensors measure charging parameters, and the Arduino calculates battery level and charging status in real time. The data are displayed on an LCD for continuous monitoring.

This design promotes automation, efficiency, and user safety while providing a scalable framework for smart cities and future EV infrastructure. It can be further enhanced with IoT integration for remote supervision and AI-based algorithms for optimal distribution. The project thus provides a foundation for research and innovation in next-generation contactless charging technology for electric vehicles.

II. EXISTING METHOD

The conventional electric vehicle (EV) charging infrastructure mainly depends on plug-in wired charging techniques. figure 1 shows the block diagram of plug in wired charging techniques, the vehicle must be physically connected to the charging station using a cable and connector. Although this approach is widely adopted, it presents several operational and safety challenges. Frequent plugging and unplugging of charging cables leads to mechanical wear and tear of connectors, increasing maintenance requirements. Additionally, wired charging systems may pose safety risks such as electric shock, short circuits, and insulation failure, particularly in outdoor environments exposed to rain, dust, and moisture.

Fig.1 Block diagram for Existing method

Basic wireless charging technologies have been introduced in recent years. However, many existing wireless systems operate without intelligent monitoring mechanisms. These systems often suffer from reduced power transfer efficiency due to coil misalignment and variations in air gap distance between the transmitter and receiver coils. Furthermore, most conventional setups lack real-time monitoring of important parameters such as voltage, current, temperature, and foreign object presence.

III. PROPOSED METHOD

The proposed Smart Wireless Charging System introduces an intelligent and automated approach for charging electric vehicles using contactless energy transfer. The system is designed to improve efficiency, safety, and user convenience by combining resonant inductive power transfer with sensor-based monitoring and microcontroller control.

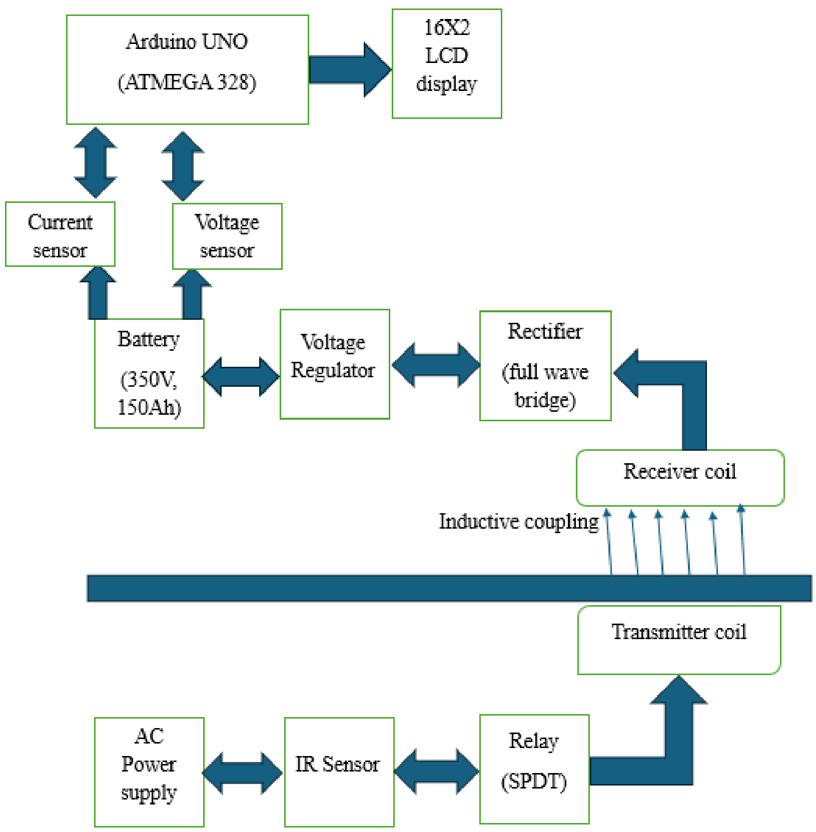

Fig.2 Block diagram for Proposed method

A) Wireless Power Transfer Mechanism

Figure 2 shows the block diagram of wireless power transfer mechanism. The system operates using resonant inductive coupling between a ground-mounted transmitter coil and a vehicle-mounted receiver coil. When alternating current flows through the primary coil, a magnetic field is produced. These magnetic field induces voltage in the secondary coil placed in the vehicle. The received AC power is rectified, filtered, and supplied to the battery for charging.

B) Sensor-Based Monitoring System

Voltage and current sensors are connected to the charging circuit to continuously measure charging parameters. Temperature sensors monitor coil and circuit heating conditions. The collected data is processed by the microcontroller to evaluate charging status, efficiency, and safety limits.

C) Vehicle Detection and Activation

An IR or proximity sensor is installed at the charging station to detect the position of a vehicle. Once the vehicle is detected, the microcontroller activates the transmitter circuit through a relay module. This ensures that power transfer occurs only when a vehicle is correctly positioned, reducing unnecessary energy consumption.

D) Closed-Loop Control Algorithm

A feedback-based control method is implemented to maintain stable power transfer. Based on sensor inputs, the system dynamically adjusts operating parameters such as switching frequency or duty cycle to maintain resonance and improve efficiency. If abnormal conditions such as over-voltage, over-current, overheating, or misalignment are detected, the system automatically interrupts charging.

E) Display and Communication Interface

A 16×2 LCD module displays real-time values such as voltage, current, and charging status. The system can be further extended with IoT modules (Wi-Fi/Bluetooth) to transmit data to a cloud platform or mobile application for remote monitoring and alerts.

IV. HARDWARE REQUIREMENT

A) Arduino Uno

The Arduino Uno is a microcontroller board. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with AC-to-DC adapter or battery to get started.

B) Wireless Power Transfer (WPT) coil

The Wireless Power Transfer and Charging Module can be used in electronic equipment in common use for close wireless charging. This module uses an electromagnetic field to transfer electric energy between a transmitter circuit and a receiver circuit. An induction coil creates an alternating electromagnetic field from within the transmitter circuit powered with 12V.

C) IR Sensor

The IR Sensor-Single is a proximity sensor. Here we use it for collision detection. The module consists IR emitter and IR receiver pair. The high precision IR receiver always detect IR signal.

D) Voltage Sensor

The interface of various sensors to a controller like the Brain Stem GP 1.0 module typically involves either conditioning or converting voltage levels into the range the controller requires. Many systems use A/D converters to make the sensor value relevant in a program or data logging configuration. These converters have a fixed range of voltages they can convert from with 0-5V being by far the most common.

E) Current Sensor

The current sensor plays a crucial role in monitoring and controlling the wireless charging process. It continuously measures the amount of current flowing from the receiver coil to the battery during charging.

F) 16x2 LCD Display

The 16×2 LCD display plays an important role in providing real-time visual feedback about the charging process. It is used to display key parameters such as battery voltage, charging current, power status, and overall charging condition. The Arduino Uno sends processed sensor data to the LCD, allowing users to monitor the system performance directly at the charging station.

G) Relay Module

The relay module functions as an electrically controlled switch that manages the flow of power in the wireless charging system. It is controlled by the Arduino Uno and is responsible for turning the wireless power transmitter ON or OFF based on sensor inputs and system conditions.

H) Rectifier

The rectifier and smoothing circuit play a vital role in converting and stabilizing the power received through wireless transmission. The receiver coil generates alternating current (AC) when it captures energy from the transmitter's magnetic field. However, the battery requires direct current (DC) for charging. The rectifier circuit converts the received AC voltage into pulsating DC.

I) Battery

The battery acts as the energy storage unit of the wireless charging system. It stores the electrical energy received from the wireless power transfer circuit after rectification and smoothing. The battery represents the electric vehicle's power source in the prototype and demonstrates how energy is accumulated during the charging process. As the wireless system transfers power, the battery voltage gradually increases, which is monitored by the voltage and current sensors.

V. SOFTWARE REQUIREMENT

A) Arduino IDE

The Arduino IDE plays a crucial role in developing and managing the software that controls the entire wireless charging system. It is the platform used to write the Embedded C program that defines how the Arduino Uno reads sensor data, controls the relay module, updates the LCD display, and ensures safety conditions.

B) Embedded C Programming

Embedded C plays a vital role in implementing the control logic of the smart wireless charging system. It is the programming language used to develop the firmware that runs on the Arduino Uno microcontroller. The Embedded C program defines how the system reads sensor inputs such as voltage, current, and temperature, processes the data, and makes decisions based on predefined conditions. It controls the relay module to start or stop charging, updates the LCD display with real-time information, and ensures safety by detecting faults like over-current or overheating

VI. EXPERIMENTAL OUTPUT

The output of our Smart Wireless Charging System demonstrates successful wireless power transfer and intelligent monitoring. When the transmitter coil is energized, power is transferred through magnetic induction to the receiver coil without any physical connection. The received AC power is converted into stable DC using a rectifier and smoothing circuit, which is then used to charge the battery.

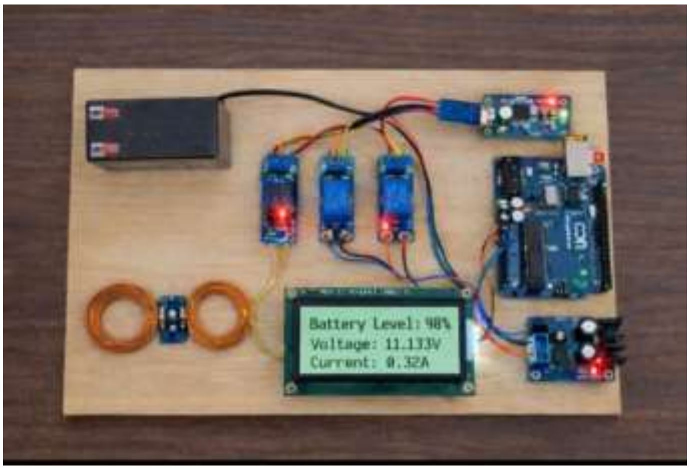

Fig.3 Arduino- Based Wireless Power Transfer System with Battery Monitoring

During operation, figure 4 shows the real-time parameters such as battery voltage and charging current. These values confirm that power is being transferred efficiently. When the vehicle (or load) is detected, the relay module activates automatically, and charging begins. If the battery reaches the preset level or if any abnormal condition such as over-current is detected, the system automatically stops charging.

Fig.4 16x2 LCD Display Sowing Real- Time Battery Parameters

VII. CONCLUSION

The Smart Wireless Charging System for Electric Vehicles successfully demonstrates efficient and contactless power transfer using resonant inductive coupling combined with intelligent sensor-based monitoring. The system integrates an Arduino-based control unit, voltage and current sensing modules, a relay control mechanism, and an LCD display to ensure automated, safe, and reliable charging. The implementation of a rectifier and smoothing circuit provides stable DC output for battery charging, while continuous monitoring protects the system from over-voltage, over-current, and other fault condition. The project proves that wireless charging can be made smarter and safer through real-time feedback and automated control. It reduces the need for physical connectors, minimizes wear and tear, and improves user convenience. Overall, the proposed system demonstrates a practical and scalable solution that can contribute to the development of smart EV infrastructure and future wireless energy transfer technologies.

VIII. FUTURE ENHANCEMENT

The proposed smart wireless charging system can be further developed to support higher power levels suitable for real electric vehicles instead of only prototype-scale operation. The efficiency of power transfer can be improved by designing advanced resonant coils and implementing better alignment techniques to reduce energy loss. Integration with IoT technology can enable remote monitoring of charging status, energy usage, and fault alerts through a mobile or web application.

In addition, fast charging techniques can be incorporated using improved power electronic converters and intelligent control algorithms to reduce charging time while maintaining battery safety. An automatic vehicle positioning system can also be introduced to ensure proper alignment between transmitter and receiver coils. Furthermore, the system can be expanded with smart authentication and billing features for public charging stations. Integration with renewable energy sources such as solar power can make the charging system more sustainable and environmentally friendly.

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