International Journal of Scientific Research & Engineering Trends
Volume 11, Issue 3, May-June-2025, ISSN (Online): 2395-566X

Wireless Charging System for Electric Vehicles

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Abstract- This article presents a comprehensive overview and proposes a system design that integrates wireless power transfer with an automated electric vehicle (EV) platform for real-time voltage monitoring and mobility. Utilizing inductive coupling technology, the system transmits power wirelessly from a stationary transmitter coil to a mobile receiver coil mounted on the EV prototype. A voltage sensor, in conjunction with an ESP8266 microcontroller, measures the received voltage, which is displayed on an LCD screen for user feedback. A motor driver and DC motors allow the vehicle to move, demonstrating the system's ability to function while wirelessly charging. This approach aims to improve efficiency in EV charging infrastructure by minimizing manual intervention and enabling autonomous, wireless power reception. The article discusses both existing charging systems and the implementation of the proposed prototype.

Keywords: Wireless Power Transmission, ESP8266, Electric Vehicles, Motor Driver, Rectification.

INTRODUCTION

Electric vehicles (EVs) are gaining widespread attention as a sustainable alternative to traditional internal combustion engine vehicles, owing to their environmental benefits and reduced reliance on fossil fuels. As the demand for EVs rises, there is a growing need for efficient, safe, and user-friendly charging solutions. Conventional charging methods typically involve manual plug-in systems, which can be inconvenient, prone to wear and tear, and unsuitable for autonomous or continuously moving platforms. These limitations pose significant challenges in terms of scalability, maintenance, and user accessibility.

Wireless power transfer (WPT) technology offers a promising solution by enabling contactless energy transmission through electromagnetic induction. This technology eliminates the need for physical connectors, thereby improving system longevity, safety, and convenience. By integrating WPT with a mobile EV platform, this project aims to demonstrate the feasibility of wireless charging in motion. The system comprises a transmitter coil connected to a rectified and regulated power source, and a receiver coil mounted on a mobile bot. The received voltage is monitored using a voltage sensor and displayed via an LCD, while an ESP8266 microcontroller manages the data and controls a set of DC motors through a motor driver.

This project seeks to simulate a real-world application of wireless EV charging, highlighting its potential to revolutionize existing infrastructure. By automating the energy reception and vehicle response, the proposed system contributes to the advancement of intelligent transport systems, paving the way for more efficient and user-friendly EV technologies.

II. LITERATURE REVIEWS

To develop an efficient and reliable wireless charging system for electric vehicles (EVs), several key insights from existing research have been integrated. A well-designed transmitter and receiver coil system is crucial for optimal power transfer efficiency and minimizing energy loss during transmission [1, 2]. Employing high-frequency resonant inductive coupling allows for efficient energy transfer even across moderate air gaps, which is essential for dynamic or semi-dynamic charging environments [2, 4, 6]. Accurate coil alignment and optimized coil geometry are critical to system efficiency, and recent designs have focused on minimizing magnetic field leakage and improving coupling coefficients [1, 3, 8].

Advanced power electronics such as buck-boost converters and rectifiers are used to regulate voltage levels, ensuring compatibility between the power source and receiver circuits [5, 6, 9]. Dynamic wireless charging systems have been extensively studied for their potential to charge moving EVs on roads, reducing the need for stationary charging stations and improving overall range and usability [1, 3, 7, 10]. These systems use embedded coils within the road and are often integrated with onboard battery management units to control charge flow and efficiency.

For system control and monitoring, microcontrollers like the ESP8266 provide low-cost, Wi-Fi-enabled communication capabilities. These controllers enable real- time monitoring of voltage and current, as well as display outputs for user feedback, making the systems more user- friendly and intelligent [4, 6]. The integration of wireless sensors and IoT platforms facilitates remote diagnostics, predictive maintenance, and automated control strategies to enhance reliability and reduce operational downtime [7, 8, 9].

From a design and implementation perspective, compact motorized platforms can be used to simulate EV motion during wireless power transfer testing. Incorporating lightweight materials, precision wheel alignments, and low-power DC motors ensures that energy consumption is minimized while still maintaining reliable movement and charging verification [4, 9, 10]. Safety measures such as electromagnetic shielding and real-time fault detection algorithms help protect users and hardware during operation [6, 8].

Lastly, renewable integration, such as using solar energy to power the transmitter side, adds to the system's sustainability and long-term economic viability [9, 10]. With continuous improvements in coil design, system integration, and wireless control, wireless charging for EVs is rapidly evolving into a scalable and environmentally friendly solution for the future of transportation.

III. RESEARCH OBJECTIVES

- **Development of Wireless Power Transfer System:** Design and implement a wireless charging setup using inductive coupling to efficiently transfer energy from a stationary transmitter coil to a receiver coil mounted on a mobile electric vehicle prototype.
- **Hardware-Software Synchronization:** Integrate microcontroller-based control (ESP8266) with hardware components including buck-boost converters, voltage sensors, motor drivers, and LCD displays to achieve real-time monitoring and response during wireless charging.
- **Optimization of Power Transmission Efficiency:** Improve the performance and reliability of the system by experimenting with coil configurations, alignment strategies, and power regulation circuits to maximize energy transfer and minimize losses during operation.
- **Embedded System Adaptation:** Configure the system to operate on compact, low-power embedded platforms while ensuring consistent performance. This involves optimizing firmware logic, managing power distribution, and ensuring compatibility with wireless communication protocols.
- **Safety and System Integrity:** Implement protective features such as voltage regulation safeguards, controlled current flow, and secure hardware enclosures to prevent system overloads, overheating, or damage to components during wireless charging.

IV. PROPOSED METHODOLOGY

The methodology encompasses the systematic approach followed in designing and implementing the wireless charging system for electric vehicles. It combines power electronics, wireless energy transfer, embedded programming, and automation to simulate a real-world dynamic wireless charging system for EVs. The implementation is structured into the following key phases:

- **Power Supply Conversion and Voltage Regulation**

The system begins with a 230V AC main power supply. To make this high voltage usable for electronic components, it is stepped down to 6V AC using a 230V/6V step-down transformer. The output from the transformer is then fed into a bridge rectifier circuit, which converts the AC voltage into pulsating DC. However, this DC output still contains ripples and is not regulated. To address this, a buck-boost converter is introduced, which adjusts and stabilizes the DC voltage to a suitable level for wireless charging operations. This regulated output is then supplied to a 12V rechargeable battery. The battery not only stores energy but also serves as a buffer, maintaining a consistent power level for the wireless transmission stage.

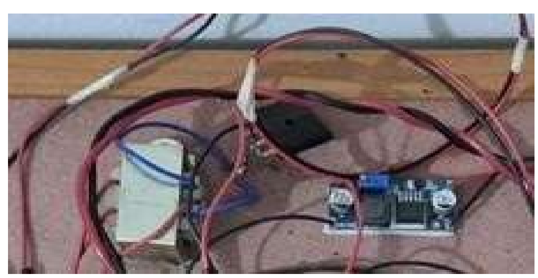

Figure.1: Power Conversion.

- **Wireless Power Transmission Unit**

After voltage regulation, the system routes the DC power to the wireless energy transmission unit, centered around a copper transmitting coil. This coil is specifically designed to create a strong, alternating magnetic field using the principle of inductive coupling. When high-frequency AC is passed through this coil, it generates a time-varying magnetic flux in the space around it. The system typically converts the regulated DC into an AC signal suitable for induction. The transmitting coil is driven by power from both the buck- boost converter and the battery in parallel, ensuring that even if one source fluctuates, the coil maintains a stable output. The position and design of the coil are optimized to maximize coupling efficiency with the receiver coil on the bot. This setup creates a wireless power hotspot which, in a real-world application, would be integrated into roads, parking spaces, or charging pads to wirelessly transmit energy to electric vehicles.

- **Wireless Power Reception and Conversion**

The receiver coil, mounted on the underside of the mobile bot, is carefully aligned to the transmitting coil to ensure optimal inductive coupling. When the bot moves into the range of the magnetic field generated by the transmitter, an electromotive force (EMF) is induced in the receiver coil, which effectively harvests energy from the air gap. This induced AC voltage, however, is not suitable for direct use, so it is immediately passed through a dedicated rectifier circuit onboard the bot. The rectifier converts the received AC into DC voltage, which is then filtered using capacitors to provide a smooth and stable DC output. This DC voltage forms the primary source of energy for the bot's operational electronics. This step closely simulates how electric vehicles can wirelessly receive energy from embedded infrastructure while moving or parked, eliminating the need for physical connectors and reducing wear and tear. In this system, energy transfer is contactless, making it more reliable in environments exposed to dust, water, or physical damage.

Figure.2: Process of Power Reception.

- **Motion Control and Power Backup System**

To ensure uninterrupted motion, the bot employs a hybrid power system that integrates wireless power transfer with an onboard battery backup. The wirelessly transmitted energy is converted into DC voltage and used to power the motion system, which includes an L293D motor driver IC and a pair of 12V DC motors. The L293D, acting as a dual H-bridge driver, allows independent bidirectional control of both motors and serves as the interface between the ESP8266 microcontroller and the motors. Although the system is primarily powered via wireless reception, environmental factors such as misalignment and interference may lead to voltage drops. To address this, the system incorporates an automatic fallback to a 12V onboard battery, ensuring smooth and uninterrupted operation. This architecture emulates the real-time switching capabilities seen in hybrid electric vehicles, providing increased reliability in dynamic conditions.

Key Highlights:

- Wireless energy is converted to DC voltage.
- L293D motor driver controls two 12V DC motors independently.
- L293D interfaces with the ESP8266 microcontroller.
- Wireless power can be unstable due to interference or misalignment.
- A 12V onboard battery provides automatic backup power.
- Seamless power switching ensures uninterrupted mobility.

- **Voltage Monitoring and Display Interface**

To visualize the efficiency of wireless power transfer, the system incorporates a real-time monitoring setup using a voltage sensor and an LCD module. The voltage sensor is connected across the output of the receiver coil on the bot and constantly measures the DC voltage being delivered via inductive coupling. This sensor provides an analog voltage signal that is read by the ESP8266 microcontroller using its ADC (Analog-to-Digital Converter) pin. The microcontroller then processes this data and converts it into a readable format to be shown on a 16x2 LCD display. This LCD is interfaced either using a direct parallel connection or an I2C module to reduce pin usage. The purpose of the display is to provide immediate, visible feedback about how much voltage is being received wirelessly, allowing users to verify the reliability and consistency of the wireless charging process in real time. This adds an important feedback loop to the demonstration, making it easier to analyze performance under different alignment and distance conditions between the transmitter and receiver coils.

Figure.3: Voltage Monitoring.

- **System Integration and Power Management**

The integration of all subsystems—power conversion, wireless transmission, motor control, sensor input, and display—is carefully managed to ensure coordinated functionality. The ESP8266 plays a central role in this integration by acting as both a monitoring and controlling unit. Its codebase includes modules to handle voltage readings, motor direction control, display updates, and conditional power logic. For example, the code can be written to activate motors only when the received voltage is above a minimum threshold, thus preventing erratic movement due to insufficient power. Moreover, the power backup system is designed such that the onboard battery supports the motor driver only when wireless power drops, ensuring smooth handover without system reset or glitch. This logical power distribution replicates a real-world hybrid energy management system and ensures the bot operates reliably under dynamic conditions. Each subsystem is tested independently before final integration to minimize faults during real-time operation.

Figure.4: Codebase for Microcontroller.

- **Hardware System**

The proposed wireless charging system comprises several essential hardware components that collectively enable power conversion, wireless transmission, reception, motion control, and monitoring. Below is a detailed overview of all major modules involved:

- **Power Conversion and Storage:** The system begins with a 230V to 6V step-down transformer that reduces the high- voltage AC supply from the mains to a safer low-voltage level. This AC output is then passed through a bridge rectifier that converts it to DC. The rectified DC is often unregulated, so it is stabilized using a buck-boost converter to ensure a constant 12V output. This regulated power is used to charge a 12V rechargeable battery, which not only acts as a backup energy source but also ensures consistent power delivery to the transmitter coil during brief fluctuations in input supply.

- **Wireless Energy Transfer System:** The core of the wireless charging mechanism lies in the inductive coupling between two coils. The transmitting coil is energized using the 12V DC supply, which generates a magnetic field around it. This coil is placed at the base of the stationary setup. The mobile bot is equipped with a receiving coil mounted underneath its chassis. When this coil comes into proximity with the transmitter's magnetic field, it induces an AC voltage, which is then converted to DC using a rectifier and smoothing capacitor circuit on the bot side. This enables contactless power transfer between the static and dynamic parts of the system.

- **Bot Locomotion and Control:** The bot uses an L293D motor driver integrated circuit to control two 12V DC geared motors. The motor driver receives logic signals from the ESP8266 microcontroller and switches motor directions accordingly. It draws its power primarily from the energy received via the receiver coil, but during times of low wireless input, the onboard 12V battery acts as a backup, supplying power to ensure uninterrupted motion. The chassis of the bot houses all key components, with adequate space provided underneath for optimal coil alignment and clearance.

- **Sensing and Microcontroller Interface:** The ESP8266 NodeMCU microcontroller plays a pivotal role in managing the system's intelligence. It is responsible for reading data from a voltage sensor module that measures the output of the receiver coil. The sensor feeds analog voltage values into the ADC pin of the ESP8266, which are then processed and used to make decisions, such as whether to activate motor movement. To ensure reliable performance, the microcontroller is powered externally through a USB source, like a laptop or power bank, isolating it from the variable nature of wireless power input.

- **Display and Feedback:** For real-time feedback, a 16x2 LCD display is interfaced with the ESP8266. It shows the voltage received wirelessly by the bot, giving users a live reading of the system's efficiency. The LCD can be connected directly using parallel data lines or through an I2C module to reduce wiring complexity. This visual interface makes it easier to monitor wireless energy reception and assess alignment accuracy between coils during motion.

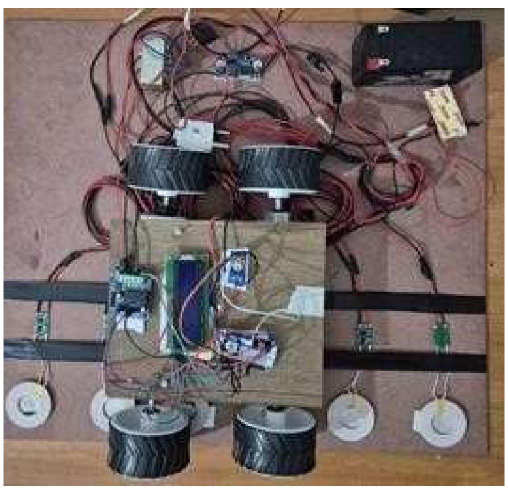

Figure.5: Hardware Setup.

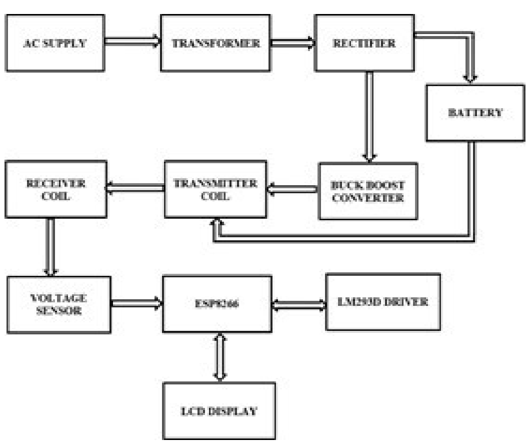

Figure.6: Block Diagram.

V. CONCLUSION

The project successfully demonstrates a working prototype of a wireless charging system for electric vehicles using inductive power transfer. By integrating key components such as a step-down transformer, rectifier, buck-boost converter, transmitter and receiver coils, and a microcontroller-controlled mobile bot, the system showcases efficient, contactless energy transfer. Real-time voltage monitoring and motor control via the ESP8266 enhance the credibility and practicality of the model. The bot's ability to operate using wirelessly received power, with backup from an onboard battery, reflects how such systems could be deployed in real-world applications—whether for stationary or dynamic charging scenarios. This solution not only eliminates the need for physical connectors but also opens pathways toward implementing smart, embedded charging systems in road infrastructure. With further improvements in transmission efficiency, alignment mechanisms, and scalability, this wireless charging approach presents a promising step toward sustainable, automated electric mobility.

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