Design of Wireless Electric Vehicle charging station

Sowmya G[1], Nandan N M[2], K Vaishnavi[3], Madhusoodhan M Baraker[4], Nagaraj C K[5]
[1]*Assistant Professor, Department of Electrical & Electronics Engineering, Vidya Vikas Institute of Engineering and Technology, Mysuru, India*
[2,3,4,5]*Student*

***Abstract*—The increasing adoption of electric vehicles has created a growing need for safer, more convenient, and automated charging solutions. Traditional plug-in chargers often face issues such as cable wear, user handling errors, and safety risks in outdoor environments. This project addresses these challenges by designing a wireless electric vehicle charging station that enables contactless power transfer using inductive charging technology. The system uses a solar powered battery supply to ensure clean and reliable energy for the transmitter module.**

A key feature of the project is the integration of a QR-based digital interface that allows users to select charging durations easily through a mobile device. When the QR code is scanned, a webpage opens, displaying time options and initiating an automated countdown once selected. This software-controlled operation ensures that the wireless charging module activates and deactivates accurately according to the chosen duration. This approach removes the need for physical interaction with the charging equipment and provides a seamless and user-friendly experience.

I. INTRODUCTION

The rapid global transition toward clean energy and sustainable transportation has resulted in a tremendous rise in the adoption of electric vehicles (EVs). With increasing concern over climate change, pollution, and the depletion of non-renewable energy resources, EVs have emerged as an effective solution that offers zero tailpipe emissions and improved energy efficiency. However, as EV usage increases, the demand for convenient, safe, and reliable charging infrastructure has also grown significantly. Traditional plug-in charging stations, although widely implemented, still present challenges such as manual cable handling, physical wear and tear, safety issues in wet conditions, and user inconvenience. These limitations have created a strong need for advanced charging technologies that provide a more seamless and automated experience. Wireless electric vehicle charging, based on inductive power transfer (IPT), has become one of the most innovative and promising solutions for next-generation EV infrastructure.

Wireless electric vehicle charging stations work on the principle of electromagnetic induction, where electrical energy is transferred from a stationary transmitter coil to a receiver coil installed on the underside of the vehicle. When both coils are tuned to the same resonant frequency, typically around 85 kHz, a strong magnetic field is established, allowing energy to be transferred efficiently across an air gap of several centimeters. This eliminates the need for physical connectors and cables, making the charging system highly user-friendly. The vehicle simply needs to be parked over the charging pad, and the system automatically initiates the charging process. This technology greatly benefits residential parking, public charging sites, smart city infrastructure, and particularly autonomous vehicle systems where plug-in charging is impractical. Wireless charging also enhances safety by reducing electrical exposure, preventing cable vandalism, and eliminating risks associated with improper plug handling.

II. OBJECTIVE OF THE PROJECT

1. To design and develop a wireless electric vehicle charging system that can safely and efficiently transfer power across a small air gap using inductive coupling.
2. To create a simple, reliable, and user-friendly charging setup that eliminates physical cables and demonstrates effective wireless charging for electric vehicles.

III. LITERATURE SURVEY

Wireless Electric Vehicle (EV) charging has advanced significantly due to continuous research in Wireless Power Transfer (WPT) technologies. Early foundational work by Tesla demonstrated the principle of resonant inductive coupling, which later evolved into practical mid-range power transfer through the breakthrough research by Kurs et al. at MIT in 2007, showing efficient strongly coupled magnetic resonance for wireless power delivery [1]. Li and Mi provided a comprehensive analysis of inductive charging systems for EVs, highlighting power electronics design, coil efficiency, and compensation networks that form the core of modern wireless chargers [2]. The development of optimized coil structures such as the Double-D (DD) geometry improved magnetic coupling and misalignment tolerance, making wireless charging more reliable for automotive applications [3]. Standardization efforts by SAE led to the establishment of the SAE J2954 guidelines, defining operating frequency, alignment categories, communication protocols, and safety limits for EV wireless charging systems, thereby enabling global interoperability [4]. Research on dynamic and quasi-dynamic charging further expanded possibilities by enabling charging during vehicle motion or short stops, which enhances practicality for buses and public transport fleets [5], [6]. Additional studies focused on compensation topologies, foreign-object detection (FOD), and safety mechanisms necessary for efficient and secure operation in real-world environments [7], [8]. Collectively, these works demonstrate the evolution of wireless EV charging from conceptual theory to a practical, standardized, and scalable solution capable of supporting future smart and autonomous mobility.

IV. SYSTEM ARCHITECTURE

A. Overall Block Diagram

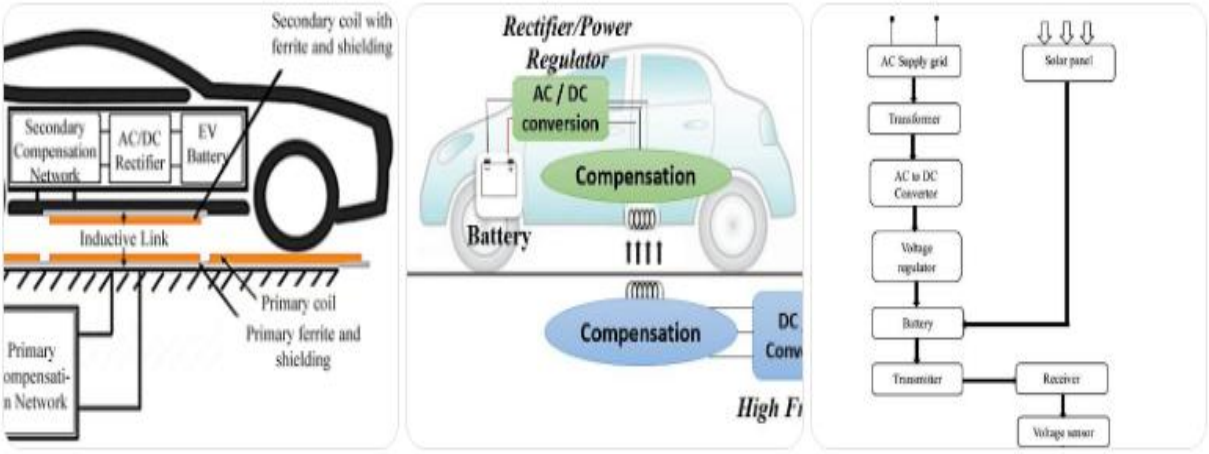


Fig. 1. Block diagram of the proposed wireless electric vehicle charging system

The system consists of a solar panel, charge controller, lithium-ion battery, wireless power transmitter, receiver module, Arduino microcontroller, sensing unit, and display module. The solar panel charges the battery, which powers the transmitter coil. The receiver coil transfers energy to the EV battery under microcontroller supervision.

B. Hardware Components

i. Solar Panel and Charge Controller

The solar panel converts sunlight into electrical energy, while the charge controller regulates voltage and current to protect the battery from overcharging and deep discharge.

ii.Lithium-Ion Battery

The lithium-ion battery acts as the main energy storage unit, ensuring continuous power supply even during low solar availability.

iii. Wireless Power Transmitter and Receiver

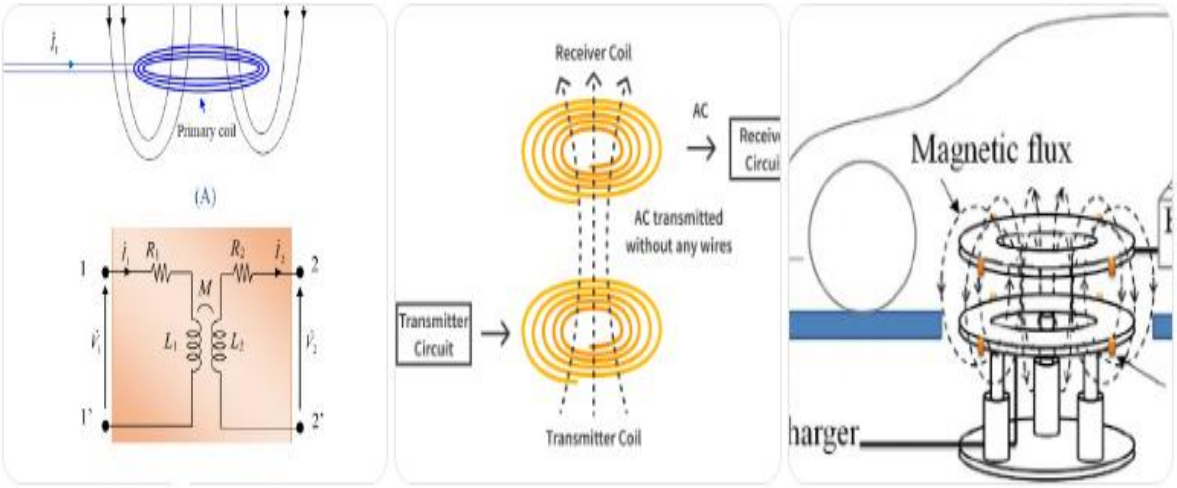


Fig. 2. Inductive wireless power transfer between transmitter and receiver coils

The transmitter generates a high-frequency magnetic field, which induces voltage in the receiver coil mounted on the vehicle, enabling contactless charging.

iv. Arduino Microcontroller and Sensors

The Arduino microcontroller controls charging duration, monitors voltage and current parameters, and ensures system safety using feedback from sensors.

v. LCD Display

The LCD provides real-time display of battery voltage, charging status, and system information.

V. METHODOLOGY

The project involves a systematic approach that combines hardware integration, software development, and wireless charging technology to build a functional electric vehicle charging station. The process begins with designing the wireless power transfer system using a transmitter and receiver coil configured for inductive coupling. The transmitter coil is powered through a regulated supply derived from the Li-ion battery, which is charged using a solar panel and TP4056 charging module. Components such as the DC-DC converter, voltage regulator, and protection circuit are connected to ensure stable power delivery. An Arduino microcontroller is then interfaced with the wireless charging module, battery sensing unit, and LCD display. The Arduino is programmed to read battery voltage, calculate battery percentage, and display these values on the LCD in real time.

Parallel to the hardware setup, a web-based QR system is developed using HTML, CSS, and JavaScript. The QR code directs users to a webpage where charging duration options are provided. When the user selects a time, the JavaScript countdown timer begins and sends control signals to the Arduino, which activates the wireless charging transmitter for the selected duration. Once the timer finishes, the Arduino automatically stops the charging process, and the webpage displays a “Charging Completed” message. The final step involves integrating all hardware and software modules into a single working model and testing the entire system for wireless charging performance, countdown accuracy, battery monitoring, and solar-powered operation. This structured methodology ensured the creation of a fully functional prototype that demonstrates safe, automated, and contactless EV charging.

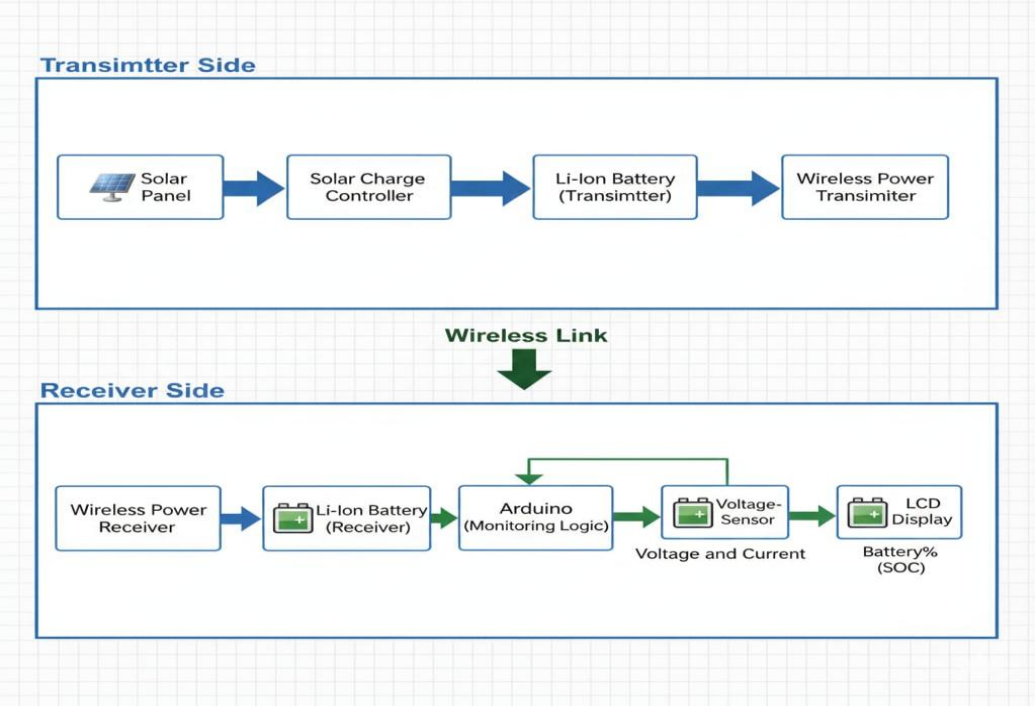
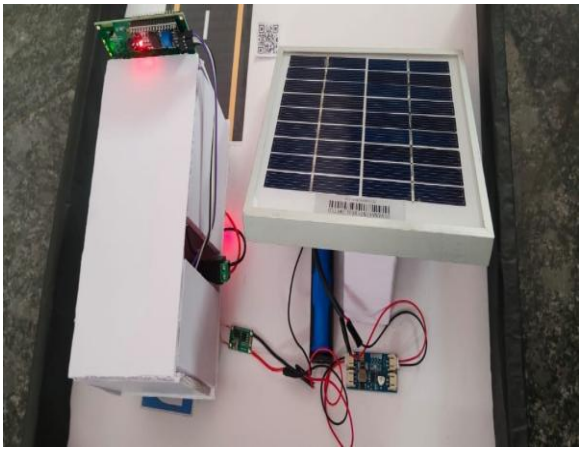


Fig 3: Block Diagram

VI. RESULTS AND DISCUSSION

The developed wireless electric vehicle charging station successfully demonstrated the ability to transfer power without physical cables using the inductive charging system. When the QR code was scanned, the user was redirected to the web interface where charging time could be selected, and the countdown timer worked accurately for all preset durations. The wireless transmitter turned ON and OFF exactly according to the selected time, showing correct synchronization between the software timer and the hardware module. The charging coil consistently powered the receiver coil placed on the model vehicle, confirming that the inductive power transfer worked effectively across a short air gap.

The system also performed well in terms of power management. The solar panel charged the Li-ion battery through the TP4056 module, and the regulated output provided stable power to the microcontroller and transmitter. The Arduino-based battery monitoring system accurately measured the battery voltage and displayed the battery percentage in real time, proving the reliability of the voltage-sensing code. LED indicators across the modules provided visual confirmation of power flow, charging status, and system activity.



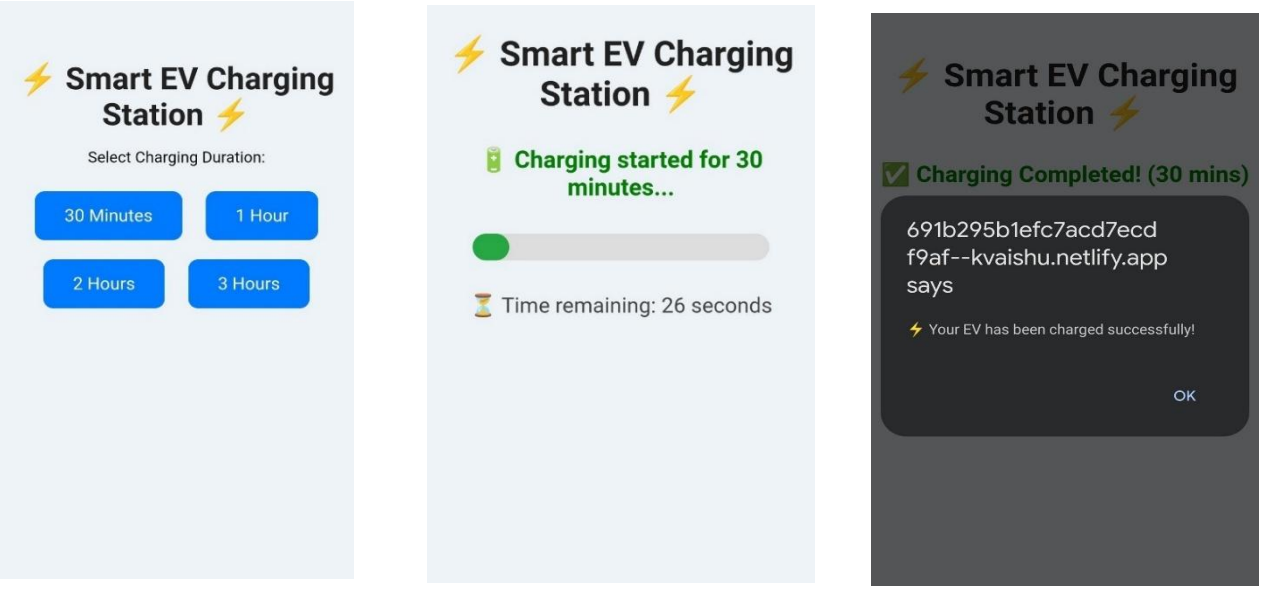


Fig 4: Charging Indication

The working model of the wireless electric vehicle charging station produced clear and successful outputs across all major components. When the system was powered ON, the wireless transmitter coil generated a stable electromagnetic field, and the receiver coil collected this energy effectively, allowing contactless charging. LED indicators on the transmitter, receiver, TP4056 module, and converter circuits confirmed active power flow and correct operation. The solar panel also provided visible output by charging the Li-ion battery, shown through the TP4056 status LEDs. Along with this, the Arduino-based monitoring setup continuously read the battery voltage and converted it into an accurate battery percentage, which was displayed in real time on the LCD screen, giving immediate visual feedback to the user about battery health and available power.

VII. CONCLUSION

The design of the wireless electric vehicle charging station developed in this mini project successfully proves that contactless charging can be made simple, safe, and highly user-friendly using inductive power transfer technology. By integrating a QR-based interface that allows users to select a charging duration and monitor a real-time countdown, the system eliminates the need for manual plugging and reduces common issues like cable wear, electrical hazards, and connection errors. The project demonstrates how wireless charging can operate reliably in various environments with minimal maintenance while offering clear feedback through an automatic completion message. This model highlights the potential of wireless charging as a modern alternative to traditional wired chargers, especially for public spaces, smart parking systems, and future autonomous vehicles. Overall, the project shows that wireless EV charging is a practical, efficient, and future-ready solution that can significantly enhance the convenience, safety, and sustainability of electric mobility.

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