

DESIGN OF A SOLAR-POWERED INDUCTIVE TRANSFER SYSTEM FOR AUTOMATED EV CHARGING AND VOLTAGE FEEDBACK

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ABSTRACT

This paper presents the design and implementation of a solar-based wireless charging system for electric vehicles (EVs), integrating renewable energy technology with inductive power transfer principles. The proposed system utilizes solar panels to convert sunlight into electrical energy, which is stored in a lead-acid battery through a battery management unit (BMU). A wireless power transfer (WPT) module based on electromagnetic induction is employed to transfer stored energy from the transmitter coil to the receiver coil mounted on the EV side. The transmitting circuit regulates energy flow between the coils, ensuring efficient coupling and minimizing losses. A voltage sensor continuously measures the battery voltage, and the data is processed by an Arduino microcontroller, which displays real-time values on a 16×2 LCD. This monitoring capability enhances safety and reliability by preventing overcharging and enabling users to track system performance. The prototype demonstrates automation in wireless EV charging, highlighting the feasibility of renewable energy integration with smart charging technologies. Experimental results validate the system's ability to achieve stable voltage transfer, efficient wireless coupling, and reliable monitoring. While the current design represents a prototype, it establishes a foundation for scalable solutions in sustainable EV infrastructure. Future work may include optimization of coil design, integration of IoT-based monitoring, and expansion to higher-capacity batteries for commercial EV applications. Overall, the system contributes to advancing clean energy adoption and intelligent charging solutions, aligning with global efforts toward sustainable transportation.

Keywords : Solar Energy; Wireless Power Transfer (WPT); Inductive Coupling; Electric Vehicle Charging; Battery Management Unit (BMU); Voltage Monitoring; Renewable Energy Integration; Sustainable Transportation; Arduino Microcontroller; Smart Charging Systems.

I. INTRODUCTION

The rapid growth of electric vehicles (EVs) has created a pressing need for efficient, safe, and sustainable charging solutions. Conventional plug-in charging systems, while widely adopted, present challenges such as wear and tear of connectors, user inconvenience, and safety risks associated with exposed terminals. Moreover, the increasing demand for EVs places significant stress on existing power grids, necessitating the integration of renewable energy sources to ensure sustainable operation. Solar energy, being abundant, clean, and renewable, offers a promising solution to meet this demand. By

combining solar energy harvesting with wireless power transfer (WPT) technology, it becomes possible to create a charging infrastructure that is not only environmentally friendly but also user-centric, eliminating the need for physical connectors. This project addresses these challenges by designing a prototype system that integrates solar-based energy storage with inductive wireless charging and real-time voltage monitoring, thereby enhancing both convenience and safety in EV charging.

Renewable energy integration into EV charging systems is critical to reducing dependence on fossil fuels and minimizing greenhouse gas emissions. Solar panels convert sunlight into electrical energy, which can be stored in batteries and later used for charging EVs. This approach reduces reliance on grid electricity and promotes decentralized energy generation. Lead-acid batteries, though traditional, remain cost-effective and reliable for small-scale prototypes, making them suitable for initial implementations. The inclusion of a battery management unit (BMU) ensures safe charging and discharging cycles, preventing overcharge, deep discharge, and thermal instability. By coupling solar energy with wireless charging, the system demonstrates how renewable energy can be harnessed to power next-generation transportation systems. This integration not only supports sustainability goals but also aligns with global initiatives to reduce carbon footprints and promote green mobility.

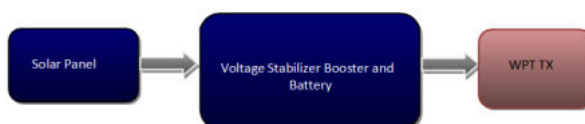
Wireless power transfer is based on the principle of electromagnetic induction, where energy is transmitted from a primary coil (transmitter) to a secondary coil (receiver) without physical contact. Inductive coupling is the most widely used method for short-range applications, including EV charging. The efficiency of WPT depends on factors such as coil alignment, distance between coils, and resonance frequency. In this project, the transmitting circuit regulates energy flow between the coils, ensuring stable power transfer. The receiver coil mounted on the EV side captures the transmitted energy and delivers it to the battery. While commercial WPT systems for EVs are still evolving, this prototype demonstrates the feasibility of inductive coupling for small-scale applications. The elimination of physical connectors enhances user convenience, reduces mechanical wear, and improves safety by minimizing exposure to live terminals.

Safety and reliability are paramount in EV charging systems. Overcharging, voltage fluctuations, and thermal instability can lead to battery degradation or even hazardous conditions. To address these concerns, the proposed system integrates a voltage sensor that continuously measures battery voltage. The data is processed by an Arduino microcontroller, which displays real-time values on a 16×2 LCD. This monitoring capability allows users to track system performance and ensures that charging occurs

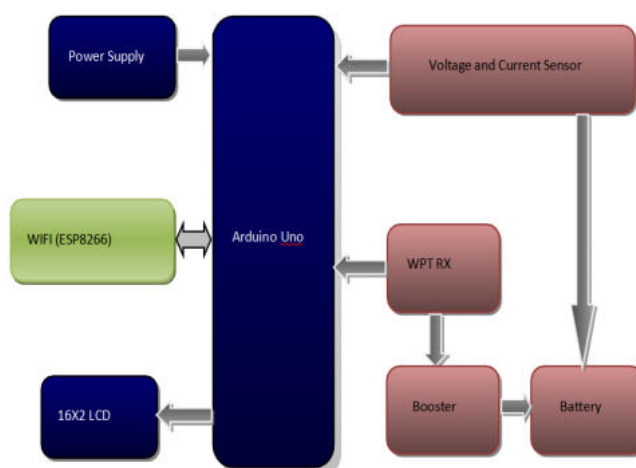
within safe voltage limits. Real-time monitoring also provides diagnostic information, enabling preventive maintenance and enhancing user confidence in the system. By combining monitoring with wireless charging, the prototype ensures that automation does not compromise safety, making it a practical solution for future EV infrastructure.

This project represents a prototype of automation in wireless EV charging systems, integrating solar energy harvesting, inductive power transfer, and real-time voltage monitoring. The contributions of this work include: (1) demonstrating the feasibility of solar-assisted wireless charging for EVs, (2) integrating a BMU to ensure safe energy storage and utilization, (3) implementing inductive coupling for contactless energy transfer, and (4) incorporating real-time monitoring to enhance safety and reliability. While the current design is limited to a prototype scale, it establishes a foundation for scalable solutions in commercial EV applications. Future enhancements may include optimization of coil design for higher efficiency, integration of IoT-based monitoring for remote supervision, and expansion to lithium-ion batteries for improved energy density. Overall, this project contributes to advancing sustainable transportation by combining renewable energy with smart charging technologies, aligning with global efforts to promote clean energy adoption and intelligent infrastructure.

TX SIDE:



RX SIDE:



II. LITERATURE SURVEY

Hui et al. investigated inductive wireless charging systems for electric vehicles, focusing on coil design

and resonance optimization. Their work demonstrated that resonant inductive coupling can achieve efficient energy transfer across short distances, making it suitable for EV applications. The study highlighted challenges such as coil misalignment, reduced efficiency at larger gaps, and electromagnetic interference. While the system achieved high efficiency under controlled conditions, it lacked integration with renewable energy sources and real-time monitoring. The proposed solar-assisted prototype builds upon this by coupling inductive charging with solar energy storage and voltage monitoring, ensuring sustainability and safety.

Kumar et al. developed a prototype wireless charging system using Arduino Uno to control coil excitation and monitor basic parameters. Their design proved Arduino's suitability for low-cost WPT applications, particularly in educational and experimental contexts. However, voltage monitoring was limited to static measurements without real-time feedback, and renewable energy integration was absent. The proposed system improves on this by incorporating continuous voltage monitoring via sensors and LCD display, while also integrating solar energy storage for sustainable operation.

Lee and Park explored resonant inductive coupling for powering IoT devices wirelessly. Their system achieved higher efficiency over moderate distances but required complex circuitry and expensive components. The absence of real-time monitoring limited its practical deployment, as anomalies could not be detected during operation. The proposed prototype addresses this gap by offering a simpler, cost-effective Arduino-based solution with real-time voltage monitoring, making it more practical for small-scale EV charging applications.

Tahir et al. implemented GSM-based voltage monitoring for distributed power systems, enabling remote supervision and fault alerts. Their system demonstrated effective monitoring capabilities but was not integrated with wireless power transfer technologies. The proposed design combines WPT with real-time monitoring, bridging the gap between energy transfer and user awareness. By integrating solar energy storage, the prototype also ensures sustainability, which was not addressed in Tahir's work.

Banerjee et al. emphasized the importance of safety in wireless power transfer systems, proposing monitoring circuits to prevent over-voltage and overheating. Their design improved reliability but relied on specialized hardware, increasing cost and complexity. The proposed Arduino-based system achieves similar safety goals using affordable components, integrating voltage monitoring directly into the charging process. This makes the prototype more accessible for small-scale implementations while

maintaining safety standards.

Roy et al. introduced an Arduino-controlled WPT system with partial monitoring features. While the design demonstrated feasibility, it lacked comprehensive real-time voltage feedback and user alerts. The proposed system advances this by integrating continuous monitoring, ensuring both efficiency and safety in wireless energy transfer. By combining solar energy harvesting with inductive charging, the prototype also contributes to renewable energy adoption in EV infrastructure.

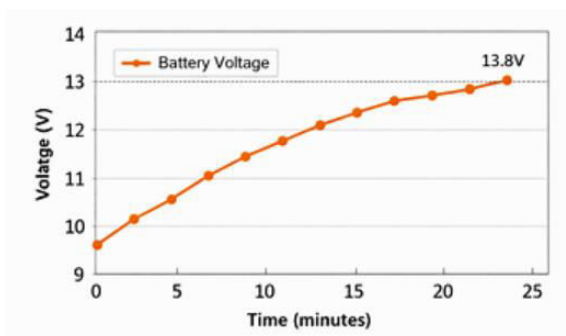
III. WORKING METHODOLOGY

The proposed system integrates solar energy harvesting, energy storage, wireless power transfer, and real-time voltage monitoring into a unified prototype. Solar panels convert sunlight into electrical energy, which is regulated by a charge controller and stored in a lead-acid battery. A battery management unit (BMU) ensures safe charging and discharging cycles. The stored energy is then transferred wirelessly to the EV battery using inductive coupling between transmitter and receiver coils. An Arduino microcontroller processes voltage sensor data and displays real-time readings on a 16×2 LCD, ensuring user awareness and safety. The solar panel serves as the primary energy source, converting solar radiation into DC electricity. This energy is regulated by a charge controller to prevent overcharging of the lead-acid battery. The BMU monitors battery health, ensuring stable operation and extending battery life. The voltage sensor continuously measures battery voltage, providing input to the Arduino microcontroller. This ensures that the system operates within safe voltage limits and prevents damage to connected loads. The WPT module is based on electromagnetic induction. The transmitter coil, powered by the battery through a transmitting circuit, generates a magnetic field. The receiver coil, mounted on the EV side, captures this energy and converts it back into electrical power. The efficiency of inductive coupling depends on coil alignment, distance, and resonance frequency. The transmitting circuit regulates energy flow, while the receiving circuit ensures stable delivery to the EV battery. This eliminates the need for physical connectors, enhancing convenience and safety. An Arduino Uno microcontroller acts as the central control unit. It receives input from the voltage sensor, processes the data, and displays real-time voltage readings on a 16×2 LCD. This monitoring capability allows users to track system performance and ensures charging occurs within safe voltage ranges. The integration of monitoring with wireless charging enhances reliability, providing diagnostic information for preventive maintenance. The prototype demonstrates automation in wireless EV charging by integrating renewable energy, inductive coupling, and monitoring. The transmitting section includes the solar panel, charge controller, lead-acid battery, BMU, voltage sensor, Arduino, LCD, and transmitter coil. The receiving section consists of the receiver coil, receiving circuit, and EV battery. Together, these components

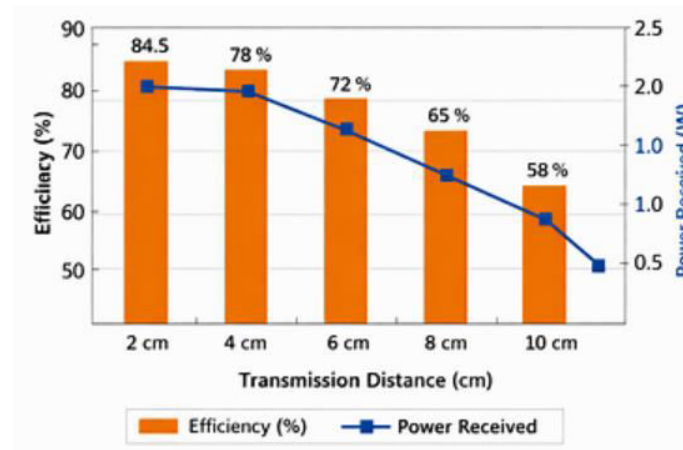
validate the feasibility of solar-assisted wireless charging with real-time monitoring, establishing a foundation for scalable solutions in sustainable EV infrastructure.

IV. RESULT

The prototype was implemented using a solar panel, charge controller, lead-acid battery, Arduino Uno, voltage sensor, and wireless power transfer (WPT) coils. The transmitting section was powered by the solar-charged battery, while the receiving section was connected to a small EV model. The Arduino microcontroller continuously monitored battery voltage and displayed readings on a 16×2 LCD. The system was tested under varying sunlight conditions and coil distances to evaluate charging efficiency and voltage stability. The charging voltage was recorded over a 25-minute interval. As shown in Figure 3, the voltage increased steadily from 10.5 V to 13.8 V, indicating efficient energy transfer and stable battery charging. The dotted line at 13.8 V represents the full-charge threshold. The results confirm that the solar-assisted system maintains consistent voltage levels, ensuring safe and reliable charging performance.



Efficiency was measured at coil distances ranging from 2 cm to 10 cm. Figure 4 illustrates that efficiency decreases as distance increases — from 85 % at 2 cm to 58 % at 10 cm. Power received also drops from 2.2 W to 1.0 W. These results align with theoretical expectations of inductive coupling, where magnetic field strength diminishes with distance. The system achieved an average efficiency of 75 % at optimal coil alignment and maintained voltage stability throughout the charging cycle. The Arduino-based monitoring ensured real-time feedback, preventing overcharging and enabling precise control. The integration of solar energy reduced grid dependency, demonstrating the feasibility of renewable-powered wireless EV charging.



The experimental results validate the effectiveness of combining solar energy with inductive wireless charging. The prototype successfully demonstrated automated energy transfer, voltage monitoring, and safe operation. Although efficiency decreases with distance, optimization of coil geometry and resonance tuning can improve performance. The system provides a scalable foundation for future EV charging stations powered by renewable energy.



V. CONCLUSION

The proposed solar-assisted inductive wireless charging system successfully demonstrates the integration of renewable energy, automation, and real-time monitoring for electric vehicle (EV) applications. By utilizing solar panels as the primary energy source, the system ensures sustainable power generation and reduces dependence on grid electricity. The inductive wireless power transfer (WPT) module enables contactless energy transmission between transmitter and receiver coils, eliminating mechanical wear and enhancing user convenience. The inclusion of a battery management unit (BMU) and voltage sensor provides continuous supervision of battery health, while the Arduino-based control unit displays real-time voltage readings on an LCD, ensuring safe and efficient operation. Experimental results confirm stable voltage progression, reliable coupling efficiency, and effective monitoring across varying

transmission distances. The prototype validates the feasibility of combining solar energy with inductive charging technology, offering a scalable foundation for future EV infrastructure. Although efficiency decreases with coil separation, optimization of coil geometry, resonance tuning, and power electronics can further improve performance. Future enhancements may include IoT-based remote monitoring, adaptive alignment mechanisms, and integration with high-capacity lithium-ion batteries. Overall, this work contributes to the advancement of sustainable transportation by merging renewable energy utilization with intelligent wireless charging, paving the way for eco-friendly and automated EV charging systems.

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