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Smart, Solar-Based Wireless EV Power-Transfer System

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Abstract

This project presents a solar wireless electric vehicle (EV) charging system that integrates solar energy with inductive wireless power transfer (WPT) to achieve a sustainable and eco-friendly charging approach. The proposed system utilizes a 12 V solar panel as the primary renewable energy source, which charges a 3.7 V lithium-ion battery through a transistor-based control circuit. This stored solar energy then powers the primary coil, generating an alternating magnetic field that enables contactless energy transfer to the secondary coil mounted in the EV. The received power is rectified and utilized to charge the onboard battery, with an LED indicator providing visual confirmation of active charging. The system eliminates the need for physical connectors, reducing mechanical wear and improving user convenience, especially in outdoor or adverse weather conditions. Through experimental testing, the setup demonstrated efficient short-range energy transfer, though challenges such as coil misalignment, distance sensitivity, and conversion losses were observed. These factors slightly affected overall system efficiency but can be mitigated through improved coil design and alignment mechanisms. Overall, the proposed design illustrates the feasibility of off-grid, solar-assisted wireless EV charging as a step toward green mobility and sustainable transportation infrastructure. It emphasizes the potential for expanding renewable-powered wireless systems in future smart cities and electric mobility ecosystems, promoting a cleaner and more energy-independent future.

Keywords: Renewable energy, automatic EV charging, green energy solution, solar wireless electric vehicle (EV), current, LED, solar energy

INTRODUCTION

Numerous research journals and technical publications contributed valuable insights toward the development of the solar wireless electric vehicle (EV) charging system. Various studies explored similar methodologies that combine solar energy harvesting and inductive wireless power transfer, yet each model incorporated distinct design improvements and innovative features. By analyzing these existing approaches, the proposed system integrates the advantages of both solar and wireless technologies to achieve efficient, contactless, and eco-friendly EV charging [1]. Unlike conventional plug-in systems, this design eliminates mechanical connectors, reducing maintenance and enhancing convenience. The review of prior work guided the optimization of coil configuration, resonance tuning, and power management circuitry, ensuring reliable energy transfer under variable conditions. Additionally, comparative analysis of journal findings helped identify performance challenges such as coil misalignment, range limitations, and efficiency losses, which were addressed through careful experimental validation and system refinement to create a more sustainable and practical charging solution [2]. Capacitive wireless power transmission (CWPT) is an emerging technology that enables efficient wireless energy transfer by using coupling capacitors instead of conventional coils or magnetic induction. In this

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method, an alternating current (AC) voltage is applied to an H-bridge converter equipped with power factor correction (PFC) circuitry to ensure efficient and stable operation [3]. The H-bridge generates a high-frequency AC signal, which is transmitted through the coupling capacitors to the receiver side, where it is converted back into usable electrical power. Unlike traditional inductive power transfer (IPT) systems that rely on magnetic fields, CWPT transfers energy through the electric field established between capacitor plates [4]. This allows the system to operate at high voltage and low current, reducing transmission losses and enhancing efficiency. CWPT offers advantages such as lightweight design, reduced electromagnetic interference, and suitability for compact electronic devices and electric vehicle charging applications [5]. Magnetic Gear Wireless Power Transfer (MGWPT) represents an advanced evolution of wireless energy transfer techniques, differing significantly from Conventional Wireless Power Transfer (CWPT) and Inductive Power Transfer (IPT) systems. MGWPT employs two synchronously rotating permanent magnets (PMs) positioned adjacent to each other, enabling both magnetic coupling and mechanical torque transfer [6]. In this mechanism, the transmitter winding functions as the primary power input, serving as a current source that generates a rotating magnetic field [7]. This field interacts with the secondary magnet to induce mechanical torque and corresponding electrical energy on the receiver side. Unlike conventional inductive systems, MGWPT combines electromagnetic and mechanical energy conversion, resulting in higher torque density, reduced losses, and improved transmission efficiency over short distances. The system holds significant promise for contactless power transmission in applications such as electric vehicles, robotics, and renewable energy systems, offering improved alignment tolerance and efficient energy conversion. The primary permanent magnet (PM) rotates through mechanical interaction, inducing motion in the secondary PM, which experiences torque as a result of this mechanical coupling. During operation, the primary PM functions in generator mode, converting mechanical energy into electrical energy [8]. This generated power is wirelessly transmitted to the secondary PM, where it is conditioned and delivered to the vehicle's battery through a power converter and a Battery Management System (BMS) to ensure optimal charging efficiency and safety. This setup allows efficient power transfer without direct electrical connections, minimizing losses and enhancing system reliability. Among various wireless power transfer techniques, resonant inductive power transfer (RIPT) is considered a more advanced and efficient method compared to conventional Inductive Power Transfer (IPT). RIPT achieves higher power density, greater transfer distances, and improved alignment tolerance, making it a promising technology for next-generation electric vehicle charging systems and sustainable energy applications.

LITERATURE SURVEY

Wireless Power Transfer (WPT) is a promising technology that enables contactless energy transfer, especially useful in electric vehicle (EV) charging. Inductive coupling, which uses a primary and secondary coil, allows energy to transfer through alternating magnetic fields. A study highlighted how magnetic resonance can enhance transfer range and efficiency, addressing common alignment challenges in EVs [9].

Simultaneously, solar energy has gained traction as a sustainable power source. Studies, including those published in IEEE Transactions on Sustainable Energy, emphasize the integration of solar panels in EV charging stations to reduce grid dependency and promote clean energy solutions. This supports the development of off-grid, eco-friendly charging systems [10].

Because of their small size, dependability, and efficiency, lithium-ion batteries are utilized extensively. They effectively store solar energy and ensure a steady supply to the wireless charging circuit, making them ideal for renewable energy applications.

Transistors, like the BC547, are essential to the system's switching functions. Because of their small size, dependability, and efficiency, lithium-ion batteries are utilized extensively. By controlling current flow from the battery to the primary coil, they help regulate energy transfer and improve system efficiency [11].

The viability of integrating WPT with renewable energy sources, such as solar power, has been shown by several prototypes and small-scale models. These setups confirm the practicality of developing cost-effective, environmentally friendly wireless charging systems using readily available components.

PROPOSED METHODOLOGY

In order to create the suggested system, solar energy is first captured by a 12 V solar panel and subsequently stored in a 3.7 V lithium-ion battery. This stored energy is supplied to a primary coil through a transistor-based switching circuit that controls the current flow, allowing the coil to generate an alternating magnetic field. A secondary coil, placed within a small electric vehicle model, receives this magnetic field through inductive coupling [12]. The received energy is then converted back into electrical power, lighting up an LED on the car module to indicate successful charging. The entire setup is tested under natural sunlight to ensure proper energy flow from the solar panel to the car, demonstrating the effective working of a wireless EV charging system powered by clean, renewable energy. Figure 1 shows the block diagram of the proposed system.

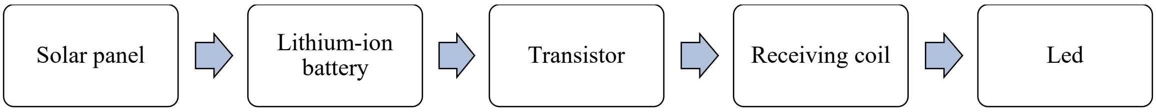

Figure 1. Block diagram of the proposed system.

Working

A 12 V solar panel is installed to harness sunlight and generate DC power. This power is stored in a 3.7 V lithium-ion battery, which serves as the main power source for the transmitter. By controlling the current flowing from the battery to the primary coil, a transistor functions as a switch [13]. The secondary coil in the EV model receives the magnetic field produced by the primary coil. When wireless charging is effective, the secondary coil transforms the magnetic field back into electrical energy to power an LED.

Hardware Description

Solar Panel

A 12 V solar panel is a photovoltaic device that converts sunlight into electrical energy, typically producing around 12 V of DC output (Figure 2). It is commonly used for small-scale applications like battery charging, lighting systems, and portable electronics to obtain the necessary voltage. The panel is made up of several solar cells connected in series. It is lightweight, eco-friendly, and provides a reliable, renewable energy source, especially in off-grid systems [14].

Figure 2. Solar Panel.

Transmitting Coil

The transmitting coil creates a magnetic field when powered by the lithium-ion battery (Figure 3). It acts as the primary element in the inductive coupling system. When current flows through it, an alternating magnetic field is produced, enabling wireless energy transfer. This coil is placed beneath the car module and must be properly aligned with the receiving coil for efficient operation. The coil's number of turns and material affect the transfer distance and strength.

Figure 3. Transmitting coil.

Receiving Coil

The receiving coil is installed on the car module to capture the magnetic field from the transmitting coil (Figure 4). To obtain the necessary voltage, the panel is made up of several solar cells connected in series. Good alignment and matching resonance with the transmitting coil are crucial for maximizing efficiency [15]. This coil demonstrates the principle of wireless power reception in electric vehicles. It forms the core component of the receiver unit.

Figure 4. Receiving coil.

LED

The LED acts as a visual cue that wireless energy transmission is accomplished (Figure 5). When the receiving coil produces enough voltage, it lights to show that charging is underway. LEDs are effective, low-power parts that provide dependable feedback in electronic circuits. The LED in this project stands for the vehicle's successful power delivery. Additionally, it facilitates troubleshooting by displaying system status visually.

Figure 5. LED.

Transistor (BC 547)

An NPN bipolar junction transistor called the BC547 regulates the amount of current that flows from the battery to the primary coil (Figure 6). It functions similarly to a switch in that a greater current can flow from the collector to the emitter when a smaller current is applied at the base. This enables controlled power delivery, improving the efficiency and safety of the system. It plays a crucial role in switching the coil circuit on and off as required [16].

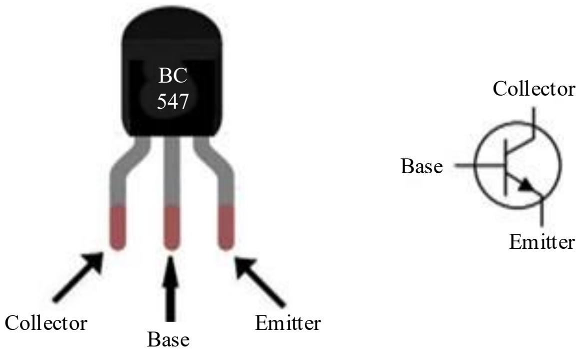

Figure 6. Transistor.

Car Module

The car module in this project simulates a miniature electric vehicle (Figure 7). It houses the receiving coil and LED to demonstrate the concept of wireless EV charging. When placed near the transmitting coil, it receives energy wirelessly and lights up the LED. The module represents how future EVs can be charged without physical connectors. It is an essential part of the prototype to showcase practical implementation.

Figure 7. Car module.

Lithium-Ion Battery

The lithium-ion battery stores energy from the solar panel and powers the primary coil during operation (Figure 8). It is well-known for being lightweight, having a high energy density, and having a low self-discharge rate, making it perfect for tiny, portable systems. It guarantees a steady power supply to the coil even in the absence of sunlight [17]. It is a popular option for energy storage in renewable systems due to its efficiency and rechargeability.

Figure 8. Lithium-ion battery.

RESULTS

The solar wireless EV charging system prototype successfully demonstrates the integration of solar energy with inductive wireless power transfer to charge an electric vehicle (EV) model (Figures 9 and 10). The 12 V solar panel effectively charges the 3.7 V lithium-ion battery, which in turn powers the primary coil through a transistor-based switching circuit. When the toy car (representing an EV) with a secondary coil is brought near the primary coil, energy is transferred wirelessly via magnetic induction. The LED in the car lights up, confirming successful energy reception. This validates the concept of short-range wireless charging using renewable energy, highlighting its potential as a sustainable, off-grid EV charging solution.

Figure 9. Solar wireless EV charging system.

Figure 10. Output of solar wireless EV charging system (LED glows).

CONCLUSION

The solar wireless EV charging system developed in this project provides an innovative solution for clean, efficient, and contactless charging of electric vehicles. By integrating solar energy with inductive wireless power transfer, the system eliminates the dependency on conventional wired chargers and promotes the use of renewable energy sources. The implementation of a 3.7 V lithium-ion battery for energy storage and wireless energy delivery to the vehicle successfully demonstrates the working principle. This project highlights the feasibility of combining green energy with wireless technology to create a sustainable and user-friendly EV charging system.

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