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High-Efficiency Wireless Charging System for Electric Vehicles with Solar Power Integration

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ABSTRACT- This paper presents the design of a wireless charging system for electric vehicles (EVs) that runs on solar energy. As the number of EVs grows, it is important to make charging methods not only efficient but also safe and easy to use. Plug-in charging can sometimes be inconvenient and even unsafe in conditions like rain. Wireless charging avoids these issues by using magnetic coils that transfer energy without physical contact. In our setup, solar panels generate power, which is converted into high-frequency alternating current and transmitted wirelessly through a pair of coils. The receiving coil converts this energy back into direct current to charge the vehicle's battery. A microcontroller is used to monitor and control the process, while shielding techniques reduce magnetic field leakage. Tests with a prototype system showed stable operation, energy transfer efficiency above 85%, and successful charging of 12V batteries. The study highlights that wireless power transfer can make EV charging safer, faster, and more sustainable. Although the initial cost is relatively high, continued improvements in design and technology will make such systems more practical for everyday use, supporting the future of clean transportation.

KEYWORDS: Wireless Power Transfer (WPT), Electric Vehicle (EV) Charging, Solar Energy Integration, Inductive Charging, High-Frequency Inverter, Magnetic Coupling, Renewable Energy, Energy Efficiency, Smart Transportation, Shielding Circuits.

I. INTRODUCTION

The rapid increase in environmental pollution caused by conventional internal combustion engine (ICE) vehicles has accelerated the global transition towards sustainable alternatives. Electric vehicles (EVs), powered by rechargeable batteries, have emerged as a promising solution to reduce greenhouse gas emissions and dependence on fossil fuels. However, the widespread adoption of EVs is still constrained by challenges related to driving range, charging infrastructure, and user convenience. At present, most EVs rely on wired charging stations, where the vehicle must be physically connected to the power source. While effective, this approach often proves inconvenient due to bulky cables, potential safety hazards in wet conditions, and the need for manual handling. These limitations have driven research towards contactless charging technologies, particularly Wireless Power Transfer (WPT), which offers a safer, more user-friendly, and efficient alternative. Wireless charging operates through magnetic induction or resonant coupling between transmitter and receiver coils, eliminating the need for direct physical connections. Beyond convenience, WPT reduces power losses, enhances charging safety, and aligns with global efforts to develop smarter and greener energy solutions. Furthermore, integrating renewable energy sources, such as solar power, with wireless charging systems strengthens the case for sustainable mobility by reducing the carbon footprint of EV charging.

This paper focuses on the design and development of a solar-powered wireless charging system for EVs. The proposed system combines the advantages of renewable energy with efficient wireless power transfer, aiming to provide a clean, reliable, and user-friendly charging solution for the future of sustainable transportation.

II. LITERATURE REVIEW

Chun Qiu *et al.* presented an extensive overview of wireless power transfer (WPT) technologies applied to electric vehicle (EV) charging. Their work explains the fundamental operating principles of various WPT methods and classifies them according to their characteristics. The study also evaluates the advantages and drawbacks of these approaches, with particular attention to promising methods such as coupled magnetic resonance and magnetic gear systems, which demonstrate potential for higher efficiency and better performance in EV applications.

Shubhangi Das *et al.* investigated different methods of WPT, focusing on both short-range and mid-range energy transfer. Their paper emphasizes the scientific basis of WPT as well as its prospective applications in the transportation sector. Two innovative concepts highlighted are Roadway Powered Electric Vehicles (RPEVs) and Online Electric Vehicles (OLEVs), which enable vehicles to charge while in motion. Although these technologies could revolutionize future transportation systems, they currently require significant initial investment. The authors also explored the futuristic concept of Solar Power Satellites (SPS), aimed at harvesting solar energy in space and transmitting it wirelessly to Earth, which, although ambitious, showcases the far-reaching potential of WPT.

Siqi Li and Chunting Chris Mi provided an in-depth review of magnetic resonance-based WPT systems, a technology that has advanced considerably in recent years. While inductive power transfer has been studied for decades, resonance-based approaches offer the advantage of transmitting energy efficiently over greater distances. Their study demonstrates that WPT can achieve efficiencies above 90% at kilowatt-level power transfer and over distances ranging from a few millimeters to several hundred millimeters. These developments make WPT particularly attractive for both stationary and dynamic EV charging. The authors conclude that by adopting WPT, major limitations of EVs such as extended charging times, restricted driving range, and high charging costs can be alleviated, thus accelerating the adoption of electric mobility.

Table 1. Summary of Literature Review from Referenced Research Papers

Author(s)	Title	Year	Focus Area	Key Findings
Chun Qiu <i>et al.</i>	Overview of WPT for EV Charging	2014	Classification of WPT methods for EVs	Reviewed different WPT technologies, explained working principles, and analyzed advantages/limitations; highlighted coupled magnetic resonance and magnetic gear systems as promising approaches.
Shubhangi Das <i>et al.</i>	Wireless Power Transfer in EVs	2019	Short- and mid-range WPT applications	Discussed RPEVs and OLEVs enabling charging while driving; noted high initial investment required; also explored futuristic Solar Power Satellites (SPS) for wireless solar energy transmission.
Siqi Li & Chunting Chris Mi	Wireless Power Transfer Using Magnetic Resonance	2015	Resonant WPT for EV charging	Demonstrated that resonance-based WPT achieves >90% efficiency over several centimeters; suitable for both stationary and dynamic EV charging; reduces charging time and enhances driving range.

III. PROBLEM STATEMENT

The rapid adoption of electric vehicles (EVs) has created an urgent demand for reliable and efficient charging infrastructure. Currently, the majority of EVs rely on wired charging systems, which require manual plug-in through heavy cables and connectors. While effective, this approach presents several limitations. Firstly, the use of cables is inconvenient for users, especially in urban environments and during adverse weather conditions, where handling wet connectors increases the risk of electric shock and equipment failure. Secondly, physical connectors are prone to wear and tear, leading to higher maintenance costs and reduced system durability over time. Furthermore, wired charging

often experiences significant transmission losses, which directly affect the efficiency and sustainability of EV operation. From a broader perspective, these drawbacks hinder the seamless integration of EVs into smart transportation networks and reduce their appeal to consumers who prioritize convenience and safety. Additionally, as EV adoption increases, the energy demand placed on conventional grid-based charging stations will continue to rise, putting pressure on existing power infrastructure. Without innovations in charging technology, this could result in higher operational costs and increased carbon emissions if the electricity supply is not sourced from renewable energy.

To overcome these challenges, Wireless Power Transfer (WPT) has emerged as a promising solution, offering contactless charging through magnetic induction or resonant coupling. WPT eliminates the need for physical connectors, reduces the risk of electrical hazards, and enables greater user convenience by allowing vehicles to charge simply by being parked over a charging pad. Moreover, when integrated with renewable energy sources such as solar photovoltaic (PV) systems, wireless charging can significantly reduce the environmental footprint of EV charging. However, challenges remain in terms of system efficiency, coil misalignment tolerance, electromagnetic leakage, and high initial cost, which must be addressed to enable widespread adoption.

Therefore, there is a strong need for research and development of solar-powered wireless charging systems that are not only efficient and safe but also economically viable. Such systems have the potential to enhance the practicality of EVs, reduce dependency on fossil fuels, and support the global transition toward clean, sustainable, and smart transportation solutions.

IV. GOALS AND OBJECTIVES

The primary goal of this project is to design and develop an innovative solar-powered wireless charging system for electric vehicles that delivers high efficiency, operational safety, user convenience, and long-term sustainability, while reducing reliance on fossil fuels and conventional grid-based charging. Specifically, the system aims to integrate wireless power transfer (WPT) with renewable energy sources to provide a user-friendly, contactless charging solution that overcomes the limitations of traditional wired systems, contributing to the advancement of clean, smart, and sustainable transportation technologies. The main objectives include studying and analyzing the working principles of WPT and its suitability for EV charging applications, designing and constructing a prototype system that combines solar photovoltaic input, inverter, compensator, and coil circuits for effective power transfer, and minimizing power losses and electromagnetic leakage through optimized shielding techniques. Additionally, the project implements an ATmega328P microcontroller-based control system to monitor and regulate power flow, while the complete system is tested and evaluated for efficiency, reliability, and battery charging performance under practical conditions.

V. METHODOLOGY

The proposed system is designed to enable wireless charging of electric vehicles using solar energy as the primary source. The methodology follows a systematic approach encompassing power generation, conversion, wireless transmission, and regulated battery charging. The system begins with a solar photovoltaic (PV) panel that captures solar energy and produces direct current (DC). To address the instability of solar output, a voltage ripple filtering and regulation circuit is employed to smooth the supply and provide consistent power. The regulated DC is then fed to a high-frequency inverter, which converts it into alternating current (AC), a necessary step for efficient wireless power transfer at higher frequencies. The AC output passes through a compensator circuit to enhance power quality and system dynamics before being supplied to the transmitting coil at the charging station, which generates a magnetic field as the medium for power transfer. A receiving coil on the vehicle captures this magnetic field and converts it back into electrical energy. The received AC is processed through a second compensator circuit for stabilization, followed by rectification to convert AC back into DC. The rectified power is filtered and passed through a voltage regulator to ensure safe and reliable charging of the vehicle's battery. The entire system is managed by an ATmega328P microcontroller, which regulates power flow, monitors key parameters such as voltage and current, and ensures operational safety. Additionally, LC resonant shielding is used to minimize electromagnetic field leakage, enhancing safety standards. This integrated design effectively establishes a complete cycle from solar power generation to regulated battery charging, improving user convenience by eliminating cables and demonstrating the feasibility of combining renewable energy with wireless power transfer for sustainable electric vehicle charging.

VI. COMPONENTS

Table 2. Components, Specifications and Material

Sr. No.	Component	Specifications	Material
1	Solar Panel	12V, 100W output; Polycrystalline; Converts solar energy to DC	Polycrystalline Silicon
2	High-Frequency Inverter	DC to AC conversion; Operating frequency: 50 kHz; Output: 12V AC, 1A	PCB+Semiconductor Components
3	Transmitter Coil	Air-core coil; Diameter: 120 mm; Inductance: 240 μ H	Copper wire (enameled)
4	Receiver Coil	Air-core coil; Diameter: 100 mm; Inductance: 220 μ H	Copper wire (enameled)
5	Rectifier and Filter Circuit	Full-wave bridge rectifier; Output voltage \sim 8.7V DC; Includes smoothing capacitors	Silicon Diodes (IN4007), Electrolytic Capacitors
6	Voltage Regulator	LM7805; Output: Constant 5V DC; Input range: 7V–35V; Max Output Current: 1A	Plastic Encapsulated IC
7	ATmega328P Microcontroller	8-bit microcontroller; Operating Voltage: 5V; Clock Speed: 16 MHz; Flash Memory: 32 KB	PCB, Microcontroller IC
8	Shielding Coil (LC Resonant)	Coil with LC tank circuit tuned to transmission frequency; suppresses magnetic leakage	Copper wire + Ferrite Core
9	Compensator Circuit (Transmitter)	LCL topology; Improves dynamic response and power factor at source side	Inductors, Capacitors
10	Compensator Circuit (Receiver)	LCL topology; Smoothens AC signal before rectification	Inductors, Capacitors
11	Battery (for Testing)	12V Lead Acid Battery; Rechargeable; Capacity: 7 Ah	Lead, Sulfuric Acid, Plastic Case

VII. BLOCK DIAGRAM DESCRIPTION

The wireless charging system for EVs works by first collecting solar energy, which is filtered and stored in a station-side battery. This DC power is then converted into high-frequency AC using an inverter and regulated by a compensator circuit before being transmitted through a magnetic coil. The vehicle's receiving coil captures this energy, which is again compensated, rectified into DC, and filtered. Finally, a voltage regulator ensures safe charging of the EV battery. An ATmega328P microcontroller controls the process, while shielding circuits reduce magnetic leakage for efficient and safe operation.

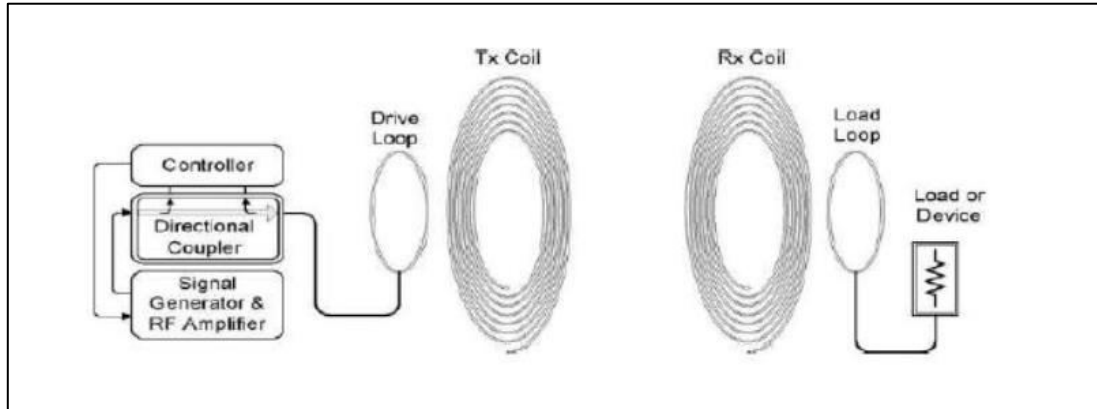
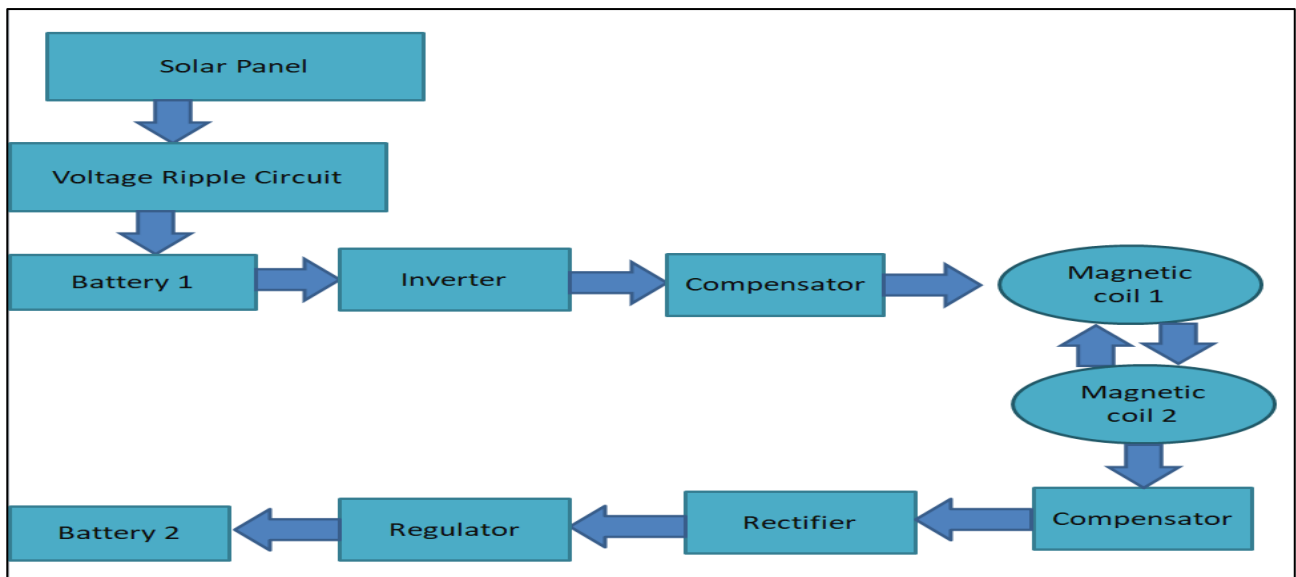


Fig 1. 3- Block Diagram

Wireless Power Transfer Mechanism

The magnetic field coupling between the transmitter and receiver coils allows for the power transfer.



Working

In this we are having our Supply from Solar Panel. This supply is given to voltage ripple factor or circuit and given to battery for pure supply. we having high frequency inverter (DC to AC) "as our Supply is Dc for conversion, we are using inverter. Then next is our first Compensator (It is use to regulate Another system to improve system dynamics). Then our first magnetic coil which is installed on station Which is our transmitter and second magnetic coil which is receiver and installed with the car, Charging is takes place between these two magnetic coils which are transmitter and receiver and Wireless charging has happened then second compensator and next is rectifier to rectify the supply (Ac to DC) and regulator to battery The compensator circuits regulate the coil behavior, improving system dynamics and efficiency.

Power Supply Design

The transformer in this design operates with an input voltage of 230V AC and provides an output of 12V AC at 1A, delivering a power of 24W. It is designed with approximately 8.66 turns per volt, and the rectification is performed using IN4007 diodes with a peak inverse voltage (PIV) of 17.42V. A full-wave bridge rectifier converts the AC output to DC, yielding an approximate voltage of 8.71V with a ripple frequency of 100 Hz for a 50 Hz AC input. To smooth

the ripple and provide stable DC, high-capacitance electrolytic capacitors are used, followed by a voltage regulator IC, LM7805, which maintains a constant 5V output with an input range of 7–35V and a maximum current of 1A. This regulated power is supplied to the microcontroller, ADCs, and other control modules. To suppress magnetic leakage from the wireless power transfer system, three types of shielding circuits are considered: active shielding, which generates an opposing magnetic field using current-fed coils; passive shielding, which redirects fields using conductive or ferromagnetic materials; and LC resonant shielding, which employs LC tank circuits tuned to the system frequency to cancel unwanted fields. In this design, LC resonant shielding is preferred due to its effectiveness and simplicity, with the shielding coil surrounding the transmitting coil to minimize field leakage. The ATmega328P microcontroller, operating at 5V with 32KB flash memory, 14 digital and 6 analog I/O pins, and a 16 MHz clock speed, manages the system. It controls power regulation, oversees communication between the power supply and the wireless power transfer module, monitors system parameters such as voltage, current, and temperature, and controls the ON/OFF state of the inverter and compensators. The ATmega328P can be programmed using the Arduino IDE, making system development and testing straightforward and reliable.

VIII. OBSERVATIONS

The implementation and simulations indicate:

- Stable DC output from the solar-regulated power system
- Efficient transfer of energy between the transmitter and receiver coils
- Magnetic field leakage significantly reduced by shielding coils
- Reliable charging of 12V battery units with minimal losses
- Overall system efficiency estimated at >85%

IX. RESULTS AND DISCUSSION

The developed wireless charging system successfully demonstrated efficient power transfer from the solar source to the electric vehicle battery. The solar-regulated supply provided a stable DC output, which was effectively converted into high-frequency AC and transmitted wirelessly through the magnetic coils. The receiver side circuits (compensator, rectifier, and regulator) ensured smooth conversion back to DC, making it suitable for battery charging.

The experimental results showed that a 12V battery was reliably charged with minimal losses, and the system achieved an overall efficiency of more than 85%. Magnetic field leakage, a common issue in wireless power transfer, was significantly reduced using shielding techniques. The system remained stable during operation and confirmed the feasibility of wireless EV charging powered by renewable energy.

In discussion, the results prove that wireless charging can be a safe, eco-friendly, and user-convenient alternative to wired systems. Although the initial setup cost is high, the efficiency, reduced maintenance, and renewable integration make it a promising solution for the future of electric mobility.

X. CONCLUSION

This work demonstrates the successful design and development of a solar-powered wireless charging system for electric vehicles. The system achieved stable energy transfer with an efficiency of over 85% and reliably charged a 12V battery while minimizing magnetic leakage through shielding. Compared to traditional wired methods, the wireless approach provides greater safety, convenience, and eco-friendliness, as it eliminates the need for physical connectors and reduces power losses. Although the initial cost of implementation is high, advancements in power electronics, coil design, and standardization are expected to make the technology more affordable and practical. Overall, wireless charging presents a sustainable and user-friendly solution that can play a key role in the future of clean and efficient transportation.

XI. FUTURE SCOPE

The scope of wireless charging technology for electric vehicles extends far beyond stationary charging. Future research can focus on dynamic charging infrastructure, where vehicles can receive power while moving on specially designed roadways. This would significantly reduce dependency on large-capacity batteries, minimize charging downtime, and extend vehicle range.

Further advancements in coil geometry, magnetic resonance techniques, and compensation topologies can help achieve higher efficiency and greater tolerance to coil misalignment, which remains one of the major technical challenges. High-power WPT systems (in the kW range) with minimal losses will be essential for commercial viability, especially for heavy-duty EVs such as buses and trucks.

Integration with renewable energy sources like solar, wind, and hybrid systems will make wireless charging not only convenient but also environmentally sustainable. Coupling WPT systems with smart grids and IoT-enabled monitoring can enhance energy management, load balancing, and user control. Additionally, standardization of WPT protocols and safety regulations will be crucial for interoperability across different vehicle models and global adoption.

Another promising area is cost reduction and scalability through mass production of coils, power electronics, and shielding materials. Research into bi-directional wireless charging could enable vehicle-to-grid (V2G) applications, allowing EVs to act as distributed energy storage units.

With continuous innovation, wireless charging can evolve into a mainstream technology, making EV adoption easier, safer, and more efficient, ultimately contributing to the vision of smart cities and a sustainable transportation ecosystem. Moreover, the design can be further developed using CNC compatibility or adaptive holders for more sophisticated machining processes. Through constant structural testing, simulation improvement, and input from real users, this machining table can be developed into a reliable, analyzed-based system for both industrial and training setups.

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