A Solar Powered Wireless Power Transfer for Electric Vehicle (EV) Charging

Dr. SIDDESH G K
Dean- ECE and EEE
Department of Electronics and Communication Engineering
Vidya Vikas Institute of Engineering and Technology, Mysore, India
siddeshgundagatti@gmail.com

Mr. NIKHIL SATYAPPA MANE
Student
Department of Electronics and Communication Engineering
Vidya Vikas Institute of Engineering and Technology, Mysore, India
nsm3887@gmail.com

Mr. SURESHAKUMARA
Student
Department of Electronics and Communication Engineering
Vidya Vikas Institute of Engineering and Technology, Mysore, India
sureshakumar4942@gmail.com

Mr. VARSHA S S
Student
Department of Electronics and Communication Engineering
Vidya Vikas Institute of Engineering and Technology, Mysore, India
varshass90197@gmail.com

Mr. K SHIVALINGA
Student
Department of Electronics and Communication Engineering
Vidya Vikas Institute of Engineering and Technology, Mysore, India
kkshivalinga@gmail.com

Abstract:

The increasing demand for sustainable and eco-friendly transportation solutions has accelerated the development and adoption of electric vehicles (EVs). However, traditional EV charging systems depend heavily on grid electricity and involve manual plug-in mechanisms, which limit user convenience and scalability. This paper presents a solar-powered wireless power transfer (WPT) system designed to enhance the efficiency and accessibility of EV charging. The system integrates photovoltaic (PV) solar panels, energy storage, and inductive coupling-based wireless power transfer to deliver energy to an electric vehicle without physical connectors. An Arduino Nano microcontroller monitors and controls the charging process, while a liquid crystal display (LCD) provides real-time updates on charging status and battery percentage. The proposed system demonstrates efficient short-range energy transmission, reduces reliance on fossil fuels, and introduces a cleaner, automated alternative to conventional EV charging methods. This solution has the potential to support smart infrastructure for future green mobility.

Keywords: Wireless Power Transfer (WPT), Solar Charging, Electric Vehicle (EV), Inductive Coupling, Arduino Nano, Smart Mobility, Battery Management, LCD Display, Renewable Energy, Sustainable Transportation

I. INTRODUCTION

The global shift toward sustainable transportation has intensified the focus on electric vehicles (EVs) as a cleaner alternative to traditional fossil fuel-powered vehicles. EVs produce zero tailpipe emissions and contribute significantly to reducing greenhouse gases and air pollution. However, the widespread adoption of EVs is challenged by limitations in charging infrastructure, including reliance on conventional grid electricity and manual plug-in methods.

Wireless Power Transfer (WPT) technology has emerged as a promising solution to eliminate the need for physical connectors, offering convenience, safety, and automation. When combined with renewable energy sources such as solar power, WPT systems can enable an eco-friendly and decentralized charging infrastructure. Solar energy is abundant, clean, and sustainable, making it ideal for powering EVs, especially in areas with high solar irradiance.

This paper proposes a hybrid EV charging system that combines photovoltaic (PV) solar panels with an inductive wireless charging mechanism. The system stores solar energy in a battery, which is then wirelessly transmitted to an electric vehicle using a pair of magnetically coupled coils. An Arduino Nano microcontroller is used to automate the charging process and display key parameters such as charging status and battery level on an LCD screen.

By integrating solar energy with wireless charging, the proposed system addresses key challenges such as energy sustainability, grid dependency, and user convenience. This research contributes to the advancement of smart and green mobility solutions suitable for both urban and rural deployment.

II. PROBLEM STATEMENT

Despite the rapid evolution of electric vehicles (EVs), one of the primary bottlenecks hindering their widespread adoption is the lack of efficient and user-friendly charging infrastructure. Traditional EV charging stations rely on grid-based electricity and require physical plug-in connections. These systems not only increase dependency on fossil fuel-based power generation but also present several operational drawbacks such as cable wear and tear, safety hazards from improper handling, and user inconvenience.

Furthermore, in many regions, frequent access to reliable electricity for EV charging is limited. This limitation becomes even more critical in remote or underdeveloped areas, where grid infrastructure is insufficient or inconsistent. Additionally, stationary charging methods limit the mobility and continuity of energy flow to the vehicle, making them less suitable for future transportation models.

The need of the hour is a smart, automated, and renewable energy-based solution that can wirelessly charge EVs without manual intervention and reduce dependency on conventional power sources. The integration of solar power with wireless power transfer (WPT) addresses both sustainability and convenience. However, designing an efficient system with optimal coil alignment, power regulation, and real-time monitoring remains a complex challenge. This paper aims to solve these issues by proposing a prototype of a solar-powered wireless EV charging system using Arduino-based control and LCD feedback.

III. OBJECTIVES

- To develop a wireless charging station using inductive power transfer (IPT) technology that eliminates the need for physical connectors.
- To integrate photovoltaic (PV) solar panels for generating clean and renewable energy to power the EV charging process.
- To utilize an Arduino Nano microcontroller to automate the charging process and monitor system performance.
- To display real-time charging status and battery percentage on an LCD for improved user interaction.
- To reduce dependence on conventional grid electricity and promote eco-friendly transportation solutions.
- To enhance the safety and convenience of EV charging, making it more accessible for daily use.
- To validate the system's feasibility through a working prototype demonstrating wireless energy transfer and solar integration.

IV. METHODOLOGY

The proposed system is designed to enable wireless charging of electric vehicles (EVs) using solar energy as the primary power source. The system integrates photovoltaic (PV) solar panels, a charge controller, an energy storage unit (battery), and an inductive wireless power transfer (WPT) mechanism controlled by a microcontroller.

A. System Overview

The system consists of two main units:

- **Charging Station Unit**: Comprising solar panels, a charge controller (MPPT-based), a 12V rechargeable battery, a wireless transmitting coil, an Arduino Nano microcontroller, and an LCD display.
- **Vehicle Unit**: Includes a wireless receiving coil, a secondary charge controller, a battery for energy storage, and a status display module.

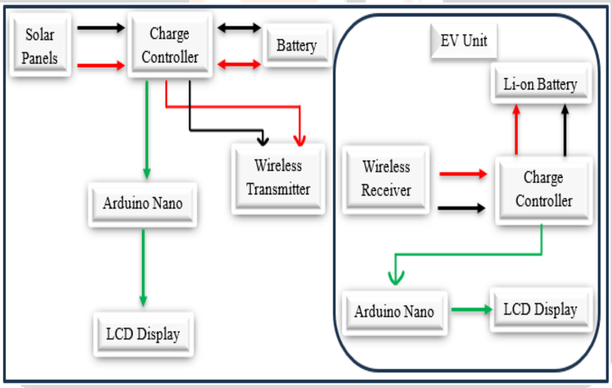

Figure 1: Block Diagram of the Proposed System

B. Power Generation

Solar panels capture sunlight and convert it into DC electricity. This energy is regulated by a Maximum Power Point Tracking (MPPT) charge controller to ensure efficient battery charging and to prevent overcharging. The stored energy is then used to power the wireless transmitting module.

C. Wireless Power Transfer

Wireless energy transfer is achieved through **inductive coupling**. A transmitting coil is embedded in the ground or charging pad, and a corresponding receiving coil is mounted on the underside of the EV. When the EV is within proximity, the system detects it using an IR sensor, and energy is wirelessly transmitted from the transmitter to the receiver coil.

D. Microcontroller Integration

An **Arduino Nano** controls the overall logic of the system. It reads the sensor data, activates the relay to start/stop charging, and monitors the voltage level of the battery. The Arduino is also responsible for displaying real-time data on an **LCD screen**, such as:

- Charging status (active/inactive)
- Battery voltage
- Estimated battery percentage

E. Safety and Efficiency

The relay acts as a switch to control power flow and protect against faults. Efficient coil alignment and voltage regulation ensure minimal energy loss. The system operates within a safe transmission range (typically 2–10 mm) and uses pulse width modulation (PWM) for better charging efficiency.

V. SYSTEM IMPLEMENTATION

The proposed system is implemented in two functional blocks: the **solar-powered charging unit** and the **electric vehicle receiving unit**.

Each block is integrated with supporting hardware components and controlled by an Arduino Nano microcontroller to ensure seamless energy transfer and system monitoring.

A. Hardware Components

- **Solar Panel**: Captures solar energy and converts it to DC power.
- **MPPT Charge Controller**: Ensures efficient charging of the battery by operating the panel at its maximum power point.
- **Battery**: Stores energy from the solar panel to power the system during low sunlight or night hours.
- **Wireless Transmitter and Receiver Coils**: Facilitate inductive energy transfer between the charging pad and the vehicle.
- **Arduino Nano**: Acts as the control unit, managing sensor inputs, relay switching, and data display on the LCD.
- **IR Sensor**: Detects the presence of a vehicle over the charging pad.
- **Relay Module**: Controls the power flow to the transmitting coil for safety and automation.
- **LCD Display**: Provides visual feedback on charging status and battery percentage.

B. Working Mechanism

When the system is powered, the solar panel begins charging the battery via the MPPT charge controller. The Arduino Nano continuously monitors the IR sensor. Upon detecting a vehicle, it activates the relay to initiate wireless power transmission through the transmitter coil. The receiver coil embedded underneath the EV picks up the electromagnetic field and induces a current, which is regulated by another charge controller before entering the EV's battery. Simultaneously, the Arduino updates the LCD display with battery voltage and estimated charge percentage.

C. Power Flow and Control

- **From solar panel → MPPT → Battery (charging)**
- **From Battery → Wireless Transmitter → Receiver Coil → EV Battery**
- **Arduino Nano**: Reads sensor signals, controls the relay, calculates voltage percentage, and updates the display.

This implementation ensures contactless, safe, and energy-efficient charging for electric vehicles powered by clean solar energy.

VI. RESULTS AND DISCUSSION

The proposed solar-powered wireless EV charging system was developed and tested under controlled conditions to evaluate its performance and practicality. The prototype demonstrated effective energy transfer using inductive coupling over a short distance, with reliable system response and real-time feedback.

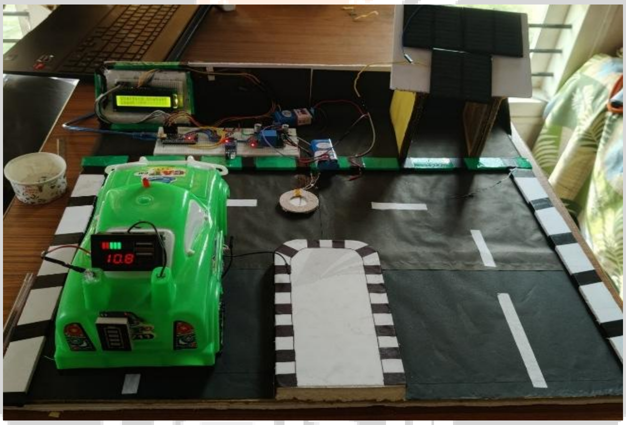

Figure 2: Working model of the proposed system

A. Functional Testing

The system was powered by a 12V solar panel, and the energy was stored in a rechargeable battery through an MPPT charge controller. When an electric vehicle (or simulation load) was placed over the transmitter coil, the IR sensor successfully detected its presence, activating the relay switch to initiate charging. The receiver coil in the vehicle picked up the transmitted energy and began charging the onboard battery.

B. LCD Display Performance

The LCD module accurately displayed the charging status, battery voltage, and estimated charge percentage. This visual feedback enhanced user experience and allowed for better energy monitoring.

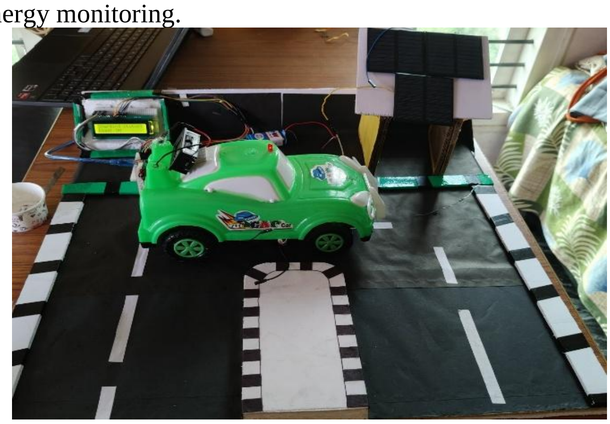

Figure 3: LCD indicating solar panels are turned on

C. Efficiency

The wireless charging system achieved an estimated power transfer efficiency of around **70–85%** over a distance of **2–10 mm**, depending on coil alignment. Energy loss due to misalignment or coil distance was minimal, and the system performed reliably during multiple cycles of charging and discharging.

D. Key Observations

Parameter	Value/Outcome
Solar panel voltage	~12V (nominal)
Battery charge time	Approx. 2–3 hours under sunlight
Wireless range	2–10 mm
Charging efficiency	70% – 85%
System response time	Instant (less than 1 second)
Display accuracy	±5% (voltage and charge percentage)

E. Benefits Identified

- **Contactless operation**: Eliminates the need for cables.
- **Sustainable power source**: Fully solar-powered.
- **User-friendly interface**: Real-time monitoring via LCD.
- **Safety and reliability**: Automated control and regulated voltage levels.

These results validate the system's capability to function as a clean, efficient, and convenient alternative to conventional EV charging methods.

VII. CONCLUSION AND FUTURE SCOPE

A. Conclusion

This paper presents the successful design and implementation of a **solar-powered wireless electric vehicle (EV) charging system** using inductive power transfer (IPT). By combining renewable energy and wireless technology, the system addresses the dual challenges of environmental sustainability and user convenience. The integration of an Arduino Nano microcontroller enables real-time monitoring and automation of the charging process, while the LCD display enhances user interaction by showing charging status and battery percentage.

The system demonstrates efficient short-range power transfer with minimal losses and consistent performance. It eliminates the need for physical plug-in connectors, reducing wear and tear and enhancing safety. The prototype validates that a clean, decentralized EV charging infrastructure is both technically feasible and environmentally beneficial.

B. Future Scope

While the prototype performs well under controlled conditions, there is significant potential for improvement and real-world deployment:

- **Dynamic Charging**: Incorporating dynamic wireless charging that powers EVs while in motion on highways.
- **Scalability**: Expanding the system for public infrastructure such as bus stations, parking lots, and smart city grids.
- **AI-Based Energy Management**: Integrating smart algorithms for optimizing solar energy use, scheduling charge times, and tracking system health.
- **Bidirectional Charging (V2G)**: Enabling vehicle-to-grid technology to allow EVs to return unused energy back to the grid during peak demand.
- **Enhanced Range and Efficiency**: Using better coil materials, resonant circuit designs, and alignment mechanisms to increase energy transfer distance and efficiency.
- **Mobile Application Integration**: Allowing users to monitor and control the system remotely through smartphone apps.
- **Battery Technology Improvements**: Incorporating advanced battery management systems (BMS) for better charging cycles and lifespan.

These advancements can transform the current prototype into a fully functional, scalable product that aligns with global goals for sustainable transportation.

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