

Solar Powered Wireless Vehicle Charging Station

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Abstract - Wireless charging technology for electric vehicles (EVs) provides a convenient and efficient solution to overcome the limitations of conventional plug-in charging systems. This project presents the design and implementation of a Solar-Powered Wireless Vehicle Charging Station with dual charging spots. The system leverages inductive power transfer to enable cord-free battery charging. Powered primarily by a solar panel with battery storage backup, an Arduino Nano microcontroller manages the charging process using vehicle detection sensors (HC-SR04) to automatically activate the corresponding transmitter coil only when a vehicle is present. A 16×2 LCD screen provides a real-time user interface. The system successfully demonstrates a proof-of-concept for a decentralized, eco-friendly charging solution, integrating renewable energy with smart, sensor-based control. The high-frequency inductive coupling technique transfers electrical power wirelessly between a stationary charging station and an electric vehicle using a half-bridge inverter and air-core coils, achieving safe, contactless, and reliable energy transfer.

Keywords: Wireless Power Transfer (WPT), Electric Vehicle (EV) Charging, Solar Energy, Inductive Coupling, Arduino Nano, HC-SR04 Ultrasonic Sensor, KA3525 PWM Controller, Sustainable Energy.

I. INTRODUCTION

The global transportation sector is undergoing a profound shift from internal combustion engines to Electric Vehicles (EVs), driven by the urgent need to reduce greenhouse gas emissions and combat climate change. However, widespread EV adoption is intrinsically linked to the availability of robust, convenient, and accessible charging infrastructure. Traditional conductive (plug-in) charging systems present several hurdles such as the need for physical connectors, cable management issues, connector compatibility, and potential wear and tear. Furthermore, simply increasing plug-in stations does not address the root energy source, which often still comes from fossil fuels.

This project addresses these challenges through the convergence of two transformative technologies: wireless power transfer (WPT) and solar energy harvesting. Wireless charging offers a seamless "park-and-charge" user experience

that enhances convenience and safety. Simultaneously, powering this system with solar energy creates a truly sustainable, off-grid solution that decouples EV charging from the conventional power grid, reducing its carbon footprint and promoting energy independence.

Wireless charging for EVs is primarily based on the principle of electromagnetic induction, where electrical energy is transferred across an air gap through a magnetic field. This approach offers contactless power transfer, reducing maintenance requirements while improving safety and ease of use. This project focuses on the development of a stationary wireless charging station using high-frequency inductive coupling.

II. PROBLEM STATEMENT

The current ecosystem for EV charging faces several critical challenges:

- **Grid Dependency:** Most charging stations draw power from the electrical grid, which may still be heavily reliant on non-renewable sources, thereby offsetting the environmental benefits of EVs.
- **Inconvenience:** Plug-in charging requires manual effort, standardized connectors, and can be problematic in adverse weather conditions.
- **Infrastructure Scalability and Cost:** Installing traditional charging stations with extensive wiring and grid connections can be costly and complex, limiting their deployment in certain areas.
- **Energy Inefficiency:** Stations may remain powered and consuming energy even when no vehicle is present for charging.

III. OBJECTIVES

The primary aim of this project is to design, prototype, and test a functional model of a solar-powered, wireless charging station for electric vehicles. The specific objectives are:

- To integrate a solar photovoltaic panel with a battery storage system to create a renewable energy source for the station.

V. PROPOSED SYSTEM

A. System Overview

The proposed wireless charging station consists of two major subsystems: the transmitter unit and the receiver unit, powered by a solar-battery combination and managed by an Arduino Nano microcontroller. The system provides dual charging spots with automatic vehicle detection and activation.

IV. LITERATURE REVIEW

Wireless power transfer (WPT) for electric vehicle charging has been an active area of research due to its potential to improve charging convenience and system reliability. The following review summarizes significant studies relevant to the proposed system.

Kurs et al. (2007) demonstrated highly efficient, mid-range transfer of power using strongly coupled magnetic resonances, powering a 60-watt light bulb at two meters with ~40% efficiency. This work forms the direct theoretical basis for modern resonant inductive charging [1].

Covic and Boys (2013) provided a comprehensive review of inductive power transfer (IPT) systems, emphasizing that air-core circular coils are well suited for high-power applications due to their robustness and reduced core losses [2].

Mi et al. (2016) investigated modern advancements in wireless charging systems for roadway-powered EVs, emphasizing high-frequency inverters and optimized coil geometries. Their findings demonstrate that properly designed inductive systems operating in the tens of kilohertz range can achieve reliable and efficient power transfer [3].

Budhia, Covic, and Boys (2011) focused on the design and optimization of circular magnetic structures for IPT systems. Their study concluded that circular planar coils with optimized winding parameters provide uniform magnetic flux distribution and improved tolerance to lateral misalignment [6].

Singh et al. (2022) addressed dual-receiver wireless charging, finding that with proper frequency tuning and time-division multiplexing (TDM), a single source could effectively power two receivers. This research directly supports the dual-spot objective of the present project.

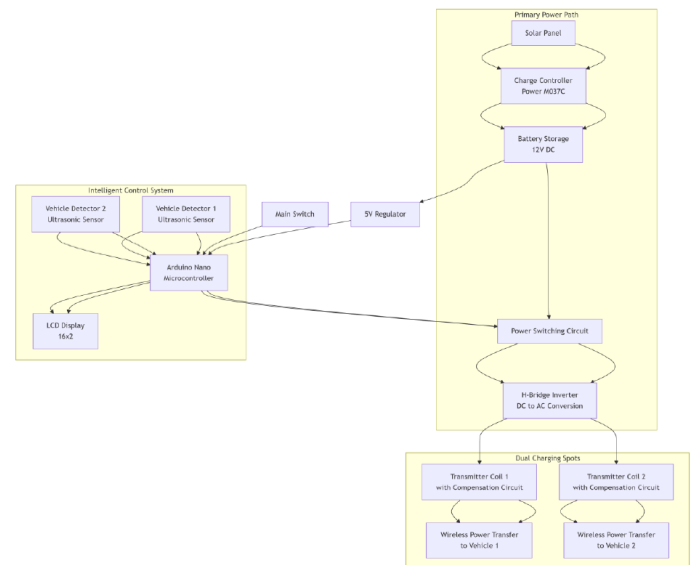


Figure 1: Block diagram of Proposed System

B. Transmitter Unit

The transmitter unit is powered by a 12 V DC supply derived from the solar-battery storage system. This DC voltage is converted into high-frequency AC using a MOSFET-based half-bridge inverter controlled by a KA3525 PWM generator IC. The inverter operates at a switching frequency of 65 kHz, selected to ensure efficient inductive coupling while minimizing core losses and electromagnetic interference. The high-frequency AC output is fed to a ferrite-core transformer (EC28 type) that provides isolation and appropriate voltage drive for the transmitter coil. The transmitter coil generates an alternating magnetic field that propagates across the air gap to the receiving coil.

C. Receiver Unit

On the receiver side, a coil mounted beneath the EV intercepts the magnetic field and produces a corresponding high-frequency AC voltage. This voltage is rectified using a fast-switching bridge rectifier and filtered using a capacitor to obtain a stable DC output suitable for charging a lithium-ion battery. Voltage feedback from the rectifier output is provided to the PWM controller to maintain stable inverter operation.

D. Solar Power and Energy Storage

The station is powered primarily by a solar panel, making it a green and self-sustaining solution that reduces the load on the conventional power grid. A battery storage system ensures energy availability during periods of low sunlight or at night, providing uninterrupted charging capability.

E. Control System

An Arduino Nano microcontroller intelligently manages the charging process. HC-SR04 ultrasonic sensors detect vehicle presence and automatically activate the corresponding transmitter coil only when a vehicle is detected, optimizing energy efficiency and safety. A 16×2 LCD screen provides a real-time user interface displaying system status such as vehicle detection and charging activity.

VI. WIRELESS POWER TECHNOLOGY

The principles upon which wireless electric power transmission is realized are generally categorized into three types:

- Electromagnetic Induction Type: Employs the phenomenon in which application of an electric current to one of adjacent coils induces an electromotive force in the other coil with magnetic flux as the medium.
- Radio Reception Type: Utilizes propagating electromagnetic waves for power transfer over longer distances.
- Resonance Type: Employs strongly coupled magnetic resonances for efficient mid-range power transfer.

This project utilizes the resonant inductive coupling approach. When the vehicle's power receiver's resonance frequency matches that of the transmitter unit, electrical power flows from the transmitter coil inside the platform to the receiving coil inside the bottom of the electric vehicle. This approach is one million times more efficient than simple electromagnetic induction for mid-range applications.

VII. KEY HARDWARE COMPONENTS

A. Arduino Nano Microcontroller

The Arduino Nano serves as the central control unit. It processes sensor signals from the HC-SR04 ultrasonic distance sensors and controls the activation of each charging transmitter coil accordingly. It also drives the LCD display for real-time status output.



Figure 2: Working Prototype

B. HC-SR04 Ultrasonic Sensor

The HC-SR04 sensor provides vehicle detection capability. It generates an ultrasonic burst and measures the echo return time to calculate the distance to an object, enabling the system to determine whether a vehicle is positioned over the charging pad.

C. Power MOSFET

Power MOSFETs are used in the half-bridge inverter to switch the DC supply at 65 kHz. Their main advantages include high commutation speed and good efficiency at low voltages, making them ideal for high-frequency power conversion.

D. KA3525 PWM Controller

The KA3525 regulating pulse width modulator contains all control circuitry necessary to implement switching regulators. It includes a 5V voltage regulator, control amplifier, oscillator, pulse width modulator, phase-splitting flip-flop, dual alternating output switch transistors, and current limiting and shutdown circuit. The device operates beyond 100 kHz with 2% frequency stability with temperature.

E. EC28 Ferrite Core Transformer

The EC28 vertical ferrite core transformer provides isolation and appropriate voltage conversion. Specifications: Primary – 15 turns, 18 SWG; Secondary – 24 turns, 20 SWG. Bobbin size: 25 × 23 × 32 mm; Ferrite core size: 28.5 × 11.5 × 14 mm.

VIII. WIRELESS POWER CALCULATIONS

A. Air Core Coil Inductance

The inductance of the air-core transmitter and receiver coils was calculated based on the physical dimensions including coil diameter, number of turns, and wire gauge.

These values were verified using standard inductance calculation tools.

B. LC Resonance Frequency

The LC resonance frequency of both the transmitter and receiver circuits was calculated using the formula:

$$f = 1 / (2\pi\sqrt{LC})$$

The resonance frequencies of the transmitter and receiver coils were matched to ensure maximum power transfer efficiency.

C. PWM Frequency of KA3525

The PWM operating frequency of the KA3525 IC is determined by the timing resistor (RT), timing capacitor (CT), and dead-time resistance (RD):

$$f = 1 / [CT(0.7(RT + RD) + 3RD)]$$

Component values were selected to achieve the target operating frequency of 65 kHz for efficient inductive coupling.

IX. SUSTAINABLE DEVELOPMENT GOALS

This project directly contributes to the United Nations' Sustainable Development Goals (SDGs):

- SDG 7 – Affordable and Clean Energy: By utilizing solar power, the project promotes access to sustainable and clean energy sources for transportation.
- SDG 9 – Industry, Innovation, and Infrastructure: Fosters the development of resilient and sustainable infrastructure by integrating innovative wireless technology with renewable energy.
- SDG 11 – Sustainable Cities and Communities: Supports development of sustainable urban environments by providing clean transportation infrastructure.
- SDG 13 – Climate Action: Facilitates the use of EVs with renewable energy, directly contributing to actions against climate change.

X. APPLICATIONS AND ADVANTAGES

A. Applications

- Wireless charging of electric vehicles in parking lots, residential complexes, and commercial areas.
- Powering of cell phones, laptops, and other battery-operated devices in close proximity to the transmitter.
- Medical applications: providing electric power to commercially available medical implantable devices.

- Future applications include dynamic charging where vehicles can be charged while in motion.

B. Advantages

- No Need for Line of Sight: Power transmission is possible even if obstructions like wood or metal are placed between the transmitter and receiver.
- No Power Cables or Batteries Required: Wireless power replaces the use of power cables and connectors.
- Weather Resistant: Eliminates electrical contacts, making the system unaffected by rain, snow, dust, and dirt.
- High Efficiency: Resonant induction is far more efficient than simple electromagnetic induction for mid-range transfer.
- Low Cost: Transmitter and receiver components are commercially available at low cost.
- Safe and Reliable: Eliminates the risk of electric shock through contactless energy transfer.

XI. SCOPE AND LIMITATIONS

A. Scope

This project covers the development of a small-scale, low-power prototype to demonstrate the core concept, including: designing the electronic circuits for power management, control, and wireless transfer; programming the microcontroller for automatic sensor-based operation; using commercially available components like Arduino, HC-SR04 sensors, and standard inductive coils; and testing the system's functionality in a controlled environment.

B. Limitations

- Power and Scale: The prototype is designed for low-power demonstration and is not scaled to charge a full-sized EV due to cost and safety constraints.
- Efficiency: The efficiency of the wireless power transfer at this small scale may be lower than that of commercial systems.
- Environmental Factors: Solar charging capability depends on simulated or ideal lighting conditions in a lab setting.
- Regulatory Compliance: The prototype is not designed to meet all commercial safety and electromagnetic interference (EMI) regulations.

XII. CONCLUSION

This project successfully demonstrates the design and operation of a wireless charging station for electric vehicles using high-frequency inductive power transfer. By employing a half-bridge inverter and air-core coils operating at 65 kHz, the system achieves safe, contactless, and reliable energy

transfer. The elimination of physical connectors enhances user convenience and system durability. The integration of solar energy harvesting with intelligent microcontroller-based control results in a self-sustaining, eco-friendly charging solution.

While the current implementation is suitable for prototype and educational purposes, the concept can be extended to higher power levels and integrated with smart control systems for real-world EV charging applications. Wireless charging technology holds significant potential in shaping the future of sustainable and intelligent transportation systems. The system's weather-resistant contactless design makes it safe, reliable, robust, and clean, paving the way for sustainable and intelligent EV charging infrastructure in urban environments.

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