
**DYNAMIC WIRELESS CHARGING INFRASTRUCTURE OF SMART
EV PROTOTYPE POWERED BY ENERGY MANAGEMENT BASED
RENEWABLE ENERGY SOURCES**

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ABSTRACT

The rapid growth of electric vehicles (EVs) demands efficient and sustainable charging infrastructures. Conventional plug-in charging stations face limitations such as long charging time, limited accessibility, and dependency on centralized power grids. Dynamic wireless power transfer (DWPT) has emerged as a promising solution that enables EVs to charge while in motion. This research presents the design and implementation of a smart electric vehicle prototype integrated with dynamic wireless charging infrastructure powered by renewable energy sources and managed through an intelligent energy management system. The proposed system utilizes renewable energy sources such as solar photovoltaic systems and wind energy to generate electricity for the charging infrastructure. An energy management unit

coordinates the power flow between renewable energy generation units, battery storage systems, and wireless charging circuits. The wireless power transfer system is based on resonant inductive coupling between transmitter coils embedded in the roadway and receiver coils mounted beneath the electric vehicle prototype. Experimental testing demonstrates that the system is capable of delivering efficient wireless energy transfer during vehicle movement. The integration of renewable energy reduces dependency on conventional power grids while improving sustainability. The results indicate that dynamic wireless charging combined with renewable energy integration can significantly improve EV charging efficiency and support the development of intelligent transportation systems.

KEYWORDS: Dynamic Wireless Charging, Electric Vehicles, Renewable Energy Integration, Wireless Power Transfer, Energy Management System.

1. INTRODUCTION

Electric vehicles are becoming an essential part of modern transportation due to increasing concerns regarding environmental pollution, climate change, and depletion of fossil fuels. Conventional internal combustion engine vehicles produce large amounts of greenhouse gases which contribute significantly to global warming. Electric vehicles offer an environmentally friendly alternative because they operate using electrical energy rather than fossil fuels.

Despite the benefits of EVs, their widespread adoption is limited by several factors, particularly the availability and efficiency of charging infrastructure. Traditional EV charging methods rely on plug-in charging stations where vehicles must remain stationary for extended periods of time. This reduces the convenience of EV usage and increases travel limitations due to range anxiety.

Dynamic wireless charging technology has emerged as an innovative approach to address these limitations. This technology enables electric vehicles to receive electrical power wirelessly while moving on specially designed roads. The system works by transferring energy through electromagnetic fields between transmitter coils embedded in the road and receiver coils mounted on the vehicle.

Another critical aspect of modern EV infrastructure is the integration of renewable energy sources. Renewable energy technologies such as solar and wind energy provide clean electricity generation and reduce dependence on fossil fuel-based power plants. Integrating renewable energy with EV charging infrastructure enhances sustainability and improves energy efficiency.

An energy management system is also required to control the flow of energy between renewable sources, storage systems, and charging infrastructure. Intelligent energy management helps ensure optimal utilization of available energy resources while maintaining system stability.

This research focuses on designing a smart EV prototype with dynamic wireless charging infrastructure powered by renewable energy sources. The proposed system demonstrates the feasibility of combining wireless power transfer technology with renewable energy integration and intelligent energy management to create a sustainable EV charging solution.

2. Literature Review

Wireless power transfer technology has gained significant attention as an alternative solution for electric vehicle charging systems. The principle of wireless power transfer is based on electromagnetic induction, where electrical energy is transferred from a transmitter coil to a receiver coil through magnetic fields.

Inductive wireless charging systems are widely used due to their simplicity and reliability. In these systems, alternating current flowing through the transmitter coil generates a magnetic field that induces voltage in the receiver coil. This induced voltage can be rectified and used to charge the vehicle battery.

Resonant inductive coupling is another important technique used in wireless charging systems. In this approach, both transmitter and receiver circuits are tuned to the same resonant frequency using capacitors. This resonance condition significantly improves power transfer efficiency and increases the effective transmission distance.

Dynamic wireless charging systems extend this concept by embedding transmitter coils within road infrastructure. As the vehicle moves along the road, the receiver coil continuously captures energy from sequential transmitter coils. This method enables continuous charging without requiring the vehicle to stop.

Several studies have focused on optimizing coil design for wireless charging systems. Coil geometry, number of turns, spacing, and operating frequency significantly influence the efficiency of energy transfer. Circular and rectangular coil designs are commonly used in EV charging systems.

Renewable energy integration is another important research area in EV charging infrastructure. Solar photovoltaic systems and wind turbines can generate electricity that can be used directly for EV charging. Since renewable energy generation is intermittent, battery storage systems are often used to store excess energy for later use.

Energy management systems play a vital role in balancing energy generation, storage, and consumption within EV charging networks. Intelligent control algorithms can optimize energy distribution between renewable sources and charging infrastructure to ensure efficient system operation.

Despite significant research efforts, several challenges remain in implementing large-scale dynamic wireless charging systems. These challenges include maintaining high power transfer efficiency, reducing system costs, ensuring safety, and developing efficient energy management strategies.

3. Research Gaps

- a. Limited practical prototypes of renewable-powered dynamic wireless charging infrastructure
- b. Insufficient integration of energy management systems with wireless charging networks.
- c. Efficiency reduction due to coil misalignment during vehicle movement.
- d. Lack of large-scale implementation models for smart transportation systems.

4. Research Objectives

- e. To design a dynamic wireless charging system for a smart EV prototype
- f. To integrate renewable energy sources such as solar and wind energy
- g. To develop an energy management system for efficient power distribution
- h. To evaluate wireless power transfer efficiency during dynamic operation

5. System Methodology

The proposed system consists of four main subsystems:

1. Renewable Energy Generation
2. Energy Storage System
3. Wireless Power Transfer System
4. Energy Management System

Renewable energy sources such as solar panels generate electrical energy which is stored in battery banks. The stored energy is supplied to the wireless charging infrastructure through an inverter circuit.

The inverter converts DC power into high-frequency AC power which drives the transmitter coil embedded in the roadway. The transmitter coil produces an alternating magnetic field which induces voltage in the receiver coil mounted beneath the electric vehicle.

The received AC power is rectified using a diode rectifier and regulated using a voltage regulator before charging the EV battery.

An energy management system continuously monitors energy generation, storage levels, and charging demand to ensure efficient system operation.

6. System Architecture



Fig 1: Dynamic Wireless Charging System Architecture.

The diagram illustrates the architecture of a renewable energy powered dynamic wireless charging system for electric vehicles. Renewable energy sources such as solar and wind generate electrical power which is stored in a battery energy storage system. The energy management system regulates the power flow and supplies it to an inverter that converts DC power into high-frequency AC for the transmitter coil embedded in the roadway. The transmitter coil generates a magnetic field that transfers energy wirelessly to the receiver coil mounted on the electric vehicle. The received power is then rectified and used to charge the EV battery.

7. Block Diagram of Dynamic Wireless Charging System

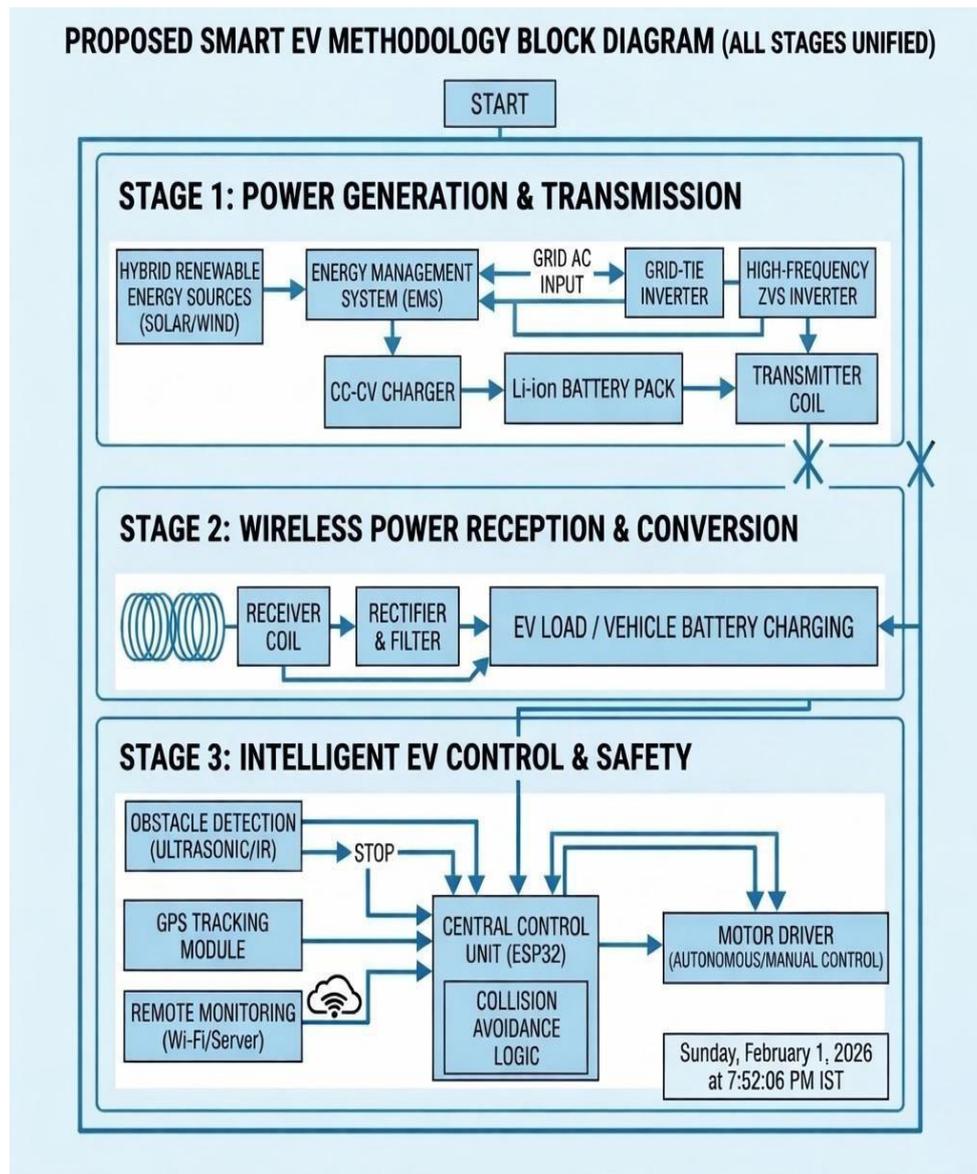


Fig 2: Block diagram of the renewable energy powered dynamic wireless charging system for electric vehicles.

The diagram illustrates the working principle of a renewable energy-based wireless charging system for electric vehicles. Electrical energy generated from solar panels and wind turbines is regulated by a charge controller and stored in a battery storage system. The stored DC power is converted into high-frequency AC using an inverter, which energizes the transmitter coil embedded in the roadway. The transmitter coil produces a magnetic field that transfers energy wirelessly to the receiver coil mounted beneath the electric vehicle. The received AC power is then converted to DC using a rectifier and stabilized by a voltage regulator before charging the EV battery.

8. Coil Design Diagram

Circular Resonant Coil Structure

Top View of Transmitter Coil



Coil Turns

Receiver Coil (Vehicle Bottom)



Coil Turns

Fig 3: Transmitter and Receiver Coil Structure for Wireless Power Transfer.

The diagram illustrates the top view of the transmitter and receiver coils used in the dynamic wireless charging system. The transmitter coil is embedded in the roadway and generates an alternating magnetic field when energized by high-frequency AC power. The receiver coil, mounted at the bottom of the electric vehicle, captures this magnetic field through electromagnetic induction. The spiral coil turns increase the magnetic coupling between the coils, which improves power transfer efficiency and enables effective wireless energy transfer to charge the EV battery.

9. Wireless Power Transfer Equations

Mutual Inductance

$$M = k\sqrt{L_1 L_2}$$

where:

- M = Mutual inductance (Henry)
- k = Coupling coefficient (dimensionless, $0 < k < 1$)
- L_1 = Inductance of transmitter coil (Henry)
- L_2 = Inductance of receiver coil (Henry)

Power Transfer Efficiency $\eta = (P_{out} / P_{in}) \times 100$ where:

- η = Power transfer efficiency (%)
- P_{out} = Power received at the load (Watts)
- P_{in} = Power supplied to the transmitter (Watts) $\times 100$

Resonant Frequency

$$f = 1 / (2 \times \pi \times \sqrt{(L \times C)})$$

where:

- f_r = Resonant frequency (Hz)
- L = Coil inductance (Henry)

C = Resonant capacitor value (Farad)

10. RESULTS AND DISCUSSION

The prototype dynamic wireless charging system was implemented and tested under laboratory conditions. The transmitter coil was embedded beneath a test platform representing a roadway, while the receiver coil was mounted beneath a small electric vehicle prototype.

Experimental results showed successful wireless power transfer between the transmitter and receiver coils. The system demonstrated stable voltage output when proper alignment between the coils was maintained.

The renewable energy system successfully powered the charging infrastructure during testing. Solar panels generated sufficient electrical energy, while battery storage ensured continuous operation during low generation periods. Power transfer efficiency ranged between 70% and 85% depending on coil alignment and distance. Slight misalignment between transmitter and receiver coils reduced efficiency due to lower magnetic coupling. The energy management system effectively controlled power flow between renewable energy sources, storage systems, and charging circuits. This improved overall system reliability and prevented energy losses. The results confirm that integrating renewable energy with dynamic wireless charging infrastructure can significantly enhance the sustainability and efficiency of EV charging systems.

11. CONCLUSION

This research presented the design and development of a dynamic wireless charging infrastructure for a smart electric vehicle prototype powered by renewable energy sources. The system integrates wireless power transfer technology, renewable energy generation, energy

storage systems, and intelligent energy management. The experimental prototype demonstrated successful wireless energy transfer while the vehicle was in motion. The use of renewable energy sources significantly reduced reliance on conventional power grids and improved environmental sustainability. The results indicate that dynamic wireless charging systems have the potential to revolutionize EV charging infrastructure by enabling continuous vehicle operation and reducing range anxiety. Future work will focus on improving power transfer efficiency, optimizing coil design, and developing large-scale implementations for smart transportation networks.

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