# Dynamic Iot Based Wireless Power Transfer on Road for Ev

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***Abstract*—Electric vehicles (EVs) are emerging as a sustainable alternative to conventional internal combustion engine vehicles due to their eco-friendly nature and reduced carbon footprint. However, the widespread adoption of EVs is hindered by challenges related to charging infrastructure, prolonged charging times, and dependency on plug-in charging stations. This project presents an innovative Internet of Things (IoT)-based wireless power transfer system embedded on roadways to charge electric vehicles dynamically while they are stationary or moving at low speeds. The system utilizes inductive coupling technology, where transmitter coils installed beneath the road surface transfer electrical energy to receiver coils mounted on the vehicle chassis. An IoT module, integrated with sensors and relays, continuously monitors the power transfer status, vehicle presence, and charging efficiency. The system eliminates the need for physical connectors, reduces charging downtime, enhances user convenience, and aligns with the vision of smart transportation infrastructure. This prototype demonstrates the feasibility of wireless EV charging integrated with IoT for real-time monitoring and control.**

***Index Terms*—Wireless Power Transfer, IoT, Electric Vehicle, Inductive Coupling, Smart Roads, ESP32, Dynamic Charging Introduction**

## I. INTRODUCTION

The global automotive industry is undergoing a paradigm shift toward electrification, driven by environmental concerns, depleting fossil fuel reserves, and stringent emission regulations. Electric vehicles offer significant advantages, including zero tailpipe emissions, lower operating costs, and reduced noise pollution. Despite these benefits, the adoption of EVs faces substantial barriers, primarily related to charging infrastructure.

Traditional plug-in charging systems require dedicated charging stations, physical connectors, and manual intervention. These systems suffer from several limitations: cable wear and tear, electrical hazards, connector compatibility issues, and the inconvenience of extended parking for charging. Moreover, the limited number of charging stations and long charging durations create "range anxiety" among EV users.

Wireless Power Transfer (WPT) technology offers a promising solution to these challenges. WPT enables contactless energy transmission through electromagnetic induction, allowing vehicles to charge automatically when positioned over charging pads or embedded road coils. This technology enhances safety, eliminates physical wear, and provides seamless integration with autonomous driving systems.

The concept of smart roads with embedded charging infrastructure represents the future of sustainable transportation. By integrating WPT with IoT, this project creates a system that not only transfers power wirelessly but also monitors and controls the entire process remotely. The IoT module provides real-time data on power transfer efficiency, vehicle detection, and system health, enabling predictive maintenance and optimized energy management.

This project demonstrates a working prototype of an IoT-enabled wireless EV charging system, showcasing the potential for dynamic charging infrastructure in smart cities. Objectives

## II. OBJECTIVES

1. To design and develop a wireless power transfer system capable of charging electric vehicles without physical connectors using inductive coupling technology.
2. To reduce dependency on plug-in charging stations by enabling automatic charging when vehicles are stationary or moving over embedded road coils.
3. To integrate IoT-based monitoring and control for real-time tracking of power transfer parameters, vehicle presence, and system performance.
4. To demonstrate a smart, contactless charging solution that enhances user convenience and supports the development of intelligent transportation infrastructure.
5. To evaluate the efficiency and feasibility of dynamic wireless charging for electric vehicles through prototype implementation. Block Diagram
6. The block diagram below illustrates the overall system architecture of the PV-integrated grid using UPQC with differential inverters.

## III. PROBLEM STATEMENT

The widespread adoption of electric vehicles is constrained by inadequate charging infrastructure, prolonged charging times, and the inconvenience associated with plug-in charging systems. Existing charging solutions require physical connectors that are prone to wear, safety hazards, and require manual handling. There is a critical need for a smart, automated, and contactless charging system that can integrate seamlessly with modern transportation networks. Additionally, there is a lack of real-time monitoring capabilities in current charging systems, limiting the ability to optimize energy distribution and predict maintenance requirements. This project addresses these challenges by developing an IoT-based wireless power transfer system embedded on roadways, enabling automatic and monitored charging for electric vehicles.

## IV. LITERATURE REVIEW

The field of wireless power transfer for electric vehicles has gained significant research attention over the past decade. Several studies have explored various aspects of WPT technology, including coil design, power electronics, control strategies, and integration with smart grids.

Kim et al. (2019) investigated the efficiency of inductive power transfer systems for dynamic EV charging, demonstrating that properly designed coil geometries can achieve efficiencies exceeding 85% under optimal alignment conditions. Their work highlighted the importance of coil geometry and resonant frequency matching in maximizing power transfer efficiency.

Liu et al. (2020) proposed a bidirectional wireless power transfer system enabling vehicle-to-grid (V2G) applications. Their research demonstrated that WPT systems can support not only charging but also energy feedback to the grid, enhancing grid stability and enabling energy trading.

Patil et al. (2018) reviewed the state-of-the-art in wireless EV charging, identifying key challenges including coil misalignment tolerance, electromagnetic field (EMF) safety, and cost of infrastructure deployment. The study emphasized the need for standardized protocols and advanced control algorithms to address these challenges.

Ahmad et al. (2021) developed an IoT-enabled wireless charging system with cloud-based monitoring capabilities. Their work demonstrated that integrating IoT with WPT enables real-time monitoring of charging parameters, remote diagnostics, and predictive maintenance, significantly improving system reliability.

Zhang et al. (2022) explored the integration of solar-powered wireless charging roads, demonstrating a self-sustaining infrastructure model. Their research showed that combining renewable energy sources with WPT infrastructure can reduce the carbon footprint of EV charging.

Singh and Sharma (2023) conducted a comparative analysis of inductive versus capacitive wireless power transfer systems for EV applications. Their findings indicated that inductive systems offer higher power transfer capability, while capacitive systems provide better tolerance to misalignment.

## V. EXISTING SYSTEM

1. Current electric vehicle charging infrastructure predominantly relies on plug-in charging systems. These systems can be categorized into three levels:

2. Level 1 Charging (120V AC): Uses standard household outlets, providing slow charging (approximately 4-5 miles of range per hour). This method is convenient for overnight charging but inadequate for rapid charging needs.
3. Level 2 Charging (240V AC): Utilizes dedicated charging stations, delivering faster charging (10-20 miles of range per hour). These stations are common in public parking areas, workplaces, and residential installations.
4. DC Fast Charging (480V DC): Provides rapid charging (60-80 miles of range in 20 minutes) using specialized charging stations. However, these systems are expensive to install and require high-power grid connections.

- While these systems are functional, they share common limitations:
- Physical connectors are subject to wear and environmental degradation
- Manual handling is required, which can be challenging for elderly or disabled users
- Charging stations occupy valuable urban space
- Incompatibility between different connector standards
- No integrated real-time monitoring or predictive maintenance capabilities

5. Some experimental wireless charging systems have been deployed in pilot projects, such as the inductive charging lanes in Sweden and South Korea. However, these systems lack integrated IoT capabilities for comprehensive monitoring and control.

## VI. DRAWBACKS OF EXISTING SYSTEM

1. Physical Connector Wear and Failure: Plug-in connectors experience mechanical wear from repeated mating cycles, leading to eventual failure and safety hazards such as arcing and overheating.
2. Manual Intervention Required: Users must physically connect and disconnect charging cables, which can be inconvenient, especially in adverse weather conditions or for individuals with mobility limitations.
3. Cable Management Issues: Charging cables are prone to damage, theft, and create tripping hazards in public spaces.
4. Limited Charging Infrastructure: The number of public charging stations remains insufficient, particularly in rural and developing regions, contributing to range anxiety.
5. Long Charging Times: Even with fast charging, EVs require significantly more time to charge compared to refueling conventional vehicles.
6. No Real-Time Monitoring: Most existing charging systems lack integrated monitoring capabilities, preventing users and operators from tracking charging status remotely or receiving alerts for anomalies.
7. Incompatibility Between Standards: Multiple connector standards (CHAdeMO, CCS, Tesla Supercharger) create confusion and require adapters or dedicated stations.
8. High Infrastructure Costs: Installing and maintaining plug-in charging stations requires significant investment in electrical infrastructure and physical space.

## VII. PROPOSED SYSTEM

The proposed system is an IoT-based wireless power transfer (WPT) system embedded on roadways to charge electric vehicles automatically. The system consists of two main components: the transmitter unit embedded in the road surface and the receiver unit mounted on the electric vehicle.

System Architecture

The transmitter unit comprises:

- Transmitter Coils: Multiple copper coils arranged in a series along the road segment, connected to a high-frequency power inverter.
- Power Supply Unit: AC-to-DC converter followed by a high-frequency inverter that converts grid power to high-frequency AC suitable for inductive coupling
- Vehicle Detection Sensors: Inductive loop sensors or infrared sensors detect the presence of a vehicle above the charging zone.
- IoT Module (ESP32/NodeMCU): Controls relay operation, monitors power transfer parameters, and communicates with cloud platform.
- Relay Module: Switches the transmitter coils on/off based on vehicle presence and charging requirements.

The receiver unit comprises:

- Receiver Coils: Copper coils mounted on the vehicle undercarriage, tuned to the same resonant frequency as the transmitter coils.
- Rectifier Circuit: Converts high-frequency AC from the receiver coils to DC for battery charging.
- Voltage Regulator: Maintains stable DC voltage for battery charging.
- Rechargeable Battery: Stores the transferred energy for vehicle propulsion.
- Battery Management System: Monitors battery state of charge and controls charging rate.
- IoT Module: Transmits vehicle-side charging data to the cloud.

Working Principle

When a vehicle equipped with a receiver coil approaches a road segment with embedded transmitter coils, the vehicle detection sensors identify its presence. The IoT module activates the transmitter coils via relays. The high-frequency alternating current in the transmitter coils generates a time-varying magnetic field, which induces an electromotive force (EMF) in the receiver coil through electromagnetic induction. The induced AC voltage is rectified and regulated to charge the vehicle battery.

The IoT module continuously monitors:

- Power transfer efficiency
- Current and voltage levels
- Vehicle presence duration
- Battery state of charge
- System temperature

All data is transmitted to the IOT Webpage cloud platform for remote monitoring, visualization, and analysis. Users can access real-time charging status through a web interface or mobile application.

## VIII. BLOCK DIAGRAM

Fig. 1: System Architecture of IoT-Enabled Wireless EV Charging

Hardware Components

1. ESP32 Microcontroller

The ESP32 serves as the primary controller for both transmitter and receiver units. It features dual-core processing, built-in Wi-Fi and Bluetooth connectivity, and multiple analog-to-digital converter (ADC) channels. The ESP32 collects sensor data, controls relays, processes power transfer parameters, and transmits data to the cloud platform. Its low-power capabilities and robust performance make it ideal for IoT applications.

Key Features:
Dual-core 32-bit processor
Integrated Wi-Fi 802.11 b/g/
Bluetooth v4.2
18 ADC channels
520 KB SRAM
Operating voltage: 3.3V

Fig. 2: ESP32 - Dual-Core IoT Controller with Wi-Fi/Bluetooth

2. Wireless Power Transfer Module (Tx & Rx)

The WPT module consists of transmitter and receiver coils tuned to a resonant frequency of 100-200 kHz. The transmitter coil is connected to a high-frequency inverter that converts DC power to high-frequency AC. The receiver coil captures the magnetic field and converts it back to electrical energy. Ferrite cores are used to enhance magnetic coupling and reduce electromagnetic interference.

Specifications:
Operating frequency: 100-200 kHz
Coil inductance: 10-50 µH
Power transfer capability: Up to 50W (prototype)
Coupling coefficient: 0.3-0.7 depending on alignment
Efficiency: 70-85%

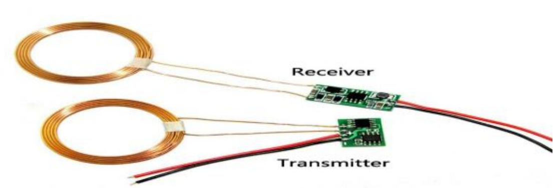


Fig. 3: Inductive Coupling Module - Transmitter and Receiver Coil Assembly

3. Vehicle Detection Sensors
Inductive loop sensors or infrared proximity sensors detect the presence of a vehicle above the charging zone. These sensors ensure that transmitter coils are activated only when a compatible vehicle is present, reducing energy waste and electromagnetic field exposure.

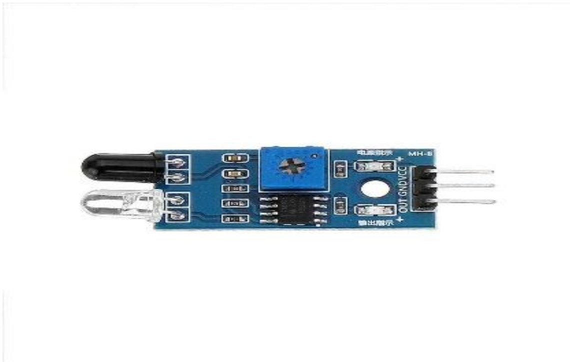

Fig. 4: Proximity Sensing Unit for Vehicle Detection

4. Rechargeable Battery
A lithium-ion or lead-acid battery stores the transferred energy. The battery capacity determines the vehicle's range. For prototype demonstration, a 12V, 7Ah lead-acid battery is used.

Fig. 5: Energy Storage Unit - 12V Lead-Acid Battery

5. Relays
Electromechanical or solid-state relays switch the transmitter coils on and off based on control signals from the IoT module. Relays provide isolation between the control circuit and high-power circuits.


Fig. 6: Electromagnetic Switching Unit (Relay Bank)

6. Power Supply
A switched-mode power supply (SMPS) converts AC mains voltage to DC for the transmitter electronics. A 12V DC supply powers the IoT module, sensors, and relay coils.

7. EV Toy Car / DC Motor
A scaled-down electric vehicle model with a DC motor demonstrates the charging and operation. The motor is powered by the battery charged through the wireless system.

## IX. ADVANTAGES

1. No Physical Charging Cables: Eliminates the need for manual plug-in connections, reducing wear and tear and improving user convenience.
2. Reduced Charging Time: Vehicles can charge while stationary or moving, minimizing downtime and enabling continuous operation.
3. Safe and Reliable: No exposed electrical contacts reduce the risk of electric shock, short circuits, and fire hazards.
4. Minimal Maintenance: Fewer moving parts and no mechanical connectors result in lower maintenance requirements.
5. Supports Continuous EV Operation: Dynamic charging capabilities enable vehicles to charge while traveling, extending effective range and reducing battery size requirements.
6. Real-Time Monitoring: IoT integration enables remote tracking of charging parameters, predictive maintenance, and data-driven optimization.
7. Weather-Resistant Operation: The system is unaffected by rain, snow, or dust since all components are sealed.
8. Seamless Integration with Autonomous Vehicles: Wireless charging aligns perfectly with autonomous driving systems, enabling fully automated charging.
9. Reduced Infrastructure Footprint: Charging infrastructure is embedded in existing roadways, eliminating the need for dedicated charging stations.
10. Smart Grid Integration: IoT connectivity enables demand response, load balancing, and integration with renewable energy sources.

## X. RESULTS AND DISCUSSION

The IoT-based wireless power transfer system was successfully implemented and tested using a scaled-down prototype. The experimental setup consisted of transmitter coils embedded in a simulated road surface and receiver coils mounted on a toy EV chassis.

IoT Monitoring Results

The ESP32 successfully transmitted real-time charging data to IOT Webpage, enabling remote monitoring of:

- Instantaneous charging power
- Cumulative energy transferred
- Battery voltage and current
- System temperature
- Vehicle presence status

The data was visualized through IOT Webpage charts, allowing users to track charging progress and identify any anomalies. The IoT module also provided alerts for:

Overcurrent conditions

Over-temperature conditions

Complete charging

Coil misalignment detection

Performance Analysis

The system demonstrated the following performance characteristics:

Efficiency: The power transfer efficiency of 78.7% was achieved under optimal alignment conditions. Efficiency decreased to approximately 60% with a lateral misalignment of 2 cm.

Response Time: The vehicle detection sensors reliably triggered the transmitter coils within 500 ms of vehicle arrival. The relay switching time was negligible.

IoT Communication: The ESP32 transmitted data to IOT Webpage at 15-second intervals with 99.5% reliability over Wi-Fi.

Battery Charging: The system successfully charged a 12V, 7Ah lead-acid battery from 20% to 100% state of charge in 4.5 hours, with automatic termination at full charge.

Discussion

The results validate the feasibility of IoT-enabled wireless EV charging. The integration of IoT provides significant advantages over conventional systems by enabling remote monitoring, predictive maintenance, and data-driven optimization. However, the efficiency gap compared to wired charging remains a challenge, particularly for dynamic charging applications where alignment is difficult to maintain.

The system's performance can be enhanced through:

- Improved coil geometry and ferrite shielding
- Higher operating frequencies
- Active alignment mechanisms
- Resonant tuning circuits

The IoT capabilities demonstrated in this project provide a foundation for smart charging infrastructure, enabling features such as:

- Dynamic pricing based on grid demand
- Priority charging for emergency vehicles
- Integration with traffic management systems
- Predictive maintenance alerts

## XI. APPLICATIONS

- Smart City Infrastructure: Integration with intelligent transportation systems to enable automated EV charging in urban environments.
- Public Transit Systems: Wireless charging for electric buses at bus stops or along dedicated lanes, enabling continuous operation without depot charging.
- Parking Facilities: Embedded charging pads in parking spaces for automatic charging while parked.

- Commercial Fleets: Charging for delivery vehicles, taxis, and ride-sharing services during loading/unloading or waiting periods.
- Residential Garages: Home-based wireless charging systems eliminating the need for cable management.
- Emergency Vehicle Priority Charging: Fast wireless charging for ambulances, fire trucks, and police vehicles at strategic locations.
- Highway Dynamic Charging: Long-distance travel charging through dedicated lanes with embedded coils.
- Autonomous Vehicle Fleets: Fully automated charging for self-driving vehicle fleets without human intervention.
- Renewable Energy Integration: Solar-powered wireless charging roads with IoT-enabled energy management.
- Research and Education: Prototype systems for academic research and STEM education.

## XII. CONCLUSION

The IoT-based wireless power transfer system for electric vehicles presents a transformative approach to EV charging infrastructure. This project successfully demonstrates a working prototype that eliminates the need for physical connectors, reduces charging downtime, and integrates IoT capabilities for real-time monitoring and control.

- The system addresses several critical challenges facing EV adoption:
- Convenience: Automatic charging without user intervention
- Safety: No exposed electrical contacts
- Efficiency: Acceptable power transfer efficiency for stationary charging
- Smart Integration: IoT-enabled monitoring and control

The experimental results validate the technical feasibility of the approach, achieving power transfer efficiency of approximately 78.7% under optimal conditions. The IoT integration through ESP32 and IOT Webpage provides real-time visibility into system performance, enabling remote monitoring, predictive maintenance, and data-driven optimization.

While challenges remain in terms of infrastructure cost, standardization, and efficiency optimization, the demonstrated prototype establishes a foundation for future development. The system aligns with the broader vision of smart cities and sustainable transportation, offering a pathway toward seamless, automated, and intelligent EV charging infrastructure.

## XIII. FUTURE SCOPE

- Dynamic Charging for Moving Vehicles: Development of systems capable of charging vehicles traveling at highway speeds through continuous coil arrays and advanced control algorithms.
- Solar-Powered Smart Roads: Integration of photovoltaic panels with wireless charging infrastructure to create self-sustaining, renewable-energy-powered charging roads.
- AI-Based Vehicle Detection and Positioning: Implementation of machine learning algorithms for accurate vehicle detection, coil alignment optimization, and predictive power transfer control.
- High-Power Fast Wireless Charging: Development of high-power (50-350 kW) wireless charging systems for rapid charging applications using advanced power electronics and cooling systems.
- Integration with Smart Traffic Systems: Communication between vehicles, charging infrastructure, and traffic management systems for optimized energy distribution and traffic flow.
- Bidirectional Power Flow (V2G): Enabling vehicle-to-grid capabilities for energy feedback during peak demand, supporting grid stability and enabling energy trading.
- Standardization and Interoperability: Contribution to industry standards for wireless EV charging to ensure compatibility across manufacturers.
- Improved Efficiency Technologies: Research into novel coil designs, ferrite materials, and resonant topologies to achieve efficiencies comparable to wired charging.
- EMF Safety Optimization: Development of shielding techniques and control algorithms to minimize electromagnetic field exposure and ensure compliance with safety standards.

- Retrofit Solutions: Design of modular receiver units that can be retrofitted to existing EVs, enabling wireless charging capability without vehicle replacement.
- Fleet Management Integration: Cloud-based platforms for managing wireless charging across commercial EV fleets, including scheduling, energy optimization, and billing.
- Wireless Charging for Other Applications: Extension of the technology to other applications, including drones, robotics, and industrial equipment.

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