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Dynamic Hybrid Wireless Charging on Road for Electric Vehicles

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ABSTRACT: The rapid adoption of electric vehicles (EVs) plays a vital role in reducing greenhouse gas emissions and dependence on fossil fuels. However, limited charging infrastructure, long charging durations, and range anxiety remain major barriers to widespread EV deployment. Dynamic Hybrid Wireless Charging on Road presents an innovative solution by enabling wireless power transfer to EVs while they are in motion. This system eliminates the need for frequent charging stops and allows vehicles to operate with smaller and lighter batteries, reducing overall cost and weight. By embedding transmitter coils within road infrastructure and using electromagnetic induction for power transfer, continuous charging becomes possible during vehicle movement. This technology enhances energy efficiency, supports integration of renewable energy sources, and significantly improves the practicality of EVs for long-distance and commercial transportation. The proposed system represents a major advancement towards sustainable and intelligent transportation systems.

Keywords: Electric Vehicles, Wireless Power Transfer, Dynamic Charging, Inductive Coupling, Smart Transportation.

1. Introduction

The global transportation sector is undergoing a significant transition toward electric vehicles to mitigate environmental pollution and reduce reliance on fossil fuels. Electric vehicles offer a cleaner alternative to internal combustion engine vehicles; however, their large-scale adoption is constrained by challenges such as inadequate charging infrastructure, extended charging times, and limited driving range.

Dynamic Hybrid Wireless Charging on Road addresses these challenges by enabling EV stocharge wirelessly while traveling. Based on electromagnetic induction principles, this system removes dependency on stationary charging stations. Transmitter coils embedded within specially designed roadways transfer power to receiver coils mounted on vehicles. This approach not only minimizes charging interruptions but also reduces battery size requirements, leading to lighter and more cost-effective vehicles. The proposed system enhances convenience, supports long-distance travel, and contributes to efficient energy management.

2. System Overview

The Dynamic Hybrid Wireless Charging system consists of a road-embedded power transmission unit and a vehicle-mounted power reception unit. Electrical energy from the grid is converted into high-frequency alternating current and supplied to transmitter coils installed beneath the road surface. As the vehicle passes over the energized coils, electromagnetic induction enables wireless energy transfer to the vehicle's receiver coils. The received power is then rectified, regulated, and stored in the vehicle battery, enabling continuous charging during motion. The proposed dynamic hybrid wireless charging system consists of two major subsystems: the ground-side infrastructure and the vehicle-side unit.

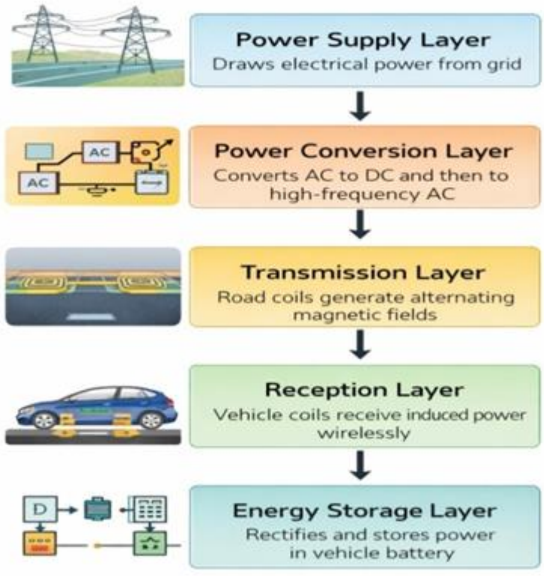
2.1 Ground-Side Infrastructure

The ground-side system includes power supply units, high-frequency inverters, control modules, and segmented transmitter coils embedded beneath the road surface. Electrical energy from the utility grid is converted into high-frequency alternating current to energize the transmitter coils. Intelligent control ensures that only the road segments directly beneath the vehicle are activated, reducing energy loss and electromagnetic interference.

2.2 Vehicle-Side Unit

The vehicle-side unit comprises receiver coils, rectifiers, DC–DC converters, and a battery management system. As the vehicle moves over the energized road segments, the receiver coils capture the magnetic flux generated by the transmitter coils. The induced voltage is rectified and regulated before being supplied to the battery or directly to the vehicle load.

Inductive power transfer technology is used to enable efficient wireless energy transmission. The system is designed to support dynamic charging, reduce range anxiety, and promote the use of smaller batteries, thereby lowering vehicle cost and weight.



Layered Architecture of Dynamic Hybrid Wireless Charging

3. Hardware Implementation

The hardware components include transmitter coils embedded in road infrastructure, receiver coils mounted on the vehicle, power inverters, rectifiers, voltage regulators, and battery management units.

3.1 Software Implementation

The software module controls power conversion, coil activation, voltage regulation, and battery charging processes. It ensures stable energy transfer, monitors charging efficiency, and protects the system from overvoltage and overheating conditions. Intelligent control algorithms optimize power delivery based on vehicle speed and alignment with transmitter coils.

4. Results and Discussion

The proposed dynamic hybrid wireless charging system demonstrates effective power transfer to electric vehicles during motion. Simulation and system-level analysis indicate a significant reduction in charging interruptions compared to conventional plug-in and static wireless charging methods. Continuous charging enables the use of smaller battery packs, leading to reduced vehicle weight and improved energy efficiency.

The system also supports better utilization of the power grid and offers potential integration with renewable energy sources such as solar and wind. These advantages make dynamic wireless charging a viable solution for future electric mobility, particularly in public transportation and logistics applications.

5. Conclusion

Dynamic hybrid wireless charging on road represents a major advancement in electric vehicle charging technology. By enabling continuous wireless power transfer during vehicle motion, the proposed system addresses key challenges associated with range anxiety, charging downtime, and battery limitations. The presented architecture, hardware implementation, and control strategy demonstrate the feasibility and effectiveness of the approach. Future work will focus on experimental validation, cost optimization, and large-scale deployment in smart transportation infrastructures.

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