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ELECTRIFIED ROAD FOR CHARGING ELECTRIC VEHICLES WIRELESSLY

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ABSTRACT

Electric vehicles (EVs) are a promising solution for reducing emissions and improving air quality. Wireless power transfer (WPT) can help extend the range of EVs by allowing them to charge dynamically or while parked. This report investigates the feasibility of WPT for EV charging, focusing on different technologies, system design, and performance validation. This project will investigate the feasibility of using WPT to charge EVs in dynamic and stationary applications. The report will focus on the following specific objectives: • To identify and evaluate the different WPT technologies that are suitable for EV charging. • To design and develop a WPT system for EV charging, taking into account the technical and economic constraints. • To conduct simulations and experiments to validate the performance of the proposed WPT system. The report is expected to make significant contributions to the field of WPT for EV charging. The project outcomes are expected to help in the development and commer cialization of WPT systems for EVs, which will play a key role in the transition to sustainable transportation.

KEYWORDS: Wireless Power Transfer, Electric Vehicles, Dynamic Charging, Inductive Coupling, Smart Roads, IoT Transportation.

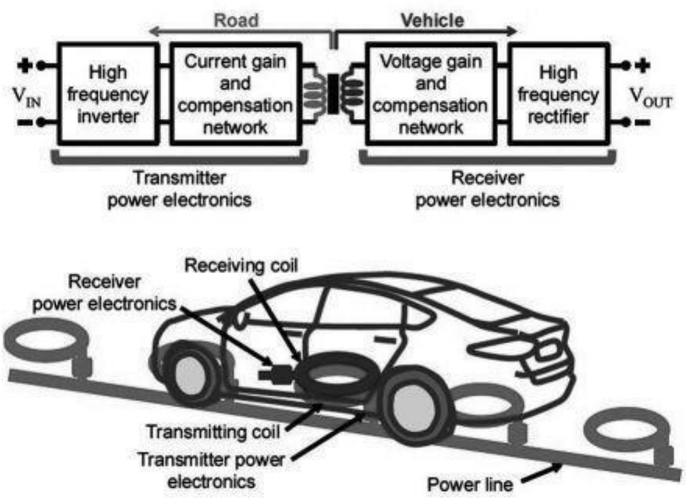
1. INTRODUCTION

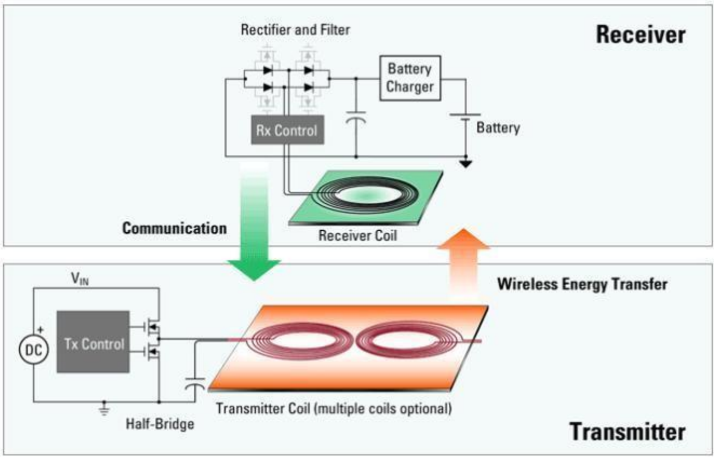
The depletion of fossil fuels and global warming push the need for sustainable transportation. EVs provide a viable solution but are limited by battery capacity and charging time. Wireless charging offers a safer, more convenient alternative to traditional conductive charging methods. This project explores the potential of WPT to enhance EV adoption. 1. Vehicle-based internal combustion engines are no longer desired, they contribute significantly to climate changes, and they are dependent to the petroleum product. The electric vehicle (EV) is an alternative choice, it can be considered as a suitable method for a sustainable transportation, it has the advantage of zero emissions and it is powered by electricity which can be considered as a renewable energy. However, the basic configuration of an EV contains a rechargeable battery pack which can be considered as its main drawback. The battery needs to be recharged frequently. Because of its low capacity; thus, the charging operation takes several hours, which reduce the driving range of the EV and limit its success in the market. Several methods are used to recharge EV batteries. In the conductive charging, the power is transferred efficiently to the vehicle by cables, but the user must intervene in this operation which is dangerous in certain specific conditions such as snow and rain that can cause electric shocks 2. Powering an electric vehicle using the wireless method is much easier and safer for the user, thus, the absence of physical contact (no mechanical friction) can prolong the product life and reduce its maintenance. The wireless power transfer (WPF) can be in a stationary or dynamic way. In stationary mode, the vehicle is wirelessly charged while parked in a location (parking or garage) equipped with a specialized power utility. The dynamic charging which means that the vehicle can he recharged while moving is invented as an attempt to reduce the size of the battery (i.e, reduce long charging times and vehicle weight) and extend the vehicle driving range. In general, the electric field (EF) and the magnetic field (MF) are used in the wireless power transfer. In the Inductively Coupled Power Transfer (ICPT) method, the power is transferred wirelessly between separated coils via MF, while the Capacitive Power Transfer (CPT) relies on the EF to transfer power between two pairs of metal plates. Recently, several automobile manufacturers are adopting the WPT charging method, especially the ICPT, one can quote Toyota, Nissan, Chevrolet, Audi, and BMW. The CPT has been widely used in applications where low powers (few watts) and short distances (few mm) are required but despite these limitations several recent researches are devoted to make it a suitable method for EV applications. 3. Transportation is a necessity and facilitator for people to meet their needs in to day's society. At the same time, side effects of the current, fossil-based transport system, such as emissions of carbon dioxide, particulate matters, nitrogen and sulphur oxides, undermine human health as well as eco-system quality. In the EV, the transportation sector accounts for one third of the total energy use and one fifth of all greenhouse gas (GHG) emissions. At the same time, living up to the Paris Agreement requires drastic emission reductions and Europe wants to be the leading region in the transition towards a sustainable society. Electrification of vehicles has been pointed out as a key factor for success, due to zero exhaust emissions in the use phase. However, there are still sustainability constraints in other life-cycle phases. So far, most attention has focused on electric vehicles (EVs) for passenger transport. Still, trucks account for 25% of GHG emissions of EU's transport sector and the number of heavy trucks, especially, is increasing more and more. 4. Battery electric vehicles are often regarded as the main solution and several fully electric, battery-powered trucks have been presented to the public, for example the Tesla Semi and the Nikola One.

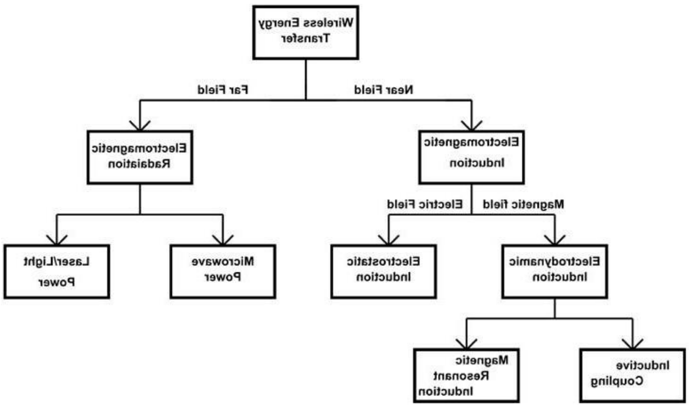
Enabling a heavy truck to drive 800 km on one charge, however, requires large batteries. Batteries have a substantial sustainability impact during their life-cycle, at least with current designs., the substitution of today's global truck fleet with battery-powered freight transport is limited by resource constraints, especially considering metals like cobalt and lithium. In addition, the batteries account for a major part of the vehicle cost, which is one of the largest barriers for the introduction of EVs. Electric Road Systems (ERS)-defined as roads that support dynamic power transfer from the road to vehicles while the vehicles are in motion could be a supplement to overcoming some of the challenges of battery EVs. Still, it is important to reflect on the original aim of pursuing EV technology, namely making the transition towards a sustainable transport system, and to investigate if and how ERS can contribute to reaching this aim. Previous studies have so far investigated technical aspects of ERS or conducted environmental comparisons based on specific life-cycle stages, focusing on the potential for GHG emission reductions.

2. Working Principle

Wireless charging is based on **Electromagnetic Induction**.

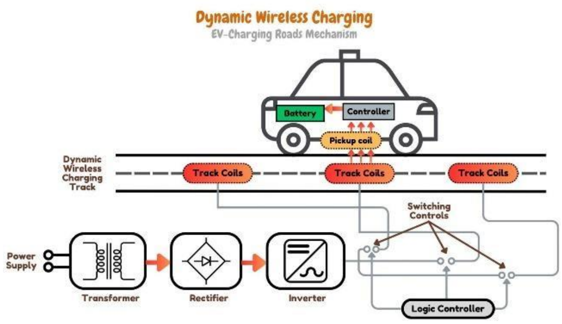






Explanation:

- Alternating current flows through the
- **Transmitter coil** embedded in the road.
- This generates a **magnetic field**.
- The **receiver coil** in the vehicle picks up this field.
- Electrical energy is induced and converted into DC to charge the battery.



3. System Architecture

3. **Transmitter Coils (Road Embedded)**
   - Installed beneath road surface in segments.
4. **Receiver Coil (Vehicle Mounted)**
   - Mounted under EV chassis.
5. **Rectifier & Battery System**
   - Converts AC to DC for battery charging.
6. **Control System**
   - Enables communication between road and vehicle.

4. Types of Wireless Charging

4.1 Static Charging

- Vehicle charges when parked.
- Used in parking lots and stations.

4.2 Dynamic Charging

- Charging occurs **while vehicle is moving**.
- Most advanced and efficient system.

5. Mathematical Model

Power transferred depends on mutual inductance

$$P \propto \frac{M^2 \cdot \omega^2 \cdot I^2}{R}$$

Main Components:

1. **Power Supply Unit**
   - Grid-connected or renewable energy sources.
2. **Inverter**
   - Converts DC to high-frequency AC.

Where:

- M= Mutual inductance
- ω= Angular frequency
- I= Current
- R= Resistance

6. Advantages

- Continuous charging → **Extended driving range**
- Smaller battery size → **Reduced vehicle cost**
- No cables → **Convenience & safety**
- Supports **autonomous vehicles**
- Reduced charging station dependency

7. Challenges

- High infrastructure cost
- Energy losses due to air gap

- Standardization issues
- Electromagnetic interference
- Road maintenance complexity

8. APPLICATIONS

Urban Centers: Promote EV adoption and sustainable transportation practices in cities and towns by establishing wireless charging infrastructure.

- Research And Development Projects: Support ongoing research and development of dynamic wireless charging technology for in-motion charging of EVs.
- Future Infrastructure Development: Collaborate with transportation authorities and infrastructure planners to integrate dynamic wireless charging technology into future road and highway designs.
- Electric Buses And Shuttles: Provide efficient and sustainable charging solutions for electric buses and shuttles used in public transportation systems and tourist attractions.
- Autonomous Vehicles And Robotic Systems: Support the development and deploy ment of autonomous vehicles and robotic systems by providing wireless charging infrastructure for their energy needs.

9. Future Scope

- Integration with **IoT & Smart Grid**
- Renewable energy powered roads
- AI-based energy optimization
- Autonomous EV ecosystems
- Government-supported smart infrastructure

10. CONCLUSION

The development of a solar-powered wireless charging system for electric vehicles represents a significant step forward in the transition towards sustainable transportation. By combining renewable energy sources with innovative charging technology, this project has the potential to address several key challenges associated with EV adoption, including range anxiety, limited charging infrastructure, and reliance on fossil fuels. The proposed system offers several compelling, advantages, including its ability to provide uninterrupted and eco-friendly charging for EVs, enhance the convenience and usability of EVs, and reduce the overall cost of EV ownership.

Additionally, the integration of solar energy into the system further promotes sustainability by reducing reliance on grid electricity and minimizing carbon emissions. While there are some potential challenges to overcome, such as the initial investment cost, lower charging efficiency, and limited range, the potential benefits of this project far outweigh the disadvantages. The ability to charge EVs while they are in motion or parked could revolutionize transportation infrastructure and accelerate the adoption of EVs as a mainstream mode of transportation. By promoting sustainable transportation practices and reducing environmental impact, this project aligns with the global effort to combat climate change and transition to wards a more sustainable future. The successful implementation of this technology could have a profound impact on the transportation sector and contribute to a cleaner, more sustainable world

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