Ganpat University
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University Journal of Research: Computer Science and Applications

An Annual, Peer-reviewed Research Journal of FCA
UJRCSA
University Journal of Research : Computer Science and Applications

# Dynamic Wireless Charging in EV

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**Abstract**

The increasing adoption of electric vehicles (EVs) presents both an opportunity and a challenge for sustainable transportation, with limited charging infrastructure and long charging times being major barriers. This research explores the concept of dynamic wireless charging (DWC) for EVs, a technology that enables vehicles to be charged while moving on roads equipped with embedded wireless power transfer (WPT) systems. Through the use of resonant inductive coupling or capacitive power transfer, charging coils embedded beneath the road surface transfer energy to receiver coils installed in EVs, allowing continuous or intermittent energy supply during motion. This paper investigates the technical principles and infrastructure requirements of dynamic charging systems, including energy transfer efficiency, vehicle alignment, and real-time battery management. Furthermore, it examines the potential of integrating renewable energy sources, such as solar-powered roads, into this system to enhance sustainability. The study discusses the environmental and economic impact of implementing wireless charging highways, along with the future vision of smart cities where electric vehicles continuously charge while on the move. This technology could play a crucial role in accelerating the global transition to electric mobility, offering a scalable solution to the limitations of current EV charging infrastructure.

**Keywords:** Resonant Inductive Coupling; Capacitive Power Transfer; Energy Transfer Efficiency; Renewable Energy Sources

## 1. Background Study

Dynamic wireless charging (DWC) is a revolutionary technology that has the potential to revolutionize electric vehicles (EVs) by enabling continuous charging on the go. DWC operates through wireless power transfer (WPT), allowing energy to be transferred without physical contact, allowing for uninterrupted travel and eliminating the need for frequent stops to recharge batteries. The technology behind WPT relies on two key methods: resonant inductive coupling and capacitive power transfer. One of the major advantages of DWC is its potential to significantly reduce the need for large, heavy batteries in EVs. Current EVs are equipped with large batteries to provide sufficient driving range between charging stops, which increases vehicle weight and production costs. With DWC, EVs could be fitted with smaller batteries since they would have the ability to continuously charge while on the road, allowing for lighter vehicles and more cost-effective production. This technology also has the potential to extend the driving range of EVs, making them more practical for long-distance travel and contributing to the development of smart transportation networks. However, DWC faces several challenges before it can be widely adopted. One of the main obstacles is the high cost of infrastructure, which requires significant investment from both public and private sectors. Another challenge is improving energy transfer efficiency, as maintaining efficient energy transfer while the vehicle is moving is still a technical challenge that requires further research and development. Moreover, ensuring proper vehicle alignment with the charging coils is crucial for efficient charging. Real-time sensors and advanced positioning systems could be integrated into smart road technology, monitoring vehicle alignment and traffic conditions to optimize the charging process. In conclusion, dynamic wireless charging has the potential to transform how electric vehicles are powered, offering a scalable solution to many of the limitations of current EV charging infrastructure. By integrating wireless charging into roads and combining it with renewable energy sources, DWC can contribute to a cleaner, more sustainable transportation network. (Patel, 2014) (AWJ Research Desk, 2024)

## 2. Components

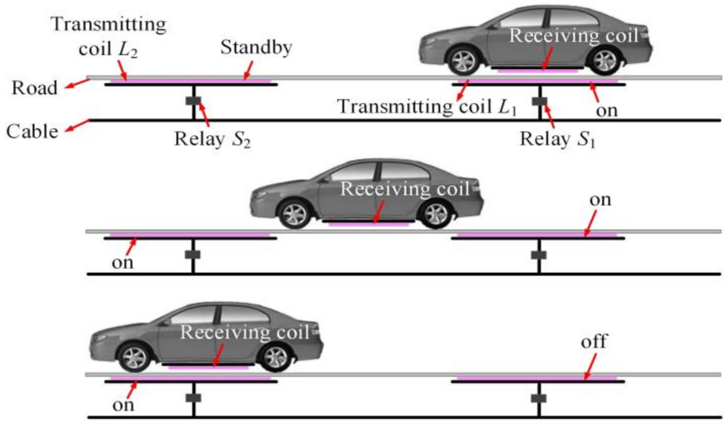


**Figure 1. Fundamental Diagram**

### 2.1 *Transmitting Components (Road Infrastructure)* (Blog Archives, 2024)

- Transmitting Coils: These are embedded beneath the road surface to create a magnetic field for power transfer. They are a critical part of the wireless power transfer system.
- Power Inverters: Convert grid-supplied AC power into high-frequency AC power, which is then sent to the transmitting coils.
- Control Systems: Used to control the activation of the transmitting coils, ensuring they are only powered when a vehicle is present. This helps conserve energy.
- Power Supply (Grid Connection or Renewable Sources): Provides electrical power to the charging infrastructure, either from the local grid or renewable energy sources such as solar panels or wind turbines.
- Smart Sensors: Detect when an EV is approaching or passing over the charging infrastructure, activating the power transfer only when needed.

### 2.2 *Receiving Components (In-Vehicle)* (toan, 2014)

- Receiver Coils: Installed underneath the vehicle, these coils capture the magnetic field generated by the transmitting coils and convert it into usable electrical energy.
- Power Receiver Module: Converts the captured electromagnetic energy into DC power to charge the vehicle's battery.

- Battery Management System (BMS): Ensures the efficient distribution of the received energy to the EV's battery. It controls the charge rate and monitors battery health.
- On-board AC-DC Converter: Converts the AC power received from the road into DC power required for charging the vehicle's battery.

### 2.3 ***Additional Components (****Lukic & Pantic, 2013)*

- Communication Module: For communication between the vehicle and the road infrastructure. It helps optimize charging and ensures the system is functioning properly.
- Vehicle Alignment Sensors: Ensure proper alignment between the vehicle and the charging coils to maintain efficient energy transfer during motion.
- Cooling Systems: Both the road and vehicle-side components may require cooling to prevent overheating, especially during high-power energy transfer.
- Insulation and Shielding Materials: To prevent electromagnetic interference (EMI) and ensure safety for the vehicle and passengers.
- Road Surface Materials: Durable and weather-resistant materials for embedding the transmitting coils in roads, ensuring longevity and functionality.

### 2.4 ***Renewable Energy Integration (Optional)*** (Tavakoli & Pantic, 2018)

- Solar Panels: For generating clean energy that can be used to power the wireless charging system.
- Energy Storage Systems (ESS): Such as batteries, to store excess energy generated by solar or wind power for use during periods of low generation.

### 2.5 ***Software and Control Systems*** (Zhang et al., 2016)

- Smart Grid Integration Software: For managing energy flow between the grid, renewable energy sources, and charging infrastructure.
- Energy Management Software: Optimizes energy distribution and ensures efficiency, preventing overloading of the grid.

## 3. Flowchart

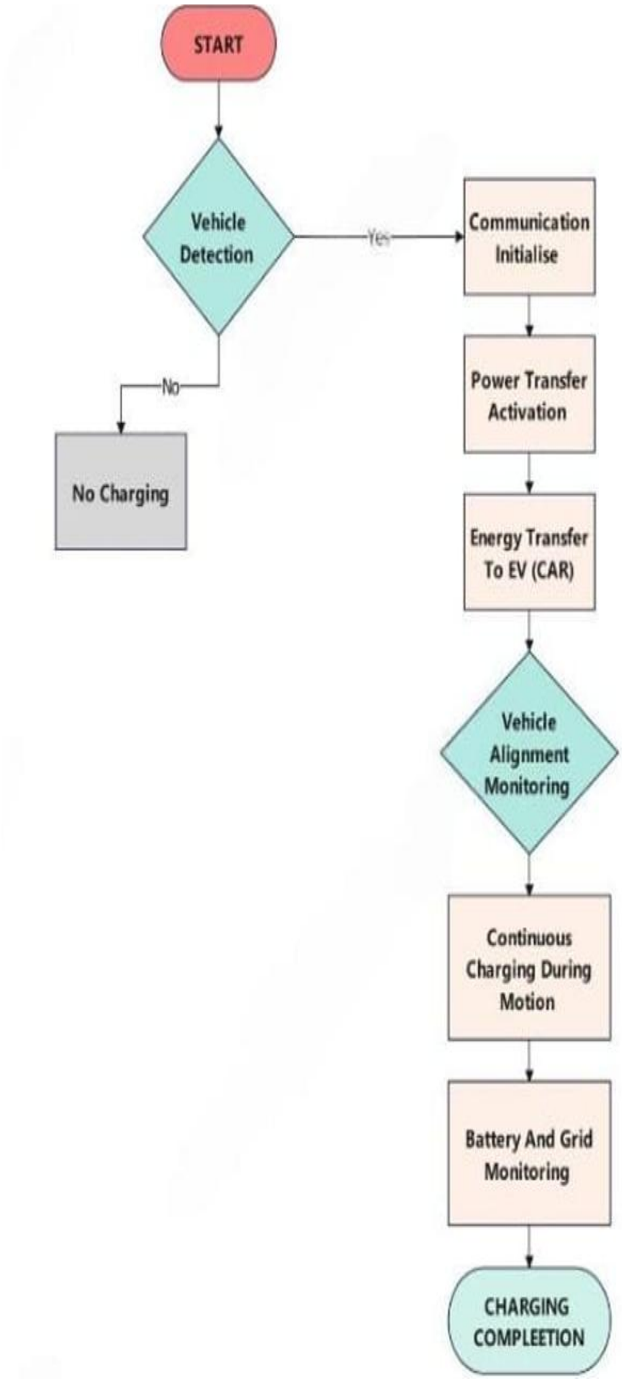


**Figure 2. Flow Chart**

### *3.1 Flow*

- Vehicle Detection: EV presence is identified when the vehicle reaches the charging zone.
- Initialization of Communication: Vehicle exchanges Vehicle ID and battery status information with infrastructure.

 

- Electricity Transfer Activation: Grid electricity is transformed to high-frequency AC by activating road coils.
- Energy Transfer to EV: Receiver coils capture transmitted energy; AC power converted to DC via on-board AC-DC converter.
- Vehicle Alignment Monitoring: Sensors monitor alignment over coils for optimal power transfer.
- Continuous Charging During Motion: Additional Road coils activate as vehicle moves.
- Battery and Grid Monitoring: BMS ensures proper battery charge and energy management software adjusts power flow.
- Charging Completion: Vehicle exits charging zone, deactivates road coils, transmits final charging data.

### *3.2 Vehicle Detection*

- Function: Detect when an electric vehicle (EV) approaches the charging zone.
- Components:
  - Sensors: Infrared, radar, or ultrasonic sensors to identify the presence of an EV.
  - Data: The system notes the vehicle's speed and proximity to the charging area.

### *3.3 Communication Initialization*

- Function: Establish communication between the vehicle and the charging infrastructure.
- Components:
  - Vehicle Communication Module: Sends the vehicle's ID and battery status.
  - Infrastructure System: Validates the vehicle against a database for authorization (e.g., checking if it's a registered user).
- Outcome: Authorization is confirmed, allowing charging to proceed.

### *3.4 Power Transfer Activation*

- Function: Prepare the charging system to transfer power.
- Components:
  - Road Coils: Embedded coils in the road are activated.
  - Inverter: Converts grid power into high-frequency AC power suitable for inductive charging.

    - Process: Power is transmitted using resonant inductive coupling, where alternating magnetic fields facilitate energy transfer.

### *3.5 Energy Transfer to EV*

- Function: Transfer the energy to the vehicle's battery.
- Components:
    - Receiver Coils: Located in the EV, these coils capture the magnetic energy.
    - On-board AC-DC Converter: Converts AC power from the coils into DC for battery storage.
    - Battery Management System (BMS): Monitors and controls the charging rate to ensure safety and efficiency.
- Outcome: The EV battery receives a charge according to its requirements.

### *3.6 Vehicle Alignment Monitoring*

- Function: Ensure the vehicle remains properly aligned over the charging coils.
- Components:
    - Alignment Sensors: Monitor the position of the vehicle in real time.
    - Adjustment Mechanism: If misalignment is detected, the system can adjust power transfer to optimize efficiency.
- Outcome: Maintains optimal power transfer throughout the charging process.

### *3.7 Continuous Charging During Motion*

- Function: Facilitate power transfer even when the vehicle is in motion.
- Components:
    - Additional Road Coils: More coils can be activated as the vehicle moves along the charging path.
    - Process: The system can dynamically adjust the power transfer based on vehicle speed and position.
- Outcome: Allows for seamless charging without the need for the vehicle to stop.

### *3.8 Battery and Grid Monitoring*

- Function: Oversee the battery's health and optimize energy flow from the grid.
- Components:
    - Battery Management System (BMS): Continuously monitors the battery’s state of charge and health.

- Energy Management Software: Balances energy distribution between the grid, renewable energy sources, and the EV.
- Outcome: Ensures the vehicle battery is charged safely while optimizing grid resources.

### *3.9 Charging Completion*

- Function: Finalize the charging session when the vehicle exits the zone.
- Components:
    - Deactivation Mechanism: Shuts down the road coils to stop power transfer.
    - Data Transmission: Sends final charging information to both the vehicle and the road infrastructure for records and billing.
- Outcome: The vehicle exits the charging zone, and the system prepares for the next vehicle.

## 4. EXPERIMENT AND DISCUSSION:

We build a dynamic wireless charging system and do an experiment using upgraded receiving coil to evaluate system performance. Dynamic wireless charging for electric vehicles uses a bulb as the system load, thereby acting as an experimental device. Precision Power Scope records also the current, voltage, and gearbox efficiency. With 20W, the frequency tracing power supply has consistent power. Every movement distance of the receiving coil is 2.5 cm, so Precision Power Scope records waveforms. The system appropriately keeps its resonance frequency at 87.7kHz, which satisfies the wireless charging requirements. (Zhang et al., 2016) (Patil, et al., 2018)

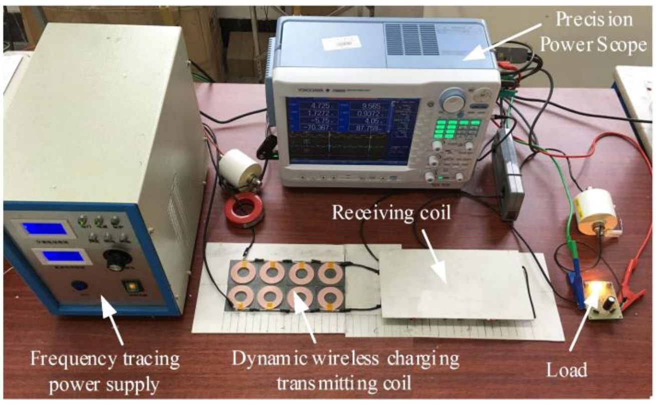


**Figure 3. Experiment**

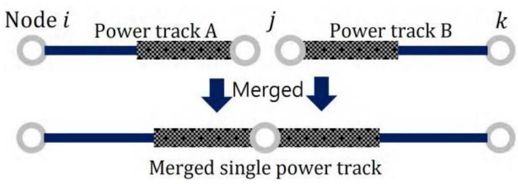


**Figure 4. Node**

## 5. CONCLUSION

Dynamic wireless charging systems for electric vehicles (EVs) represent a transformative solution in the realm of sustainable transportation (Chowdhury et al.2019). By enabling efficient, continuous power transfer while vehicles are in motion, these systems have the potential to alleviate range anxiety and enhance the overall convenience of EV ownership. As this technology evolves, addressing challenges such as energy efficiency, integration with renewable resources, and standardization will be critical for widespread adoption. Future research and development efforts should focus on optimizing system performance, improving user interfaces, and ensuring economic viability (Smart, 2024). Ultimately, the successful implementation of dynamic wireless charging infrastructure will play a vital role in accelerating the transition to electric mobility, contributing to reduced emissions and a more sustainable future for urban transportation.

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