

Renewable based Contactless Wireless Charging System

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Abstract— The rapid expansion of electric vehicles (EVs) has significantly increased the demand for advanced, sustainable, and scalable charging infrastructure. Conventional plug-in charging systems require vehicles to remain stationary for extended durations, thereby contributing to range anxiety and increasing battery capacity requirements. Dynamic Wireless Charging (DWC) enables vehicles to charge while in motion using wireless power transfer. Although DWC can reduce battery size requirements and charging downtime, most implementations remain grid-dependent and therefore vulnerable to peak demand and carbon-intensity concerns. Integrating solar photovoltaic (PV) generation and energy storage with dynamic wireless charging lanes creates a renewable, lower-carbon pathway for in-motion charging. This review surveys recent literature on wireless power transfer technologies, dynamic charging architectures, solar-integration approaches, smart energy management techniques, and IoV-enabled control strategies for DWC corridors, and it identifies remaining technical and economic challenges and promising research directions for large-scale deployment.

Keywords—component, formatting, style, styling, insert (key words)

I. INTRODUCTION

Electrification of road transport is central to many countries' decarbonization strategies, but the pace of EV adoption is constrained by charging infrastructure limitations, charger availability, and concerns about driving range. Static charging (plug-in and fast DC chargers) requires vehicles to stop and often imposes long dwell times and high instantaneous grid loads during peak periods. Dynamic Wireless Charging (DWC) addresses those constraints by transferring energy from coils embedded in the road to onboard receiver coils while the vehicle is in motion, thereby reducing required onboard battery capacity and the need for long charging stops [1], [3].

Although many technical prototypes and pilot studies have demonstrated resonant inductive WPT (RIPT) at useful power levels and efficiencies near or above 90% under ideal alignment and short air-gap conditions, most systems demonstrated to date rely on grid-supplied power. To improve sustainability and reduce grid stress, researchers have recently explored coupling DWC with distributed renewable generation (notably roadside solar PV) and co-located energy storage to provide renewable energy directly to the charging lane, reduce grid draw, and smooth intermittent solar output [2], [4].

In this review, we synthesize the current research on DWC technologies and solar-integrated DWC systems, compare key coil/topology choices and control strategies, summarize

energy management and IoV-based coordination approaches, and highlight open research questions including misalignment mitigation, EMI/safety, cost models, and standardization needs [1]–[6].

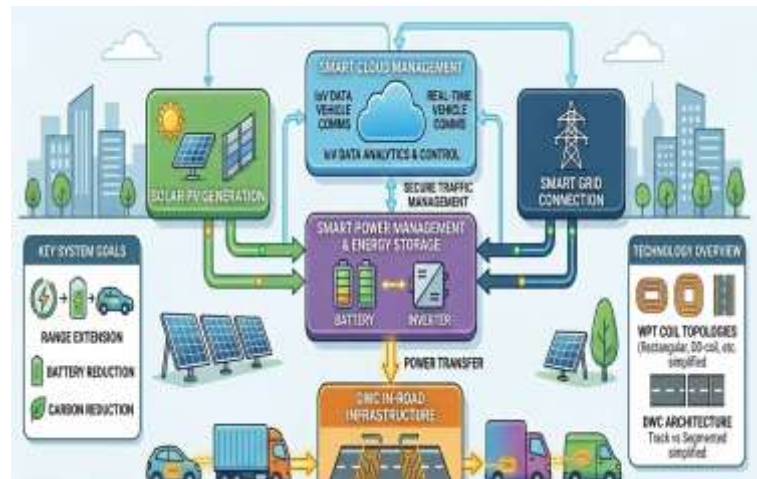


Fig. 1 Overview of system

II. WIRELESS POWER TRANSFER TECHNOLOGIES

Wireless power transfer for automotive applications principally relies on inductive methods. Resonant Inductive Power Transfer (RIPT) is the dominant approach for medium-to-high power dynamic charging because resonance (series-series or other compensation topologies) allows high transfer efficiency across modest air gaps and tolerates some misalignment when proper coil geometry and compensation are used. The resonant frequency depends on the coil inductances and compensation capacitances; researchers commonly target tens of kHz to low hundreds of kHz (e.g., 40–100 kHz) for EV-scale systems to balance component size, switching device capability, and magnetic coupling performance [1], [6].

Capacitive WPT has been proposed as an alternative but is generally considered less mature for high-power EV charging due to lower achievable power densities and more challenging safety/regulatory issues for high electric fields. Recent surveys emphasize RIPT for DWC and discuss coil geometries (circular, Double-D, bipolar, quadrature) and segmented transmitter pad layouts that reduce idle energy and allow selective activation of only the segment under the vehicle [4].

Table 1: Comparison of Wireless Power Transfer Technologies for EV Charging

Technology	Efficiency	Distance	Complexity	Suitability
IPT	High	Short	Medium	Good
RIPT	Very High	Medium	High	Best
CWPT	Moderate	Short	Low	Limited

III. DYNAMIC WIRELESS CHARGING ARCHITECTURE

Dynamic charging lanes typically embed segmented transmitter coils beneath the pavement; segmentation enables the infrastructure to energize only those coil segments that are occupied by a vehicle and thereby reduces losses. Coil geometry and arrangement strongly influence coupling coefficient, sensitivity to lateral misalignment, and overall power density. Double-D and quadrature arrangements improve lateral tolerance compared to single circular coils; bipolar pad arrangements and careful ferrite shielding reduce leakage flux and improve safety and EMI performance [1], [4]. Experimental and simulation studies have shown that realistic air gaps (typically 150–300 mm for passenger vehicles) significantly influence mutual inductance and thus the delivered power, and coil designs must be tuned for the expected air-gap and expected lateral vehicle position range [1], [3].

IV. SOLAR INTEGRATION AND ENERGY MANAGEMENT

Solar integration into DWC corridors has two primary roles: (i) to supply renewable energy directly to the dynamic charging lane, and (ii) to charge local storage to enable continuous operation during low-sun or night periods. Solar arrays can be deployed adjacent to the roadway, on median strips, or as overhead canopies; each option presents tradeoffs in installation complexity and available irradiance [3], [8]. A hybrid system that combines PV generation, local battery energy storage, and a grid connection (for backup) yields good operational flexibility: PV supplies the lane when available, the BESS smooths PV intermittency, and the grid supplies deficit energy when both PV and storage are insufficient [3], [8].

Energy management strategies for solar-DWC systems must coordinate three resources (PV, storage, grid) and multiple consumers (multiple EVs, possibly bi-directional V2G interactions). Recent studies have proposed hierarchical controllers and predictive algorithms that use traffic/vehicle arrival forecasts and PV generation forecasts to optimize segment activation schedules, minimize grid draw, and maximize renewable utilization; such predictive scheduling becomes more beneficial on high-traffic corridors where many short charging events occur [2], [8].

V. IOT AND SMART CONTROL FOR LANE COORDINATION

Vehicle-to-Infrastructure (V2I) and Internet-of-Vehicles (IoV) communications provide essential data (vehicle

presence, speed, state-of-charge, authentication, billing) used to selectively energize coil segments, negotiate power transfer, and implement dynamic billing. Integration of IoV with DWC enables lane-level coordination (which vehicle gets priority when capacity is constrained), predictive activation (so a coil is energized slightly before a vehicle arrives), and safety interlocks. Reviews on IoV-enabled EV charging show that coordinated IoV + DWC deployments improve QoE and facilitate overall grid/load balancing when combined with smart scheduling algorithms [2].

VI. CONTROL STRATEGIES AND CHARGING PROFILES

Control of RIPT power electronics must ensure stable operation under varying coupling and load. Series-series compensation with appropriate inverter control can provide acceptable performance for dynamic lanes; however, advanced control strategies are needed to realize safe CC-CV (constant current-constant voltage) charging behavior and to cope with highly variable coupling as the vehicle traverses successive transmitter segments. Recent control literature demonstrates both direct and indirect control methods for RIPT systems that achieve robust CC-CV behavior and reduce over/under-voltage events across a wide range of alignment scenarios [6], [9].

VII. TECHNICAL CHALLENGES

Despite progress, several technical challenges persist. Misalignment (both lateral and longitudinal), variable air gap due to suspension and road surface irregularities, and vehicle speed cause large variations in coupling and require mitigations such as multi-coil receiver arrangements, adaptive tuning, and segmented activation. Electromagnetic interference (EMI), human exposure limits, and stray field management require careful ferrite shielding, ground-plane designs, and compliance testing. Infrastructure cost, roadworks complexity, lifecycle maintenance, and economic models for charging lane deployment remain significant barriers; comprehensive techno-economic studies and pilot projects are urgently needed to prove the business case at scale [1], [3], [4].

VIII. FIELD TRIALS, DEMONSTRATIONS, AND PILOT STUDIES

A growing number of demonstrations and field pilots exist worldwide (various ICPT and inductive road trials), and several recent simulation and demonstration studies quantify the potential benefits (range extension, reduction in required battery capacity, and reductions in grid peak demand under mixed operation). However, the literature still lacks many multi-km, high-traffic, long-duration field trials with integrated PV + storage feeding real dynamic lanes; such long-duration, large-scale pilots would provide the techno-economic data needed by municipalities and highway authorities [1], [4].

IX. RESEARCH GAPS AND FUTURE DIRECTIONS

Key research gaps include: large-scale demonstration studies combining renewable supply and storage with DWC; standardization of coil geometries, operating frequencies, safety limits and communication protocols; improved AI-driven demand forecasting and energy allocation; improved EMI mitigation and human-exposure studies; and thorough techno-economic analyses that include civil costs, maintenance, and revenue models. Future work should also explore high-power (>50 kW) dynamic segments for heavy vehicles, integration with V2G to allow storage-to-grid value streams, and modular lane architectures that reduce initial capital expenditure through phased deployment strategies [2], [3], [5].

IX. COMPARATIVE ANALYSIS

From the comparison, Resonant Inductive Power Transfer (RIPT) clearly demonstrates superior efficiency and higher power handling capability compared to IPT and CWPT. RIPT is widely adopted in dynamic charging applications due to its improved tolerance to moderate air gaps and higher coupling efficiency. However, the requirement of compensation networks and high-frequency inverters increases system complexity. Capacitive WPT remains less suitable for high-power EV dynamic charging due to lower efficiency and limited transfer distance.

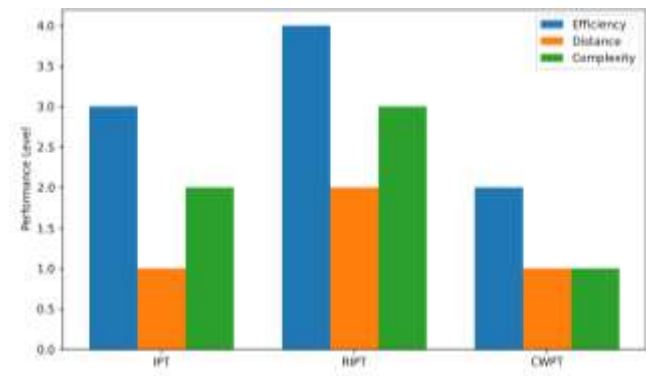


Fig.2 Comparison of Wireless Power Transfer Technologies for EVs

Static charging systems remain widely deployed but impose high grid dependency and peak load stress. Grid-based dynamic charging reduces range anxiety but still relies heavily on centralized power supply. Solar-integrated dynamic charging systems provide improved sustainability and reduced grid stress by utilizing renewable energy and storage support. Although infrastructure cost remains high, long-term operational benefits and carbon reduction potential make solar-integrated systems more viable for future smart highways.

Table 2: Comparison of Charging Methods

Parameter	Static Plug-in Charging	Grid-Based Dynamic Charging	Solar-Integrated Dynamic Charging
Charging While Driving	No	Yes	Yes
Grid Dependency	High	High	Low
Renewable	Limited	Limited	High

Parameter	Static Plug-in Charging	Grid-Based Dynamic Charging	Solar-Integrated Dynamic Charging
Integration			
Peak Load Impact	High	Medium	Low
Battery Size Requirement	Large	Medium	Reduced
Infrastructure Cost	Moderate	High	High

TABLE 3: COMPARISON OF COIL GEOMETRIES IN DYNAMIC CHARGING

Coil Type	Misalignment Tolerance	Coupling Efficiency	Field Uniformity	Complexity
Circular Coil	Moderate	High	Uniform	Low
Double-D Coil	High	Very High	Improved lateral tolerance	Medium
Bipolar Coil	High	High	Strong flux control	High
Quadrature Coil	Very High	High	Excellent misalignment control	High

Double-D and Quadrature coil geometries exhibit improved lateral misalignment tolerance compared to conventional circular coils. In dynamic charging environments where vehicle positioning varies, misalignment significantly affects power transfer. Advanced coil geometries enhance coupling coefficient stability and reduce efficiency drops during motion. However, increased geometric complexity raises manufacturing cost and installation difficulty.

Table 4: Comparison of Energy Management Strategies

Strategy	Renewable Utilization	Grid Support Requirement	Suitability
Direct Solar Feed	High (daytime only)	High (nighttime)	Limited
Solar + Battery Storage	High	Low	Good
Solar + Storage + Smart Grid	Very High	Minimal	Best for large-scale deployment

Direct solar-fed systems are limited by solar intermittency. Integration of battery energy storage significantly improves reliability by compensating for solar variability. The most advanced configuration combines solar, storage, and smart grid coordination, which minimizes grid dependency and optimizes renewable energy utilization. However, this approach requires advanced energy management algorithms and communication infrastructure.

Table 5: Comparison of types of charging

Feature	Static Charging	Dynamic Charging	Solar-Dynamic Charging
Charging While Driving	No	Yes	Yes
Grid Dependency	High	High	Low
Renewable Usage	Limited	Limited	High
Infrastructure Cost	Medium	High	High
Battery Size Requirement	Large	Medium	Small

Resonant inductive power transfer (RIPT) is the preferred WPT approach for dynamic charging corridors because it delivers the best compromise between transfer efficiency and practical transmit-receive separation; reported experimental and simulation studies commonly show efficiencies above ~88–90% under favorable alignment and small air-gap conditions [1], [5]. Coil geometry is crucial: Double-D and quadrature configurations demonstrably improve lateral misalignment tolerance compared with single circular pads, at the cost of added geometric complexity and some manufacturing overhead [1], [4]. Integrating PV with DWC and adding battery storage substantially reduces grid dependency and lowers peak grid impact, but this requires higher capital cost and advanced energy management (MPPT, BESS control, predictive scheduling using IoV data) to fully realize renewable utilization [3], [7]. Field pilots and techno-economic studies remain limited, so many cost and maintenance parameters still need real-world validation [4], [8].

XI COMPONENT AND IT'S SPECIFICATIONS

A. Solar Panel

Semiconducting materials, such as silicon, are used to make these cells. They produce electrical energy from sunlight. The PV cells are held together and shielded from environmental harm by a strong frame. The PV cells are protected from weathering and environmental elements by a clear glass cover. The electrons in the PV cells are excited when sunlight is absorbed by solar panels. An electrical current is produced as the excited electrons move through the substance. An inverter is used to transform the DC electricity produced by the solar panel into AC power.



Fig. 3 Solar Panel

Using a 36V solar panel for the Smart Solar Wireless Charging System for Dynamic Electrical Vehicles is a great choice.

Solar Panel Specifications:

Voltage: 36V

Current: Depending on the panel's power rating (e.g., 10A for a 360W panel)

Power: 360W (or other ratings, e.g., 300W, 320W)

Efficiency: Typically around 15-20%

B. Charger Controller

The 36V solar panel and the charging controller should work together. The charge controller ought to be capable of managing the solar panel's maximum current output. Energy harvesting from the solar panel is optimized with the aid of MPPT technology. For monitoring and control, the charge controller ought to be compatible with communication protocols such as Bluetooth, CAN, or Modbus. Verify that the charge controller is appropriate for the system's battery type and chemistry. Ascertain that the charge controller is compatible with the system's inverter beforehand. Your Smart Solar Wireless Charging System for Dynamic



Electrical Vehicles' battery may be charged safely and effectively by choosing the right charge controller.

Fig. 4 Solar Charge Controller

- Efficiency:** To reduce energy losses, look for charge controllers with high efficiency ratings (>95%).
- Temperature Compensation:** To modify charging settings in response to temperature changes, make sure the charge controller incorporates temperature compensation.
- Overcharge Protection:** To guard against battery damage, the charge controller needs to feature overcharge protection.

Charge controllers with integrated monitoring and control features, including Bluetooth or Wi-Fi connectivity, should be taken into consideration.

C. Battery

The 36V solar panel and charge controller should work with the battery. The battery's capacity (Ah) must to be adequate for storing any extra energy produced by the solar panel during the day. Without sacrificing longevity, the battery should be able to withstand deep discharges (e.g., 80% DOD). To ensure longevity, the battery should have a high cycle life (e.g., 3000-5000 cycles). Li-ion batteries offer high energy density, long cycle life, and low self-discharge rates.

Ensure the battery is compatible with the charge controller used in the system. Verify the battery is compatible with the inverter used in the system. By selecting a suitable battery,

you can ensure efficient and reliable energy storage. A higher voltage and greater power capacity can be achieved with a 24V battery.

Minimal energy loss during non-use is achieved with a low self-discharge rate. High charging efficiency is necessary to reduce energy loss during charging.

D. Inverter

The electric vehicles are charged by the inverter, which transforms DC electricity from the battery into AC power. To transform DC electricity into AC power, the inverter combines a number of power electronic components, including MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors) and IGBTs (Insulated Gate Bipolar Transistors).

The battery provides the inverter with DC power, usually 24V DC. Rectification: To guarantee a steady and smooth input, the DC power is first rectified. Filtering: Any undesired noise or ripples are eliminated by filtering the rectified DC power. Inverter Stage: Using power electronic components like IGBTs or MOSFETs, the filtered DC power is then delivered into the inverter stage, where it is transformed into AC power. AC Output: Next, at a frequency of 50 Hz or 60 Hz, the inverter outputs the AC electricity. Charging the Vehicle: The electric car is thereafter charged using the AC electricity.

➤ Transmitting Coil

One essential part of the wireless charging system is the transmitting coil, sometimes referred to as the transmitter coil. It operates on the electromagnetic induction principle, which states that a magnetic field is produced when an alternating current (AC) passes through a coil.

The inverter supplies the transmitting coil with AC power, usually at a frequency of 50 Hz or 60 Hz. A magnetic field is created by the AC power passing through the coil.



Fig. 5 Transmitting coil

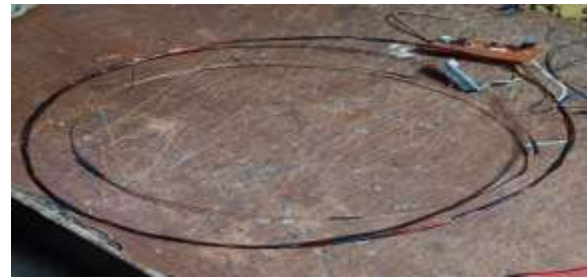
- 1) *Convenience:* Wireless charging eliminates the need for physical connections, making it more convenient for users.
- 2) *Safety:* Wireless charging reduces the risk of electrical shock and other safety hazards associated with physical connections.
- 3) *Efficiency:* Wireless charging can be more efficient than traditional wired charging methods, particularly for high-power applications

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E. Receiving Coil

The receiving coil, sometimes referred to as the receiver



coil, is an essential part of the wireless charging setup. According to the electromagnetic induction principle, the receiving coil experiences an electromotive force (EMF) as a result of the magnetic field produced by the transmitting coil.

The magnetic field produced by the transmitting coil is transferred to the receiving coil. EMF Induction: The receiving coil experiences an EMF that is proportionate to the magnetic field's rate of change. Generation of AC Power: The receiving coil receives an AC power from the generated EMF, which is subsequently rectified and filtered to create a steady DC power. Charging the Vehicle Battery: The electric vehicle's battery is subsequently charged using the DC electricity.

Fig.6 Receiving coil side circuit

The coil's diameter, number of turns, and wire thickness are among its geometrical characteristics that impact the wireless charging system's effectiveness and range. Operating Frequency: The wireless charging system's range and efficiency are impacted by the coil's operating frequency. Air Gap: The wireless charging system's effectiveness and range are impacted by the air gap between the transmitting and receiving coils.

Users find wireless charging more convenient because it does not require physical connections. By eliminating the need for physical connections, wireless charging lowers the risk of electrical shock and other safety risks. For high-power applications in particular, wireless charging may be more effective than conventional wired charging techniques.

F. Rectifier

An essential part of the wireless charging system, the rectifier transforms the AC power generated in the receiving coil into DC power. The rectifier operates on the basis of employing semiconductor devices like diodes or thyristor to convert AC electricity to DC voltage.

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