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"Peer-to-Peer Wireless Charging for Electric Vehicles": A Literature Review of Existing Technologies and Future Directions

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ABSTRACT

The global trend towards eco-friendly and sustainable modes of transport has significantly boosted the use of Electric Vehicles (EVs), necessitating the development of efficient, user-friendly, and dependable EVs. Solutions for charging. Modern charging stations, while effective, encounter issues like scarcity, lengthy queues, and inconsistent setups. Allocation, particularly within urban and rural settings. These limitations frequently result in "range anxiety," a significant worry for electric vehicle owners who fear running out of charge before reaching a charging station. To surmount these limitations, the P2P Wireless Charging concept has been introduced as a groundbreaking approach enabling electric vehicles to exchange energy directly among themselves, eliminating the requirement for conventional charging stations. P2P wireless charging utilizes techniques like resonant inductive coupling or magnetic resonance for power transfer, allowing vehicles to exchange energy through electromagnetic fields. Incorporated alongside intelligent energy management systems and blockchain-based transaction protocols, this strategy enables vehicles to function as both energy suppliers and consumers within a decentralized network. The technology facilitates on-demand, efficient, and secure charging, optimizing energy consumption and alleviating pressure on public charging systems. This document investigates the foundational concepts, essential attributes, and prospective developments of peer-to-peer wireless power transfer technologies for electric vehicles, emphasizing their advantages, drawbacks, and anticipated influence on the future of electric transportation.

P2P wireless charging could significantly improve charging accessibility, potentially transforming how energy is managed in smart cities by incorporating electric vehicles into the overall energy infrastructure. When integrated with Vehicle-to-Grid technology and renewable energy sources, electric vehicles can act as mobile energy storage devices that help manage local power needs, support grid stability, and facilitate energy sharing during crises. This interconnected system facilitates reduced reliance on centralized power plants, enhances the efficient use of renewable energy, and promotes community-based energy trading models. With ongoing improvements in WPT efficiency, communication protocols, and safety standards, peer-to-peer wireless charging might evolve into a crucial element in constructing a robust, eco-friendly, and highly flexible transportation and energy network

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INTRODUCTION

The rapid shift towards electrically powered vehicles is making EVs a pivotal element in sustainable urban and regional development planning. Despite its swift expansion, this growth presents challenges. Complicated, multifaceted issues that transcend vehicle technology and significantly influence existing infrastructure, energy sectors, and consumer habits [2]. The pressing necessity for current research Is to create a robust charging infrastructure that is financially sustainable and widely available. The widespread deployment of electric vehicles is currently limited by three main issues:

The substantial burden on the reliability and durability of the electrical infrastructure.The complexity of designing optimal, user-centric electric vehicle charging systems;the dependence on static charging techniques, which heightens range apprehension. To tackle these issues, a thorough examination of cutting-edge developments in advanced power transmission, predictive grid management systems, and decentralized energy exchanges is required. Outline and Classification of the Evaluation.

The methodology for this review Is designed to offer a straightforward and comparative analysis of the current landscape, drawing upon established frameworks used in thorough technological assessments. The methodologies and frameworks governing the electric vehicle charging sector are meticulously organized into four thermal categories.

Grid Resilience and Impact Assessment: Investigating techniques to reduce harmonics and power quality issues through the application of predictive technologies such as the Electrical Grid Impact Indicator (ECGII) and localized energy storage solutions.

2.Methods

1. Advanced Power Transfer Technologies: Dynamic Optical Wireless Power Transfer (OWPT)

Dynamic Optical Wireless Power Transfer (OWPT) is a cutting-edge development that tackles electric vehicle range issues by facilitating on-the-go charging for both ground and airborne vehicles. This study introduces and examines a dynamic OWPT system, employing an overhead facility to house laser transmitters and renewable energy sources. Materials and energy storage systems [1]. The system is engineered for operational adaptability, incorporating downward-pointing laser transmitters for ground electric vehicles and upward-pointing ones for aerial electric vehicles, like drones. A significant discovery pertains to enhancing operational capacity through the incorporation of tracking cameras, which enable laser transmitters to rotate in any direction, thereby ensuring continuous tracking and uninterrupted connectivity with moving vehicles [1].

Nevertheless, the examination uncovered a crucial technical obstacle specific to laser-powered energy transfer. The highest attainable power and energy are found to be inversely proportional to the environmental attenuation coefficient [1]. This implies that the efficiency and charging speed of the OWPT system are adversely affected by atmospheric conditions, with unfavorable weather, such as fog, severely hampering performance by causing more laser light to be absorbed. The study offers the essential mathematical formulas for assessing the system's performance metrics, emphasizing that the fastest charging occurs when the electric vehicle is precisely aligned with the transmitter. These findings indicate that OWPT has significant potential for enhancing mobility, but its practical implementation requires careful consideration of geographical and climatic conditions to ensure reliable service. Beyond technical aspects such as power transfer and tracking, OWPT offers compelling structural and economic advantages for the future of electric vehicle infrastructure. Integrating renewable energy sources and energy storage components directly into the facility's structure enables the system to maximize sustainable power usage and reduce dependency on the utility grid, effectively tackling issues related to grid congestion and sustainability. This integration improves the system's energy self-sufficiency while offering a more economical, uninterrupted charging option compared to traditional wired stations. In the end, the OWPT system signifies a significant change towards a highly efficient, smooth, and interconnected charging process essential for high-speed electrified transportation corridors [1].

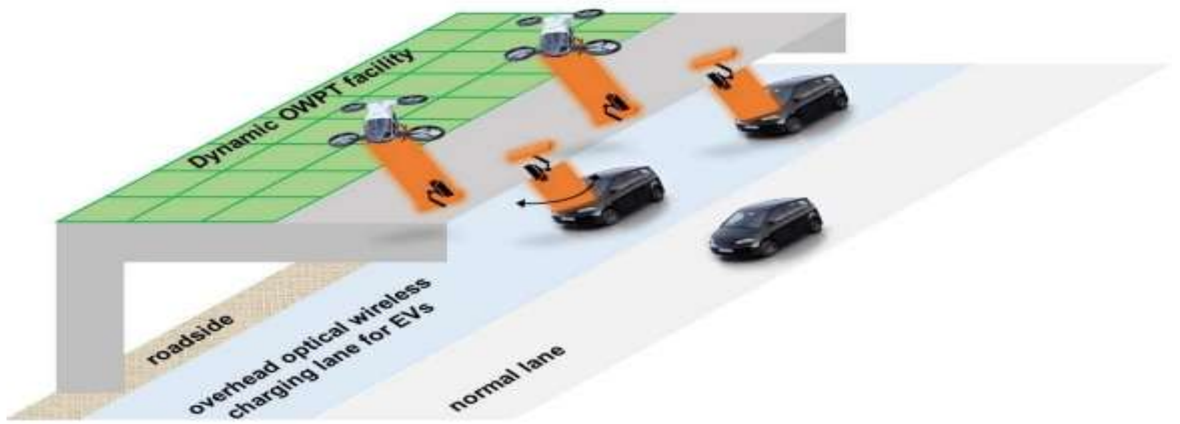

Fig 1. Illustration for Optical Wireless charging of EVs

2. Charging Network Design and Economics Findings

The study tackles the significant issue of creating effective charging infrastructures for electric vehicles by considering both consumer preferences and network administrators' goals. The main outcomes revolve around developing the most efficient and computationally efficient solutions to this problem.

Hierarchical Model Formulation: The challenge of designing charging networks and setting service prices was effectively addressed through a bi-level hierarchical approach.

Upper Level Concentrates on the network operator's strategic choices, with the goal of reducing facility deployment expenses while boosting revenue from charges.

At the lower level (User Equilibrium UE), models the autonomous choices of electric vehicle (EV) users, who seek to minimize their personal total costs, which encompass travel time and charging expenses.

The proposed bi-level model was transformed into an equivalent single-level model through the application of complementary equations. Subsequently, an iterative active-set method was devised and employed.

The computational performance was evaluated, revealing that the proposed algorithm efficiently solves the problem. Through comparative analyses, the devised methodology demonstrated a substantial reduction in solution time, specifically achieving approximately 2. 3 hours, as opposed to conventional system-level optimization benchmarks, which typically took longer. In 173. 1 hours, this method demonstrates its computational strength for handling large-scale applications.

The study revealed that travelers' charging choices are significantly influenced by two factors that affect the overall user cost: the price at the charging station and the time spent waiting for service. These results underscore the importance of integrating user-focused considerations into network planning. The hierarchical optimization model, effectively tackled with an iterative active-set approach, demonstrated substantial computational efficiency. The numerical outcomes indicated that the proposed algorithm successfully addressed the design challenge within about 2. 3 hours.

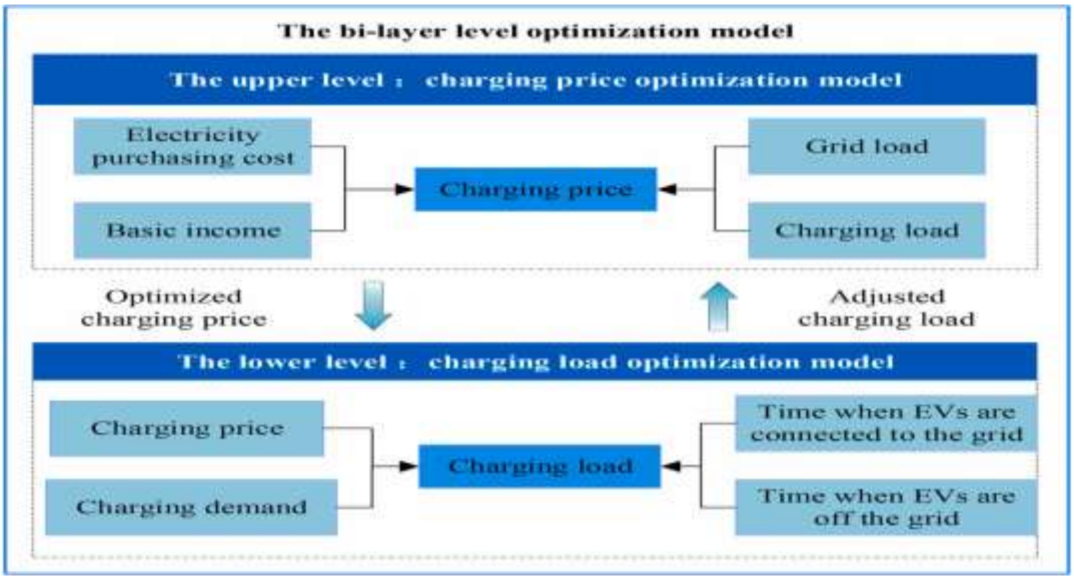

Fig 2. Bi-level optimization framework

3.Grid Resilience and Impact Assessment [3]

This applied research highlighted the necessity for advanced grid management strategies, demonstrating that the substantial power demands of fast charging stations and the inherent properties of electric vehicle power converters contribute significantly to harmonic distortion and other power quality issues within the energy distribution network [3].

Predictive Assessment and Mitigation

The primary result of this research is the creation and verification of the Electrical Grid Impact Indicator (ECGII), a predictive tool that continuously evaluates the FCS's impact on the grid by monitoring critical electrical parameters such as power demand, short-circuit power, total harmonic distortion (THD), and power factor. The ECGIl enables utility operators to predict potential operational limits, facilitating prompt corrective actions and adherence to power quality regulations [3].

Moreover, the document highlights that although the ECGII indicates the risk, the deployment of Battery Energy Storage Systems (BESS) close to the FCS proves to be the most efficient hardware solution for mitigating the issue. The BESS is demonstrated to smooth out instantaneous power surges, lessen the strain on the upstream transformer, and ultimately stabilize the grid, guaranteeing ongoing adherence to regulatory requirements [3].

Experimental Validation:

The methodology's reliability was shown by an empirical case study that examined the harmonic content and power flow fluctuations. The study conclusively demonstrated that the ECGII's method of correlating charging patterns with the risk of exceeding harmonic standards, such as those defined by IEEE 519, was highly accurate.

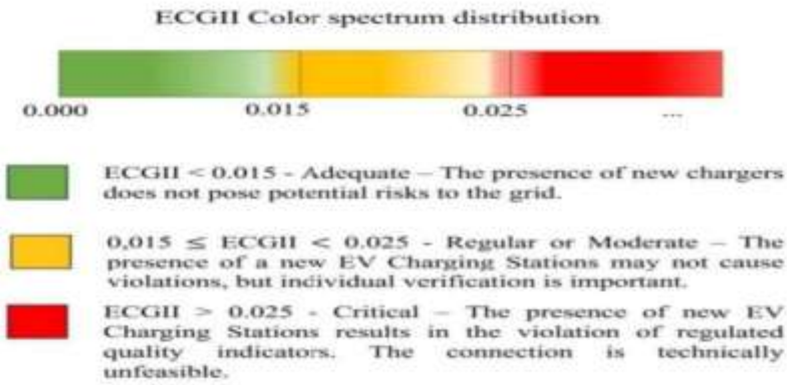

Fig 3. Colour spectrum distribution of Electrical Grid Impact (ECGII)

4.Advanced Power Transfer Technologies: Vehicle-to- Vehicle (V2V) (Shafiqurrahman et al., 2024)

This detailed evaluation substantiates that Vehicle-to-Vehicle (V2V) power transmission is a vital, rapidly developing technology designed to alleviate range anxiety and enhance the overall robustness of the electric transportation sector by facilitating direct peer-to-peer energy exchange [4]. The analysis underscores the necessity of a seamless integration of robust electrical and communication advancements for a successful V2V deployment.

The research conducted an in-depth examination of the essential power electronics topologies required for effective and secure V2V communication. This involved assessing diverse wired DC fast-charging methods tailored for V2V, necessitating complex control systems to handle substantial current and guarantee the safety of both vehicles and individuals during energy transfer. Additionally, the review examined the suitability of various wireless power transfer topologies for vehicular-to-vehicle communication applications. The results highlighted the significance of optimizing power density and efficiency, emphasizing that the selected wireless power transfer (WPT) topology must minimize energy loss and charging time through efficient coil design and positioning to guarantee practicality and user acceptance [4]. Moreover, the success of V2V communication relies on seamless and secure data exchange. The study extensively examined the procedures and necessary for overseeing the entire charging process, from the initial negotiation to the transaction's conclusion. Technologies such as Dedicated Short Range Communications (DSRC) and cellular standards like Long-Term Evolution (LTE) were examined in this review. These protocols are essential for transmitting critical data like battery State-of-Charge (SoC), requested power levels, and transaction authentication, guaranteeing the secure, efficient, and fair handling of the V2V session [4]. The has been restated in a different manner.

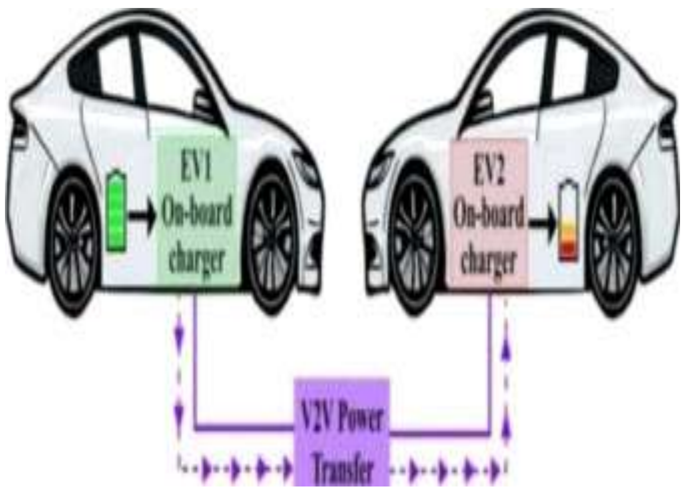

Fig 4.a) V2V Power transfer

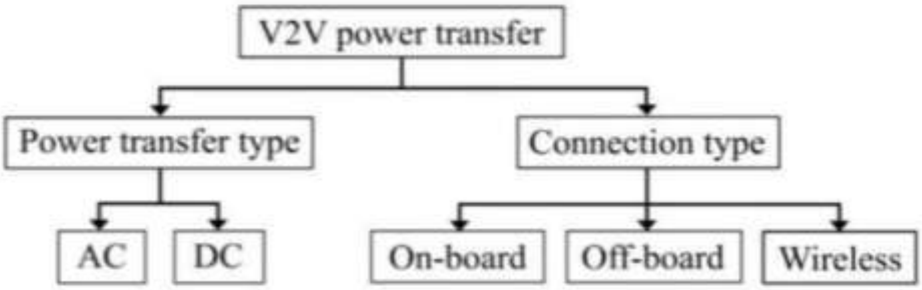

Fig 4.b) V2V Power transfer classification

5.Decentra1ized Energy Markets (Biswas et a1., 2025)

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This case study thoroughly assesses the feasibility and benefits of P2P energy trading between EVs and a microgrid, demonstrating its capability to improve energy flexibility and facilitate the integration of RES [5].

Core Findings and Economic Benefits.

The main outcome demonstrates that peer-to-peer energy trading successfully creates a decentralized energy marketplace. This design enables electric vehicles (EVs) to directly exchange energy with one another or with various microgrid elements, thus optimizing the efficient distribution and utilization of locally produced energy. Economically, the peer-to-peer (P2P) model showed substantial advantages, especially.

Decrease in Utility Bills: The distributed energy system encourages local energy consumption, resulting in lower overall expenses for participating individuals and the microgrid manager.

Improved Energy Adaptability: Electric vehicles' capability to act as mobile energy reservoirs that can purchase and sell electricity enhances the microgrid's operational flexibility and stability. Particularly when incorporating intermittent renewable energy sources [5]. Elements of functionality and procedural considerations.

The research evaluated the technical components of the P2P trading model through practical examples, concluding that the system is computationally strong and adept at handling user engagement and energy distribution effectively. A significant discovery highlights the imperative of a foundational secure system to enable these transactions. The document extensively highlights the significance of blockchain technology and smart contracts.

Fig 5 P2P Energy trading algorithm

DISCUSSION

The reviewed literature indicates that the integration of Electric Vehicles (EVs) is evolving from focusing on individual technical issues to managing a sophisticated, interconnected Smart Charging Ecosystem. The results, presented in Table 1, underscore four separate, yet interconnected, research paths: Grid Influence (1), Network Economics (2), Advanced Transfer Technologies (3), and Decentralized Markets (4). The combination of these regions, depicted in Figure 6, highlights essential connections and notable research voids that shape the future direction of the field.

1.The Centralization vs. Decentralization Parados

A significant contradiction arises between the requirement for unified grid stability and the increasing preference for decentralized energy control. The research on Grid Resilience unveiled the Electrical Grid Impact Indicator (ECGII) [3], a validated predictive tool, allowing utility operators to forecast and prevent power quality issues arising from fast charging stations. Nevertheless, this model relies on a conventional, centralized information distribution. Conversely, the high operational efficiency of peer-to-peer energy trading [5] depends on market autonomy and decentralized decision-making among producers and consumers. The current gap in research is the absence of a framework that effectively combines ECGII's centralized risk prediction with the dynamic, decentralized distribution of power from peer-to-peer energy exchanges and Battery Energy Storage Systems (BESS). To achieve true grid resilience, a methodology is needed that leverages predictive analytics to guide and motivate market behavior, rather than merely imposing restrictions.

2.The Mobility Gap in Network Optimization Models

The core of static network planning is based on a two-level approach.

Hierarchical optimization models [2], which offer high computational efficiency. These models are effective because they incorporate the User-Equilibrium (UE) principle, where traveler decisions are streamlined by considering time and cost factors. The possibility of charging while driving through Optical Wireless Power Transfer (OWPT) or receiving emergency power from Vehicle-to-Vehicle (V2V) communication significantly impacts the perceived 'range anxiety' and travel time in the UE cost function. Current network models inadequately account for: the probabilistic service availability of OWPT, due to its technical limitations caused by environmental attenuation.

The utility of V2V energy as a readily available, mobile resource. Ongoing studies should concentrate on creating advanced hybrid optimization models that integrate the stationary network with the mobile service layer, while updating the User Equipment (UE) component to account for the real, fluctuating costs of travel in dynamic charging environments.

3.Standardization and security are significant barriers to interoperability in advanced technologies, such as Category III and IV. The robust performance of peer-to-peer markets relies on secure, transparent transactions, which are realized through blockchain technology and smart contracts [5]. Consequently, the robust deployment reliability of V2V necessitates the adoption of universally recognized communication protocols, such as DSRC and LTE, for secure negotiation and power transmission [4].

The absence of standardized hampers compatibility. For example, a P2P market could greatly benefit from incorporating V2V protocols within a blockchain layer for authentication and transaction recording.

RESULTS

This literature review conducted a thorough and evaluative examination of pre-selected peer-reviewed articles, ultimately synthesizing the current state-of-the-art in Electric Vehicle (EV) charging infrastructure and management. This strategy aimed to elevate the review beyond a basic summary, offering a comprehensive, comparative analysis. The literature selection encompassed four interrelated, functional areas: grid influence and management, charging network efficiency, advanced power transfer techniques, and decentralized market solutions. This extensive coverage guarantees that the review tackles the complex issues that arise from widespread EV adoption across various fields. The letter FV.

The documents were examined and combined using a method based on previously used techniques for evaluating various technologies. This systematic approach categorized the literature into four main categories for in-depth analysis.

Examining the influence of high-power charging on power quality, particularly the introduction of harmonics and the utility of predictive tools such as the Electrical Grid Impact Indicator (ECGII) for mitigation [3].

Network Design and Economics: Investigating intricate optimization techniques, including the bi-level hierarchical formulation, aimed at strategically positioning charging stations and determining service pricing according to User-Equilibrium (UE) decisions [2].

Exploring cutting-edge technologies aimed at boosting charging versatility and mobility, this review covers essential electrical topologies and communication protocols for Vehicle-to-Vehicle power transfer and the potential of Dynamic Optical Wireless Power Transfer [4].

Peer-to-Peer Energy Trading: Investigating the design and advantages of P2P energy exchanges between electric vehicles and microgrids, highlighting how these decentralized systems improve energy adaptability and secure transactions via blockchain technology (5).

A qualitative synthesis was utilized for data extraction, concentrating on gathering the fundamental models, technical specifications, and reported limitations from each study. This process emphasized articles featuring explicit visual content (schematics, diagrams, etc.).

Flowcharts and comprehensive technical findings are included, with the final review emphasizing both the benefits and remaining issues. Identifying discrepancies in all examined areas.

CONCLUSION

This review indicates that the future of electric vehicle charging is moving from individual technologies to a sophisticated, interconnected Smart Grid system. The evidence shows significant progress in four domains: comprehensive grid impact evaluation (ECGII), computationally efficient network configuration (bi-1eve1 models), sophisticated dynamic power transfer (V2V, OWPT), and flexible decentralized market systems (P2P). The main obstacle is overcoming the disparity between centralized grid management and the highly adaptable, decentralized structure of mobile electric vehicle charging. Future studies should focus on two crucial domains: 1) establishing comprehensive, secure standards (utilizing blockchain for peer-to-peer communication and standard protocols for vehicle-to-vehicle interactions) to ensure smooth integration, and 2) developing advanced optimization algorithms that effectively account for the probabilistic availability and service value of dynamic and mobile charging systems, ultimately achieving a highly efficient and robust electric transportation network.

COMPARITIVE ANALYSIS OF LITERATURE REVIEW

Table 1: Key findings of reviewed literature

Paper name	*Author*	*Method*	*Year*	*Accuracy*
Dynamic Optical Wireless Power transfer	Nguyen	Analytical Mathematical Formulation for Dynamic OWPT System	2023	Technical Limitation(Max Power invetsely depent on environment attentuation coefficient)
Electric V2V Power transfer: Elaectrical an communication Developments	Shafiqurrahman et al	Comprehensive literature review(Ana1yzing Power Electronics & Communication Protocols)	2024	High development reliability
Assessment of Electric Vehicles charging grid impact via predictive indicator	Vasconcelos	Development & Validation of ECGII Predictive model	2024	Validative Predictuve Capability
Charging Network Design and Service pricing for Ev with user-equiliburim decisions	Mirheli and Hajibabai	Bi-level Hierarchial Formulation & Active-Set technique	2023	High computational efficiency
Enhancing Energy flexibility: A Case study on P2P Energy trading between Electric vehicles & Microqrid	Biwas et el	Case study & Analysis of P2P Energy trading model	2025	High operation efficiency

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