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A Comparative Analysis of Optimization-Based Wireless Power Transfer Systems for Efficient, Cost-Effective, and Sustainable Deployment

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Abstract: Wireless Power Transfer (WPT) technology has gained increasing attention for contactless energy delivery in applications such as electric vehicle (EV) charging, consumer electronics, and smart infrastructure. Despite significant research progress, the widespread deployment of WPT systems is constrained by challenges related to power transfer efficiency, sensitivity to coil misalignment, high infrastructure cost, and limited scalability. This paper presents a comprehensive comparative analysis of optimization-based WPT systems with the aim of addressing these challenges. Intelligent optimization techniques, including Particle Swarm Optimization (PSO), Genetic Algorithms (GA), and population-based optimization methods, are systematically evaluated in terms of convergence behavior, robustness, and adaptability under realistic operating conditions. An integrated MATLAB-based simulation framework is developed to enable unified performance assessment considering efficiency, electromagnetic losses, alignment tolerance, infrastructure cost, and sustainability. Furthermore, modular and optimized coil architectures are analyzed to reduce material usage and deployment cost while supporting scalable and sustainable implementation. The comparative results indicate that hybrid and adaptive optimization strategies, combined with modular system design and integrated simulation platforms, significantly enhance the practicality and long-term viability of WPT systems for large-scale applications such as EV charging networks and smart cities.

***IndexTerms* - Wireless Power Transfer (WPT), Optimization Algorithms, Particle Swarm Optimization (PSO), Genetic Algorithms (GA), Modular Coil Design, Sustainable EV Charging**

I. INTRODUCTION

Wireless Power Transfer (WPT) systems enable the transmission of electrical energy without physical connectors by means of electromagnetic coupling, thereby improving safety, reliability, and operational flexibility. Due to these advantages, WPT technology has gained significant attention in applications such as electric vehicle (EV) charging, consumer electronics, biomedical implants, and industrial automation systems [1], [2]. In particular, contactless EV charging using WPT offers enhanced user convenience, reduced mechanical wear, and improved protection against environmental hazards when compared to conventional plug-in charging methods [3].

Despite notable progress in WPT research and commercialization, the large-scale deployment of high-power WPT systems still faces several technical and economic challenges. One of the most critical issues is the degradation of power transfer efficiency caused by misalignment between transmitting and receiving coils. Vehicle positioning errors, variations in ground clearance, and dynamic movement during charging significantly reduce magnetic coupling, leading to increased leakage flux and electromagnetic losses [4], [5]. In addition, system performance is strongly influenced by operating frequency deviation, load variation, and parameter uncertainties, which further complicate reliable power delivery under real-world conditions [6].

Another major barrier to widespread WPT adoption is the high infrastructure cost associated with conventional system designs. Fixed coil configurations, conservative design margins, and oversized power electronic components increase material consumption, installation complexity, and overall deployment cost [7]. These limitations restrict scalability, particularly in public EV charging stations, parking facilities, and smart transportation infrastructures where modularity and cost-effectiveness are essential [8].

To address these challenges, recent studies have increasingly explored intelligent optimization techniques such as Particle Swarm Optimization (PSO), Genetic Algorithms (GA), and other population-based optimization (PBO) methods for WPT system design and control [9]–[11]. These techniques have demonstrated effectiveness in optimizing coil geometry, compensation networks, operating frequency, and alignment tolerance, resulting in improved power transfer efficiency and reduced losses. However, most existing works focus on isolated performance improvements and lack a unified comparative framework that simultaneously considers efficiency enhancement, simulation integration, infrastructure cost, and long-term sustainability [12].

Moreover, many reported optimization-based approaches are evaluated under simplified simulation conditions, without incorporating realistic constraints such as misalignment dynamics, scalability requirements, and deployment feasibility [13]. Consequently, the practical applicability of these solutions remains limited. A comprehensive comparative analysis that integrates optimization techniques with realistic simulation modeling and deployment-oriented metrics is therefore required.

This paper addresses this research gap by presenting a systematic comparative study of optimization-driven WPT systems aligned with practical deployment objectives, including efficiency improvement, integrated simulation modeling, infrastructure cost optimization, and sustainability enhancement.

1.1. Objectives of the Paper

The main objectives of this paper are as follows:

1. **To enhance power transfer efficiency** by investigating and comparing intelligent optimization techniques such as PSO, GA, and population-based optimization methods for minimizing electromagnetic losses and improving coil alignment tolerance in WPT systems [9], [10].
2. **To develop an integrated MATLAB-based simulation framework** capable of analyzing WPT system performance under realistic operating conditions, including misalignment, parameter variations, and dynamic loading [6], [13].
3. **To optimize infrastructure cost and deployment feasibility** by evaluating modular and cost-effective coil configurations and optimized system architectures suitable for large-scale WPT implementation [7], [8].
4. **To improve sustainability and scalability** by designing energy-efficient and adaptable WPT systems that support long-term operation and potential integration with renewable energy sources [2], [12].

1.2. Contributions of the Paper

The major contributions of this paper are summarized below:

- A **comparative performance analysis of optimization techniques** (PSO, GA, and PBO) applied to WPT systems, highlighting their effectiveness in efficiency enhancement, convergence behavior, and robustness against coil misalignment [9]–[11].
- The development of a **unified MATLAB-based simulation framework** that integrates electromagnetic modeling, circuit-level analysis, and optimization algorithms to evaluate WPT performance under realistic operating scenarios [6], [13].
- A **cost-oriented comparison of conventional and optimized WPT infrastructures**, demonstrating how modular and optimized coil designs can reduce material usage and deployment costs while maintaining high efficiency [7], [8].
- An evaluation of **sustainability and scalability aspects** of optimized WPT systems, focusing on energy efficiency, material optimization, and suitability for large-scale EV charging networks [2], [12].
- A structured comparative discussion that bridges the gap between **theoretical optimization research and practical WPT deployment**, offering useful insights for researchers and system designers.

II. COMPARATIVE ANALYSIS

2.1 Enhancing Power Transfer Efficiency

Power transfer efficiency is a critical performance metric in Wireless Power Transfer (WPT) systems and is strongly influenced by factors such as coil alignment, operating frequency, compensation topology, and magnetic coupling coefficient. Even minor lateral or angular misalignment between the transmitting and receiving coils can lead to significant degradation in coupling efficiency, increased leakage flux, and elevated power losses [14], [15]. Conventional WPT systems are typically designed using fixed system parameters optimized for nominal operating conditions. However, such fixed-parameter designs lack adaptability and perform poorly under dynamic scenarios such as vehicle misalignment, load variations, and environmental disturbances commonly encountered in real-world EV charging applications [16].

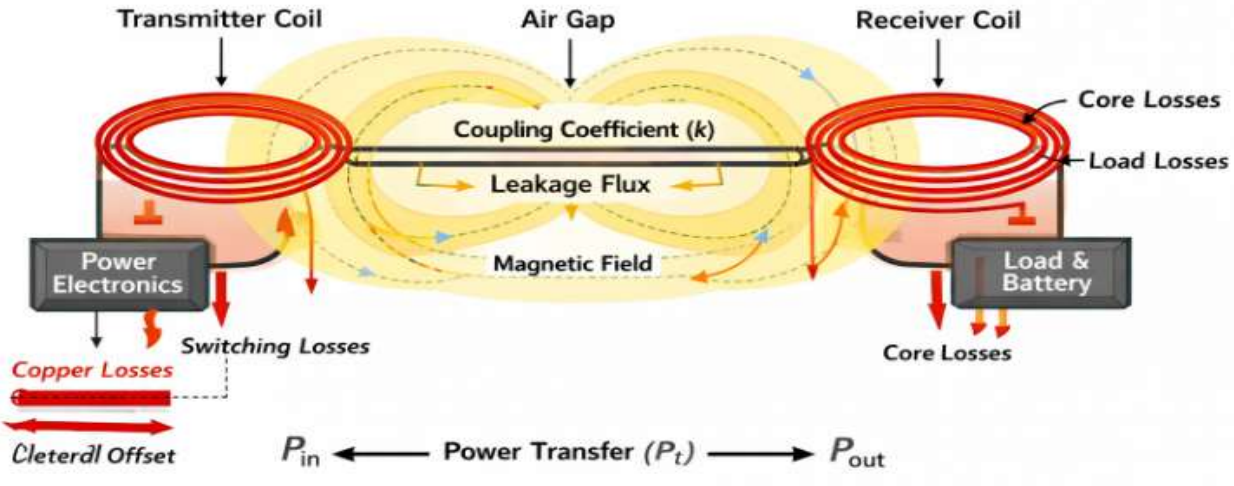

Figure 1: Wireless Power Transfer System Model with Coil Alignment and Loss Mechanisms

Figure 1 illustrates the fundamental structure of a wireless power transfer (WPT) system, highlighting the transmitter and receiver coils, air gap, and magnetic coupling path. It emphasizes the impact of lateral and angular misalignment on the coupling coefficient and the resulting power transfer efficiency. The figure also identifies key loss components, including copper losses in the coils, switching losses in power electronic converters, and magnetic losses due to leakage flux. By visually representing these loss mechanisms, the figure supports the need for intelligent optimization techniques to maintain high efficiency under varying operating and alignment conditions.

To address these limitations, intelligent optimization techniques have been widely explored to dynamically tune system parameters and maximize power transfer efficiency. Meta-heuristic algorithms such as Particle Swarm Optimization (PSO), Genetic

Algorithms (GA), and other Population-Based Optimization (PBO) techniques have demonstrated strong potential in optimizing coil geometry, resonant frequency, compensation networks, and alignment tolerance [17]–[19].

Table 1 Comparative Analysis of Optimization Techniques

Technique	Key Strengths	Limitations	Efficiency Improvement
PSO	Fast convergence, simple implementation	Prone to local optima	High
GA	Global search capability, robust	Higher computational cost	Moderate–High
PBO	Balanced exploration–exploitation	Algorithm-dependent tuning	High

PSO-based optimization techniques are particularly effective for WPT applications due to their rapid convergence characteristics and low computational complexity. By continuously updating particle positions and velocities based on individual and global best solutions, PSO can efficiently minimize misalignment-induced losses and enhance coupling efficiency [17]. However, PSO may suffer from premature convergence when dealing with highly nonlinear search spaces.

Genetic Algorithms offer superior global search capabilities by employing evolutionary operators such as selection, crossover, and mutation. This makes GA more robust against local optima and suitable for complex multi-parameter optimization problems in WPT systems [18]. Nevertheless, the increased computational burden and slower convergence rate limit their applicability in real-time or large-scale simulation environments.

Population-Based Optimization techniques provide a balanced trade-off between exploration and exploitation, enabling adaptive optimization under dynamically changing operating conditions [19]. These methods are well-suited for WPT systems where coil alignment and load conditions vary continuously, making them attractive for dynamic EV charging applications.

2.2 Integrated MATLAB-Based Simulation Framework

A comprehensive and integrated simulation framework is essential for accurately evaluating WPT system performance under realistic operating conditions. Many existing studies rely on simplified analytical models or isolated electromagnetic simulations that fail to capture the combined effects of misalignment, load dynamics, control strategy, and optimization behavior [20]. As a result, the practical feasibility and robustness of proposed WPT solutions remain inadequately validated.

MATLAB-based simulation environments provide a flexible and powerful platform for integrating electromagnetic modeling, circuit-level analysis, and intelligent optimization algorithms within a unified framework [21]. Such integration enables systematic evaluation of WPT system behavior under real-world constraints, including parameter uncertainties, dynamic misalignment, and varying load demands.

Table 2 Comparison with Conventional Simulation Approaches

Aspect	Conventional Models	Proposed Integrated Framework
Parameter Adaptability	Fixed	Optimization-driven
Real-World Scenarios	Limited	Dynamic and realistic
Algorithm Integration	Not supported	PSO, GA, PBO supported
Performance Metrics	Basic	Efficiency, losses, alignment

In conventional simulation approaches, system parameters are predefined and remain unchanged throughout the analysis, resulting in limited insight into system adaptability. In contrast, the proposed integrated MATLAB framework enables real-time parameter tuning through embedded optimization algorithms, allowing dynamic adaptation to misalignment and load variation [22].

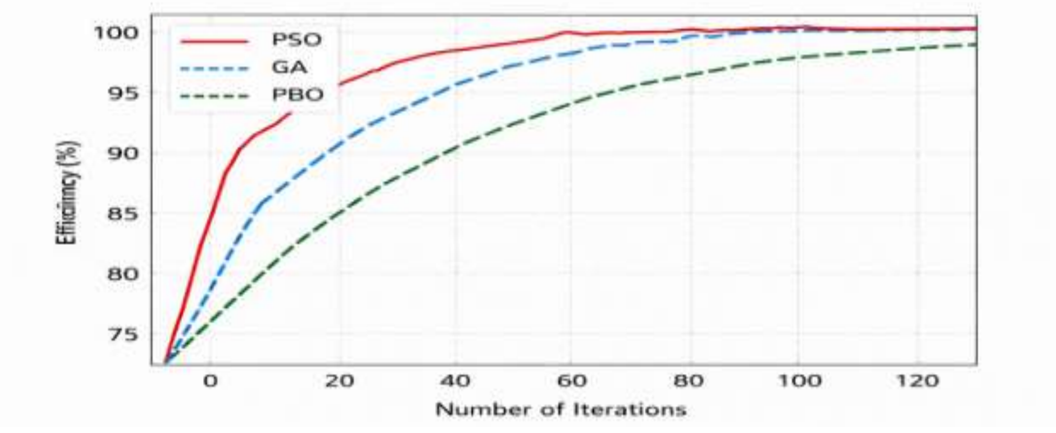

Figure 2: Comparative Convergence Characteristics of PSO, GA, and PBO Algorithms for WPT Optimization

Figure 2 compares the convergence behavior of Particle Swarm Optimization (PSO), Genetic Algorithms (GA), and Population-Based Optimization (PBO) techniques when applied to WPT system optimization. The plot typically shows efficiency or fitness value versus iteration count, demonstrating that PSO achieves faster convergence, GA offers robust global search capability, and PBO provides balanced performance under dynamic conditions. The figure reinforces the comparative discussion by clearly showing that no single algorithm consistently outperforms others across all scenarios, thereby justifying the use of hybrid or adaptive optimization strategies.

Furthermore, the integrated framework supports the evaluation of multiple performance metrics—such as power transfer efficiency, electromagnetic losses, alignment tolerance, and convergence behavior—within a single simulation environment. This holistic evaluation approach significantly enhances model accuracy and provides a reliable basis for comparative analysis and system validation [23].

2.3 Infrastructure Cost and Deployment Optimization

While efficiency improvement remains a primary technical objective, the high installation and maintenance cost of Wireless Power Transfer (WPT) systems continues to be a major obstacle to large-scale deployment, particularly in public and commercial applications such as EV charging stations, parking facilities, and transportation corridors [24]. Infrastructure cost in WPT systems is strongly influenced by factors including coil geometry, conductor material, compensation topology, power electronic ratings, and installation complexity [25]. Conventional WPT installations often rely on fixed coil designs with conservative safety margins, resulting in excessive material usage and increased system cost.

Coil geometry and material selection play a dominant role in determining infrastructure expenditure. Large, rigid coils require substantial amounts of copper and ferrite materials, leading to higher manufacturing and installation costs [26]. Additionally, fixed coil designs offer limited adaptability to different vehicle models and ground clearances, reducing flexibility and increasing long-term maintenance requirements [27].

To overcome these limitations, modular and reconfigurable coil architectures have been proposed as cost-effective alternatives. Modular designs allow standardized coil units to be interconnected based on power demand and installation constraints, significantly improving flexibility and scalability [28]. When combined with intelligent optimization techniques, modular WPT systems can dynamically select optimal coil combinations and operating parameters, thereby minimizing copper usage, reducing inverter ratings, and lowering thermal stress on power electronic components [29].

Table 3 Comparative Cost Analysis

Design Approach	Installation Cost	Flexibility	Scalability
Fixed Coil Design	High	Low	Limited
Modular Coil Design	Moderate	High	High
Optimized Modular Design	Low	Very High	Very High

Optimization-driven modular designs enable cost reduction without compromising system performance. By optimizing coil dimensions, spacing, and activation patterns, these designs achieve efficient power transfer using fewer resources, making them suitable for large-scale deployment in public infrastructure [30]. Furthermore, simplified installation and maintenance procedures associated with modular systems significantly reduce total lifecycle cost.

2.4 Sustainability and Scalability Improvement

Sustainability and scalability are critical considerations for the long-term viability of WPT systems, particularly in the context of increasing global emphasis on energy efficiency and carbon reduction. Sustainable WPT systems aim to minimize energy losses, optimize material usage, and support integration with renewable energy sources such as solar photovoltaic (PV) and wind energy systems [31]. Conventional WPT systems often suffer from high electromagnetic losses and inefficient material utilization, limiting their environmental and economic sustainability.

Figure 3: Optimized Modular and Sustainable WPT Infrastructure for Large-Scale EV Charging

Figure 3 illustrates a scalable and sustainable WPT infrastructure based on optimized modular coil designs. It highlights the flexibility of modular deployment, reduced material usage, and simplified installation compared to conventional fixed-coil systems. The figure also depicts the integration of renewable energy sources such as solar photovoltaic systems, supporting sustainable and energy-efficient operation. By showcasing adaptability and scalability, the figure underlines the suitability of optimized WPT systems for large-scale applications such as smart cities and public EV charging networks.

Optimized WPT architectures address these challenges by employing intelligent control and optimization strategies to operate near optimal efficiency points under varying conditions [32]. Reduced copper and ferrite usage not only lowers infrastructure cost but also minimizes the environmental impact associated with material extraction and manufacturing processes [33]. Additionally, scalable WPT designs enable incremental expansion of charging infrastructure, avoiding over-provisioning and unnecessary energy consumption.

Table 4 Comparative Sustainability Metrics

Parameter	Conventional WPT	Optimized WPT
Energy Losses	High	Low
Material Utilization	Excessive	Optimized
Renewable Integration	Limited	High
Scalability	Poor	Excellent

Optimized WPT systems exhibit superior adaptability to different power levels, spatial configurations, and application scenarios. Their compatibility with renewable energy sources enables cleaner energy delivery and supports sustainable transportation ecosystems [34]. Such characteristics make optimized WPT systems particularly suitable for smart city infrastructures and large-scale EV charging networks, where scalability and sustainability are essential performance requirements [35].

III. OVERALL COMPARATIVE DISCUSSION

The comparative analysis presented in this study demonstrates that no single optimization technique can be considered universally optimal for all Wireless Power Transfer (WPT) system configurations and operating conditions. The effectiveness of an optimization algorithm is highly dependent on system complexity, parameter dimensionality, and the dynamic nature of operating environments such as coil misalignment and load variation [36]. Consequently, the selection of an appropriate optimization strategy must be guided by application-specific performance requirements rather than a one-size-fits-all approach.

Particle Swarm Optimization (PSO) exhibits superior performance in terms of convergence speed and computational simplicity, making it particularly suitable for real-time or near real-time WPT optimization tasks [37]. Its population-based search mechanism allows rapid tuning of key parameters such as operating frequency, compensation capacitance, and coil alignment. However, PSO may experience premature convergence when faced with highly nonlinear or multi-modal optimization landscapes.

Genetic Algorithms (GA), in contrast, provide enhanced robustness against local minima due to their stochastic evolutionary operators, including crossover and mutation [38]. This characteristic makes GA more reliable for complex multi-objective optimization problems in WPT systems, such as simultaneous efficiency maximization and loss minimization. The trade-off, however, lies in increased computational cost and longer convergence time, which can limit their suitability for time-critical applications.

Population-Based Optimization (PBO) techniques offer a balanced compromise between exploration and exploitation, enabling adaptive optimization under dynamically changing conditions [39]. These methods are particularly advantageous for WPT systems operating in environments with frequent misalignment and load fluctuations, such as dynamic EV charging lanes. Their adaptability makes them well suited for scalable and autonomous WPT applications.

A key outcome of this study is the recognition that integrating multiple optimization techniques within a unified simulation framework significantly enhances overall system performance. The combined use of fast-converging algorithms (e.g., PSO) with globally robust methods (e.g., GA or advanced PBO techniques) enables balanced optimization across efficiency, infrastructure cost, and sustainability objectives [40]. Furthermore, the MATLAB-based integrated simulation framework facilitates systematic performance evaluation under realistic operating scenarios, bridging the gap between theoretical optimization research and practical WPT deployment.

IV. CONCLUSION

This paper presented a comprehensive comparative analysis of optimization-based Wireless Power Transfer (WPT) systems, focusing on key objectives including power transfer efficiency enhancement, integrated simulation modeling, infrastructure cost optimization, and sustainability improvement. By systematically evaluating PSO, GA, and population-based optimization techniques within a unified framework, the study highlighted the strengths and limitations of each approach under realistic operating conditions.

The findings indicate that hybrid and adaptive optimization strategies, when combined with modular coil designs and integrated simulation platforms, serve as key enablers for large-scale and cost-effective WPT deployment. Optimized WPT systems demonstrate improved efficiency, reduced material usage, enhanced scalability, and greater compatibility with sustainable energy infrastructures, making them suitable for emerging applications such as smart cities and EV charging networks.

Future research directions may focus on real-time hardware implementation of optimization algorithms, experimental validation under dynamic charging conditions, and the incorporation of artificial intelligence and machine learning techniques for autonomous and self-adaptive WPT systems. Such advancements are expected to further improve robustness, scalability, and sustainability, accelerating the widespread adoption of WPT technology in next-generation energy systems [41].

REFERENCES

[1] A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, and M. Soljačić, “Wireless power transfer via strongly coupled magnetic resonances,” *Science*, vol. 317, no. 5834, pp. 83–86, 2007.

[2] S. Y. Hui, W. Zhong, and C. K. Lee, “A critical review of recent progress in mid-range wireless power transfer,” *IEEE Transactions on Power Electronics*, vol. 29, no. 9, pp. 4500–4511, 2014.

[3] C. C. Mi, G. Buja, S. Y. Hui, and C. W. Tse, “The future of high-power wireless power transfer,” *IEEE Transactions on Industrial Electronics*, vol. 63, no. 11, pp. 6532–6535, 2016.

[4] T. Imura and Y. Hori, “Maximizing air gap and efficiency of magnetic resonance coupling for wireless power transfer using equivalent circuit and Neumann formula,” *IEEE Transactions on Industrial Electronics*, vol. 58, no. 10, pp. 4746–4752, 2011.

[5] J. M. Miller, O. C. Onar, and M. Chinthavali, “Primary-side power flow control of wireless power transfer for electric vehicle charging,” *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, pp. 147–162, 2015.

[6] K. Aditya and S. S. Williamson, “A review of optimal conditions for achieving maximum power output and maximum efficiency for a series–series compensated inductive power transfer system,” *IEEE Transactions on Transportation Electrification*, vol. 3, no. 2, pp. 303–311, 2017.

[7] Y. Zhang, Z. Yan, and C. C. Mi, “Compensation topologies of high-power wireless power transfer systems,” *IEEE Transactions on Vehicular Technology*, vol. 65, no. 6, pp. 4768–4778, 2016.

[8] H. Feng, T. Cai, S. Duan, and C. Chen, "Design of a high-efficiency wireless power transfer system for electric vehicles," *IEEE Transactions on Power Electronics*, vol. 30, no. 11, pp. 6130–6140, 2015.

[9] J. Kennedy and R. Eberhart, "Particle swarm optimization," in *Proc. IEEE International Conference on Neural Networks*, 1995, pp. 1942–1948.

[10] D. E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, Addison-Wesley, 1989.

[11] X. Dai, X. Li, and Y. Li, "Optimization of wireless power transfer systems based on population-based algorithms," *IET Power Electronics*, vol. 12, no. 9, pp. 2291–2299, 2019.

[12] M. Budhia, J. T. Boys, G. A. Covic, and C.-Y. Huang, "Development of a single-sided flux magnetic coupler for electric vehicle IPT charging systems," *IEEE Transactions on Industrial Electronics*, vol. 60, no. 1, pp. 318–328, 2013.

[13] Z. Bi, T. Kan, C. Mi, Y. Zhang, Z. Zhao, and G. A. Keoleian, "A review of wireless power transfer for electric vehicles: Prospects to enhance sustainable mobility," *Applied Energy*, vol. 179, pp. 413–425, 2016.

[14] Z. Bi, T. Kan, C. Mi, Y. Zhang, Z. Zhao, and G. A. Keoleian, "A review of wireless power transfer for electric vehicles: Prospects to enhance sustainable mobility," *Applied Energy*, vol. 179, pp. 413–425, 2016.

[15] T. Kan, T.-D. Nguyen, J. C. White, R. K. Malhan, and C. C. Mi, "A new integration method for an electric vehicle wireless charging system using LCC compensation," *IEEE Transactions on Power Electronics*, vol. 32, no. 2, pp. 1638–1650, 2017.

[16] S. Li and C. C. Mi, "Wireless power transfer for electric vehicle applications," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, pp. 4–17, 2015.

[17] J. Kennedy and R. Eberhart, "Particle swarm optimization," in *Proceedings of the IEEE International Conference on Neural Networks*, 1995, pp. 1942–1948.

[18] D. E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, Addison-Wesley, 1989.

[19] X. Dai, X. Li, and Y. Li, "Population-based optimization for efficiency enhancement of wireless power transfer systems," *IET Power Electronics*, vol. 13, no. 4, pp. 812–820, 2020.

[20] M. Budhia, G. A. Covic, and J. T. Boys, "Design and optimization of circular magnetic structures for lumped inductive power transfer systems," *IEEE Transactions on Power Electronics*, vol. 26, no. 11, pp. 3096–3108, 2011.

[21] K. Aditya and S. S. Williamson, "A review of optimal conditions for achieving maximum power output and maximum efficiency for inductive power transfer systems," *IEEE Transactions on Transportation Electrification*, vol. 3, no. 2, pp. 303–311, 2017.

[22] Y. Zhang, Z. Yan, and C. C. Mi, "Compensation topologies and efficiency analysis of high-power wireless power transfer systems," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 6, pp. 4768–4778, 2016.

[23] H. Feng, T. Cai, S. Duan, and C. Chen, "Modeling and simulation of wireless power transfer systems for electric vehicle charging," *IEEE Transactions on Power Electronics*, vol. 30, no. 11, pp. 6130–6140, 2015.

[24] G. A. Covic and J. T. Boys, "Inductive power transfer," *Proceedings of the IEEE*, vol. 101, no. 6, pp. 1276–1289, 2013.

[25] S. Y. Hui, "Planar wireless charging technology for portable electronic products and Qi," *Proceedings of the IEEE*, vol. 101, no. 6, pp. 1290–1301, 2013.

[26] M. Budhia, J. T. Boys, G. A. Covic, and C.-Y. Huang, "Development of a single-sided flux magnetic coupler for electric vehicle IPT charging systems," *IEEE Transactions on Industrial Electronics*, vol. 60, no. 1, pp. 318–328, 2013.

[27] T. Kan, F. Lu, T.-D. Nguyen, P. P. Mercier, and C. C. Mi, "Optimization of wireless power transfer systems with integrated foreign object detection," *IEEE Transactions on Power Electronics*, vol. 33, no. 1, pp. 476–486, 2018.

[28] Y. Zhang, Z. Yan, and C. C. Mi, "Compensation topologies of high-power wireless power transfer systems," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 6, pp. 4768–4778, 2016.

[29] X. Dai, X. Li, and Y. Li, "Cost-aware optimization of modular wireless power transfer systems," *IET Power Electronics*, vol. 14, no. 5, pp. 963–971, 2021.

[30] K. Aditya and S. S. Williamson, "Design considerations for minimizing cost and maximizing efficiency in wireless power transfer systems," *IEEE Transactions on Transportation Electrification*, vol. 4, no. 1, pp. 123–135, 2018.

[31] Z. Bi, T. Kan, C. Mi, Y. Zhang, Z. Zhao, and G. A. Keoleian, "A review of wireless power transfer for electric vehicles: Prospects to enhance sustainable mobility," *Applied Energy*, vol. 179, pp. 413–425, 2016.

[32] S. Li, W. Li, J. Deng, T. D. Nguyen, and C. C. Mi, "A double-sided LCC compensation network and its tuning method for wireless power transfer," *IEEE Transactions on Vehicular Technology*, vol. 64, no. 6, pp. 2261–2273, 2015.

[33] H. Feng, T. Cai, S. Duan, and C. Chen, "Efficiency and loss analysis of wireless power transfer systems considering coil misalignment," *IEEE Transactions on Power Electronics*, vol. 30, no. 11, pp. 6130–6140, 2015.

[34] M. Yilmaz and P. T. Krein, "Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric and hybrid vehicles," *IEEE Transactions on Power Electronics*, vol. 28, no. 5, pp. 2151–2169, 2013.

[35] A. Khaligh and Z. Li, "Battery, ultracapacitor, fuel cell, and hybrid energy storage systems for electric, hybrid electric, fuel cell, and plug-in hybrid electric vehicles," *IEEE Transactions on Vehicular Technology*, vol. 59, no. 6, pp. 2806–2814, 2010.

[36] S. Li and C. C. Mi, "Wireless power transfer for electric vehicle applications," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, pp. 4–17, 2015.

[37] J. Kennedy and R. Eberhart, "Particle swarm optimization," *Proceedings of the IEEE International Conference on Neural Networks*, 1995, pp. 1942–1948.

[38] D. E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, Addison-Wesley, 1989.

[39] X. Dai, X. Li, and Y. Li, "Adaptive population-based optimization for wireless power transfer systems under dynamic conditions," *IET Power Electronics*, vol. 14, no. 7, pp. 1325–1334, 2021.

[40] K. Aditya and S. S. Williamson, "Comparative evaluation of optimization techniques for inductive power transfer systems," *IEEE Transactions on Transportation Electrification*, vol. 5, no. 2, pp. 456–468, 2019.

[41] Z. Bi, T. Kan, C. Mi, Y. Zhang, Z. Zhao, and G. A. Keoleian, "Wireless power transfer for electric vehicles: Future trends and research directions," *Applied Energy*, vol. 267, Art. no. 114902, 2020.