IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Dynamic Wireless Charging Systems for Electric Vehicles

Mahesh . S [1], Sirivanth.S[2], Tejas S.N [3], Thanishq D Gaikwad [4] , Mrs.Vishalini Divakar [5]

[1 - 4] Students, Electronics and Communication Engineering, K. S. Institute of Technology, Bangalore, India.

[5]Assistant Professor, Electronics and Communication Engineering, K. S. Institute of Technology, Bangalore, India

Abstract: This project presents a Dynamic Wireless Charging System (DWCS) for electric vehicles using inductive power transfer. The system enables EVs to charge while moving through mutual inductive coupling between coils placed under the road and on the vehicle. Experimental results show a pulsating DC output of around 12 V and 3 A, with an efficiency of 75–85%, and an optimal charging speed of 3–4 m/s. The study demonstrates that dynamic wireless charging can reduce EV downtime, extend driving range, and support continuous on-road power. This technology offers a promising step toward smart and sustainable transportation by integrating clean energy, automation, and contactless charging infrastructure.

Index Terms - Dynamic Wireless Charging, Electric Vehicles, Wireless Power Transfer, Inductive Power Transfer, Mutual Inductance, Charging Efficiency, Transmitter Coil, Receiver Coil, Smart Transportation Systems, Renewable Energy Integration.

1. INTRODUCTION :

Electric Vehicles (EVs) are increasingly recognized as a feasible and sustainable solution to modern mobility needs, offering a significant reduction in the harmful emissions associated with the fossil fuel- based transport sector. Moreover, with proper management, EVs can support the integration of renewable energy sources by adding flexibility to grid operations. However, the widespread adoption of this technology is hindered by several key challenges, including limited driving range, the associated "range anxiety," and the long charging downtimes required by conventional plug-in methods. These factors can limit the convenience offered by personal vehicles and slow the transition away from traditional internal combustion engines.

To address these limitations, Dynamic Wireless Charging (DWC) has emerged as a transformative technology that enables EVs to recharge their batteries while in motion. By embedding wireless power transmitters into the road surface, DWC systems can transfer energy to vehicles as they drive, effectively realizing the concept of "charging while driving". This innovation offers profound advantages: it can significantly reduce the required size of on-board batteries, thereby lowering vehicle cost and weight, while simultaneously increasing the effective cruising range and eliminating charging-related delays. The feasibility of DWC is not merely theoretical; it has been successfully tested in several pilot projects in cities across the globe, including projects in South Korea, Spain, France, and Italy.

2. LITERATURE REVIEW

2.1 City-Wide Optimization of Dynamic Wireless Charging Infrastructure

[1] Elmeligy et al. They proposed a comprehensive framework for the optimal planning of DWC infrastructure at a city-wide scale. Their methodology integrates realistic traffic simulations using the Simulation of Urban Mobility (SUMO) tool to accurately model EV charging demand. A key contribution is the use of a Mixed Integer Non-Linear Programming (MINLP) model that not only determines the optimal locations, lengths, and power levels for DWC lanes but also allocates Distributed Generation (DG) resources, such as solar panels and battery storage, to support the power grid. The study, conducted for a large road network in Sharjah, UAE, concluded that a DWC system is economically feasible and profitable with a 30% EV penetration level

2.2 Efficient Coil Design Using Equivalent Layer Modeling for DWC Systems

[2] Trivino et al. they addressed the significant computational demand required for designing complex DWC coils, such as the DD and DDQ topologies. The authors demonstrated the feasibility of using a simplified "equivalent layer" to model the Litz wire conductor in Finite Element (FE) simulations. This homogenization technique was shown to reduce the computational time of each

design iteration by up to 20 times while maintaining accuracy. Their work presents an efficient iterative algorithm for designing coils that accounts for performance under various misalignment conditions, using an efficiency-to-length ratio as a key figure of merit for selecting the best configuration.

2.3 Optimization of Ground-Side Transmitting Coil Length for High-Speed Dynamic Charging

[3] Tan et al. it focused on optimizing the parameters of the ground-side power transmitting coil, specifically its length, for long-track DWC systems suitable for high-speed driving. The study uses an LCC-S resonance compensation topology and aims to balance system efficiency, laying cost, and the charging power required to offset an EV's consumption at maximum speed. It incorporates the "2 seconds principle" for safe braking distances to determine minimum coil lengths and establishes a methodology to select the number of coil segments that meets both economic and efficiency requirements, aiming for an efficiency of at least 80%.

2.4 Comprehensive Review of WPT Technologies and Unified Charging Model

[4] Mohamed et al. It provided a comprehensive analysis and review of WPT systems for EVs, covering key technologies, compensation topologies, and coil designs. The paper compares Inductive, Capacitive, and Magnetic Resonance power transfer methods, highlighting IPT as most suitable for high-power EV applications. It details the four main compensation topologies (SS, SP, PS, PP) and discusses various coil shapes used to mitigate misalignment. A significant contribution is the proposal of a general mathematical model (DS-WCSEV) that can accurately evaluate charging performance in both static and dynamic scenarios by incorporating vehicle speed and position.

2.5 Traffic-Aware Deployment of DWC Lanes Considering Road Capacity Impacts

[5]Lingshu Zhong They investigated the optimal deployment of DWC lanes while considering their adverse effect on road capacity. The authors acknowledged that EV drivers may be incentivized to travel slower on charging lanes to maximize the energy received. This behavior can increase the total travel time across the road network and reduce overall traffic efficiency. Their model addresses this interplay between driver behavior and infrastructure deployment, providing a more nuanced perspective on the traffic impacts of DWC systems.

2.6 Accelerated 3D Finite Element Simulation Through Litz Wire Homogenization

[6] Delgado et al. This work provides the foundational methodology for significantly accelerating the 3D Finite Element (FE) simulations used to design Inductive Power Transfer (IPT) coils. The authors addressed the major computational bottleneck caused by modeling Litz wire, which consists of hundreds or thousands of fine, insulated strands that are extremely difficult to mesh and simulate directly. Their solution is a homogenization process that replaces the complex Litz wire winding with a single, solid "equivalent conductor layer". The properties of this layer—its homogeneous conductivity (σl) and complex permeability (μl) are mathematically derived to ensure that it accurately represents the same energy storage, magnetic losses, and electrical losses of the actual winding. The equations are based on the physical characteristics of the Litz wire, such as the number and diameter of its strands. This simplification dramatically reduces the complexity of the simulation mesh, allowing for much faster and more efficient computation without sacrificing accuracy. The method is particularly vital for designing DWC systems, where the need to simulate numerous coil configurations under various misalignment conditions makes the iterative design process impractical with conventional modeling techniques.

2.7 Development of the Double-D Magnetic Coupler for Misalignment-Tolerant EV Charging

[7] Budhia et al. This research was instrumental in developing a practical magnetic coupler for EV charging systems that is highly tolerant to misalignment. Standard circular or rectangular charging pads suffer from a significant drop in efficiency when the transmitter and receiver are not perfectly aligned, a constant issue for real-world EV charging. The authors designed and optimized a "single-sided flux magnetic coupler," now widely known as the Double-D (DD) coil. Unlike a circular pad that generates a perpendicular magnetic field, the DD structure consists of two D-shaped coils that produce a more uniform and contained parallel magnetic flux path. This polarized flux provides superior magnetic coupling even with significant positional offsets, especially along the direction of vehicle travel. The DD coil has since become a foundational technology for both static and dynamic WPT systems, as its inherent misalignment tolerance is a critical enabler for efficient and reliable on-the-move charging.

2.8 Fundamental Power Transfer and Bifurcation Analysis in Loosely Coupled IPT Systems

[8] Wang, Covic, and Stielau This foundational paper explored the fundamental power transfer characteristics and stability issues inherent in "loosely coupled" inductive power systems, which are the basis for all WPT technology. Because the magnetic coupling between the transmitter and receiver coils is weak, the system's performance is highly sensitive to changes in load and the coupling coefficient . A primary contribution of their work was the detailed analysis of the "bifurcation phenomenon". Bifurcation occurs when a system's single resonant frequency splits into multiple frequencies, typically under conditions of strong coupling or light loads. Attempting to operate the system at its original design frequency during bifurcation can lead to a drastic reduction in power transfer and system instability. The authors provided the analytical framework to predict the conditions under which bifurcation occurs, allowing engineers to design compensation networks and control strategies that avoid these unstable regions. Their analysis is essential for creating robust WPT systems that can maintain stable and efficient operation across the wide range of conditions experienced during EV charging.

2.9 State-of-the-Art Review of Wireless Power Transfer for Vehicular Systems

[9] Patil et al. This paper provides a broad and insightful review of the state-of-the-art in wireless power transfer for all vehicular applications, summarizing the technology's progress and outlining its persistent challenges. The authors trace the evolution from Static WPT (SWPT) to Dynamic WPT (DWPT), emphasizing DWC's potential to significantly reduce EV battery sizes and alleviate range anxiety. The review critically examines different system components, such as compensation topologies. For instance, it notes

that while the simple Series-Series (S-S) topology is common, its transmitter-side current varies with the charging state, making energy losses difficult to control in a multi-vehicle DWC system. The paper identifies several key challenges that are critical for the commercialization of WPT, including the need for higher power density, improved efficiency, greater misalignment tolerance, effective electromagnetic field containment, and cost reduction. Crucially, it highlights the pressing need for industry-wide standardization to ensure interoperability between charging infrastructure and vehicles from different manufacturers.

2.10 System-Level Design Methodology for Inductive Charging of EV Batteries

[10]Sallan et al. This work presented one of the early, comprehensive methodologies for the optimal design of a complete Inductively Coupled Power Transfer (ICPT) system specifically for charging EV batteries. Rather than focusing on a single component, the authors took a holistic, system-level approach to the design process. Their methodology involves creating an integrated model that includes all major system components: the power inverter, the magnetic coupler (coils), the resonant compensation network, and the final battery load. By analyzing the system as a whole, their approach allows for the optimization of key design parameters to maximize overall efficiency and ensure stable power delivery to the battery. This research was significant because it provided a structured engineering framework for designing practical, real-world wireless chargers, moving beyond purely theoretical concepts. It helped establish the design principles needed to create reliable and effective ICPT systems tailored to the specific demands of EV battery charging applications.

3. SYSTEMS DESIGN AND IMPLEMENTATION

The Dynamic Wireless Charging System (DWCS) allows electric vehicles to receive power while moving. The system works on Inductive Power Transfer (IPT), where energy is transmitted from coils embedded under the road to a receiving coil installed beneath the vehicle. The goal is to deliver continuous charging during motion without requiring the vehicle to stop or plug in.

3.1 . BLOCK DIAGRAM

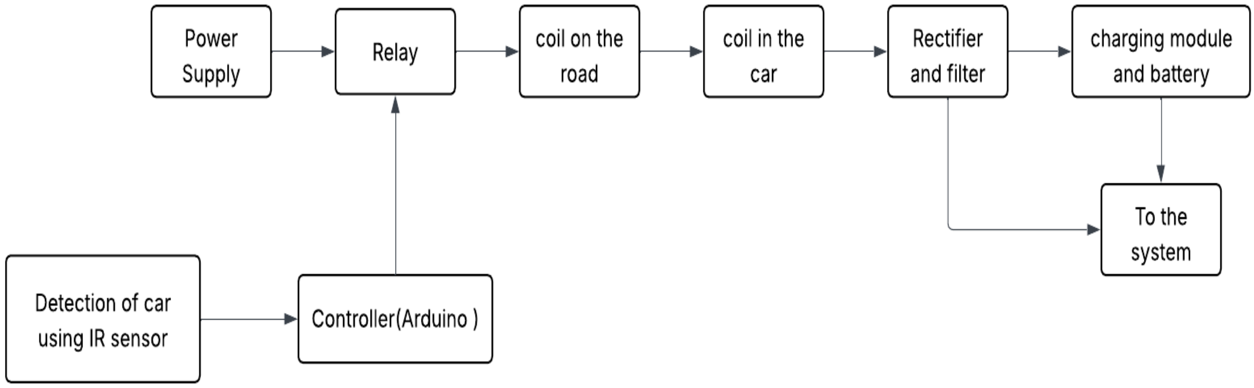

Figure 3 .1 .1. Block Diagram of Dynamic Wireless Charging Systems for Electric Vehicles.

- The dynamic wireless charging architecture operates through a coordinated sequence of sensing, control, power conversion, and inductive transfer stages. Vehicle detection is achieved through an array of infrared (IR) sensors embedded along the roadway, which generate discrete digital signals upon the presence of a passing chassis.
- These signals are processed by a microcontroller (Arduino), which executes the segment-activation logic and determines the appropriate transmitter coil to energize based on real-time vehicle position. The controller drives a relay switching network, where each relay corresponds to a specific road-embedded coil, enabling the low-power control signal to interface with the high-power charging circuitry.
- Once activated, the relay connects the selected coil to a high-frequency AC power supply, which provides the 20–100 kHz excitation required for efficient inductive power transfer.
- The energized transmitter coil establishes an alternating magnetic field that couples with the resonant receiver coil mounted beneath the vehicle.
- As the vehicle traverses the charging lane, the magnetic coupling induces high-frequency AC in the receiver coil, in accordance with Faraday's law of electromagnetic induction.
- This induced AC is subsequently processed by a rectifier and filter stage, which performs AC-to-DC conversion and ripple reduction to produce a stable DC output. The conditioned DC power is delivered to the vehicle's charging module and battery management system (BMS), which regulates current, voltage, and thermal conditions to ensure safe and efficient charging.
- The system can additionally supply power to onboard vehicle electronics as required, enabling continuous energy flow during dynamic operation.

3.2 FLOW CHART

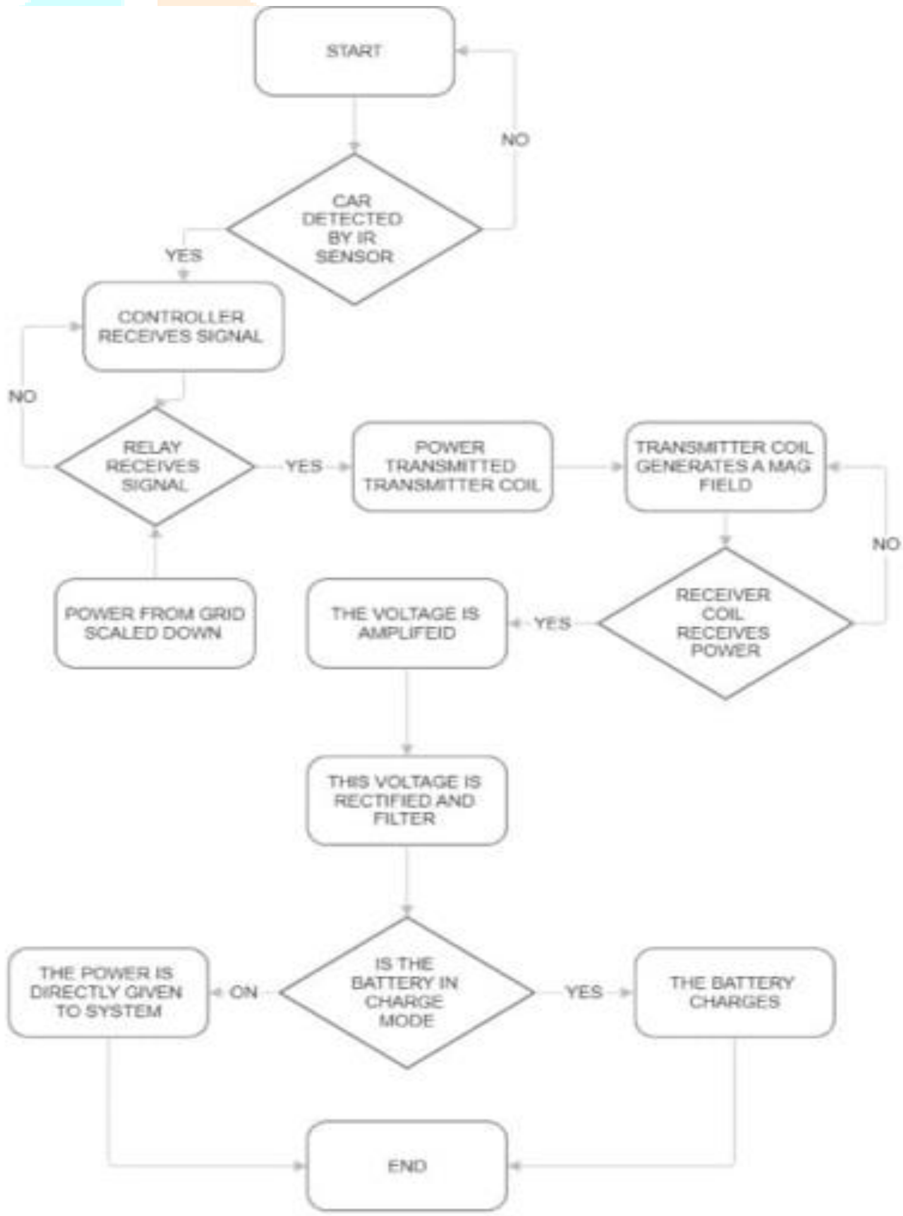

Figure 3.. 2. 2 Flow Chart Of Dynamic Wireless Charging Systems for Electric Vehicles.

- The operation of the dynamic wireless charging system begins when the process starts and the roadway sensors continuously monitor for an approaching vehicle.
- Once a car is detected by the IR sensor, a signal is sent to the controller, which processes the detection and activates the appropriate relay.
- The relay then closes the circuit that allows power from the grid scaled and conditioned as needed to be delivered to the transmitter coil.
- When energized, the transmitter coil generates a high-frequency magnetic field.
- As the vehicle moves over this active coil, the receiver coil mounted underneath the car captures the magnetic flux and converts it into electrical power.
- This induced AC voltage is then amplified, rectified, and filtered to produce a clean DC output.
- The system then checks whether the vehicle's battery is in charge mode. If the battery requires charging, the DC power is routed to the battery, allowing it to charge safely.
- If the battery does not need charging, the power is supplied directly to the vehicle's electrical system.
- Once the charging or power transfer process is complete, the system returns to its idle state, ready to detect the next vehicle.

4. RESULTS

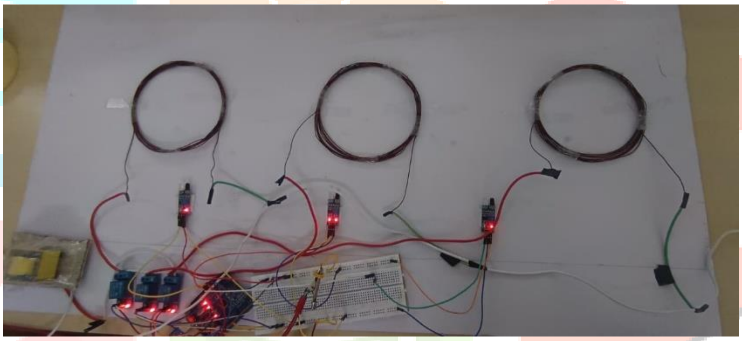

Figure 4.1 : Construction on the road part

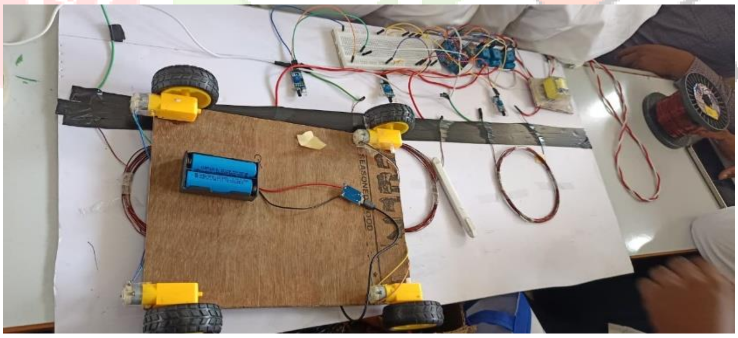

Figure 4 .2 : Charging part of the project while moving

The Dynamic Wireless Charging (DWC) system for electric vehicles highlights the strong potential of wireless power transfer technology to transform the future of electric mobility. Using the principle of mutual inductance, the system enables seamless energy transfer between transmitter coils embedded in the roadway and receiver coils mounted beneath the vehicle, allowing EVs to charge continuously even while in motion. In the implemented design, the transmitter circuitry converts 220 V DC into high-frequency AC, while the receiver side delivers a stable pulsating DC output of 12 V at 3 A. This demonstrates that wireless energy transfer is not only practical but also effective for real EV charging needs. By providing consistent power delivery without any physical contact, the system directly addresses major limitations of conventional charging methods, such as long charging times and the need for oversized batteries.

Overall, the proposed DWC system offers a safe, efficient, and sustainable alternative to plug-in charging. It reduces charging downtime, enhances operational efficiency, and supports smooth integration into smart transportation networks. With continued improvements in coil alignment, resonance tuning, power electronics, and infrastructure design, Dynamic Wireless Charging has the potential to become a key technology for enabling next-generation smart and environmentally friendly transportation systems.

5 . CONCLSUTIONS AND FUTURE SCOPE

The development of Dynamic Wireless Charging Systems for Electric Vehicles demonstrates a promising step toward overcoming the limitations of conventional plug-in charging methods. By enabling continuous energy transfer through inductive coupling, the system effectively reduces charging downtime, supports extended travel ranges, and enhances the practicality of electric mobility. The experimental results confirm that wireless power delivery is both feasible and efficient, reinforcing its potential as a reliable charging solution for future EV applications. Overall, the system contributes to a cleaner, smarter, and more convenient transportation ecosystem.

Looking ahead, there are several opportunities to further advance this technology. Improvements in coil design, magnetic alignment, and resonance compensation can significantly enhance power transfer efficiency. Integrating renewable energy sources and real-time communication systems can make dynamic charging lanes more sustainable and intelligent. Additionally, large-scale deployment will benefit from cost-effective infrastructure materials, advanced safety mechanisms, and standardized design protocols. With continued research and development, Dynamic Wireless Charging has the potential to become a core component of next-generation smart transportation networks and play a critical role in accelerating global EV adoption.

6. REFFERNCES

[1] Madawala UK, Thrimawithana DJ (2011) A bidirectional inductive power interface for electric vehicles in V2G systems. IEEE Trans Ind Electron 58:789–4796

[2] Hori Y (2013) Looking at cars 100 years in the future. Paper presented at the IEEE international conference on mechatronics (ICM), 2013

[3] Chi KL, Zhong WX, Hui SYR (2012) Effects of magnetic coupling of nonadjacent resonators on wireless power domino-resonator systems. IEEE Trans Power Electron 27:1905–1916

[4] Karalis A, Joannopoulos JD, Soljačić M (2008) Efficient wireless non-radiative mid-range energy transfer. Ann Phys 323:34–48

[5] Mecke R, Rathge C (2004) High frequency resonant inverter for contactless energy transmission over large air gap. Paper presented at the IEEE 35th annual power electronics specialists conference, 2004

[6] S. Jia, C. Chen, S. Duan, and Z. Chao, ‘‘Dual-side asymmetrical voltage- cancelation control for bidirectional inductive power transfer systems,’’ IEEE Trans. Ind. Electron., vol. 68, no. 9, pp. 8061–8071, Sep. 2021S. Jia, C. Chen, S. Duan, and Z. Chao, ‘‘Dual-side asymmetrical voltage- cancelation control for bidirectional inductive power transfer systems,’’ IEEE Trans. Ind. Electron., vol. 68, no. 9, pp. 8061–8071, Sep. 2021

[7] E. Asa, O. C. Onar, J. Pries, V. Galigekere, and G.-J. Su, ‘‘A tradeoff analysis of series/parallel three-phase converter topologies for wireless extreme chargers,’’ in Proc. IEEE Transp. Electrific. Conf. Expo (ITEC), Jun. 2020, pp. 1093–1101.

[8] M. Khalid, F. Ahmad, B. K. Panigrahi, and L. Al-Fagih, ‘‘A com- prehensive review on advanced charging topologies and methodologies for electric vehicle battery,’’ J. Energy Storage, vol. 53, Sep. 2022, Art. no. 105084

[9]. V. Cirimele, R. Torchio, A. Virgillito, F. Freschi, and P. Alotto,’‘Challenges in the electromagnetic modeling of road embedded wireless power transfer,’’ Energies, vol. 12, no. 14, pp. 1–22, 2019.

[10]. T. Imura, K. Hanawa, K. Sasaki, and N. Abe, ‘‘Coil performance and evaluation of pavement durability of dynamic wireless power transfer system using ferrite-less and capacitor-less coil for road construction methods,’’ in Proc. 5th Int. Electr. Vehicle Technol. Conf. (EVTeC). Noda, Japan: Tokyo Univ. Science, May 2021.

[11]. K. Furuta, R. Baba, E. Shun, K. Nunokawa, W. Takahashi, and T. Maruyama, ‘‘Wireless power transmission applied the mutual coupling between coils,’’ in Proc. AIP Conf., vol. 1865, 2017, Art. no. 070003.

[12]. C. Jiao, Y. Xu, X. Li, X. Zhang, Z. Zhao, and C. Pang, ‘‘Electromagnetic shielding techniques in the wireless power transfer system for charging inspection robot application,’’ Int. J. Antennas Propag., vol. 2021, pp. 1–15, Jul. 2021.

[13]. W. Mou and M. Lu, ‘‘Research on electric vehicle electromagnetic protection considering radiation of two wireless chargers,’’ World Electric Vehicle J., vol. 13, no. 6, p. 95, May 2022.

[14].S. Cruciani, T. Campi, F. Maradei, and M. Feliziani, ‘‘Wireless charging in electric vehicles: EMI/EMC risk mitigation in pacemakers by active coils,’’ in Proc. IEEE PELS Workshop Emerg. Technol., Wireless Power Transf. (WoW), Jun. 2019, pp. 173–176.

[15].SAE International, ‘‘Power quality requirements for plug-in electric vehicle chargers,’’ SAE Int., Warrendale, PA, USA, Tech. Rep. J2894/1_201112, [Online]. Available: Accessed: Oct. 6, 2022. [Online]. Available: https://www.sae.org/standards/content/j2894/1_201112/