

Inductive (Dynamic) Wireless Electric Vehicle Charging System

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Abstract

Wireless charging of electric vehicles (EVs) is a good example where an application of electric vehicle supply equipment (EVSE) can be automated and convenient so as to improve acceptance. Inductive, capacitive, and magnetic devices are the three types of wireless charging technologies. An experimental setup intended to assess the effectiveness of a wireless inductive charging system specifically used for EV battery charging is presented in the paper. This configuration shows how inductive technology can be modified to satisfy EVs' high energy requirements. The study focuses on practical factors that have a big impact on how well wireless energy transmission works, like coil alignment, magnetic coupling efficiency, inverter performance, and thermal behavior. It is crucial to comprehend these factors since effective wireless charging can significantly improve the viability of EV use in daily situations. The experimental setup for a wireless inductive system applied for charging of EV batteries is introduced, and the considerations of such progress for modules integration into the system performance, enabling effective energy delivery, are important for vehicles with high energy demands. The scopes were limited by the resonant settings of the flexible load with various transmitters and battery parameters, and only tuning control of the high frequency (HF) inverter was applied. One possible answer to the major problems regarding EV charging is a control system for a wide range of charging voltage and current. The dimensions of the transmitters, Bobbin's inductance, and the distance between the sender and the receiver are all optimization problems that are defined and resolved.

Keywords: Electric vehicle (EV), inductive power transfer (IPT), dynamic charging system, compensation circuits, converters, control techniques, wireless charging

INTRODUCTION

Wireless charging systems (WCS) have been widely used in high-power applications, including EVs [1] and plug-in electric vehicles (PEVs) [2] in inactive [3] applications. Compared to plug-in charging systems, WCS can provide additional advantages in terms of user happiness, durability, and convenience of use [4]. The issue or curb associated with WCS is that it can only be used when the vehicle is parked or in a stationary state, such as at traffic signals, garages, or parking lots [3]. Additionally, there are some drawbacks to stationary WCS, such as electromagnetic compatibility (EMC), limited power transfer, large buildings, lower range, and better efficiency [5–7]. To improve both the range and battery storage capacity, the dynamic mode of operation of the WCS for EVs has been investigated [8, 9]. This technique allows battery storage devices to be charged while the car is moving, the vehicle's transportation range is extended, and a smaller

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Received Date: November 28, 2025

Accepted Date: November 29, 2025

Published Date: December 31, 2025

Citation: Ashish Mishra, Tej Prakash Verma. Inductive (Dynamic) Wireless Electric Vehicle Charging System. International Journal of Electrical Machine Analysis and Design. 2025; 3(2): 30-44p.

volume of constrained battery storage is required [10]. A large air gap and coil misalignment are two significant challenges that a dynamic WCS must solve before it can be deployed extensively. The power transmission efficiency is determined by the coil alignment and air gap distance between the source and receiver [5, 11]. For tiny passenger cars, the average air gap distance ranges from 150 mm to 300 mm; for larger cars, it can increase. The car is driven automatically in dynamic mode, making it simple to align the transmitter coil with the ideal driving position. Additionally, to lower parasitic losses and boost the system efficiency, various compensation techniques, such as series and parallel combinations, are used on both the transmitting and receiving sides. [12, 13]. In this appraisal paper, the essential operation of the WCS for EVs and the counting methods of power transfer are analyzed. In conclusion, a variety of wireless transformer buildings have been proposed to improve power transfer efficiency.

LITERATURE REVIEW

Fundamentals of Inductive Wireless Charging

Inductive wireless power transfer (IWPT) is based on magnetic coupling between a transmitting coil (ground assembly) and a receiving coil (vehicle assembly). Reviews by Mahesh et al. (2021) and Palani and Sangamaya (2023) explained that the system consists of the following:

- A high-frequency inverter,
- Compensation networks,
- Magnetic pads with ferrite cores,
- A rectifier and battery interface.

The efficiency depends heavily on the coupling coefficient, resonant frequency, coil alignment, and compensation topology.

Static Versus Dynamic Wireless Charging

Static Charging

Static charging involves stationary energy transfer when an EV is parked. Studies have demonstrated that static IWPT has matured significantly, with commercial systems reaching efficiencies above 90%.

Dynamic Charging

- Charging is possible while the car is moving, owing to dynamic wireless power transfer (DWPT).
- Lukic and Pantic (2013) introduced early dynamic charging concepts.
- Razu et al. (2021) examined energy transfer while driving, focusing on coil segmentation and real-time switching.
- Mohamed et al. (2022) addressed the roadway-embedded coil design and lane-guidance requirements.

Continuous energy replenishment is provided by DWPT, although it is constrained by the cost, route alteration, and communication complexity.

Devious or Quasi-Dynamic Charging

Stationary charging occurs when an EV is parked for an extended period of time, including overnight charging and charging in garages, public parking lots, and businesses [11]. In this case, the charging process starts when the transmitter and receiver coils are fully or partially ranged [14, 15]. A transmitter coil is positioned inside the ground and extended for prolonged distances during dynamic charging, which occurs when the EV travels at a high speed. To charge the storage element (battery), the EV absorbs electricity from the electrified components of the transmitter coils during the program [16]. Transmission coils for in-motion charging can be segmented into coil collections made up of groups of transmitter pads buried together or single long coil pathways [9]. Owing to the high-power supplies and limited accessibility to stops, in-motion charging is the most relevant method for

charging EVs while driving on highways (long-distance and intercity travel). The technique known as “quasi-dynamic charging” allows an electric car to charge while moving slowly and during brief stops such as bus stops, traffic signals, and crossings [13, 17]. The idea of charging electric automobiles while they are traveling on highways was first introduced in 1894 with the “Transformer System for Electric Railways” patent (dynamic electric vehicle) [18, 19]. Transmission coils for in-motion charging can be segmented into coil collections made up of groups of transmitter pads buried together or single long coil pathways [9]. Owing to the high-power supplies and limited accessibility to stops, in-motion charging is the most relevant method for charging EVs while driving on highways (long-distance and intercity travel). The technique known as “quasi-dynamic charging” allows an electric car to charge while moving slowly and during brief stops such as bus stops, traffic signals, and crossings [13, 17]. The idea of charging electric automobiles while they are traveling on highways was first introduced in 1894 with the “Transformer System for Electric Railways” patent (dynamic electric vehicle) [20]. To verify technical viability, the first highway automobile development began in 1976. This led to the creation of the first IPT system model, which transfers 8 kW of power but is not entirely functional [21–24]. Consequently, another prototype was produced in 1979 with the start of the Santa Barbara electric bus project [25]. An example of an IPT system’s simplified block diagram is shown in Figure 1. The Associates for Advanced Journey and Highways (PATH) project began in 1992 and included field, laboratory, and strategy testing for an IPT system installed on a bus [26]. Subsequently, the project-built highways gave them power transmission classes and investigated any possible environmental impacts [27]. With 60% efficiency, this project was able to transfer 60 kW of power over a 76 mm air gap [28].

Inductive Power Transfer

Power transfer using induction by Nikola Tesla created traditional IPT in 1914 for wireless power transfer [9]. Figure 2 shows a block diagram of conventional IPT. This is predicted for several EV charging systems [29]. In a variety of applications ranging from milliwatts to kilowatts, IPT has been tested and used to transfer contactless power from a source to a recipient [20]. The Chevrolet S10 EV was introduced by General Motors (GM) in 1996. Level 2 (6.6 kW) slow and level 3 (50 kW) fast charges were applied utilizing the magnetic-charge IPT (J1773) system [30]. The Magne-charge’s primary coil, often referred to as an inductive coupler or charging paddle, was placed into the charging port of the car, where the secondary coil receives power and is allowed to charge the EV [31]. A 6.6 kW Level 2 EV charger was demonstrated by the University of Georgia, which was able to charge a battery voltage of 200–400 V battery voltage at 77 kHz operating frequency.

Qualcomm’s Halo, along with Auckland University (AU), created new magnetic pads called “Double-D” (DD) pads. These pads are more effective than both circular and quadrangular pads with

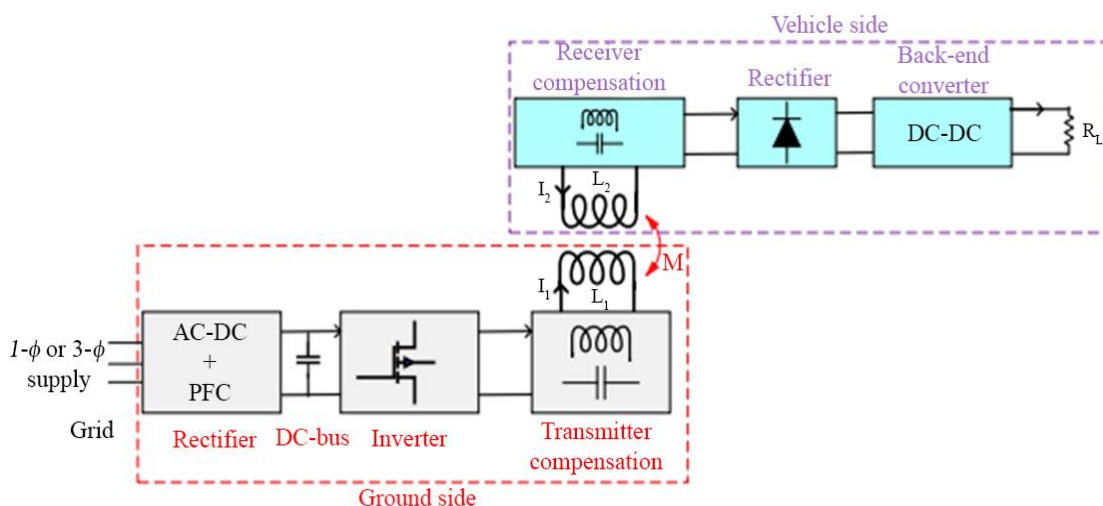


Figure 1. Simplified block diagram of an exemplary IPT system.

respect to the system efficiency and misalignment tolerance [32, 33]. Qualcomm’s halo was sold to WiTricity in 2019 [34, 35]. Elements of the New York-based company HEVO Power are also working on deployments for both static WPT and dynamic charging systems for EVs, and HEVO has developed a general smartphone app for customers to make the EV charging experience easier. In Germany, the Fraunhofer Institute has developed a test prototype of a static WPT charging system using SiC MOSFET (metal-oxide-semiconductor field-effect transistors) switches rated at 22 kW. The prototype used an innovative bidirectional controller design and has been reported to achieve an overall system efficiency of approximately 96% (DC-to-DC) [36]. Continuing with reports on emerging WPT technologies, WiTricity is one of the world’s top companies in wireless charger production Figure 3. WiTricity has developed static wireless chargers, in which some systems were rated up to 3 kW, and the chargers were designed for scaling up to further power transfers to 22 kW. With one of their systems, WiTricity reported the use of SiC MOSFET with grid-to-battery converter systems reporting greater than 91% efficiency, and other systems reporting coil-to-coil efficiencies of approximately 98% [25, 37]. The company in the US, Momentum Dynamics, has developed a 3.3 kW Static Wireless Charging (SWC) system with a gap of separation between the charging pad and the

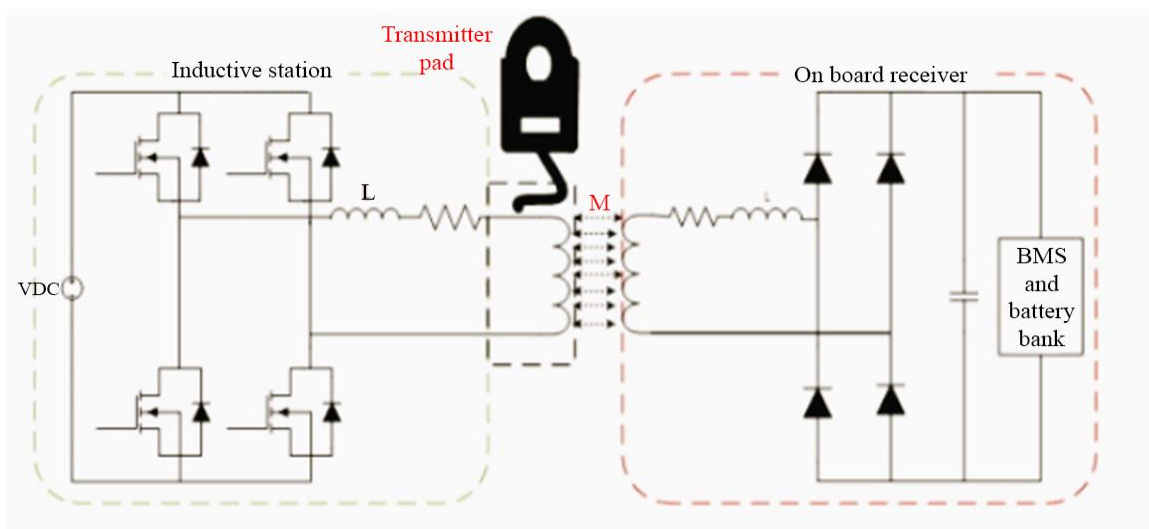


Figure 2. Schematic diagram of traditional inductive power transfer.

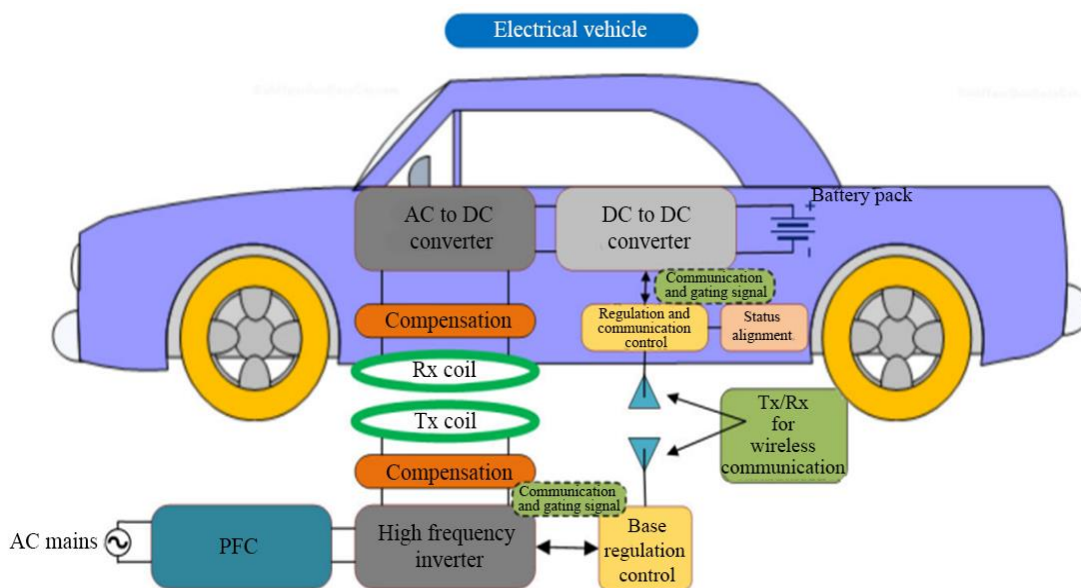


Figure 3. Generic presentation of the WPT charging system for EV.

EV reported at 24 cm, measured at a total efficiency of 92%. Momentum Dynamics also made an upgraded charger, 7.2 kW, and a charger with a 10 kW power output capable of charging vehicles such as the Chevrolet Volt in approximately 1 h [6]. Momentum Dynamics has now completed the production and testing of their 7.2 kW, 10 kW, and 21 kW SWC systems and started deployment for their customers using all three types of SWC chargers.

Resonant Inductive Power Transfer

Resonant inductive power transfer (RIPT) is one of the more sophisticated and well-known variations of conventional IPT in terms of wireless transformer coils and power electronics. A schematic diagram of the RIPT for the EVs is shown in Figure 4. As with other WPTs, the main AC voltage is transformed into an HF AC source and then sent to the transmitter or primary winding. Variations in the magnetic field transmit power to the secondary coil or receiver. For the EVs' battery bank, the received electricity was converted to DC via a filter motherboard and additional power circuitry. In addition to creating the resonant case shown in and reducing extra losses, additional recompensing networks are placed in series or parallel to both the primary and secondary windings in valuation to achieve the typical IPT.

$$f(1)_{rp,S} = \frac{1}{2\pi\sqrt{L_{p,s} \cdot C_{p,s}}}$$

Where, f_r is the resonant frequency of the primary and secondary coils, and L and C are the self-inductance and resonant capacitor values of the transmitter and receiver coils, respectively.

If the primary and secondary coils are strongly coupled, the mutual inductance worth will be complex, and vice versa.

$$k = \frac{L_m}{\sqrt{L_p L_s}}$$

At high frequencies, the skin and proximity effects are considerably effective and can affect power transfer efficiency. To avoid such glitches, individually protected thin, perverse wire-based Litz wires are ordinarily considered in the design. Additionally, this can increase the quality factor (Q) of the coil and reduce parasitic resistance. Q can be calculated using Equation (3). Equation (3) determines the frequency f and self-inductance L of the primary or secondary coil, and R is the resistance of the coils.

$$Q = \frac{\omega L_{p,s}}{R_{p,s}} = \frac{2\pi f \cdot L_{p,s}}{R_{p,s}}$$

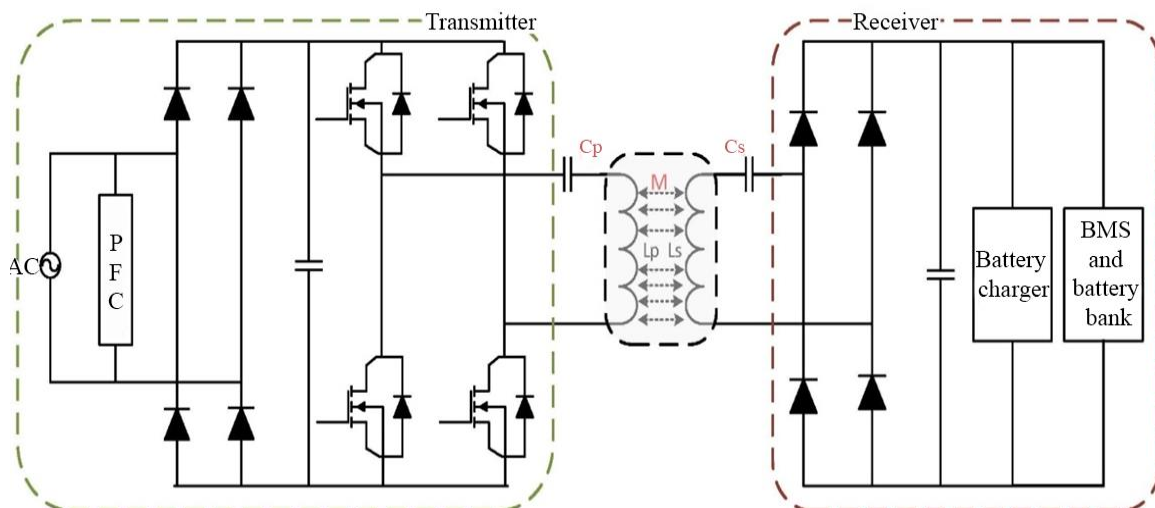


Figure 4. Schematic diagram of resonant inductive power transfer.

Compensation Networks

The effectiveness of an organization should be evaluated to determine whether an inductive connection is appropriate Figure 5. The efficiency calculation is shown in Equations (1) and (2), where M stands for mutual coupling, Q is the coil's quality factor, and U is the figure of merit for the efficiency k coupling coefficient as shown in Table 1 [6].

$$U = \frac{w_{Ms d}}{\sqrt{R_s R_d}} = k \sqrt{Q_s Q_d} \quad (1)$$

$$\eta = \frac{U^2}{(1 + \sqrt{1 + U^2})} \quad (2)$$

During resonance, the two coils have strong coupling; thus, the coupling coefficient is sufficiently high.

$$Q = \frac{w_L}{R} = w \frac{E_{\text{stored}}}{E_{\text{lost}}} = \frac{f_0}{\Delta f} = \frac{1}{R} \sqrt{\frac{L}{C}} \quad (3)$$

$$w_n = \frac{1}{\sqrt{LC}} \quad (4)$$

The proposed RIC system has four coils. The system is powered by a source coil, a battery-operated load coil, and sending and transmitting coils that are strongly coupled to one another. Figure 1 shows the four-coil system. Because each of the four coils is coupled with the others, efficiency increases according to Equations (1) and (2).

Table 1. Comparison of various wireless power transfer technologies.

Technology	Power	Distance	Frequency
Inductive	Watts to a few hundred kW	Up to 400 mm	3 kHz–1 MHz
Magnetic resonant	Watts to a few kW	A few centimeters to 2 m	100 kHz–10 MHz
Capacitive	Milliwatts to a few kilowatts	A few centimeters	Several MHz
Far-field	A few kW to MW	Ten meters up to several kilometers	300 MHz–300 GHz
Magnetic gear	Tens of watts to a few kW	100–150 mm	150 Hz–300 Hz
Auditory	Microwatts to tens of watts	70–300 mm	0.5–3 MHz

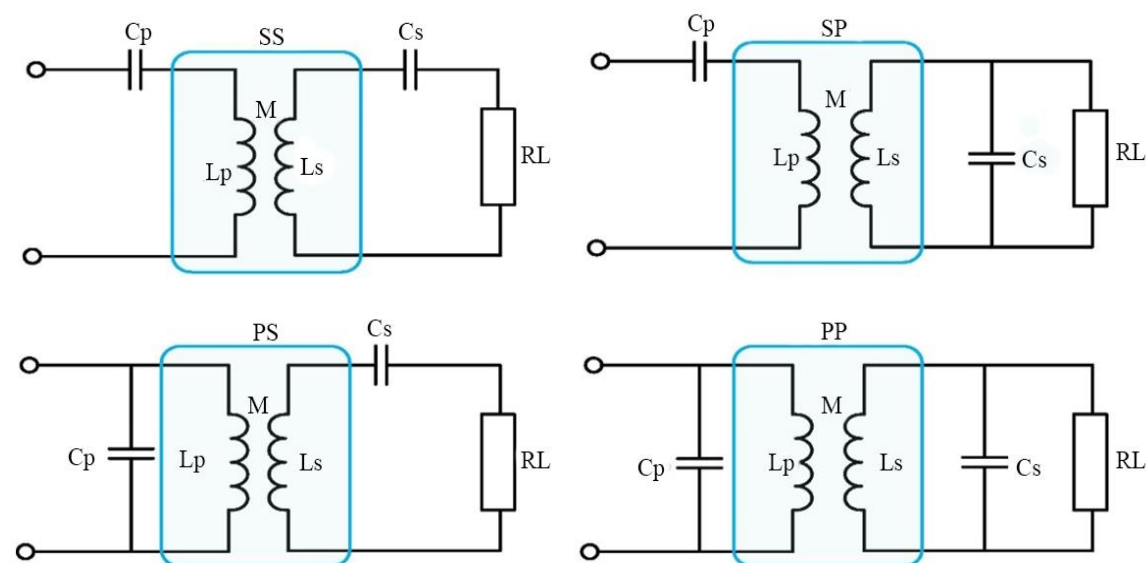


Figure 5. Compensation topology: (a) series-series, (b) Series-Parallel, (c) parallel-series, and (d) parallel-parallel.

EQUATIONS

To calculate the power flow in the proposed system, a mathematical model was created for Figure 6, which is given as follows:

$$V_1 = j\omega L_1 i_1 + j\omega M_{12} i_2 + j\omega M_{13} i_3 + j\omega M_{14} i_4 \quad (5)$$

$$V_2 = j\omega M_{12} i_1 + j\omega L_2 i_2 + j\omega M_{23} i_3 + j\omega M_{24} i_4 \quad (6)$$

$$V_3 = j\omega M_{13} i_1 + j\omega M_{23} i_2 + j\omega L_3 i_3 + j\omega M_{34} i_4 \quad (7)$$

$$V_4 = j\omega M_{14} i_1 + j\omega M_{24} i_2 + j\omega M_{34} i_3 + j\omega L_4 i_4 \quad (8)$$

$$V_s = \left(R_1 + R_s \frac{1}{j\omega C_1} \right) i_1 + V_1 \quad (9)$$

$$V_2 = - \left(R_2 + \frac{1}{j\omega C_2} \right) i_2 \quad (10)$$

$$V_3 = - \left(R_3 + \frac{1}{j\omega C_3} \right) i_3 \quad (11)$$

$$V_4 = -(R_4 + R_L) i_4 \quad (12)$$

The Ansys Maxwell program was used to determine the coils' self and mutual inductance values. The distance between the source coil and transmitter was approximately 5 mm. The receiver and load coils are considered at similar distances. The average automobile clearance between the transmitter and receiver measured approximately 13 cm. The resonance frequency is 72.5 kHz when each coil's capacitors are adjusted.

$$\eta = \left(\frac{R_L}{R_4 + R_L} \right) \left(\frac{R_{ref\ 34}}{R_3 + R_{ref\ 34}} \right) \left(\frac{R_{ref\ 23}}{R_2 + R_{ref\ 23}} \right) \left(\frac{R_{ref\ 12}}{R_1 + R_s + R_{ref\ 12}} \right) \quad (13)$$

$$R_{ref\ 34}(\omega_0) = \frac{\omega_0^2 (R_4 + R_L) M_{34}^2}{\omega_0^2 L_4^2 + (R_4 + R_L)^2} \quad (14)$$

$$R_{ref\ 23}(\omega_0) = \frac{\omega_0^2 M_{23}^2}{(R_3 + R_{ref\ 34})^2} \quad (15)$$

$$R_{ref\ 12}(\omega_0) = \frac{\omega_0^2 M_{12}^2}{(R_2 + R_{ref\ 23})^2} \quad (16)$$

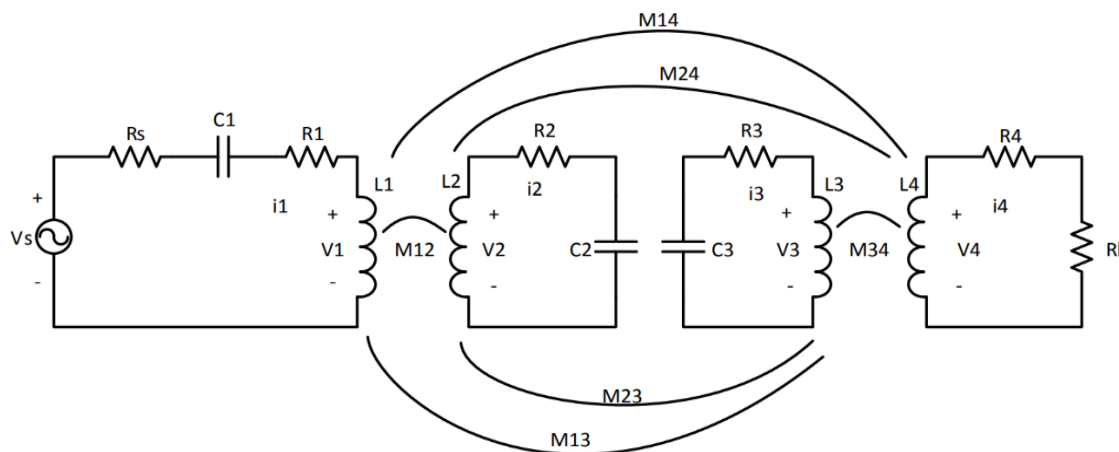


Figure 6. Coil resonant inductive coupling system.

VS: AC voltage source, *L3*: Inductor of receiving loop, *RS*: Source resistance, *C3*: Resonating capacitor of receiving loop, *L1*: Inductor of input loop, *R3*: Resistance of receiving loop, *C1*: Capacitor of input loop, *L4*: Inductor of output loop, *R1*: Resistance of input loop, *R4*: Resistance of output loop, *L2*: Inductor of transmitting loop, *RL*: Load resistance, *C2*: Resonating capacitor of transmitting loop, *M12*: Mutual inductance between *L1* and *L2*, *R2*: Resistance of transmitting loop, *M13*: Mutual inductance between *L1* and *L3*, *M23*: Mutual inductance between *L2* and *L3*, *M14*: Mutual inductance between *L1* and *L4*.

COIL SHAPE

In inductive wireless electric vehicle (EV) charging systems, coil shape is a thoughtful design factor because it directly disturbs power transfer efficiency, configuration tolerance, magnetic field circulation, and overall system safety. Wireless EV charging services use magnetic resonance or inductive coupling, both of which are based on power transmission from a transmitter coil on the ground to a receiver coil riding on the vehicle. Dissimilar coil geometries help improve magnetic coupling and reduce losses, while refining the tolerance to vehicle misalignment as shown in Tables 2 and 3.

Circular Coil

Produces a centrifugally proportionate magnetic field, which makes investigative modeling easier. High efficiency beneath perfect configuration (coupling coefficient $k = 0.1-0.25$ for several EV WPT studies). Frequently used as a benchmark coil for hypothetical WPT models, such as the derivation studies of mutual inductance, poor lateral misalignment tolerance, and commonly conveyed efficiency drops $>20\%$ at ± 100 mm shift as shown in Figure 7.

Rectangular Coil

- Larger effective coupling area than circular coils.
- Better compatibility with the rectangular underbody structures of EVs.
- Improved tolerance to longitudinal misalignment.
- The magnetic field has a strong edge concentration (“fringe effects”), increasing the leakage and EMI.
- 3.3–7.7 kW WPT systems.
- Comparative studies between the circular and DD coil efficiency as shown in Figure 8.

Table 2. Compensation topologies based on primary capacitance.

Topology	Primary capacitance	Bifurcation
Series-Series	$\frac{1}{\omega^2 L_p}$	$Q_p > \frac{4Q_s^3}{4Q_s^2 - 1}$
Series-Parallel	$\frac{1}{\omega^2 L_p \frac{M^2}{L_s}}$	$Q_p > Q_s + \frac{1}{Q_s}$
Parallel-Series	$\frac{L_p}{\left(\frac{\omega^2 M^2}{R}\right)^2 + L_p^2 \omega^2}$	$Q_p > Q_s$
Parallel-Parallel	$\frac{L_p \frac{M^2}{L_s}}{\left(\frac{R M^2}{L_s^2}\right)^2 + \omega^2 \left(L_p \frac{M^2}{L_s}\right)^2}$	$Q_p > Q_s + \frac{1}{Q_s}$

Table 3. Types of coil used in wireless charging EV.

Coil type	Common research advantages	Limitations noted in the literature	Typical use
Circular	Simple modeling, uniform field	Poor misalignment tolerance	Baseline studies
Rectangular	Large coupling area	Field non-uniformity	Early EV pads
DD (Double-D)	High efficiency, high misalignment tolerance	More complex geometry	Standardized EV chargers
DDQ	Best angular tolerance	Higher cost, complex control	Premium/robotic charging
Bipolar/Solenoid	Strong vertical flux	Heavy, core losses	Dynamic charging
Hexagonal	Good uniformity	Hard to wind	Research prototypes
Spiral Pancake	Low AC resistance	Alignment-sensitive	Lab-scale systems

Double-D (DD) Coil

Recommended and standardized by SAE J2954 for stationary wireless charging. Produces parallel magnetic flux paths, giving stronger coupling. Demonstrates high misalignment tolerance ± 200 mm shift, still maintaining $>85\%$ efficiency in many studies. Compatibility of field distribution with strong foreign object detection. K is the coupling coefficient = 0.2-0.35 in many published prototypes. Efficiency is typically reported in the 85–94% range as shown in Figure 9.

Hexagonal/Polygonal Coils

Applied in those WPT systems where circular symmetry and rectangular packing are both required. Provide better magnetic field uniformity compared to rectangular coils. Surface area optimization: electromagnetic field (EMF) reduction around human exposure limits as shown in Figure 10.

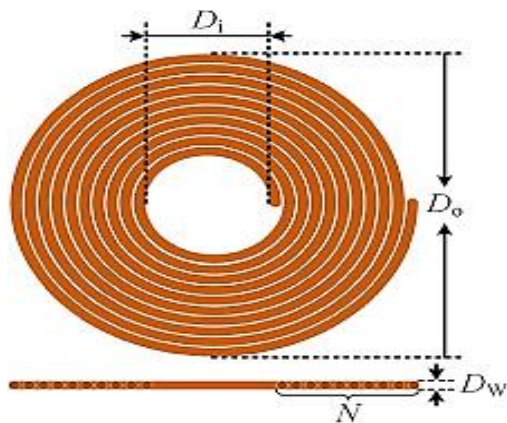


Figure 7. Circular coil.

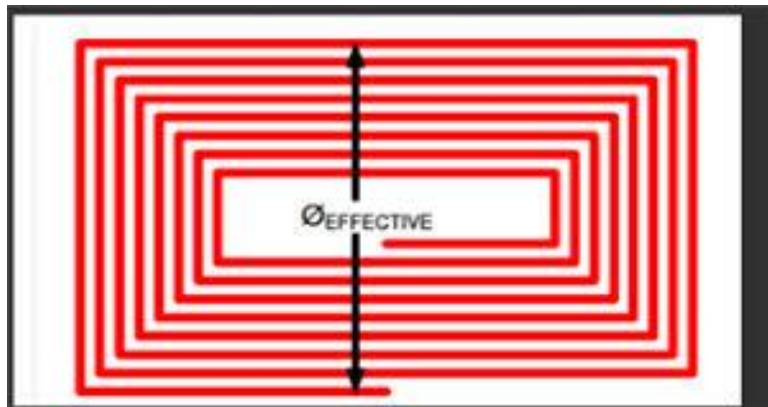


Figure 8. Rectangular coil.

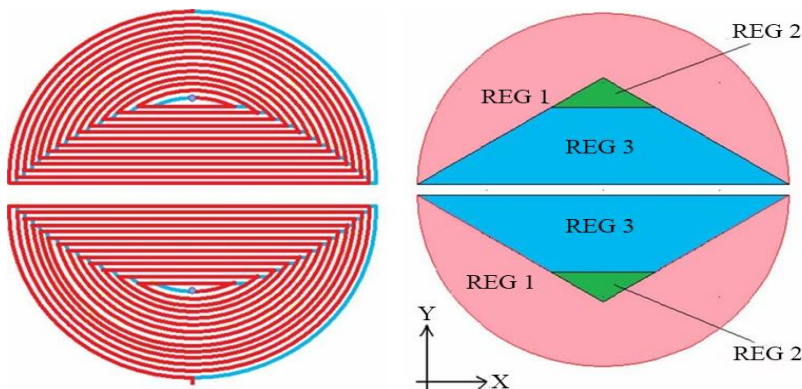


Figure 9. Double-D coil

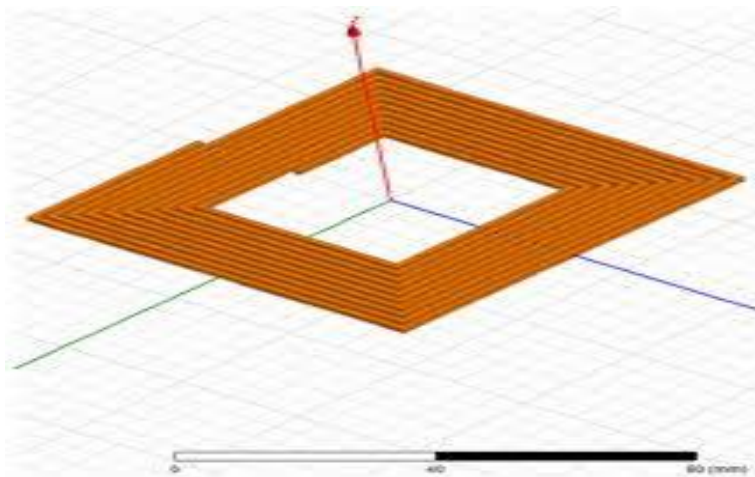


Figure 10. Hexagonal/polygonal coils.

DESIGN OF THE COILS AND COMPENSATION NETWORKS

Determining the coils' maximum and minimum dimensions is the first step in their design. For the optimal routine, we employed a superior coil on the primary sideways, as opposed to the secondary sideways. Specifically, we fixed the primary coil's dimensions to $75\text{ cm} \times 75\text{ cm}$ and the neighboring secondary coil's size to $50\text{ cm} \times 50\text{ cm}$ to restrict the exploration space. Therefore, the system was less susceptible to coil misalignment. Depending on the operating frequency, Litz wire should be used while assembling the coils. The Litz wire should have a diameter of 0.1007 mm and an aspect gauge of AWG38.

As a result, a 14-turn primary coil and a 10-turn secondary coil were chosen. Although the 13.38 mm^2 option will increase the weight and cost, the cross-section of the wire for both coils is advised at 8.51 mm^2 because the 5.35 mm^2 resolution might not be adequate for the charger's limited current (particularly if a misalignment occurs). The remaining characteristics of the selected solution are listed in the previous Table 4.

Power Electronic Device Used in Wireless Electric Vehicle

A charger is required to familiarize the power provided by the exterior source with the electrical supplies of the EV battery. Additionally, to advance the power transfer of the attached coils, an increase in the operating frequency is mandatory for WPT employment. Power messengers perform these conversions expertly, allowing them to adjust their voltage levels, frequency, currents, and/or resistivities with lower losses. Power converters are self-contained semiconductors designed to function as switches, changing their ultimate state (open or closed) at the switching frequency. Although the type and conformation of power evangelists are mostly categorized based on their functioning and degree of accomplished power, additional limitations, such as weight, cost, and electromagnetic emissions, also interfere with the choice as shown in Figure 11.

Table 4. Potential solutions derived from the design of the coils.

Number of turns of the primary coil (N1)	Number of turns of the secondary coil (N2)	Cross-section of the primary coil's wire (mm^2)	Cross-section of the primary coil's wire (mm^2)	Efficiency	Copper (kg)
14	10	5.35	5.35	0.9893	2.972
14	10	5.35	8.51	0.9906	3.538
14	10	8.51	5.35	0.9920	4.161
14	10	8.51	8.51	0.9932	4.727
14	10	13.38	5.35	0.9936	5.993
14	10	13.38	8.51	0.9948	6.560

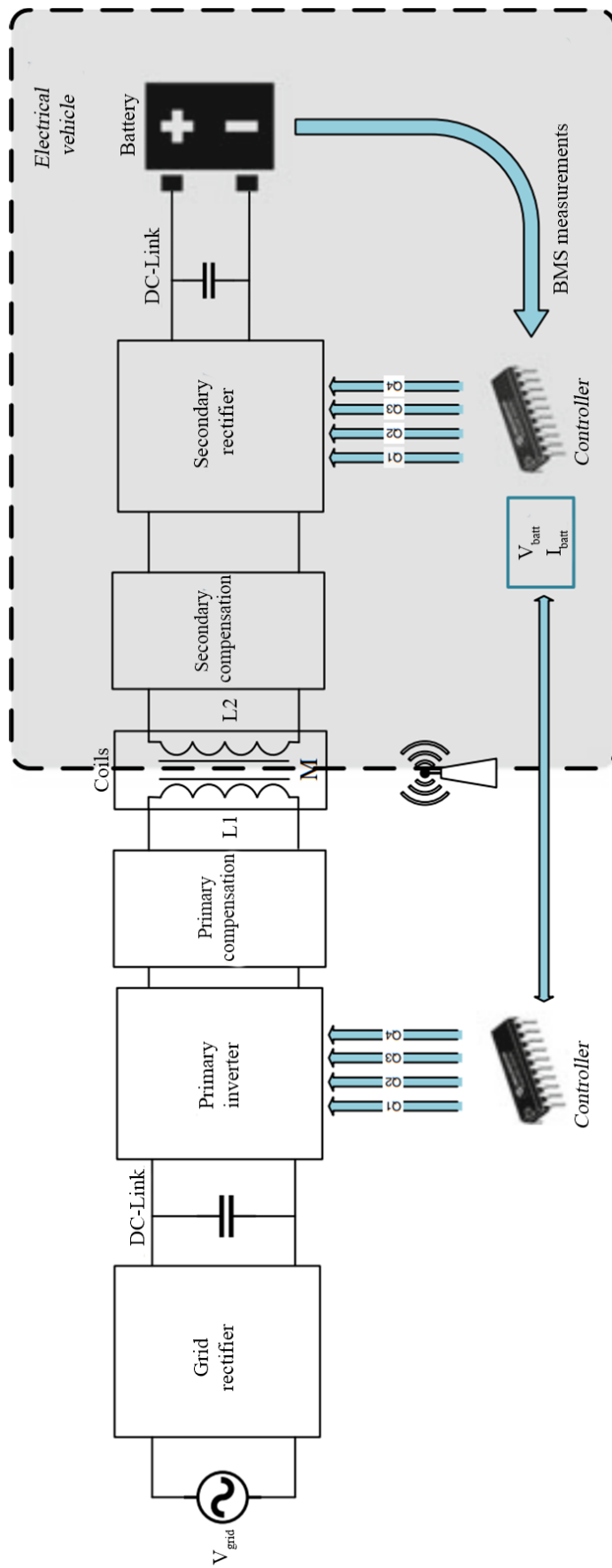


Figure 11. Diagram of a primary and secondary controlled wireless charger.

SAFETY AND HEALTH

Inductive EV charging provides electrical liveliness via an attractive field between a ground assembly (GA) and vehicle assembly (VA) without physical wiring. Although appropriate, it publicizes exclusive health, safety, and operational feelings.

Potential Risks

- Wireless charging frequently involves time-varying magnetic fields in the range of tens to hundreds of kilohertz.
- However, extreme exposure can pose health risks, predominantly to those with implanted medical devices such as pacemakers.

Mitigation

- Systems are intended to meet international commission on non-ionizing radiation protection (ICNIRP) and IEEE C95.1 EMF exposure limits.
- Magnetic fields drop off quickly with detachment.
- Safety interlocking ensures that charging only transpires when the proper configuration and clearance verification are complete.

Hazards

- High-power transmission: 3.7 kW to >100 kW in some systems.
- Danger of electrical shockwave, fault currents, or unintentional energization.

Controls

- Built-in pulverized fault detection and lagging monitoring. Foreign object detection (FOD) prevents the heating of metal objects amongst the pads.
- Reflex shutdown in case of misalignment or irregular situations.

CONCLUSION

The study concludes that IWPT and RIPT are highly promising technologies for electric vehicle charging. These systems address the many limitations of conventional plug-in charging by offering a convenient, automated, and contactless method of energy transfer. With advancements in coil design, resonant compensation, and high-frequency power electronics, wireless charging has reached efficiency levels that are suitable for both domestic and commercial EV applications.

Among various wireless charging approaches, dynamic wireless charging is a transformative solution. It enables EVs to charge while in motion, reduces dependency on large battery packs, and significantly extends the driving range. However, the successful implementation of dynamic systems requires the resolution of challenges, such as large air gaps, coil misalignment, roadway integration costs, and electromagnetic compatibility. Although these issues remain, continuous research and technological improvements are bringing dynamic charging closer to its practical deployment.

The effectiveness of wireless charging depends heavily on coil geometry, coupling coefficient, resonant tuning, and compensation topology. This study identifies the DD coil as one of the most efficient and misalignment-tolerant designs, aligned with global standards such as SAE J2954. Litz wires, optimized coil turns, and well-designed capacitive compensation networks further enhance energy transfer efficiency.

Overall, the study concludes that wireless charging, especially resonant inductive and dynamic systems, has matured into a technically viable, efficient, and user-friendly solution for the next generation of electric vehicles. Continued advancements in coil design, control systems, and infrastructure will be key to enabling large-scale adoption of truly seamless and intelligent EV charging.

Future Scope

Future systems will increase the power transfer rates and transport wireless charging times more quickly than wired schemes, according to the E3S Web of Conferences. Advanced power transfer rates are developed through improved coil strategy and power electronics, with ideals for heavy-duty vehicles directing up to kilowatts.

Investigators are working to improve the efficiency of wireless induction by minimizing energy loss during power transfer and have concluded that better coil design and constituents make it a more practical and appealing option.

A major future trend is dynamic wireless charging, in which automobiles can charge while driving by embedding charging coils on the road. This could abolish range anxiety, unify long-haul trips, and enable truly autonomous vehicle fleets, according to NCBI. Wireless charging is likely to become more integrated into everyday life and urban infrastructure.

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