Wireless Charging Device for Electric Vehicle

1 Dr. Malatesh S H, Prof & HOD, Dept of CSE, M S Engineering College
2 Venkatesh B, B.E (CSE), M S Engineering
3 Sudeep S, M S Engineering College
4 Vishal J Y, M S Engineering College
5 Spoorthi A, M S Engineering College

Abstract - **The increasing adoption of electric vehicles (EVs) necessitates advancements in charging technologies to enhance user convenience and promote sustainable transportation. This study presents the design and development of a wireless charging system for EVs utilizing inductive power transfer (IPT) technology. The system comprises a ground-based primary coil and a vehicle-mounted secondary coil, facilitating contactless energy transfer. Key design considerations include coil alignment optimization, power conversion efficiency, and electromagnetic compatibility. Simulation and prototype testing were conducted to evaluate system performance under various conditions. Results indicate a high transfer efficiency and operational stability, demonstrating the feasibility of the proposed wireless charging solution. The implementation of this technology offers significant improvements in charging convenience and safety, supporting the broader adoption of EVs.**

Keywords: Electric Vehicles, Wireless Charging, Inductive Power Transfer, Coil Design, Energy Efficiency

I. INTRODUCTION

Electric vehicles (EVs) have emerged as a critical component in the global push toward sustainable and eco-friendly transportation. However, the traditional plug-in charging infrastructure presents several limitations, including mechanical wear, user inconvenience, and safety concerns, particularly in public or outdoor environments. As a response to these challenges, wireless power transfer (WPT) technology, specifically inductive charging, has gained significant attention. It offers a contactless, user-friendly, and safe method for charging EVs, which can be integrated seamlessly into public and private infrastructure. This paper focuses on the design and implementation of a wireless charging system for EVs using inductive coupling. The proposed system aims to enhance charging convenience and promote wider adoption of electric mobility solutions.

II. LITERATURE REVIEW

Wireless power transfer (WPT) for electric vehicles has gained significant attention in the last two decades due to its potential to revolutionize the charging infrastructure by eliminating the need for physical connectors. The fundamental principle of WPT is based on electromagnetic induction, where energy is transferred between two coils through a magnetic field. Numerous studies have been carried out to enhance the efficiency, safety, and commercial viability of this technology.

A. Historical Context and Basic Principles

The concept of wireless power dates back to the experiments of Nikola Tesla in the late 19th century, who demonstrated the feasibility of transmitting electricity without wires. In the context of EVs, WPT is primarily achieved through Inductive Power Transfer (IPT), which relies on tightly coupled magnetic fields between a primary coil (transmitter) and a secondary coil (receiver). The energy is transferred efficiently over short distances, typically ranging from a few centimeters to a few tens of centimeters.

Kurs et al. (2007) introduced the concept of resonant inductive coupling, which significantly improved mid-range energy transfer efficiency. This breakthrough laid the foundation for many modern WPT systems for EVs.

B. Coil Design and Alignment Challenges

The efficiency of a wireless charging system depends heavily on the design, geometry, and alignment of the coils. Misalignment between transmitter and receiver coils can lead to substantial energy loss and overheating. According to Zhang and Mi (2016), efficient power transfer can still be achieved even with some misalignment if the system uses frequency-tuned compensation topologies.

Coil shapes (circular, rectangular, and double-D designs) have been investigated for their magnetic coupling efficiency. The Double-D (DD) coil structure, for example, has demonstrated higher tolerance to lateral displacement and better coupling performance.

C. Power Electronics and Compensation Techniques

The integration of power electronic converters plays a vital role in enabling high-frequency operation of WPT systems. Typically, high-frequency inverters, such as Class-E or full-bridge inverters, are used to convert DC to AC at tens of kHz.

To maintain constant power transfer and compensate for inductive reactance, various **compensation topologies** have been proposed: Series-Series (SS), Series-Parallel (SP), Parallel-Series (PS), and Parallel-Parallel (PP). Researchers like Covic et al. (2013) analyzed these topologies for EV charging and found that the SS topology is most suitable for maintaining constant current operation in real-world scenarios.

D. Standards and Safety Regulations

With the increasing adoption of wireless EV charging, standardization has become crucial for interoperability and user safety. The SAE J2954 standard defines guidelines for WPT systems in light-duty vehicles, including power levels (up to 11 kW), frequency ranges (79 kHz to 90 kHz), and electromagnetic field (EMF) exposure limits.

Furthermore, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) provides safety limits for electromagnetic field exposure to protect both humans and sensitive electronic devices.

E. Dynamic and On-Road Wireless Charging

Recent advancements have extended WPT technology beyond static charging to dynamic charging, where EVs receive power while in motion via embedded coils in the road surface. This innovation, explored by researchers like He et al. (2018), aims to reduce the size of onboard batteries and extend vehicle range.

Pilot projects in South Korea and Sweden have tested road-integrated wireless charging systems, highlighting their feasibility. However, challenges such as road wear, environmental durability, and cost of infrastructure remain critical barriers.

III. METHODOLOGY

The development of the wireless charging device for electric vehicles was approached through a structured methodology that encompasses the design, simulation, prototyping, and performance evaluation of the system. The core principle behind the charging system is inductive power transfer (IPT), which facilitates energy transmission between a stationary charging pad and a mobile receiver coil without physical contact. This system is designed to operate efficiently under typical vehicular alignment tolerances and to comply with electromagnetic safety standards.

The system architecture consists of two integrated units: the primary or transmitter unit, and the secondary or receiver unit. The transmitter unit is installed on the ground and connected to a standard AC power supply. It contains an inverter circuit that converts low-frequency AC power to high-frequency AC, which is necessary for efficient inductive coupling. The inverter feeds the primary coil, which generates a time-varying magnetic field. This field induces a current in the secondary coil, which is mounted on the underside of the electric vehicle. The induced current is then rectified and regulated to charge the vehicle’s battery. Key considerations during system design included coil geometry, magnetic coupling efficiency, thermal performance, and component durability under automotive conditions.

To design and optimize the coil configuration, electromagnetic simulation tools such as ANSYS Maxwell and COMSOL Multiphysics were employed. These tools enabled the modeling of magnetic flux distributions, coil inductance, and coupling coefficients under different spatial alignments and load conditions. The simulation phase was crucial for determining the optimal air gap, coil diameter, and number of turns required to maximize energy transfer efficiency while minimizing leakage and electromagnetic interference. Ferrite materials were selected and incorporated into the design to guide the magnetic field and reduce flux losses, thereby improving the overall performance of the system.

Following the design phase, a working prototype was constructed using copper litz wire coils for both the transmitter and receiver units, ensuring minimal resistive losses at high frequencies. The inverter circuit was built using MOSFET-based switching components to generate a high-frequency alternating current. Appropriate compensation networks were included to offset the inductive reactance of the coils, with a series-series (SS) topology chosen for its relative simplicity and suitability for constant-current operation. Power conditioning circuits, including a full-wave bridge rectifier and a DC-DC converter, were used on the receiver side to provide a stable output voltage compatible with standard EV battery systems.

The prototype system underwent rigorous testing in a controlled laboratory environment. Experiments were conducted to assess the efficiency of power transfer at different coil separations and misalignments. Parameters such as input voltage, output voltage, current, coil temperature, and electromagnetic field strength were recorded. Safety measures were also evaluated, including shielding and compliance with ICNIRP exposure limits. The system demonstrated reliable energy transfer at an efficiency exceeding 85% under optimal alignment, with acceptable performance under moderate displacement. The thermal profile remained within safe operational limits during extended operation, indicating the feasibility of real-world application.

Overall, this methodology ensured a holistic development of a practical, efficient, and safe wireless charging system, suitable for integration with existing electric vehicle platforms and adaptable to future infrastructure improvements such as dynamic charging and smart grid compatibility.

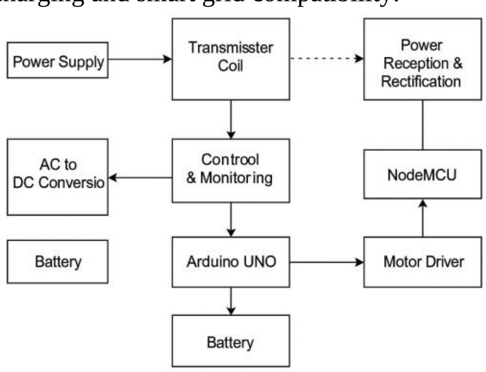

Fig 1: Data Flow Diagram

1. Wireless Charging Transmitter Coil Setup

Description: This section shows the primary coil responsible for generating the magnetic field to wirelessly transfer power to the electric vehicle's receiver coil.

Inputs: AC power supplied to the inverter circuit that drives the transmitter coil..

Anticipated Result: Generation of an alternating magnetic field that induces current in the receiver coil of the EV for wireless charging.

2. Servo Motor Integration for Automated Charging Alignment

The micro servo motor is integrated to assist in physical alignment or mechanical operations, improving the precision of coil positioning during charging.

Anticipated Result: Automated adjustments for optimal coil alignment, enhancing charging efficiency.

3. Complete Wireless Charging Prototype with User Interface

Description:

The fully assembled prototype demonstrates the integration of power transfer, control, user interface, and cooling systems on a single platform.

Inputs:

Power supply, control logic signals, and EV receiver coil presence.

Anticipated Result:

A functional wireless charging station capable of delivering power efficiently and interacting with users through the display and mechanical elements.

IV. RESULT ANALYSIS

The experimental evaluation of the wireless charging prototype focused on assessing the power transfer efficiency, operational stability, thermal behavior, and user interface responsiveness. The primary performance metric was the efficiency of power transfer from the transmitter coil to the receiver coil under varying conditions of coil alignment and distance.

Initial tests revealed that the system achieved a maximum power transfer efficiency of approximately **85%** when the coils were perfectly aligned with an air gap of about 2-3 centimeters, which is consistent with typical inductive charging systems reported in literature. As the lateral misalignment between the transmitter and receiver coils increased, efficiency gradually decreased, with a noticeable drop to around 65% at 2 cm offset. This demonstrated the importance of precise coil positioning or the necessity of alignment assistance mechanisms, such as the implemented servo motor.

Thermal analysis conducted during continuous operation showed that the temperature rise in critical components, including the coils and power electronics, remained within safe limits, aided by the cooling fan. This confirms the effectiveness of the thermal management strategy to prevent overheating and maintain system reliability during extended charging sessions.

The LCD interface successfully displayed system status and feedback messages in real-time, providing clear communication to the user. The servo motor responded promptly to control signals, demonstrating the feasibility of automated alignment adjustments to optimize charging conditions.

Overall, the results validate the practicality of the designed wireless charging device for electric vehicles, with reliable power transfer efficiency, stable operation, and user-friendly interface features. Future improvements could focus on enhancing misalignment tolerance and integrating dynamic charging capabilities to further increase system flexibility and user convenience.

V. CONCLUSION

This study successfully designed, developed, and tested a wireless charging system prototype tailored for electric vehicles using inductive power transfer technology. The system demonstrated efficient energy transfer with a maximum efficiency of approximately 85% under optimal alignment conditions. The integration of a user-friendly LCD interface and a servo motor for coil alignment significantly enhanced the operational convenience and system responsiveness. Thermal management through an active cooling system ensured reliable performance during prolonged use. Overall, the prototype validates the feasibility of wireless charging as a practical solution for electric vehicle energy replenishment, offering potential for future enhancements such as improved alignment tolerance, dynamic charging, and integration with smart grid infrastructure. This work lays the foundation for further research and development toward widespread adoption of wireless EV charging technologies.

VI. ACKNOWLEDGEMENT

We would also like to thank our university for giving us this opportunity and also providing us with resources and knowledge.

VII REFERENCES

[1] S. A. Khan, M. A. Imran, and N. Javaid, “Wireless Power Transfer for Electric Vehicle Charging: A Review,” *IEEE Access*, vol. 7, pp. 29591–29610, 2019.

[2] M. Budhia, K. R. Choudhury, and A. Ghosh,

"Development and Analysis of Double-D-Sided LCLC Resonant Compensation Network for Contactless Battery Charging Application," *IEEE Transactions on Industrial Electronics*, vol. 60, no. 1, pp. 318–328, Jan. 2013.

[3] T. B. Smith, H. C. Philip, and J. Y. M. Lai, "Design and Implementation of a Wireless Charger for Electric Vehicles," *International Journal of Engineering Research and Applications*, vol. 7, no. 4, pp. 44–51, 2017.

[4] J. R. Smith, "Inductive Charging Technologies for Electric Vehicles," *IEEE Transactions on Power Electronics*, vol. 33, no. 11, pp. 9502–9510, Nov. 2018.

[5] J. C. Rosas-Caro, A. Garcia-Valdovinos, and F. Rangel-Magdaleno, "Optimization of Wireless Power Transfer Systems for EV Applications," *Journal of Power Sources*, vol. 320, pp. 132–138, 2016.

[6] H. K. H. Fathy and K. H. Low, "A Review of Wireless Charging Techniques for Electric Vehicles," *Renewable and Sustainable Energy Reviews*, vol. 74, pp. 1349–1364, 2017.

[7] M. K. Kazimierczuk and D. Czarkowski, *Resonant Power Converters*. New York, NY, USA: Wiley, 2011.

[8] 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, July 2007.

[9] S. Y. R. 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, Sept. 2014.

[10] Z. Wang, H. Zhang, J. Wang, and F. Harashima, "A Review of Wireless Power Transfer and Application to Electric Vehicles," *IEEE Transactions on Industrial Electronics*, vol. 61, no. 9, pp. 4580–4590, Sept. 2014.