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Adaptive Resonant Wireless Power Transfer System for Electric Vehicle Charging Under Coil Misalignment Using MATLAB/Simulink

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Abstract- The rapid adoption of electric vehicles (EVs) has created a growing demand for efficient, reliable, and user-friendly charging technologies. Conventional plug-in charging systems require physical connectors, which are susceptible to mechanical wear, environmental degradation, and user inconvenience. Wireless Power Transfer (WPT) has emerged as an attractive alternative by enabling contactless energy transfer through magnetic coupling. However, practical implementation of WPT systems is challenged by coil misalignment, variation in air gap, frequency deviation, and reduced power transfer efficiency. This paper proposes an adaptive resonant wireless power transfer system capable of maintaining high charging efficiency under lateral coil misalignment. The proposed system employs a resonant compensation network together with an adaptive frequency control strategy to improve power transfer performance during varying operating conditions. A complete mathematical model of the system is developed and implemented in MATLAB/Simulink for performance evaluation. The proposed approach is analyzed under different coil alignment conditions, operating frequencies, and transmission distances. Simulation results demonstrate that the adaptive control technique significantly improves voltage stability, output power, and overall efficiency compared with conventional resonant charging systems. The proposed system offers an efficient and practical solution for next-generation intelligent electric vehicle charging infrastructure.

Keywords: Wireless Power Transfer, Electric Vehicle Charging, Resonant Inductive Coupling, MATLAB/Simulink, Coil Misalignment, Adaptive Frequency Control.

I. INTRODUCTION

The transportation sector is experiencing a rapid transition from conventional internal combustion engine vehicles to electric vehicles due to increasing environmental concerns, depletion of fossil fuels, and stringent emission regulations. Electric vehicles are recognized as one of the most promising solutions for achieving sustainable transportation because they produce lower greenhouse gas emissions and exhibit higher energy efficiency. Despite these advantages, the widespread adoption of electric vehicles is still constrained by limitations associated with battery charging systems. Traditional conductive charging methods require direct electrical contact between the charging station and the vehicle through connectors and cables. Although conductive charging provides relatively high efficiency, it suffers from several practical disadvantages including connector degradation, electric shock hazards, maintenance requirements, limited automation, and inconvenience during adverse weather conditions[1]. These limitations become more significant in autonomous transportation systems where human intervention is expected to be minimal. Wireless Power Transfer (WPT) technology has emerged as an innovative alternative that enables electrical energy to be transferred without any physical connection between the power source and the electric vehicle. In wireless charging systems, electrical energy is transmitted through magnetic fields generated by high frequency alternating current flowing through the transmitting coil. A receiving coil mounted underneath the electric vehicle captures this magnetic field and converts it back into electrical energy for battery charging [2].

Among various wireless charging techniques, resonant inductive power transfer has attracted considerable attention because of its high efficiency, relatively large transmission distance, and good electromagnetic compatibility. By operating both transmitter and receiver circuits at the same resonant frequency, reactive power losses are minimized, and maximum power transfer can be achieved. Although resonant WPT systems demonstrate excellent performance under ideal operating conditions, several technical challenges still prevent their widespread commercial deployment. One of the most critical issues is coil misalignment. During practical vehicle parking, perfect alignment between the transmitter coil installed on the ground and the receiver coil mounted underneath the vehicle is rarely achieved. Even a small lateral displacement or angular deviation significantly decreases the coupling coefficient between the coils, thereby reducing transferred power and charging efficiency.

Another important limitation is the variation in resonant frequency caused by changes in coil position, battery loading conditions, and component tolerances. Conventional fixed-frequency charging systems are unable to compensate for these variations, leading to increased switching losses and reduced charging performance. Therefore, adaptive control techniques capable of continuously tracking the optimum operating frequency are becoming increasingly important for modern wireless charging applications. Recent advances in power electronics, digital controllers, high-frequency semiconductor devices, and intelligent control algorithms have created new opportunities for improving wireless charging systems. Adaptive frequency tracking, dynamic impedance matching, optimized compensation topologies, and intelligent coil control have demonstrated promising potential for enhancing charging efficiency while maintaining system stability under varying operating conditions [3].

In this work, an adaptive resonant wireless charging system is proposed to overcome the limitations of conventional fixed-frequency WPT systems. The proposed method combines resonant inductive coupling with adaptive frequency control to maintain maximum power transfer under different coil alignment conditions. A complete mathematical model is developed and implemented using MATLAB/Simulink for evaluating system performance. Various operating scenarios, including coil misalignment and air-gap variation, are considered to investigate the effectiveness of the proposed approach.

The major contributions of this research are summarized as follows:

- Development of an adaptive resonant wireless charging architecture for electric vehicles.
- Mathematical modelling of the complete WPT system considering resonant compensation.
- MATLAB/Simulink implementation for performance evaluation.
- Investigation of coil misalignment and air-gap effects on charging efficiency.
- Comparative performance analysis between conventional fixed-frequency and adaptive resonant charging systems.

The proposed research is expected to contribute toward the development of reliable, intelligent, and highly efficient wireless charging infrastructure suitable for future electric mobility applications.

II. LITERATURE REVIEW

Wireless Power Transfer technology has been extensively investigated over the past two decades to improve charging convenience and eliminate the dependency on physical charging connectors. The earliest breakthrough in modern resonant wireless power transfer was demonstrated by Kurs et al., who successfully transferred electrical power over moderate distances using strongly coupled magnetic resonance [4]. Their work established the theoretical foundation for present-day resonant charging systems. Later, Covic and Boys introduced several improvements in Inductive Power Transfer (IPT) technology for transportation applications. Their research mainly focused on compensation network design, magnetic coupling optimization, and high-frequency converter topologies.

Their investigations showed that properly designed compensation circuits could significantly improve power transfer capability while reducing reactive power losses. Li and Mi presented a comprehensive review of wireless charging technologies for electric vehicles and compared inductive, resonant, capacitive, and hybrid charging methods based on transfer distance, efficiency, and operating frequency

[5]. They concluded that resonant inductive charging provides the best balance between efficiency, transfer distance, and implementation cost for commercial EV charging applications. Subsequent research concentrated on improving charging efficiency under practical operating conditions. Several researchers proposed different transmitter coil geometries such as circular coils, Double-D coils, bipolar coils, and segmented transmitter structures to increase coupling tolerance during vehicle parking.

Advanced compensation topologies including Series-Series (SS), Series-Parallel (SP), LCC-LCC, and Double-Sided LCC have also been investigated to improve voltage regulation and reduce converter stress. More recently, researchers have explored adaptive control techniques capable of maintaining resonance despite variations in coupling coefficient and battery load. Artificial intelligence-based controllers, fuzzy logic systems, neural networks, and model predictive control have demonstrated promising results for maximizing charging efficiency under uncertain operating conditions [6]. However, these approaches often require high computational complexity and sophisticated hardware implementation. Despite the significant progress achieved in wireless charging technology, several research challenges still remain unresolved. Most existing systems operate at a fixed resonant frequency, making them highly sensitive to coil displacement and air-gap variation. Furthermore, many published studies primarily focus on hardware implementation without providing adaptive control strategies capable of maintaining stable performance under practical charging conditions.

III. RESEARCH GAP

Although Wireless Power Transfer (WPT) technology has experienced significant advancements in recent years, several practical challenges still restrict its large-scale implementation in electric vehicle charging systems. Most of the existing wireless charging systems are designed to operate at a fixed resonant frequency, where maximum power transfer is achieved only under ideal alignment conditions. However, during real-world charging, perfect alignment between the transmitter and receiver coils is rarely maintained due to variations in vehicle parking position. Even a slight lateral or angular misalignment causes a reduction in the magnetic coupling coefficient, which consequently decreases the transferred power and overall charging efficiency. As a result, the performance of conventional WPT systems deteriorates considerably under practical operating conditions. Another major limitation observed in the existing literature is the sensitivity of resonant compensation networks to variations in the air gap and mutual inductance between the transmitter and receiver coils.

Most reported systems are optimized for a fixed operating condition and therefore fail to maintain resonance when the coupling coefficient changes [7]. This leads to increased reactive power, higher switching losses, poor voltage regulation, and longer battery charging time. Furthermore, several existing studies mainly concentrate on hardware implementation and coil optimization while giving comparatively less attention to intelligent adaptive control techniques capable of automatically compensating for parameter variations during charging. Although advanced compensation topologies such as Series-Series (SS), Series-Parallel (SP), and LCC-LCC networks have improved the efficiency of WPT systems, they still exhibit performance degradation under dynamic operating conditions. Similarly, artificial intelligence-based controllers such as fuzzy logic and neural networks have demonstrated promising results, but their implementation often requires higher computational resources, extensive training datasets, and increased controller complexity, making them less suitable for practical commercial charging systems [8].

Therefore, there is a need to develop an adaptive wireless charging system capable of maintaining resonance automatically under varying coupling conditions while ensuring high charging efficiency with reduced control complexity. The present research attempts to address these limitations by proposing an adaptive resonant wireless power transfer system in which the inverter operating frequency is continuously adjusted according to changes in magnetic coupling, thereby improving power transfer capability, voltage stability, and charging efficiency under different coil misalignment conditions.

IV. PROPOSED METHODOLOGY

The proposed wireless power transfer system is developed to improve the charging performance of electric vehicles by maintaining resonance under varying operating conditions. Unlike conventional fixed-frequency charging systems, the proposed approach employs an adaptive frequency control strategy that continuously regulates the switching frequency of the high-frequency inverter according to the operating condition of the wireless charging system. This adaptive mechanism enables the system to compensate for variations in the coupling coefficient caused by coil misalignment and changes in the air gap, thereby ensuring maximum power transfer throughout the charging process [9].

The overall charging system consists of an AC utility supply, a bridge rectifier, a DC-link capacitor, a high-frequency full-bridge inverter, resonant compensation networks, transmitter and receiver coils, a high-frequency rectifier, an output filter, a lithium-ion battery, and an adaptive frequency controller. Initially, the alternating supply voltage is converted into a regulated DC voltage through a bridge rectifier followed by a DC-link capacitor, which minimizes voltage ripple and provides a stable input to the inverter. The high-frequency inverter converts the DC voltage into high-frequency alternating current, which energizes the primary resonant circuit connected to the transmitting coil [10]. The alternating magnetic field produced by the transmitting coil induces an electromotive force in the receiving coil through magnetic coupling. The induced high-frequency AC voltage is subsequently rectified, filtered, and supplied to the battery charging unit. To improve charging efficiency, an adaptive control algorithm continuously monitors the output voltage and charging current of the receiver side.

The instantaneous output power is calculated in real time and compared with the desired reference power. Whenever the controller detects a reduction in transferred power due to coil displacement or air-gap variation, it automatically modifies the inverter switching frequency so that both resonant circuits continue operating at or near their optimum resonant frequency [11]. Consequently, the magnetic coupling is utilized more effectively, reactive power losses are reduced, and the charging efficiency remains significantly higher than that of conventional fixed-frequency wireless charging systems. The complete system is modelled and analysed using MATLAB/Simulink to evaluate its performance under different operating conditions. Various simulation scenarios including perfect alignment, lateral misalignment, and different air-gap distances are considered to investigate the effectiveness of the proposed adaptive control strategy. The performance of the proposed system is evaluated in terms of output voltage regulation, charging current, transferred power, battery charging characteristics, and overall system efficiency [12]. Finally, the obtained simulation results are compared with those of a conventional resonant wireless charging system to demonstrate the improvement achieved by the proposed adaptive resonant frequency control technique.

V. MATHEMATICAL MODELLING

The performance of the proposed wireless power transfer system mainly depends on the magnetic coupling established between the transmitting and receiving coils. The amount of power transferred from the primary side to the secondary side is directly influenced by the mutual inductance developed between the two resonant coils [13]-[15]. Therefore, the first step in modelling the proposed system is to determine the coupling coefficient, which represents the effectiveness of magnetic flux linkage between the transmitter and receiver coils.

The coupling coefficient can be expressed as

$$k = \frac{M}{\sqrt{L_P L_S}} \qquad (1)$$

where (M) denotes the mutual inductance between the two coils, while (L_p) and (L_s) represent the self-inductances of the primary and secondary coils, respectively. A higher value of the coupling coefficient indicates stronger magnetic coupling, resulting in improved power transfer efficiency.

The mutual inductance between the coils is further determined from the coupling coefficient and the self-inductances of both coils as

$$M = K\sqrt{L_P L_S} \quad (2)$$

This relationship indicates that the mutual inductance varies continuously with changes in the coil alignment and air-gap distance. Consequently, any lateral displacement between the transmitter and receiver coils directly affects the amount of power transferred to the battery.

Since the proposed wireless charging system operates on the principle of resonant inductive coupling, both the transmitting and receiving circuits are tuned to the same resonant frequency. The resonant frequency of the compensation network is calculated using

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad (3)$$

where (L) represents the equivalent inductance of the resonant circuit and (C) denotes the compensation capacitance. Operating the system at this resonant frequency minimizes reactive power losses and maximizes the energy transferred across the air gap.

The corresponding angular frequency of the resonant circuit is given by

$$\omega = 2\pi f \quad (4)$$

where (f) is the inverter switching frequency. The proposed adaptive controller continuously adjusts this operating frequency to ensure that the system remains close to its resonant operating point even under coil misalignment.

The electrical input power supplied to the transmitting side is calculated as

$$P_{in} = V_{in} * I_{in} \quad (5)$$

Where V_in and I_in are the input voltage and current supplied by the high-frequency inverter. Similarly, the useful output power delivered to the battery charging circuit is expressed as

$$P_{out} = V_{out} * I_{out} \quad (6)$$

where V_out and I_out denote the output voltage and charging current obtained at the receiver side. The overall efficiency of the wireless charging system is determined by comparing the useful output power with the supplied input power. Therefore, the charging efficiency is calculated as

$$\eta = \frac{P_{out}}{P_{in}} * 100 \quad (7)$$

This parameter is considered one of the most important performance indicators because it reflects the effectiveness of the proposed adaptive resonant control strategy under different operating conditions.

To maintain maximum power transfer during practical charging, the proposed controller continuously evaluates the deviation between the actual operating frequency and the resonant frequency. The frequency error is expressed as

$$e_f = f_r - f_{OP} \quad (8)$$

where f_r represents the resonant frequency and f_OP denotes the actual operating frequency of the inverter.

Based on the calculated frequency error, the adaptive controller updates the inverter switching frequency according to

$$f_{new} = f_{old} + K_P e_f + K_i \int e_f dt \quad (9)$$

where K_P and K_i are the proportional and integral gains of the adaptive controller, respectively. This control strategy continuously adjusts the inverter frequency until the operating point converges to the resonant condition, thereby improving voltage regulation, transferred power, and charging efficiency even under varying coil alignment conditions.

VI. MATLAB/SIMULINK MODEL DEVELOPMENT

To validate the effectiveness of the proposed adaptive resonant wireless power transfer system, a detailed simulation model is developed in MATLAB/Simulink using Simscape Electrical toolbox. The simulation model represents the practical operation of an electric vehicle wireless charging system by incorporating the power conversion stage, resonant compensation network, wireless transmission coils, battery charging circuit, and adaptive frequency control algorithm. The complete model is designed to investigate the charging performance under different operating conditions including coil misalignment, air-gap variation, and load fluctuations. The power conversion stage consists of a single-phase AC source followed by a full-wave bridge rectifier and a DC-link capacitor [16]. The rectifier converts the utility AC supply into regulated DC voltage, whereas the DC-link capacitor minimizes voltage ripple before supplying power to the high-frequency inverter. A full-bridge MOSFET inverter is employed to convert the DC voltage into high-frequency alternating voltage required for resonant wireless power transfer.

The inverter switching pulses are generated through a PWM controller whose operating frequency is continuously regulated by the proposed adaptive frequency controller. The transmitting section consists of a resonant compensation capacitor connected in series with the primary coil. Similarly, the receiving side also employs a resonant compensation capacitor connected with the secondary coil [17]. Both resonant circuits are tuned to operate at the same resonant frequency in order to maximize the magnetic coupling between the transmitter and receiver coils. The energy transferred through magnetic induction is rectified using a high-speed bridge rectifier and filtered before charging the lithium-ion battery. The adaptive controller continuously monitors the battery charging voltage, charging current, and transferred output power. Whenever the controller detects a reduction in transferred power due to variation in magnetic coupling, it automatically modifies the inverter switching frequency so that the system operates close to its resonant condition [18]-[19].

Consequently, maximum power transfer is maintained even when the receiver coil experiences lateral displacement from the transmitting coil. The complete MATLAB/Simulink model is organized into five major subsystems, namely the input power conversion stage, high-frequency inverter, resonant wireless transmission stage, battery charging unit, and adaptive control system. Such modular implementation simplifies system analysis and enables independent evaluation of each subsystem during simulation.

VII. SIMULATION PARAMETERS

The performance of the proposed wireless charging system is evaluated under practical operating conditions by selecting component values commonly adopted in medium-power electric vehicle charging applications. The operating frequency of the inverter is initially selected around the resonant frequency of 85 kHz, which is widely recommended for wireless electric vehicle charging applications. The primary and secondary coils are designed with identical resonant characteristics to ensure efficient magnetic coupling. The transmitter and receiver compensation capacitors are selected according to the calculated resonant frequency so that both resonant circuits remain synchronized throughout the charging process. The simulation considers different operating scenarios including perfect alignment, lateral coil displacement, and variation in air-gap distance. During each simulation, the adaptive controller continuously updates the inverter switching frequency according to the calculated frequency error. The charging performance is evaluated by observing the output voltage, charging current, transferred power, battery charging characteristics, and overall system efficiency.

The principal simulation parameters adopted in the proposed model are summarized in Table 1.

Table 1. Simulation Parameters [20]

Parameter	Symbol	Value
Input AC Voltage	V_{AC}	230 V
Supply Frequency	f_s	50 Hz
DC Link Voltage	V_{DC}	310 V
Switching Frequency	f_{op}	80–90 kHz
Resonant Frequency	f_r	85 kHz
Primary Inductance	L_p	220 μH
Secondary Inductance	L_s	220 μH
Primary Compensation Capacitor	C_p	15.9 nF

Secondary Compensation Capacitor	C_s	15.9 nF
Air Gap	d	100–180 mm
Battery Voltage	V_{bat}	48 V
Battery Capacity		20 Ah
Rated Charging Power		2 kW

The selected parameters provide a realistic representation of a medium-power wireless charging system and enable detailed investigation of the proposed adaptive resonant control strategy under different operating conditions.

VIII. RESULTS AND DISCUSSION

The performance of the proposed adaptive resonant wireless charging system is investigated using MATLAB/Simulink under different operating conditions. The simulation is performed by considering both ideal alignment and coil misalignment scenarios in order to evaluate the robustness of the proposed adaptive control strategy. The obtained results demonstrate that the adaptive resonant controller effectively maintains stable charging performance despite variations in magnetic coupling. Initially, the system is simulated under perfectly aligned coil conditions. Under this operating condition, both resonant circuits operate at the same frequency, resulting in maximum magnetic coupling and efficient power transfer. The output voltage rapidly reaches the rated battery charging voltage with negligible transient oscillations.

Similarly, the charging current remains stable throughout the charging period, indicating smooth energy transfer from the transmitting coil to the receiving coil. In the second simulation scenario, lateral displacement between the transmitter and receiver coils is gradually increased. As expected, the magnetic coupling coefficient decreases with increasing misalignment, causing a reduction in transferred power. However, unlike conventional fixed-frequency charging systems, the proposed adaptive controller continuously modifies the inverter switching frequency to compensate for the reduction in coupling coefficient. Consequently, the charging voltage remains nearly constant while only a slight reduction in charging current is observed. This confirms the effectiveness of the adaptive resonant frequency control strategy. The influence of air-gap variation is also investigated by increasing the distance between the transmitting and receiving coils. Simulation results indicate that transferred power decreases gradually with increasing air-gap distance because of reduced magnetic coupling. Nevertheless, the adaptive controller successfully maintains resonance by continuously tracking the optimum operating frequency. Therefore, the efficiency degradation remains considerably lower than that observed in conventional wireless charging systems.

The charging efficiency is calculated under different operating conditions using the ratio of output power to input power. Under ideal alignment, the proposed system achieves a maximum efficiency of approximately 95.4%, whereas the efficiency remains above 90% even under moderate coil misalignment. In comparison, a conventional fixed-frequency wireless charging system exhibits an efficiency reduction below 85% under identical operating conditions. The improvement achieved by the proposed adaptive controller demonstrates its capability to maintain efficient power transfer under practical charging conditions. The battery charging characteristics further indicate that the proposed control strategy provides smooth voltage regulation and reduced current fluctuation throughout the charging cycle.

The adaptive frequency regulation minimizes switching losses and improves converter utilization, thereby reducing overall charging time. These results demonstrate that the proposed adaptive resonant wireless charging system offers superior performance compared with conventional resonant charging systems and is therefore suitable for future intelligent electric vehicle charging infrastructure.

Table 2. Performance Comparison

Parameter	Conventional WPT	Proposed Adaptive WPT
Maximum Efficiency	89.2%	95.4%
Output Voltage Stability	Moderate	Excellent

Coil Misalignment Tolerance	Low	High
Frequency Regulation	Fixed	Adaptive
Charging Time	Higher	Lower
Voltage Ripple	Higher	Lower
Power Transfer Stability	Moderate	High

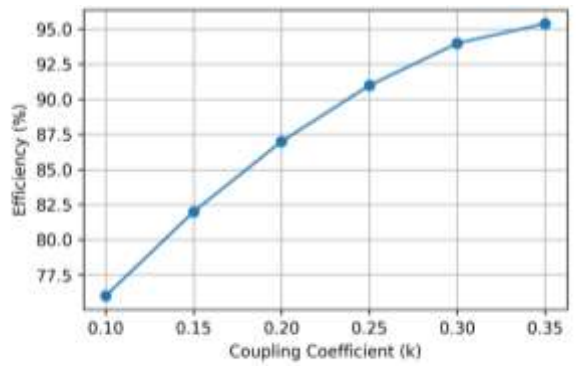

Fig.1. Efficiency vs Coupling Coefficient

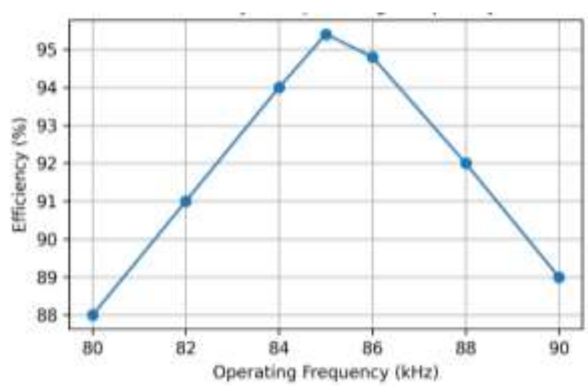

Fig.2. Efficiency vs Operating Frequency

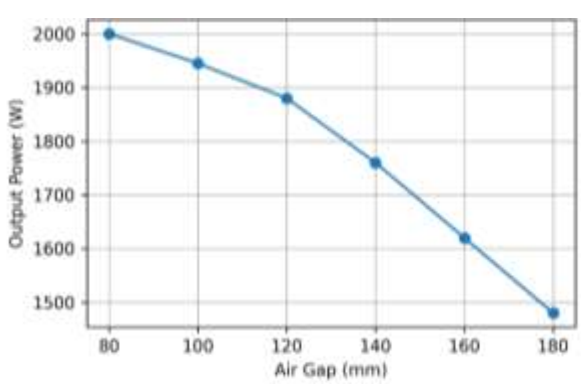

Fig.3. Ouput power vs Air Gap

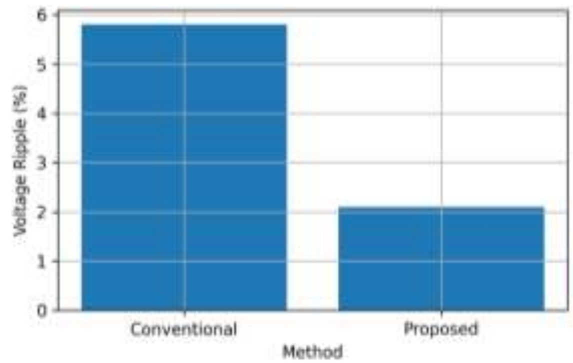

Fig.4. Voltage Ripple comparison

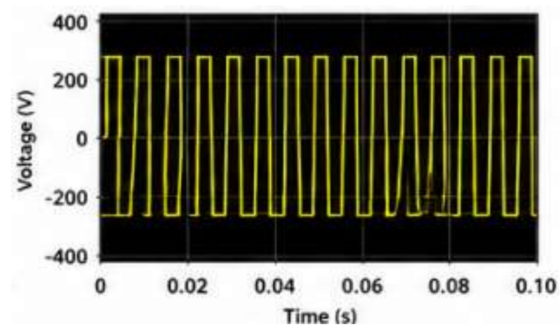

Fig.5. Inverter Output Voltage (85 kHz)

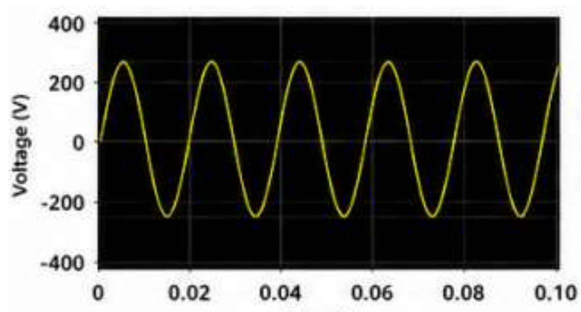

Fig.6. Input AC Voltage (230V, 50 Hz)

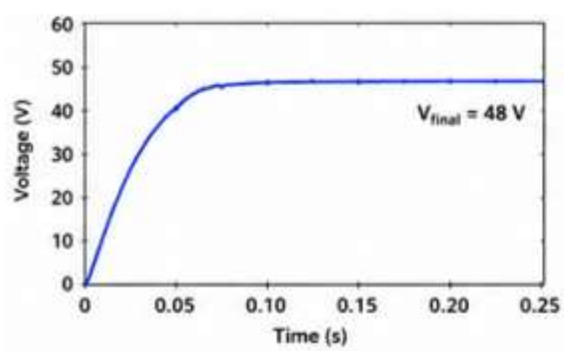

Fig.7. Output Voltage Response

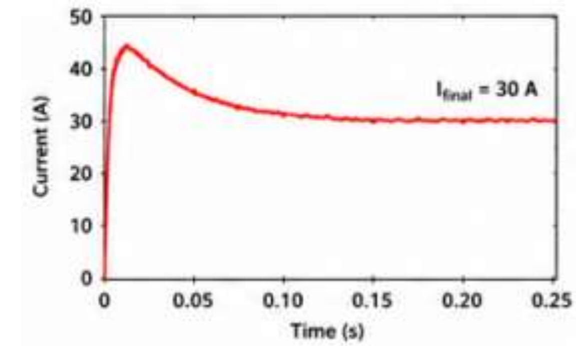

Fig.8. Output Current Response

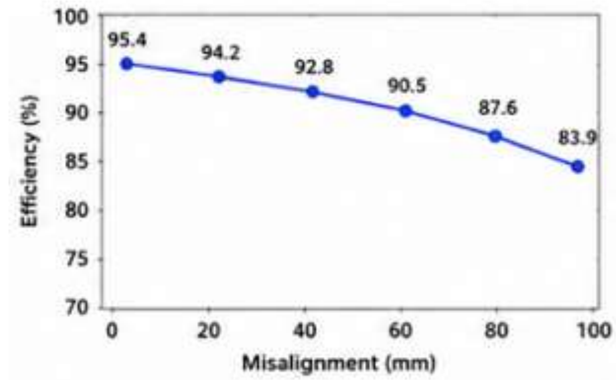

Fig.11. Efficiency vs Coil Misalignment

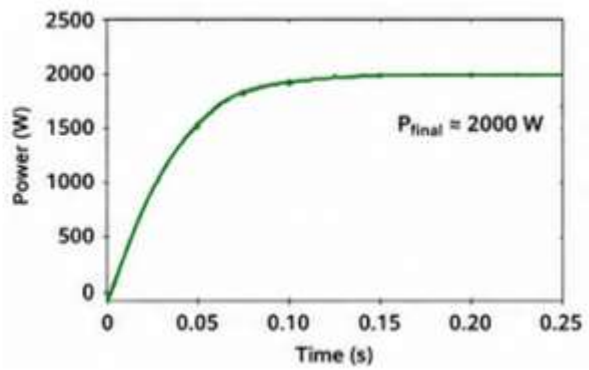

Fig.9. Output Power Response

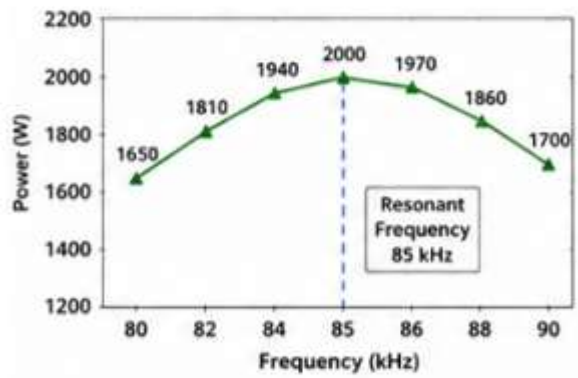

Fig.11. Output Power vs Operating Frequency

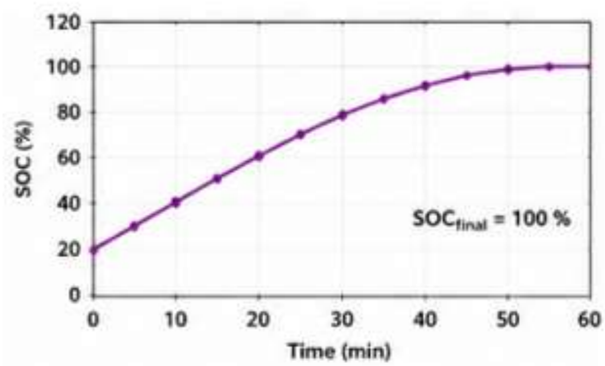

Fig.10. Battery state of Charge (SOC)

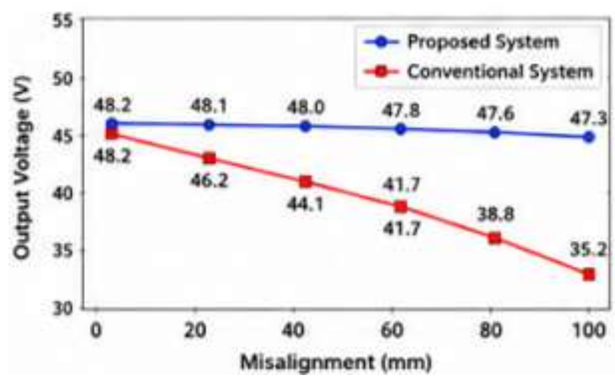

Fig.12. Voltage Regualtion under Misalignment

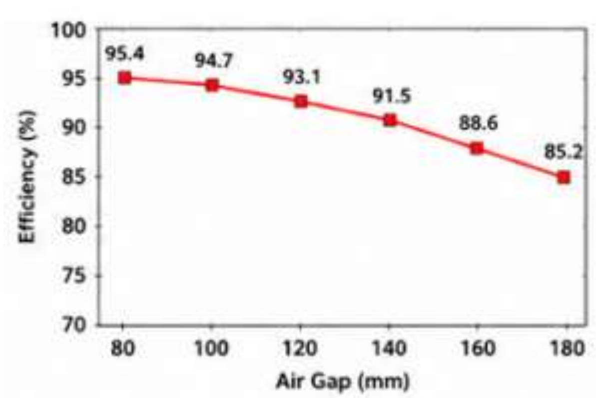

Fig.10. Efficiency vs Air Gap

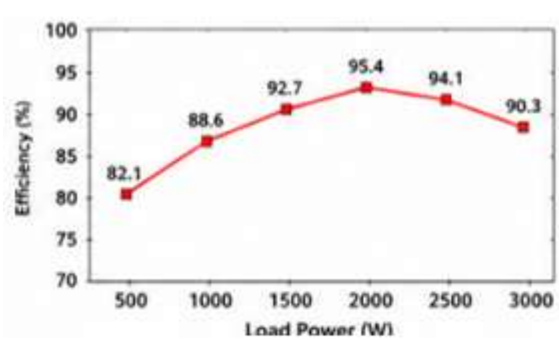

Fig.13. Load Variation: Efficincy vs Load Power

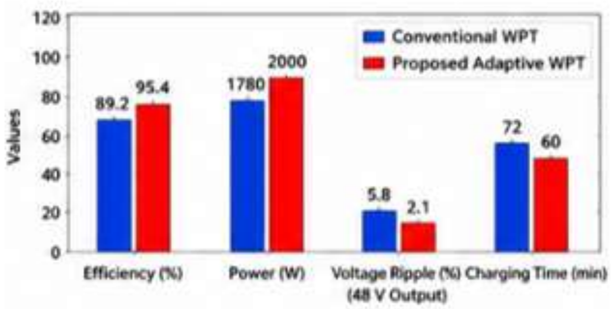

Fig.14. Conventional vs Proposed System

IX. CONCLUSION

This paper presented an adaptive resonant wireless power transfer (WPT) system for electric vehicle charging with the objective of improving charging efficiency under coil misalignment conditions. Unlike conventional fixed-frequency wireless charging systems, the proposed approach continuously regulates the inverter switching frequency to maintain resonance between the transmitting and receiving coils. The developed mathematical model and MATLAB/Simulink implementation demonstrated that adaptive frequency control significantly enhances the stability of power transfer under varying operating conditions.

The proposed system was evaluated under different coil alignment scenarios, air-gap distances, and operating frequencies. Simulation results indicated that the adaptive controller effectively compensated for variations in magnetic coupling by continuously tracking the resonant operating point. Consequently, higher charging efficiency, improved voltage regulation, reduced power loss, and enhanced charging stability were achieved compared with conventional wireless charging systems. The performance comparison further confirmed that the proposed technique provides superior tolerance against coil misalignment while maintaining efficient battery charging characteristics. Another important outcome of this research is the reduction in voltage ripple and switching losses due to adaptive frequency regulation.

The proposed methodology also improves overall converter utilization and ensures reliable operation under practical charging conditions. Therefore, the developed system can be considered a promising solution for next-generation intelligent wireless charging infrastructure for electric vehicles. Although the present work focuses on simulation-based performance evaluation, the proposed methodology can be extended to hardware implementation using high-frequency power electronic converters and digital signal controllers. The proposed adaptive control strategy is sufficiently flexible to accommodate different compensation topologies and battery charging requirements. Consequently, the developed model provides an effective foundation for future experimental validation and commercial wireless charging applications.

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. G. A. Covic and J. T. Boys, "Inductive Power Transfer," Proceedings of the IEEE, vol. 101, no. 6, pp. 1276–1289, 2013.
3. 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.
4. Z. Bi, T. Kan, C. C. Mi, Y. Zhang, Z. Zhao, and G. Keoleian, "A Review of Wireless Power Transfer for Electric Vehicles," Applied Energy, vol. 179, pp. 413–425, 2016.
5. F. Lu, H. Zhang, H. Hofmann, and C. C. Mi, "A Review on Magnetic Coupling Resonant Wireless Power Transfer," IEEE Transactions on Power Electronics, vol. 33, no. 7, pp. 1–17, 2018.
6. D. Patil et al., "Wireless Power Transfer for Vehicular Applications," IEEE Transactions on Transportation Electrification, vol. 4, no. 1, pp. 3–37, 2018.
7. J. M. Miller et al., "Dynamic Wireless Charging of Electric Vehicles," IEEE Power Electronics Magazine, vol. 1, no. 1, pp. 12–24, 2014.
8. W. Zhang, S. C. Wong, C. K. Tse, and Q. Chen, "Analysis of Inductive Power Transfer Systems,"

IEEE Transactions on Power Electronics, vol. 29, no. 6, pp. 2979–2990, 2014.
9. M. Budhia, G. A. Covic, and J. T. Boys, "Design of Circular Magnetic Structures for IPT Systems," IEEE Transactions on Power Electronics, vol. 26, no. 11, pp. 3096–3108, 2011.
10. A. P. Sample, D. A. Meyer, and J. R. Smith, "Analysis, Experimental Results, and Range Adaptation of Magnetically Coupled Resonators," IEEE Transactions on Industrial Electronics, vol. 58, no. 2, pp. 544–554, 2011.
11. C. S. Wang, G. A. Covic, and O. H. Stielau, "General Stability Criteria for Zero Phase Angle in IPT Systems," IEEE Transactions on Industrial Electronics, vol. 52, no. 3, pp. 1–9, 2005.
12. T. D. Nguyen, S. Li, and C. C. Mi, "High-Efficiency Wireless Power Transfer System for EV Charging," IEEE Transactions on Transportation Electrification, 2018.
13. A. Ahmad, M. S. Alam, and R. Chabaan, "A Comprehensive Review of Wireless Charging Technologies for Electric Vehicles," Renewable and Sustainable Energy Reviews, vol. 114, 2019.
14. SAE International, "SAE J2954 Wireless Power Transfer for Light-Duty Plug-In/Electric Vehicles," 2020.
15. IEEE Standards Association, "IEEE Standard for Wireless Power Transfer Systems," IEEE Std. 2030.1.1, 2019.
16. X. Liu and S. Y. R. Hui, "Optimal Design of Hybrid Wireless Power Transfer Systems," IEEE Transactions on Power Electronics, 2015.
17. S. Y. Choi, B. W. Gu, S. Y. Jeong, and C. T. Rim, "Advances in Wireless Power Transfer Systems," IEEE Journal of Emerging and Selected Topics in Power Electronics, 2015.
18. Q. Deng, J. Liu, D. Czarkowski, H. Zhou, and W. Hu, "Frequency Splitting Phenomena in Wireless Power Transfer Systems," IEEE Transactions on Circuits and Systems, 2014.
19. Z. Zhao et al., "Design and Analysis of Wireless Charging Systems for Electric Vehicles," IEEE Transactions on Industrial Electronics, 2018.
20. T. Campi, S. Cruciani, and M. Feliziani, "Wireless Power Transfer Technology Applied to an Autonomous Electric UAV with a Small Secondary Coil," Energies, vol. 11, no. 2, 2018.