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Advancements in Active Control of Electromagnetic Force in Wireless Power Transfer Systems

Polimeni Cárdenas*

Department of Electrical Engineering, College of Engineering, Jouf University, Sakaka 72388, Saudi Arabia

Introduction

Wireless Power Transfer (WPT) systems have emerged as a promising technology for providing convenient and efficient energy transmission without the need for physical connectors. However, one of the challenges in WPT systems is controlling the Electromagnetic (EM) force, which can cause efficiency losses, electromagnetic interference, and safety concerns. Active control of EM force has therefore become a focal point in enhancing the performance and safety of WPT systems. In WPT systems, electromagnetic force arises due to the interaction between magnetic fields generated by the transmitter and receiver coils. This force can lead to misalignment between the coils, resulting in reduced efficiency and potential damage to the system. Moreover, EM force can induce vibrations, leading to audible noise and mechanical wear. Traditional WPT systems often rely on passive methods such as magnetic shielding and mechanical alignment to mitigate EM force [1].

WPT systems operate in diverse environments with varying coil alignments and load conditions. Effective EM force control requires real-time adaptation to these changes to maintain optimal performance. Introducing active control mechanisms should not compromise the overall efficiency of WPT systems. Balancing between minimizing EM force and maximizing power transfer efficiency is crucial. EM force can pose safety risks, especially in high-power WPT applications. Active control strategies must ensure that safety standards are met to prevent hazards to users and surrounding objects. Recent advancements in control theory, sensor technology, and power electronics have enabled innovative approaches to actively manage EM force in WPT systems. Utilizing advanced control algorithms such as Model Predictive Control (MPC) and adaptive control, WPT systems can dynamically adjust the power transmission parameters to minimize EM force while maintaining efficient power transfer [2].

Description

Integration of sensors such as Hall effect sensors and accelerometers enables real-time monitoring of coil alignment, vibration, and temperature. This data is fed into control algorithms to facilitate proactive adjustments and enhance system stability. Active manipulation of magnetic fields using electronic components such as Field-Effect Transistors (FETs) allows for precise control of EM force. By adjusting the phase and amplitude of the magnetic fields, undesirable forces can be minimized. Closed-loop feedback control systems continuously monitor system parameters and adjust control actions accordingly. By incorporating feedback loops, WPT systems can react swiftly to changes in operating conditions, ensuring optimal performance and safety. By minimizing EM force-induced losses, active control improves the overall efficiency of WPT systems, leading to reduced power consumption and increased energy transfer efficiency [3].

Through real-time monitoring and proactive adjustments, active EM force control minimizes safety risks associated with WPT systems, ensuring compliance with regulatory standards. Active control enables WPT systems to adapt to changing operating conditions, including variations in coil alignment, load impedance, and environmental factors, without compromising performance. Active control of electromagnetic force represents a significant advancement in the field of wireless power transfer, offering improved efficiency, reliability, and safety. By leveraging advanced control algorithms, sensor technologies, and power electronics, WPT systems can effectively mitigate the effects of EM force, paving the way for broader adoption of wireless charging technologies across various industries. Continued research and development in this area promise to further enhance the performance and versatility of WPT systems, driving innovation in energy transmission and consumption [4].

MPC algorithms utilize predictive models of the WPT system dynamics to optimize control actions over a finite time horizon. By considering future system behavior, MPC can anticipate changes in coil alignment or load conditions and proactively adjust power transmission parameters to minimize EM force while maximizing efficiency. Machine learning algorithms, such as neural networks and reinforcement learning, can learn complex relationships between system inputs and outputs from data. AI-based control strategies offer adaptive and robust solutions for EM force control in WPT systems, capable of handling nonlinearities and uncertainties inherent in real-world applications. Traditional control strategies often focus on optimizing a single performance metric, such as efficiency or EM force reduction. However, in WPT systems, multiple conflicting objectives, such as efficiency, EM force minimization, and system stability, need to be considered simultaneously [5].

Conclusion

***Address for Correspondence:** Department of Electrical Engineering, College of Engineering, Jouf University, Sakaka 72388, Saudi Arabia; E-mail: cardenas.meni@liom.sa*

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WPT systems find applications in industrial automation for powering sensors, actuators, and other wireless devices in harsh or inaccessible environments. Active EM force control enables reliable and efficient power delivery to these devices, even in the presence of electromagnetic interference or mechanical vibrations, thereby improving system robustness and uptime. Active control of electromagnetic force represents a paradigm shift in the design and implementation of wireless power transfer systems, offering unprecedented flexibility, efficiency, and reliability. Leveraging advanced control strategies and sensor technologies, active EM force control enables WPT systems to adapt to dynamic operating conditions, optimize power transmission efficiency, and ensure compliance with safety standards across diverse applications. As research and development in this field continue to progress, active EM force control is poised to play a pivotal role in shaping the future of wireless charging technologies, driving innovation and adoption across industries.

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Conflict of Interest

None.

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