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From Theory to Practice: A Multidimensional Optimization Method for Improving the Charging Efficiency of Electric Vehicles

Shihan Yi *

School of Energy and Power Engineering, Nanjing Institute of Technology, Nanjing, 211167, China
*** Corresponding author Email:** yishihanyishihan@163.com

Abstract: This paper focuses on the optimization of dynamic wireless charging technology for electric vehicles to address challenges such as long charging time and few charging locations. The research covers transmit and receive unit optimization, system and power management improvements, and the impact of environmental conditions on charging efficiency. In terms of the optimization of transmitting and receiving devices, the paper discusses the optimization of power, frequency and directivity to improve the energy transmission distance and efficiency. In terms of system and power management optimization, energy loss is reduced through methods such as magnetic disc structure improvement, and the importance of proper power management for battery life and charging safety is emphasized. In addition, the influence of environmental conditions (such as temperature, humidity, and distance) on charging efficiency is also elaborated. High temperature, high humidity and long distance may affect the system performance. The paper puts forward some countermeasures for these effects, such as heat dissipation design, humidity cancellation technology and signal processing technology. However, further field validation and technical, cost and standard issues need to be resolved to achieve commercial application of the technology.

Keywords: Electric Vehicles; Dynamic Wireless Charging; Efficiency Optimization.

1. Introduction

With the proposal of the carbon peaking and carbon neutrality goals, the idea of replacing traditional oil vehicles with trams has once again been valued by researchers, and its characteristics such as low energy consumption, low emissions, and low environmental pollution have made electric vehicles gain wide support and development [1]. However, charging problem is very important in the development process of electric vehicles. Compared with ordinary gas-powered vehicles, electric vehicles have the disadvantages of longer charging time, fewer charging places and higher equipment cost. However, dynamic wireless charging technology does not require a fixed charging mode and location to save charging time [2]. The research and development of dynamic radio technology for electric vehicles is still in a relatively early stage, and the improvement of charging efficiency will directly affect the actual use and popularity of electric vehicles. The key factors affecting the efficiency of dynamic wireless charging are revealed through in-depth discussion of transmitting and receiving devices, system and power management, and environmental conditions, and a series of innovative optimization schemes are proposed to promote the development of electric vehicle charging technology.

2. Optimization of Transmitting and Receiving Devices

The transmitter and receiver play a crucial role in dynamic wireless charging. The transmitter needs to find the right power and frequency to reduce electromagnetic wave attenuation and increase the energy transmission distance. At the same time, it also needs to optimize the direction of energy transmission and concentrate energy for transmission. On the one hand, the receiving device needs to manage the charging state and current of the battery to ensure that the charging process is safe and efficient, and the transmission efficiency can also be improved by optimizing the transmitting coil by other methods [3]. On the other hand, it should be aligned with the launcher to improve the efficiency of energy transmission, adapt to the changes of the launcher, and use real-time control circuits to optimize the efficiency of energy transmission. In other words, in dynamic wireless charging, by adjusting the design and setting of the transmitter, the energy transmission is more concentrated and accurate towards the receiving device, so as to minimize the loss of energy in the transmission process and improve the efficiency and accuracy of energy transmission. This optimization ensures accurate directional transmission of energy in space and minimizes energy loss, thus making dynamic wireless charging technology more efficient and reliable

3. System Optimization and Power Management Optimization

The system optimization of dynamic wireless charging technology can reduce interference and improve charging efficiency. For example, when using a wireless charging system with electromagnetic resonance coupling, we can improve the transmission efficiency of the system by improving the disk structure to reduce eddy current loss [4]. Based on the current development trend of electric vehicles, it is bound to be widely used in the future, and at the same time, the requirements of the grid are increasing. Therefore, appropriate power management is of great significance, not only to maximize the utilization of energy, avoid energy waste, but also to help the protection of the battery, avoid overcharging or excessive discharge, extend the battery life, and ensure the safety of battery charging [5].The system optimization and power management optimization of wireless

charging technology can significantly improve charging efficiency, stability and reliability, while reducing energy waste and environmental impact, providing users with a better charging experience, and promoting the development and application of wireless charging technology.

4. Optimization of Environmental Conditions

In the process of dynamic wireless charging, from energy transmission efficiency to equipment performance, each link may be affected by environmental factors including temperature, humidity, distance, electromagnetic interference, terrain and so on. In order to improve the efficiency of charging, it is necessary to find and explore appropriate optimization methods to reduce the impact of environmental factors on charging efficiency. The following is an analysis of some of these factors.

4.1. Effect of Temperature on Dynamic Wireless Charging Efficiency

Researchers often conduct experiments and development at conventional temperatures (around 25 ° C), while in the actual application of wireless technology, extreme high or low temperatures usually occur. For example, in northern China, the average daily outdoor environment temperature in winter is lower than 0 ° C, and even extreme cold weather of minus 30 ° C occurs. In the southern region, the temperature of the summer system is also higher than 30℃ for a long time. At this time, when the wireless charging system is under unconventional temperature conditions, the efficiency of charging will be affected, thus failing to meet the standard of battery charging. Especially in high temperature weather, the ambient temperature makes the internal resistance of the system increase with the increase of temperature, which significantly reduces the charging efficiency [6].Meanwhile, high temperature may lead to material expansion in charging equipment, which affects the physical structure of the equipment and the relative position of internal components. And then affect the accuracy and stability of energy transmission.

4.2. Effect of Humidity on Dynamic Wireless Charging Efficiency

Due to the particularity of dynamic wireless technology, compared with ordinary static charging technology, it can be placed in a position with suitable working conditions and has more variable humidity conditions. Especially in the wet or dry season, the impact of humidity on the efficiency of wireless charging is more and more serious. On the one hand, when the humidity is higher than the normal level, the water vapor in the high humidity environment may lead to corrosion and oxidation of the metal surface, which may damage the appearance and structure of the equipment, and may cause corrosion and oxidation of the equipment, reducing its performance and efficiency. In addition, the high humidity environment will also affect the efficiency of the heat dissipation and cooling system. Wet air does not easily carry away heat, which may cause the equipment to overheat, which in turn affects the efficiency and life of the equipment. In addition, in high humidity environments, electromagnetic wave losses during energy transmission may increase. This can lead to reduced energy transfer efficiency in wireless charging systems, allowing more energy to be converted to heat rather than transmitted to the receiving device, reducing efficiency when charging.

4.3. The Effect of Distance on the Efficiency of Dynamic Wireless Charging

With the increase of transmission distance, the output power of the wireless charging system increases rapidly, the transmission efficiency gradually decreases, and the speed of reduction becomes faster and faster [7]. Meanwhile, with the increase of distance, electromagnetic waves in the process of energy transmission may experience attenuation. This means that the greater the distance, the less efficient the energy transmission, because more energy will be lost in the transmission process, thus affecting the charging efficiency. In addition, some dynamic wireless charging systems use electromagnetic wave focusing technology to improve the efficiency of energy transmission. At closer distances, focused energy transmission can reduce energy loss, thereby improving charging efficiency.

5. Conclusion

This paper mainly discusses how to optimize the efficiency of dynamic wireless charging technology from three aspects: transmitting and receiving devices, system and power management, and environmental conditions. A variety of optimization schemes are proposed from different angles to improve charging efficiency, reduce time and energy costs, and solve the important problems faced in the development of electric vehicles. At the same time, it also reveals the potential of dynamic wireless charging technology in improving charging efficiency, providing substantial support for the development of the electric vehicle industry, and is expected to promote the construction of more efficient dynamic charging infrastructure for electric vehicles. Although many key optimization schemes are proposed in this study, there are still some limitations. For example, differences in other environmental conditions (such as terrain) in different regions may affect the specific performance of charging efficiency, which requires more extensive field verification. In addition, the commercialization and large-scale application of dynamic wireless charging technology still faces technical, cost and standard challenges, which need further research and exploration.

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