

Simulation Research on Improving Wireless Charging Efficiency of Electric Vehicles

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Abstract. Accompanied by the continuous development and progress of science and technology worldwide, wireless energy transmission has become an increasingly important research focus for researchers in related fields. Wireless charging technology, with its advantages of safe operation, flexibility, convenience, and low maintenance costs, has received more and more attention and is one of the mainstream development trends of electric vehicles in the field of future power technology. The efficiency of wireless charging technology is an important factor affecting its promotion. This article summarizes and discusses the magnetic coupling resonance wireless energy transmission technology, analyzes the basic structure and working principle of the magnetic coupling resonance wireless energy transmission technology, and theoretically analyzes the magnetic coupling resonance wireless energy transmission circuit through a mutual inductance model. The circuit is built using the mutual inductance model in Multisim for simulation experiments to verify the correlation between wireless charging efficiency and circuit load and frequency. Plotted the correlation curve between wireless charging efficiency, circuit load, and frequency.

Keywords: Electric vehicles, wireless power transmission, magnetic coupling resonance, system efficiency.

1. Introduction

With the development of major global markets and the rise of emerging economies, electric vehicles have rapidly become popular due to their economic and environmental factors. With the expansion of the electric vehicle market, more and more electric vehicles are facing huge challenges in how to charge safely, efficiently, and conveniently. At present, mainstream charging technology for electric vehicles is mostly wired charging stations. Compared with traditional wired charging technology, the layout of charging stations, the impact of charging on conventional car parking, and the impact of material wear on cost and safety are all affected by the convenience of users due to charging cables, charging interfaces, and other modules. The emerging charging technology utilizes electromagnetic induction principle to enable electric vehicles to charge wirelessly across the air. The use of wireless charging technology can greatly improve the convenience of charging electric vehicles and reduce the loss of materials such as external charging cables. However, wireless charging technology still faces many challenges, such as the need to improve charging efficiency, optimize the structure of related charging equipment, and ensure the safety of circuit systems. The technology for the electric vehicles with wireless charging still needs to be continuously improved and enhanced before it can be widely promoted. This article will focus on modeling and simulating with wireless charging efficiency of the electric vehicles, and further analyze the optimization direction for efficiency improvement [1].

2. Design Principles

The magnetically-coupled resonant wireless power transfer is to generate an alternating magnetic field through the coil on the power supply side, and then couple it with the coil on the load side to transfer the electrical energy from the power supply side to the load. Compared to magnetic coupling induction and radiation based the transmission of wireless energy, it utilizes the principle of resonance to maintain relatively higher efficiency and power over a longer transmission distance, and is less

susceptible to external magnetic field interference. It is extensive use in the field of the technology with wireless charging for different type of electric vehicles [2].

2.1. Charging Process

The wireless charging module of electric vehicles is usually divided into the following parts: the circuit power input terminal and the induction coil primary side are located in the fixed wireless charging device, and the induction coil secondary side and the battery are located in the wireless charging module inside the electric vehicle [3]. As shown in fig 1, the electrical energy in the circuit is received from the power grid through the power input terminal, rectified and inverted, forming a high-frequency AC current that enters the induction coil primary side of the circuit to charge the the electric vehicle's inside battery in the end [4].

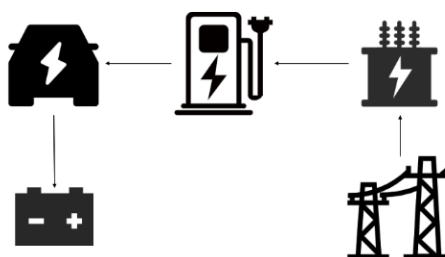


Fig. 1 Electric Vehicle Charging Process Diagram

The circuit amplifies power and matches the impedance circuit, ensuring that the electromagnetic frequency and natural frequency between coil of receiving and transmitting in the system are aligned. This allows electrical energy to be transferred between the side with transmitting and receiving coil, completing charging electric vehicles with the wireless charging.

2.2. Charging Principle

The primary components of a magnetic coupling resonant wireless charging system include a high-frequency power supply, a load driving circuit, as well as transmitting and receiving antennas formed by induction coils and resonant coils and an impedance matching network [2][5]. The main principle of magnetic coupling resonant wireless charging system is to output current to the transmitting antenna, and the induction coil in the transmitting antenna and the resonant coil in the receiving antenna produce coupling resonance, thereby transmitting electrical energy, process as shown in fig 2. Among them, when the system resonates, it can generate larger currents at lower voltages and generate stronger electromagnetic fields [2].

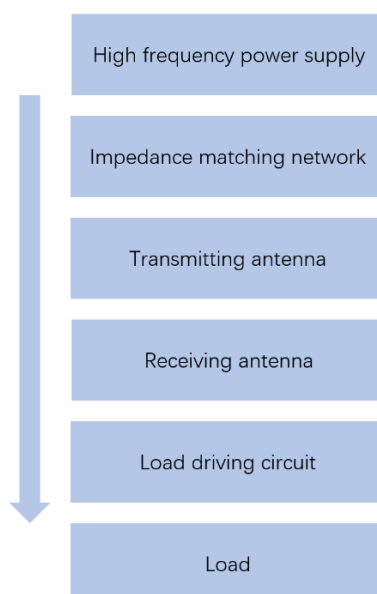


Fig. 2 WPT Basic Structure Diagram

3. Multisim Simulation

3.1. Basic Principles

When the magnetic coupling resonant wireless power transmission system resonates, the electric field energy in the circuit of the system and magnetic field energy in the circuit of the system are equal, and under ideal conditions, the electric field energy and the magnetic field energy can be exchanged with each other. The reactance of the capacitor and the reactance of the inductor cancel each other out, and the system circuit exhibits pure resistance characteristics. At this point, the system circuit is at its maximum output power [6]. The system circuit has selectivity towards resonance frequency, where the higher the quality factor, the sharper the resonance curve of the system, and the faster the current drops at a certain frequency offset, resulting in better selectivity of the circuit. To enhance the transmission efficiency of electrical energy within the system circuit, the system needs to use resonators with higher quality factors. However, the quality factor of the two coil magnetic coupling resonant wireless power transmission system seems fig 3 is relatively low, resulting in lower transmission efficiency [7].

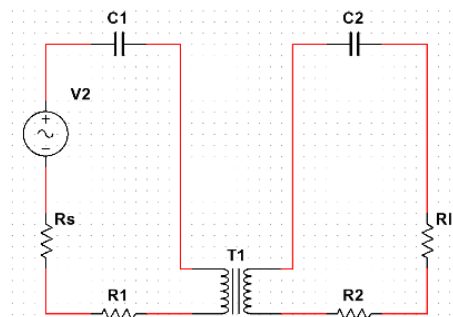


Fig. 3 Basic principle equivalent circuit diagram of two coils

Among them, V2 represents the AC signal source, RL denotes the receiving load, R1 signifies the equivalent resistance of the transmitting coil, C1 and C2 are the compensation capacitors for the transmitting and receiving coils, respectively, and R2 stands for the equivalent resistance of the receiving coil.

In a magnetic coupling resonant wireless power transmission system with a four coils structure which can be seen in fig 4, by changing the compensation capacitors on the four coils, the overall system can reach a resonant state. When energy is transferred from the transmitting end to the receiving end, the efficiency can be maximized, to enhance the improve the overall power transmission efficiency performance of the system. Connect four compensating capacitors in series with four inductive coils to achieve resonance in the system [6] [8].

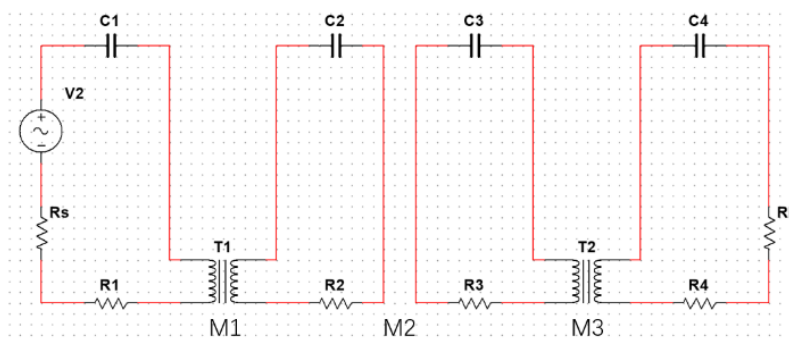


Fig. 4 Basic principle equivalent circuit diagram of four coils

Among them, M1 represents the coupling coefficient between the transmitting coil and resonant coil 1, M2 denotes the coupling coefficient between resonant coil 1 and resonant coil 2, while M3 signifies the coupling coefficient between the receiving coil and resonant coil 2. C1 and C4 serve as compensation capacitors for the inductance of the transmitting ends and the receiving ends, respectively. Additionally, C2 and C3 correspond to the parasitic capacitances of resonant coil 1 and

resonant coil 2, respectively. Furthermore, R_1 , R_2 , R_3 , and R_4 correspond to the parasitic resistances of the transmitting coil, resonant coil 1, resonant coil 2, and receiving coil, respectively. R_s stands for the internal resistance of the power supply, while R_L represents the load.

The working principle of the four coils structure magnetic coupling resonant wireless energy transmission system is to generate high-frequency AC power by inverting the DC power supply through high-frequency conversion. Under the influence of a high-frequency AC power source, the transmitting coil produces a high-frequency alternating electromagnetic field. This field causes the relay coil 1 to resonate, and the transmitting coil transfers energy to the relay coil 1; Relay coil 1 and relay coil 2, which have the same resonant frequency, resonate under the action of a high-frequency electromagnetic field, thereby achieving energy transfer from relay coil 1 to relay coil 2; Relay coil 2 and receiving coil transfer energy from relay coil 2 to receiving coil under the action of electromagnetic field, ultimately charging the load R_L [6].

3.2. Experimental Results

Through Multisim simulation experiments, according to fig 5, under the same conditions, as the total load resistance in the system circuit continues to increase, the output power gradually increases, and the transmission efficiency gradually increases. After reaching the maximum value, as the load resistance in the system circuit continues to increase, the transmission efficiency gradually decreases, and output power gradually decreases. The load resistance in the circuit is different when the transmission efficiency and output power are at their maximum values.

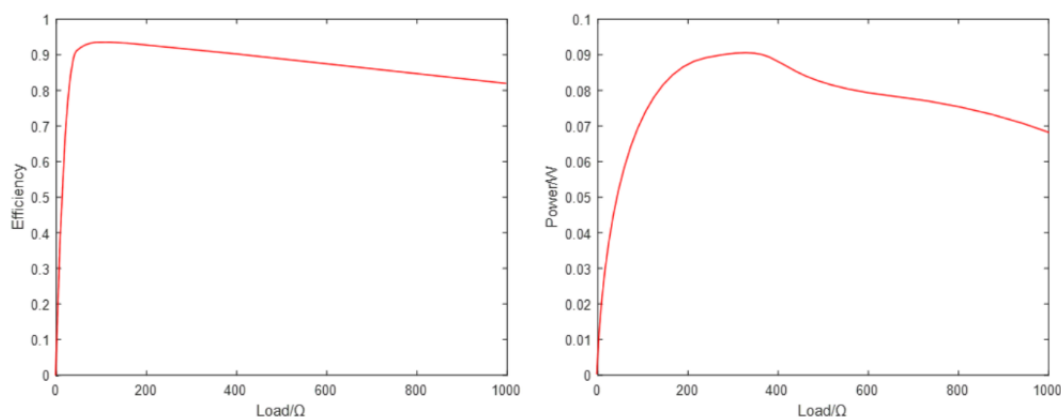


Fig. 5 Load

According to fig 6, under the same conditions, as the total load resistance in the system circuit increases, the output power gradually increases. After reaching the maximum value, as the total load resistance in the system circuit increases, the output power gradually decreases and then tends to flatten out. As the load resistance in the system circuit continues to increase, the transmission efficiency of the system gradually improves and tends to flatten out.

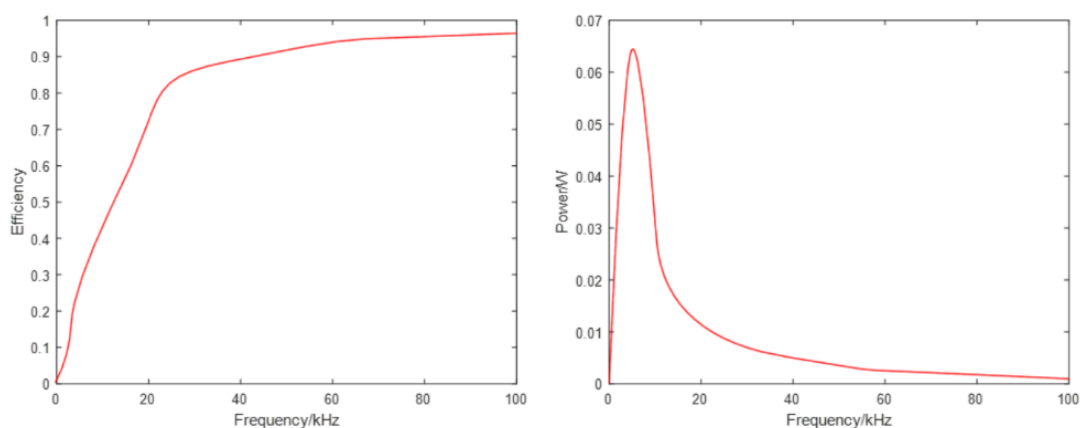


Fig. 6 Frequency

4. Analysis of Optimization Direction for Efficiency Improvement

To enhance the efficiency of electric vehicles wireless charging, system of the wireless charging should employ the system with a higher quality factor. At the same time, the load and frequency of the system circuit should be adjusted appropriately based on the specific values of the coupling coefficient between the coils, the compensation capacitance of the transmitting and receiving inductance, the parasitic capacitance of the resonant coil, the parasitic resistance of each coil, and the internal resistance of the power supply. so that its output power and its transmission efficiency are at a relatively high level.

5. Conclusion

In summary, this article analyzes the fundamental principles of magnetic coupling resonant wireless power transmission. Through simulation and theoretical calculations, the factors that improve wireless charging efficiency are analyzed. By adjusting the load and frequency in the system circuit, the transmission efficiency of the system and the output power and are balanced, thereby improving wireless charging efficiency. In the future, other methods can be used to verify ways to improve wireless charging efficiency, such as changing the number, structure, and material of system coils, or designing new circuit structures to enhance wireless charging efficiency and make related research more comprehensive. Correspondingly, the stability, economy, and the safety of the technology of electric vehicles with wireless charging still need to be tested and improved in future practical applications.

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