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Wireless Charging Technology Improvement for New Energy Vehicles

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ABSTRACT

In the operation of new energy vehicles, the energy supply method is directly related to the range and stability of the vehicle, and wireless charging technology is becoming a hot spot in the industry because of its efficient and convenient characteristics. This paper will discuss the core technology of wireless charging in new energy vehicles, covering the related equipment construction, compensation network design, and the design of key components of wireless charging technology improvement in new energy vehicles. The article will analyse the detailed results of the actual operation of the system, aiming to provide theoretical support and practical guidance for the application of wireless charging technology in new energy vehicles, and at the same time promote the further development of the new energy vehicle industry.

KEYWORDS

New Energy; Automobile; Wireless Charging.

1. INTRODUCTION

Over the past few decades, the tight supply of oil and increasing environmental pollution have made new energy vehicles a key area of global research and development. New energy vehicles aim to replace traditional internal combustion engine vehicles, thereby both improving environmental quality and reducing dependence on oil. In this context electric vehicles, with their advantages of zero emissions and high energy utilisation, are seen as the most promising new vehicle type to replace traditional fuel vehicles. However, electric vehicles also face problems such as inconvenient charging, short range and limited battery life [1]. A possible solution to these problems lies in wireless charging technology. Wireless charging technology greatly improves the convenience of charging by eliminating cable connections and making charging possible anytime, anywhere. The technology has been widely used in electronic devices such as mobile phones and computers. However, applying it to new energy vehicles faces major challenges because the size of automotive power batteries and charging standards are much larger than those of electronic products. This paper focuses on an in-depth study of wireless charging applications in new energy vehicles, firstly, discussing the core technology of wireless charging, which mainly includes the magnetic coupling device, the magnetic coupling structure of the wireless energy meter, and the wireless energy quality compensation network, etc. [2]; secondly, it discusses the improvement of wireless charging technology, such as the design of the inverter power supply system, the selection of the power switching device, and the design of the key components such as the control and power supply circuits. Finally, the results are analysed according to the actual operation of the system. These research results will provide theoretical support and technical guidance for the further development of wireless charging technology in the field of new energy vehicles.

2. CORE TECHNOLOGY OF WIRELESS CHARGING IN NEW ENERGY VEHICLES

2.1. Magnetic Coupling Device

Wireless charging utilises a magnetic coupling structure to achieve contactless electrical energy transfer, which is widely used in wireless power transmission systems. The main components include a transmitting part (ground side) and a receiving part (vehicle side). The transmitting part is equipped with a high-frequency coil L1, which converts electrical energy into high-frequency AC energy through a high-frequency power supply (e.g., an inverter) and generates a strong resonant magnetic field [3]. A matching resonant coil L2 is built-in at the receiver end, enabling the docked vehicle to absorb electrical energy from the magnetic field generated at the transmitter end. The energy transfer between the two coils as shown in Figure 1 is achieved through the mutual inductance coefficient, which reflects the degree of coupling. The transmission efficiency is maximum when the mutual inductance coefficients are optimally matched [4]. Magnetic coupling wireless energy transmission has the advantages of high efficiency and contactless, which makes the charging of new energy vehicles more convenient, efficient and safe. The research results can provide support for the development and promotion of new energy vehicle charging technology. as shown in Figure. 1.

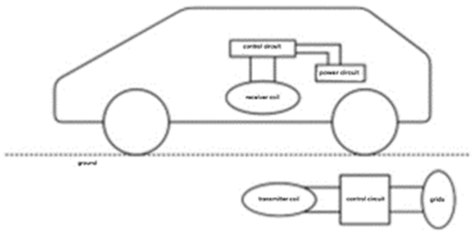

Figure 1. Operational schematic diagram of wireless power transmission (WPT) system for new energy vehicles

2.2. Magnetic Coupling Configuration of the Wireless Energy Meter

The system is implemented using two resonant coils (denoted by L1 and L2 respectively). When the circuit is excited, a high frequency electromagnetic field is created in the circuit. This varying magnetic field will create an electric potential across the receiver's L2 coil, which will generate a current. In this way, the transfer of electrical energy between the receiver and transmitter can be achieved by electromagnetic induction [5]. Using the magnetic energy transfer mode, the operating distance can be calculated according to a certain formula. As shown in equation (1)

$$d = \frac{\lambda}{2\pi} = \frac{c}{2\pi f} \tag{1}$$

In this equation, the symbol λ in metres denotes the wavelength; c denotes the speed of light in metres per second; and ʃ is the coil resonance frequency in hertz. According to the standards of the Ministry of Industry and Information Technology, a wireless charging system that satisfies the MF-WPT2 technology and 85 kHz operating frequency should be implemented. A system capable of transmitting power within 0.64 metres is proposed to work effectively within 0.56 metres, which is suitable for charging needs within this range, aiming to provide fast charging services while reducing electromagnetic radiation and power loss [6].

2.3. Wireless Energy Quality Compensation Networks

2.3.1. Single-coupling Correction Network

The single-coupling compensation network is a typical network structure, which can effectively solve the problem of energy loss and efficiency reduction due to the mismatch of line parameters. The compensation network can be realised by the following types:

(1) Series coupling (SS): In this type of compensation network, the transmitting and receiving coils L1 and L2 are connected in series with capacitors C1 and C2 respectively. When the transmitting end is energized, L1 and C1 generate resonance and strong magnetic fields at specific frequencies [7]. At the receiving end, L2 and C2 are connected in series to form a matched resonance loop, ensuring that the receiving coil L2 absorbs energy at the corresponding frequency.

(2) Parallel coupling (PS): This is a novel opto-electronic coupling compensation network that we propose in which the transmitting and receiving coils are either coupled in parallel or in series to achieve efficient signal transmission, reduce the losses, extend the transmission distance, and improve the energy transfer efficiency and stability of the system [8].

(3) Series-Parallel Coupling (SP): In this structure, both the coil at the transmitting end and the coil at the receiving end are coupled either in series or in parallel by means of capacitors.

(4) Parallel coupling (PP): In this type of network, both the transmitting and receiving coils are coupled in parallel to increase the transmitted power and reduce the transmission distance. By adjusting the parameters such as capacitors and coils, efficient and stable conversion can be achieved [9]. All these coupling compensation network types provide an important support for wireless charging technology, making energy transmission more efficient and stable.

2.3.2. Multi-functional Compensation Network

The composite compensation network is a common network architecture that combines the advantages of multiple coupling modes, which has a positive impact on enhancing the transmission efficiency and stability of wireless charging systems. In this paper, the composition of a new type of power system is elaborated in detail, especially taking the double-layer LCC framework as an example for in-depth analysis as shown in Figure. 2.

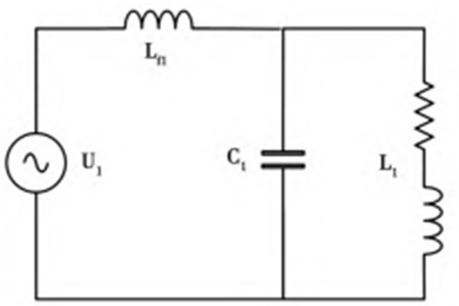

Figure 2. Schematic diagram of dual LCC composite compensation structure

3. WIRELESS CHARGING TECHNOLOGY IMPROVEMENT IN NEW ENERGY VEHICLES KEY COMPONENT DESIGN

3.1. Design of Inverter Power Supply System

In the wireless charging system of the new energy vehicle, the task of the inverter power supply is mainly to transform the DC power into high-frequency AC power, and then realise the wireless energy transmission. In the thesis, appropriate converters and circuits are selected to achieve the transformation of 220 Volt, 50 Hz power into 400 Volt, 85 Hz high-frequency AC power [10].

3.1.1. Inverter Input Power

The function of the main circuit is to convert DC power into high frequency AC power for wireless power supply. The main circuit consists of components such as inverter, power supply and transformer. In this paper, a full bridge inverter is used to complete the wireless charging implementation [11]. Meanwhile, the output is 400 volts of high frequency alternating current as shown in equation (2).

$$P_{\text{in}} = \frac{P_{\text{oat}}}{\eta} \tag{2}$$

Pin represents the input power in kilowatts; Pout represents the output power in kilowatts; and η represents the conversion efficiency, expressed as a percentage. In this example, Pout is equal to 6.6 kW and η is equal to 90 per cent, or 0.90, and by bringing these values into Equation 2, it can be concluded that Pin is equal to 7.33 kW.

3.1.2. Selection of Power Switching Components

Inside the inverter, the power switching components play a dominant role, which are responsible for switching and adjusting the power supply, as well as converting the DC power to AC power. Commonly used inverter switches include MOSFETs (Metal-Oxide-Semiconductor Field Effect Transistors), IGBTs (Insulated Gate Bipolar Transistors), SiC MOSFETs (Silicon Carbide Field Effect Transistors) and GaN (Gallium Nitride). In this project, it is expected to use MOSFETs or IGBTs to provide a stable power supply for new energy vehicles, and MOSFETs are selected for the study considering the operating cost [12].MOSFETs are a commonly used switching device for inverter power supplies, and their main features are fast switching speed, stable operation, high efficiency and low cost. Despite the high cost of IGBTs, it has a correspondingly high demand for high thermal performance in high frequency and high power environments.

3.2. Control Circuit Design

In the wireless charging system of new energy vehicles, the control circuit is mainly responsible for accurately controlling the inverter and power switch to achieve efficient and stable wireless energy transmission. In order to improve the power factor of the inverter power supply and reduce harmonic pollution, a PFC circuit is usually used to optimise the inverter power supply. In this paper, the EG8010 chip is used for the power correction of the power inverter circuit as shown in Figure. 3. The EG8010 combines PWM with an analogue preamplifier stage to achieve a highly efficient and stable output while providing precise control of MOSFETs, IGBTs and other components.

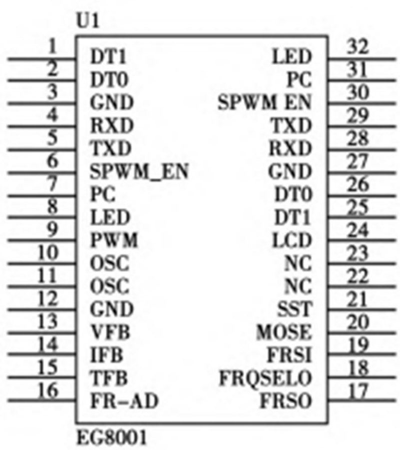

Figure 3. EG8010 Chip Pin Architecture Pattern Diagram

3.3. Power Supply Circuit Design

This power supply circuit ensures the normal operation of the inverter and control circuit to provide a stable DC power supply for the overall equipment. Usually, the function of the power control circuit can be adopted directly. On this basis, a step-down regulator based on synchronous rectification is proposed, which achieves a smooth step-down of the input voltage. By applying the synchronous rectification technique, the power consumption is reduced and the system efficiency is improved so that the whole circuit has a 3A load capacity. The power circuit design is shown in Figure 4.

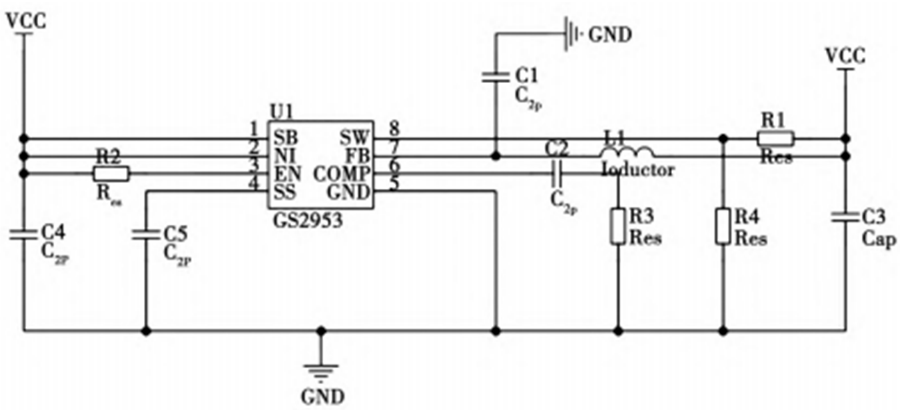

Figure 4. Power circuit design diagram

4. ACTUAL OPERATION OF THE SYSTEM AND ANALYSIS OF THE RESULTS

The transmission efficiency of the proposed scheme is verified by conducting a 25V simulation test and a 400V simulation test. This scheme not only improves the transmission efficiency and reduces the energy consumption, but also enhances the charging efficiency and performance of the system.

$$\text{transmission} = \frac{\text{Receiver out put}}{\text{Transmitter output voltage}} \tag{3}$$

Table 1 shows that the transmission efficiency varies between 83.5 per cent and 84.1 per cent, which reflects the good performance of the system in terms of transmission efficiency. Table 1 shows that the transmission efficiency is relatively stable at different power levels. However, it may be affected by factors such as system structure and environment.

Table 1. Experimental results of transmission efficiency of new energy vehicle systems

Input voltage (V)	Output voltage**(V)**	**Transmission efficiency (%)**
100	83.5	83.5
150	126.2	84.1
200	168.7	84.4
250	209.5	83.8
300	251.0	83.7
350	292.6	83.6
400	335.4	83.9

5. CONCLUSION

In this paper, based on the in-depth understanding and research of wireless charging technology for new energy vehicles, a novel multiplexed hybrid compensation network mode is proposed.1) The Complex Compensation Network (CCN) combines the advantages of multiple coupling modes, and as a commonly used compensation network, it can realise efficient and stable energy transmission. Including SS, PS, SP and PP compensation modes, it plays an important role in improving the performance of the wireless charging system.2) Observation of experimental data and simulation calculations, the simulation test of 400 V through the actual test of 25 V shows that the conversion efficiency varies from 83.5% to 84.1%, which proves that the system has a very good performance of voltage transmission and a high conversion efficiency.3) Novel Energy transmission efficiency of Wireless Charge System (WCS). The experimental results reveal that the voltage conversion efficiency of the new energy wireless charging system can reach 83.9%, which shows excellent voltage conversion performance and can achieve efficient power transmission, laying a solid foundation for the popularisation and application of wireless charging technology.

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