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Research and overview of wireless charging technology for electric vehicle

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Abstract. In recent years, in order to effectively reduce energy consumption, the development of electric vehicles has gained the attention of many countries. The wireless charging system of electric vehicles does not have exposed wires and connectors,meanwhile it can realize the indirect electrical power transmission between the grid and electric vehicles, it has gradually become an important direction of current research. This paper introduces the background of wireless charging technology in various countries, lists out the two types of wireless power transfer technology, and explains the current technology based on the principle of wireless charging for electric vehicles. Today's wireless charging technology is divided into near-field radiation power transfer and far-field radiation power transfer. The charging mode can be divided into dynamic charging and static charging. This paper illustrates the topology of compensation network used to adjust the frequency of the electromagnetic coupled resonant wireless charging system, and introduces the process of transmitting the grid voltage to the battery of electric vehicle through the inverter circuit and rectifying circuit. Finally, it analyzes the defects of current wireless charging technology and puts forward personal views for its solutions. Through the research, hope to provide some reference for the development of wireless charging technology for electric vehicles.

Keywords: Electric Vehicle, Wireless Power Transfer, Topology, Compensation Network.

1. Introduction

In recent years, with the increasingly serious environmental problems such as energy crisis and pollution emissions, the relevant research on replacing traditional fuel vehicles with clean energy has become a hot spot. At present, the mainstream charging method of electric vehicles is still wired charging, which charging by connecting the electric vehicle power connector with the public charging pile through a cable. In contrast, wireless charging of electric vehicle can avoid the shortcomings of low space utilization caused by too many charging piles, electric spark hazards to the personal safety of operators in wet weather, and the complex maintenance. The efficiency of electric vehicle wireless charging is the most important research issue [1].

2. Research background and status of wireless charging technology for electric vehicle at home and abroad

Wireless power transfer is the process of non-contact transfer of energy from the transmitting end to the receiving end by using space as a medium. Nikola Tesla proposed the concept and principle of WPT as

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early as the end of the 19th century, but due to the conditions at that time, the idea was not realized. Until 2007, the Massachusetts Institute of Technology proposed the electromagnetic coupled resonant wireless power transfer theory, and then established WiTricity company, which can implement wireless energy transfer with a power of 3.3kW. The electromagnetic coupled resonant wireless power transfer theory, is regarded as the most promising technology of wireless power transfer.

Foreign research institutions for static wireless charging mainly include the Massachusetts Institute of Technology in the United States, the University of Auckland in New Zealand, Waseda University in Japan, and automobile manufacturers such as Mercedes-Benz and BMW. Domestic static wireless charging research institutions are mainly Chongqing University, Harbin Institute of Technology, etc. ZTE, a major Chinese telecommunications equipment manufacturer, created a commercial high-power wireless charging bus line in Xiangyang, Hubei province, in 2014.

Foreign research institutions for dynamic wireless charging include the University of Tokyo, Oak Ridge National Laboratory in the United States, and the Korean Advanced Institute of Science and Technology. Their main research focus on the charging track and coil design, electromagnetic coupling device design and so on. Domestic research institutions for dynamic wireless charging are mainly Harbin Institute of Technology, Tiangong University , Chongqing University, Southeast University, etc. The main purpose of most studies is to design coils with stronger misalignment tolerance to ensure efficient energy transmission [2].

3. Introduction to wireless charging technology

3.1. Wireless charging technology classification

Different manufacturers for electric vehicle charging technology requirements are not the same, but can be roughly divided into near-field radiation and far-field radiation according to the radiation wavelength of the electromagnetic wave in the WPT system. Near-field radiation power transfer are mostly electromagnetic induction wireless power transfer and electromagnetic coupled resonant wireless power transfer. Far-field radiation power transfer is usually microwave.

Electromagnetic induction wireless power transfer is mainly used in short distance transmission, it is easy to control in the case of low power. However, because a part of the magnetic motive force in the transmission process cannot be transferred to the receiving end and is scattered in the air magnetic circuit, the efficiency is relatively low. And the interference of metal objects around the equipment also needs to be considered. Based on the improvement of electromagnetic induction wireless power transfer, the electromagnetic coupled resonant wireless power transfer makes the primary coil and secondary coil work in resonant state to strengthen the magnetic field around the device through a compensation network composed of some reactive power compensation components. It can provide high power transmission and has been widely commercialized compared to other methods. However, the technology has high energy consumption in high-power applications and also needs to consider the interference of metal objects around the equipment, so it still has room for improvement.

The microwave wavelength is short, so this charging method is used for long-distance transmission, but its output power is relatively low and there is a risk of microwave radiation [3].

3.2. Wireless charging mode

Regarding the wireless charging mode of electric vehicles, it can be roughly divided into static charging and dynamic charging.

Static charging refers to the charging of electric vehicles after stopping in a specific charging area. In this case, the wireless charging transmitter coil is connected to the power grid and laid underground, using the rectifying circuit and the inverter circuit turn it into high-frequency alternating current, through the coupling device the high-frequency alternating current transfers to the receiving coil installed at the bottom of the electric vehicle, and then using the rectifying circuit to convert it into direct current to charge the battery. Static wireless charging is mainly suitable for residential areas, shopping centers and other places. This charging method requires a series of charging facilities, so the cost is high.

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Dynamic wireless charging is the wireless charging of electric vehicles on the move, this model has been tested in several countries. The basic principle is to use the power supply track which laid in the ground ,making the high-frequency alternating magnetic field transmit electric energy to the receiving end of the electric vehicle in a specific area. According to the different structure of the power supply track installed in the ground, it can be divided into two modes: centralized track and segmented track. For the centralized track, the electric vehicle can only be coupled in a specific part of the area, and the transmission efficiency is low. For the segmented track, when the electric vehicle is driven between the adjacent two tracks, the magnetic field intensity received by it will be reduced, making the charging process unstable. And in the process of dynamic wireless charging, due to the change of the relative position of the transmitting coil and the receiving coil,making its power transfer change non-linearly. How to improve its stability and transfer efficiency through technical means has been the focus of current research [4].

4. Principle of wireless charging technology

4.1. Compensation network topology

Although the charging requirements for different brands of electric vehicle are different, the design of the coupling device is the most important. Electromagnetic coupled resonant wireless charging uses a compensation network to adjust the operating frequency of the system and make it work under resonant conditions.

The compensation network is usually divided into four basic types of topologies depending on its inductance and capacitance structure. They are series-series topology (SS), series-parallel topology (SP), parallel- parallel topology (PP), and parallel -series topology(PS) [5], as shown in the following graphic.

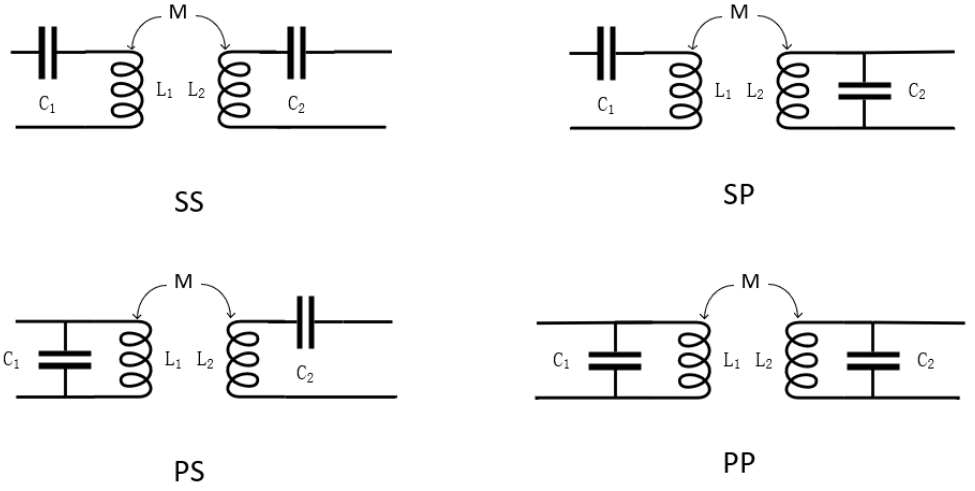

Figure1. The topology of compensation network.

Among them, the series-series topology is suitable for constant current charging, the transmission is the best in four kinds of resonant systems, and it is easy to realize and widely used. In order to deal with the complex situation such as multi-load, some scholars also proposed the compound topology. With the development of technology, it is believed that more topologies will be invented in the future.

4.2. Power electronic components

In the electromagnetic coupled resonant wireless power transfer system, power electronic components are very important. The primary circuit converts the AC voltage at grid frequency into DC voltage through the rectifying circuit, then the inverter circuit converts the output DC voltage into AC voltage, additionally the coupling coil transmits it to the secondary circuit, and finally converts the AC voltage into DC voltage to charge the battery. Taking primary rectifying circuit as an example, in order to

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complete the rectification function, this paper uses the basic Three-phase Full-bridge rectification circuit to illustrate. The circuit is composed of six diodes. When the power is switched on, due to the voltage difference of the three-phase voltage, there is a voltage difference between the anode and cathode of the diode. The upper bridge arm and the lower bridge arm each have a diode to conform to their unidirectional conductivity. The diode is then switched on so that the current flows through the load, and the voltage is generated at both ends of the load. Its structure is shown in the graphic below.

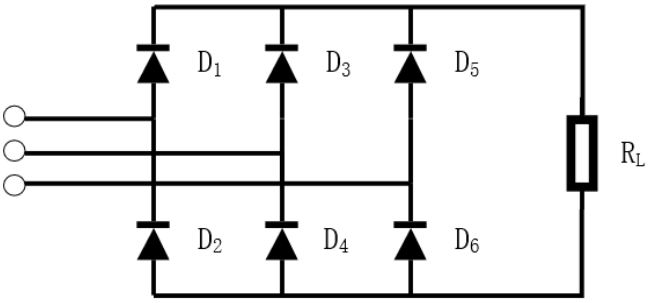

Figure 2. Three-phase Full-bridge rectification circuit.

5. Summary and prospect of wireless charging technology

At present, there are many electric vehicle brands, many companies compete in a new field, so the direction of charging technology research at home and abroad is also different. Although they will show their own advantages, unified standards are particularly important. We need to cooperate with international electric vehicle brands to standardize the charging plug, charging power, batteries and other related indicators in order to make the wireless charging technology more popular and practical.

Because striving to develop the use of electric vehicles is to save energy and environmental protection, no matter what brand of electric vehicles, its transfer efficiency is the top priority of research. In the electromagnetic coupling device, the transmitting end and the receiving end of the electromagnetic conversion process will lose a lot of energy, so the improving coil design, using more energy-saving and environmentally friendly new materials, and the electric vehicle receiving device and the transmitting device aligning can be a breakthrough to solve the energy transfer efficiency.

At the same time, the safety issues involved in wireless charging technology for electric vehicles are also one of the focuses of public attention. Since wireless charging is based on electromagnetic conversion, the research on how to reduce the interference of the surrounding metals to transfer and whether the radiation intensity causes harm to the human body still needs further research. Only with the results of scientific and effective research can we properly deal with the public's concerns about radiation safety.

6. Conclusion

This paper studies and analyzes the wireless charging technology of electric vehicles, firstly summarizes its development background and research status, then focuses on its working principle, explains the wireless charging technology of electromagnetic induction wireless power transfer and electromagnetic coupled resonant wireless power transfer, and makes a brief analysis of dynamic charging and static charging. Taking the magnetic coupling device in the electromagnetic coupled resonant wireless charging as the starting point, common topology is illustrated by the graphic, and the circuit functions and principles of the primary circuit are explained. At present, wireless charging technology is not perfect and still has a lot of room for development, this paper points out some safety problems and the technology still needs to improve the transmission efficiency. Finally points out that only standardized charging can make this technology more practical and market-oriented. But in any case, a revolutionary charging technology has arrived.

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