Feasibility Study on Application of Highway Wireless Charging Technology

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Abstract. Wireless charging technology as a new technology on the world stage, in all walks of life has played an important role, and on the road can also play a role. Based on the analysis of the principle of wireless charging on the road, this paper explores the supply mode of electric energy supply for automobiles and other electric vehicles (ground instantaneous power supply system of electric vehicles and piezoelectric technology). This paper summarizes in detail the method of uninterrupted charging of electric vehicles, that is, electric vehicles use Underbody coils for wireless charging on the road, and analyzes whether the electromagnetic field generated by the high-voltage coils can be charged at a distance, and then summarizes the challenges encountered in the future (charging efficiency, charging distance, safety and cost), and analyzes the prospects brought by future technological progress. The wide use of highway wireless charging technology in the future is reasonably demonstrated.

Keywords: Highway, wireless charging, coil.

1. Introduction

Wireless charging technology has three advantages. The first is convenience, the user only needs to put the device on the charging cable to achieve charging, and without plugging the charging cable, it is more convenient to use [1]. The second is durability because wireless charging does not require physical contact, reducing the wear and tear of the jack, thus extending the device's service life. The most important thing is safety, and wireless charging avoids the risks that open-air power can bring, especially in humid environments that may occur such as short circuits. However, wireless charging also has some disadvantages, such as slower charging speed. In addition, the alignment between the charger and the receiver is very important, and a slight deviation may lead to charging failure. In recent years, wireless charging technology has been rapidly developed and widely used in many fields such as smartphones, automobiles, home offices, public places, and medical fields. Smartphones and mobile devices have become the mainstream charging objects of wireless charging, and in the automotive industry, wireless charging has realized the demand for long-term parking charging of electric vehicles. Wireless charging pads in home and office environments are convenient for users to charge various devices, and public places and commercial applications are also beginning to provide wireless charging devices [2] [3]. In addition, medical devices and wearable devices are also using wireless charging technology to achieve remote monitoring and charging. As the technology continues to improve, wireless charging technology will continue to evolve and meet users' needs for convenient, efficient and safe charging. Over the past five years, wireless charging car technology has made rapid progress. Wireless charging technology provides a more convenient and intelligent way to charge electric vehicles. Many car manufacturers and technology companies have invested a lot of research and development and innovation, driving the development of wireless charging vehicles. First, in the automotive market, more and more automakers are starting to launch wireless charging car models. The cars are equipped with wireless charging technology, enabling owners to easily park their cars in places equipped with wireless charging facilities to charge without the need

to use a charging plug. This greatly simplifies the charging process and improves user convenience and comfort. At the same time, the development of wireless charging technology has also brought about the improvement of charging efficiency and power. The new generation of wireless charging systems can fully charge electric vehicles in a shorter time, and the charging efficiency is improved compared to traditional charging methods. This makes wireless charging cars more convenient for daily use and reduces waiting time for users. In addition, the intelligence of wireless charging technology has also made certain progress. Through the use of intelligent software and sensors, the wireless charging system is able to identify and adapt to the charging needs of different vehicle types, providing the best charging results. These smart features can also optimize energy use and minimize energy waste.

This paper first analyzes the principle of wireless charging on the road. Then, this study explores the supply of electric energy for automobiles and other electrical supplies, and analyzes and summarizes the method of uninterrupted charging of electric vehicles and the electromagnetic field generated by high-voltage coils for long-distance endurance in detail. The purpose of this study is to provide technical guidance for the wide use of highway wireless charging technology in the future.

2. The Basic Principle

The principle of highway wireless charging is mainly divided into two categories, namely radiant type and non-radiant type. Due to the low efficiency, high cost and large transmission loss of radiant transmission, the non-radiant type is the most widely used in this scenario, as shown in Figure 1.

Figure 1. Highway wireless charging principle classification

The basic principle of electric field coupling is that when the system works, the DC power supply is converted into high-frequency alternating current through the inverter, and flows into the coupling mechanism through the primary resonant compensation network. Under the action of high-frequency and high-voltage alternating current, the coupling plate of the primary side of the coupling mechanism is equivalent to a group of flat plate capacitors, and an interactive electric field is formed between the two, thus generating "displacement current". The energy is transferred from the primary side plate of the coupling mechanism to the secondary side plate of the coupling mechanism, so as to achieve non-contact transmission of energy [4], see Figure 2.

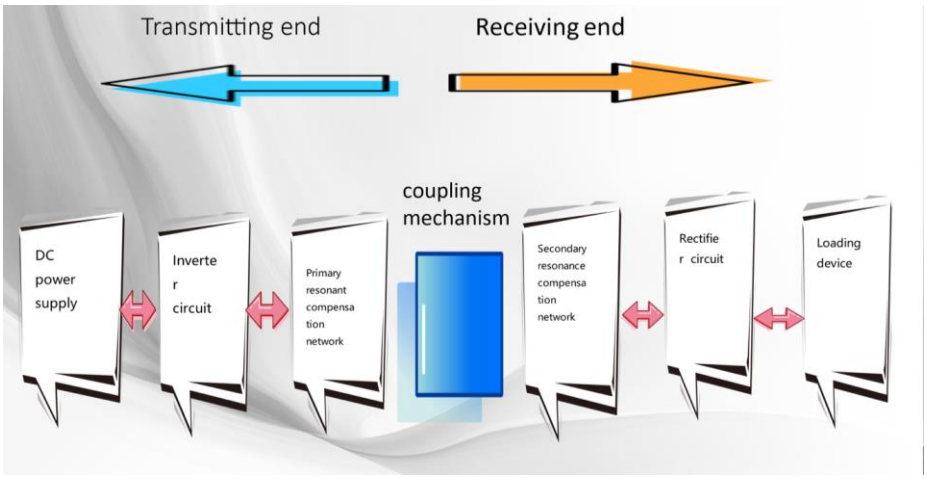

Figure 2. Basic principle of electric field coupling

The electromagnetic induction type is shown in the figure, and the rectifier and inverter circuits at the transmitting end are at the lower end of the ground. The power grid provides current to the

transmitting end, converts AC into DC through the rectifier circuit, and then converts it into high-frequency AC through the high-frequency inverter circuit to supply the transmitting coil and generate a changing magnetic field; The receiving coil generates an induced current, which is rectified and converted to charge the power battery, as shown in Figure 3.

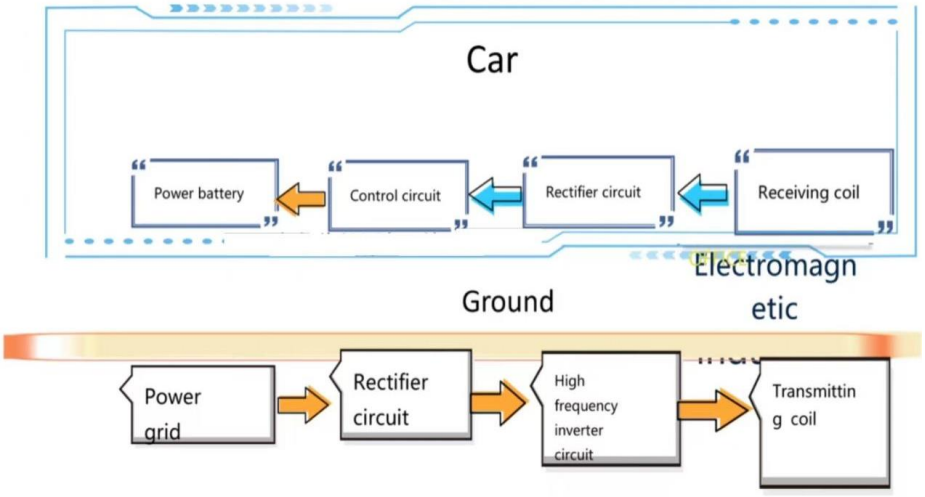

Figure 3. The basic principle of electromagnetic induction

The working principle of the magnetic-coupled resonant wireless charging system is shown in the figure. The alternating current of the power grid becomes a high-frequency AC square wave after passing through the rectifier circuit and high-frequency inverter circuit. Then, the resonant compensation circuit at the transmitting end and the receiving end makes the current of the transmitting coil and the receiving coil produce the same frequency, and resonance occurs to realize the transmission of electric energy between the transmitting and receiving coils. The electrical energy received by the receiving coil passes through the rectifier circuit in the car and charges the power battery [5], see Figure 4.

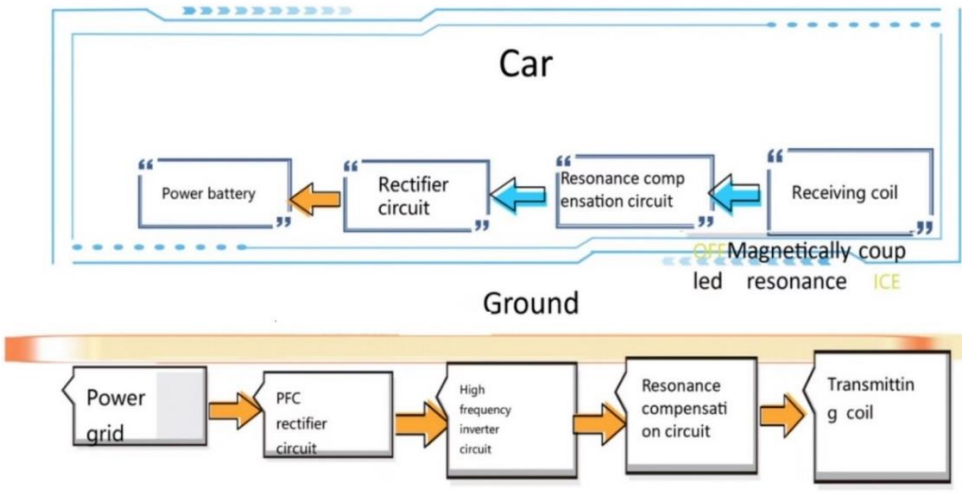

Figure 4. Basic principle of magnetic coupling resonant type

3. Analysis of Power Supply Methods for Electric Vehicles and Other Electrical Equipment

3.1. Ground Instant Power Supply System for Electrically Driven Vehicles

The ground instant power supply system for electrically driven vehicles is an innovative power supply mode that cleverly borrows from the power supply method of high-speed rail. This system integrates the power supply lines into the road surface, achieving seamless integration of power

supply and road infrastructure. Vehicles are equipped with pantograph devices, allowing them to stably draw power from ground cables while driving, thus achieving simultaneous driving and charging.

The ground instant power supply system has several significant advantages. Firstly, it ensures continuous and stable power supply during vehicle operation, avoiding interruptions due to insufficient power. Secondly, this system is widely applicable to various road environments, whether highways or urban streets, allowing for flexible deployment and greatly enhancing its practicality. Additionally, by reducing reliance on onboard batteries, vehicles can be lighter, and operating costs are correspondingly reduced. At the same time, the same power supply line can support multiple vehicles using it in parallel without interference, improving road usage efficiency. However, this system also has certain limitations, mainly in the need to lay dedicated power supply lines and adapt vehicles, which increases implementation costs and complexity to some extent.

3.2. Piezoelectric Technology

Piezoelectric technology is an innovative energy conversion technology that efficiently converts mechanical energy into electrical energy through the piezoelectric effect by utilizing the dynamic pressure exerted on the road surface by vehicles. This technology achieves an organic combination of road infrastructure and energy production, providing a new solution for power supply during vehicle operation.

Piezoelectric technology has several significant advantages. Firstly, it maximizes the utilization of road infrastructure without additional energy consumption, thereby improving resource utilization efficiency. Secondly, this technology is emission-free throughout the process, environmentally friendly, and aligns with the concept of green sustainable development. However, piezoelectric technology also has certain limitations. The power generation efficiency is constrained by various factors, such as vehicle type, driving speed, and road surface material, affecting its effectiveness in practical applications. Additionally, although piezoelectric technology has broad application prospects, its technical maturity needs improvement, and it has not yet achieved large-scale commercial application.

4. Uninterruptible Power Supply Design for Electric Vehicles Driving on the Road

For how to continuously provide electric energy for Mercedes-Benz electric vehicles on long-distance highways, and maintain high efficiency and continuity, there are many limitations that are difficult to break through, because considering the functional power, it must involve the loss rate of energy, making it difficult to sustain, if considering sustainability, it must consider energy saving and then reduce its power. However, the spread and development of wireless electromagnetic conversion technology proposed in this paper can promote the breakthrough of this difficulty. Some scholars have proposed that in order to overcome the limitations of long-distance wired charging, other energy conversion schemes can be considered, such as absorbing solar energy and converting it into a steady stream of electricity, but only during the day. There are many other schemes, such as extender-range electric vehicles, hybrid electric vehicles, fuel cell electric vehicles, hydrogen engine vehicles, etc. Although the conversion of chemical energy into electrical energy has many advantages of high efficiency and environmental protection, the limitation lies in the principle of energy conservation. The method proposed in this paper comprehensively considers the durability and efficiency of electric vehicle functions, and in view of the relevant theories of magnetic resonance electric energy conversion and transmission, Research on integrated wireless dynamic electromagnetic conversion system in the electric vehicle stage Wireless dynamic electromagnetic conversion is to use the multi-turn correlation coil neatly arranged under the road to generate high-frequency magnetic field and then carry out related electromagnetic induction and energy conversion through the pickup coil at the bottom of the electric vehicle on the road, so as to complete wireless dynamic electromagnetic

conversion and power supply. In theory, the implementation of this scheme can perfectly break through the limitations of various electric vehicle battery power supply and remote transmission cables, which can make electric vehicles continue to be obtained on the road, and then make the electric vehicle continuous power supply and high frequency in the working state. The whole system simple model of the phased integrated wireless dynamic electromagnetic conversion system using the magnetic coupling resonance correlation theory is shown in the figure 5:

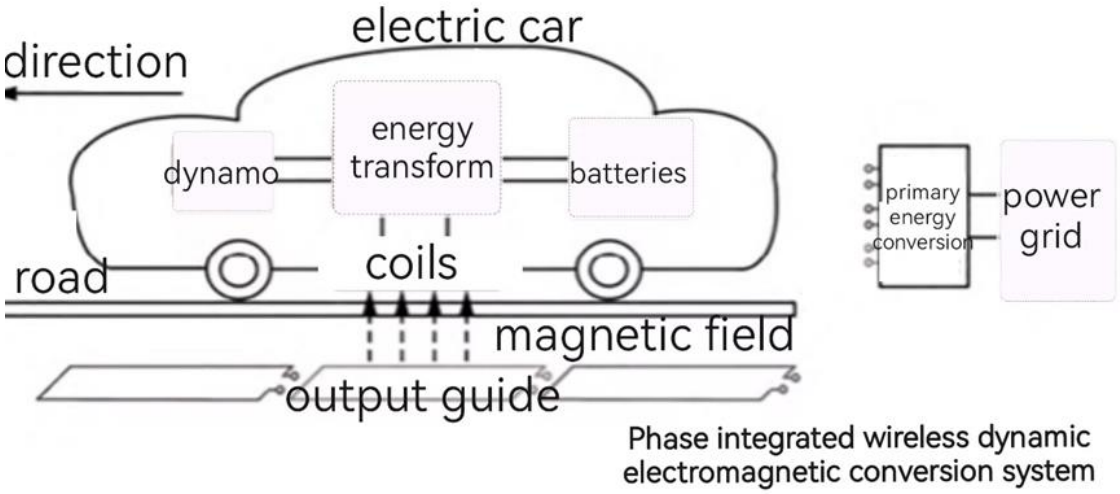

Figure 5. Wireless electromagnetic-conversion system [6]

5. Challenges and Prospects

5.1. Challenges

At present, there are still five technical challenges in the wireless charging technology of electric vehicles. The first is the charging efficiency. Due to the energy loss in the electromagnetic induction transmission process, the efficiency of wireless charging mentioned in this topic is usually lower than that of daily wired charging. At present, the efficiency of wireless charging is still in the preliminary stage of development, and the power output efficiency needs to be further improved, otherwise it is difficult to meet the needs of users. The second is the charging distance, because at present, the charging and transmission distance of wireless charging is very limited, and the maximum specifications are only tens of centimeters below. If you want to achieve the smooth charging of electric vehicles in the process of high-speed driving, the challenge of charging distance can not be ignored. Then there is the charging standard, and now there is no unified charging standard for wireless charging technology, and compatibility problems are likely to be widespread between different manufacturers and different products. In the future, it is also necessary to develop a unified wireless charging standard, so that the products of different manufacturers can be compatible with each other, and also make the use of similar or common standards between different principles of the same kind of products to avoid unnecessary side effects. The most important is its safety, wireless charging technology needs to avoid related hazards to the human body, such as electromagnetic radiation, etc., but also needs to prevent various safety hazards during the charging process, such as high temperature flammable and explosive substances. The last and most people are concerned that the cost of the current wireless charging technology may be much higher than wired charging, so if the wireless charging technology needs to be popularized, then reducing the cost is the only way to expand its market and meet the needs of most users.

5.2. Outlook

With the rapid development of science and technology, highway wireless charging technology, as an innovative technology in the future transportation field, is gradually moving from concept to reality, with unlimited potential, indicating the arrival of a more convenient, efficient and green travel era.

At present, the main challenges facing highway wireless charging technology include efficient energy conversion, long-distance stable transmission, road material compatibility and cost control. In the future, with the continuous progress of material science, electromagnetism and power electronics technology, these problems will be gradually solved. For example, more efficient energy collection and conversion devices are used to optimize electromagnetic fields and multi-turn coil distribution, reduce energy loss, and increase energy conversion efficiency. In order to promote the popularization of technology and cross-regional application, the standardization process of highway wireless charging technology will be accelerated internationally. This includes the development of unified charging standards, road construction specifications, vehicle receiving equipment interface standards, etc., to provide seamless charging services for different brands and different types of electric vehicles. The government and enterprises will increase investment and give priority to laying wireless charging facilities in key sections such as highways, urban main roads and transportation hubs. Initially, it may be carried out in the form of pilot projects to gradually verify the technical feasibility and economic benefits, and then expand the coverage to form a national and even global wireless charging network.

6. Conclusion

Highway wireless charging technology makes full use of the types and advantages and disadvantages of wireless charging technology, and makes specific use of its own characteristics to explore each link in detail. Relying on the support of the principle of wireless charging and previous research results, it can use the instantaneous power supply system of electric vehicles and piezoelectric technology. Convert magnetism into electricity by wireless charging under the car coil to efficiently supply electric energy for cars on the road, uninterrupted high-power power for electric vehicles, and the use of high-voltage coils to generate electromagnetic fields to make electric vehicles unlimited endurance. However, as far as this technology is concerned, it is not yet mature and still faces many challenges. Due to many problems such as immature technology, inappropriate product or high cost, this technology cannot be put into the market to meet the needs of people on a large scale. However, there are challenges, there must be opportunities, wireless charging in the future is likely to replace wired charging.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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