Wireless Transmission Important Technology and its Impact on the Grid

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Abstract: With the progress of science and technology, wireless transmission has entered people's field of vision as a new transmission method. This paper describes the background of wireless transmission technology, and then introduced in detail the short distance transmission of electromagnetic induction, the basic principle of magnetic resonance coupling transmission, and the long-distance transmission of microwave laser, and then discusses the development of wireless transmission technology in detail, and then introduced the important technology that need to be focused on nowadays. Finally, the impact of wireless transmission technology on the grid and its future development direction are illustrated from three perspectives including smart grid introduction, power transmission and distribution, and distributed power supply.

1. Introduction

With the development of social modernization and the deepening of electrification, the methods of transmitting electrical energy include traditional contact transmission and modern wireless transmission. The former has a relatively long development time and mature technology, but its disadvantages are difficult to solve. Electricity is transmitted through the contact of metal wires. First, sparks will be generated at the contacts due to friction, which will reduce the insulation and shorten the life\textsuperscript{[1-3]}. Finally, it will threaten the safety and stability of the power system. In addition, it is not applicable in some cases, such as working in mines and oil fields. Electric sparks may increase the possibility of explosion and pose a threat to personal safety.

In order to improve the convenience of people's lives, various portable electronic devices are widely popularized, followed by safety problems caused by frequent use of power plugs, waste of resources caused by different specifications and different types of charging cables. Considering a series of problems in "wired" transmission, a power supply mode without wires and contact points is urgently needed to solve. Wireless transmission emerged at the historic moment, and with the maturity of power electronics technology and the development of electromagnetic field theory, this transmission mode was changed from impossible to possible. The development of wireless transmission will diversify the power system in the transmission and distribution link. It uses inductive coupling, magnetic resonance coupling, microwave and other forms of energy transmission. It is a safe, reliable and convenient new transmission method.

2. Overview of Wireless Transmission Technology

At this stage, the existing wireless transmission methods are divided into three forms: electromagnetic induction, magnetic coupling resonance, and microwave. They can achieve short-distance, and medium-distance, and long-distance power transmission.
2.1 Electromagnetic induction wireless transmission system

The electromagnetic induction type wireless power transmission system is a new type of power transmission mode based on the principle of electromagnetic induction\cite{4,5}. Generally consists of three parts: energy transmitting end, intermediate medium and energy receiving end. Similar to the principle of a transformer in a power system, an alternating current flows through the energy transmitting end, and the electromotive force is induced at the energy receiving end through the principle of electromagnetic induction. User load.

![Electromagnetic induction wireless transmission system block diagram](image)

This system separates the tightly coupled structure of the transformer. When excited by high-frequency currents, there is a strong magnetic coupling between the primary and secondary windings of the transformer, which makes it possible to achieve power transmission without contact points. A large air gap will reduce the transmission efficiency. Generally, the frequency of the input power is increased to compensate. This wireless power transmission technology is characterized by large transmission power, but the efficiency of the transmission power will decrease with the increase of the distance at the receiving end, so it is suitable for short distance power transmission.

2.2 Electromagnetic resonance coupled wireless transmission system

The medium-distance wireless power transmission method is based on the electromagnetic resonance coupling principle, and the transmitting coil and the receiving coil are coupled to resonance at the system frequency to achieve efficient transmission of electrical energy\cite{6,7}. In essence, it is the conversion of electrical energy-magnetic energy-electrical energy. The structure of the entire system consists of two coils, each of which is an independent self-oscillating system. The transmitting coil is connected to the input terminal, and a non-radiative electric field is emitted by the high-frequency current generated by the oscillator to complete the conversion of electrical energy to magnetic energy. When the natural frequency of the receiving device is the same as the frequency of the emitted magnetic field, resonance occurs, and the current at this time It also reaches its peak and completes the conversion of magnetic energy to electrical energy. This transmission method has high transmission efficiency and is less affected by the distance of the receiving end. However, when the transmission power is too large, its transmission efficiency will be affected, and the distance can only be sacrificed to meet the efficiency.
2.3 Microwave-based wireless power transmission system

The above two types of wireless transmission technologies have problems with transmission power and transmission distance. To achieve long-distance and high-power wireless transmission, microwave transmission is required. Because the wavelength of the microwave is relatively short, the energy loss during transmission is small, and the directivity is well, long-distance transmission of electrical energy can be achieved. The whole system realizes the conversion of electric energy-microwave-electric energy. It is mainly composed of a transmitting antenna and a receiving antenna. The transmitting antenna emits microwave transformed by an energy converter, and is received by the receiving antenna and rectified to realize power transmission. Figure 3 below shows the structure of the system.

3. Important technology

3.1 Dynamic tracking control technology

Power transmission efficiency is a key issue for wireless power transmission. In order to solve this
problem, in order to maximize the transmission power in short and medium distance wireless power transmission, the transmission frequency and input impedance are matched. A certain degree of change has taken place. At present, the adjustment of system parameters is generally used to meet the matching of frequency and impedance. This method has certain limitations, so it is necessary to further optimize and control this type of wireless transmission.

In long-distance wireless power transmission, the key to the power transmission efficiency is the state of the transmitted energy beam and the receiving antenna. It is necessary to adopt high-precision transmission wave control, so that there is high pointing accuracy between the microwave transmitting and receiving antennas, to maximize transmission efficiency and minimize energy loss. Future research directions focus on reverse beam control technology, large-scale transmit antenna array calibration technology, and distributed signal synchronization technology.

3.2 Transmitter technology
In mid-range wireless power transmission, the key factor to improve the efficiency of wireless power transmission is the quality factor of the transmitting coil. According to the formula $Q = \omega L / R$, the quality factor of the coil is determined by the system frequency, inductance and resistance. When the quality factor of the transmission coil is increased, the resonance frequency of the transmission system is also increased, thereby improving the transmission efficiency. However, due to the presence of stray capacitance, the stability of the transmission coil is relatively low, and the quality factor is slightly reduced, which seriously affects the transmission efficiency. At this time, it is necessary to realize the impedance matching following the frequency change through the coil self-matching technology. The optimization of the parameters of the transmitting coil is generally considered from the aspects of material selection and structural design, such as multi-coil transmission technology using relay coils, and superconducting material coils.

3.3 Power Technology
In wireless power transmission systems, high-power and high-frequency power is an important part of AC / DC conversion\(^8\). However, due to the limitation of device performance, the output frequency and power are difficult to meet the requirements. Although a microwave source using a magnetron can meet these two requirements, its life is short and it cannot meet the requirements of wireless power transmission.

As for the current wireless power transmission technology, power electronics technology is generally used to control the power supply. However, it is affected by the performance and technical parameters of the switching device, it is difficult for the output frequency of the power supply to reach the level of megahertz, and with the increase of the output power, it becomes more difficult to control the frequency. However, when the power demand is not high, the power technology in the RF field is used, and the class E RF power amplifier principle is used to increase the output power. For the output frequency, this type of power supply is relatively easy to reach the megahertz level.

4. Impact on the power grid

4.1 Smart Substation
After years of technological exploration, China’s substation inspection robot technology is relatively mature. For the solution of its charging problem, inspection robots currently in operation generally use contact charging methods, but their inaccurate positioning causes charging failure, Potential safety hazards and other disadvantages. Wireless charging technology has the advantages of non-contact charging, low positioning requirements, and safety. Therefore, it has great research value in the charging of substation inspection robots\(^9\). Among them, the application prospect of coupled resonant mid-range wireless transmission technology is broader.

With the people's emphasis on the energy crisis and environmental pollution, electric vehicles and charging piles have developed rapidly, and electric vehicles can also be used to store electrical energy
in the grid after its scale. The contact interconnection will make the charging pile too concentrated, and the impact on the power grid is relatively large. Due to the many advantages of wireless charging technology, it can accelerate the interconnection between electric vehicles and the power grid, and then greatly promote the development of smart grids.

4.2 Transmission and distribution network
For the construction of transmission grids, it can basically be transported to every corner of the country. However, there are still some dead ends. Due to various reasons, it is impossible to build a tower and keep it away from the large power grid[10], which restricts the development of the local economy. Using wireless power transmission can solve such problems better.

With the development of wireless power transmission technology, the charging of batteries has changed from the original wired transmission to wireless transmission. As a non-linear load, during the charging process, it will impact the harmonics of the power grid and even cause resonance. Moreover, the storage battery as a capacitive load has a relatively low load power, which makes it difficult to meet the demand for power. With the emphasis on the environment and energy, the popularity of electric vehicles is bound to become a trend. The impact of electric vehicles on the distribution network is mainly reflected in the integrity of the power network, the stability of the synchronous motor, the stability of the system frequency, and other effects.

4.3 Introduction of distributed power
Due to the consumption of coal resources and the pollution of thermal power to the environment, new energy power generation has become a researching hotspot. Because new energy power plants are built in relatively remote areas, nearby you can choose to build electric vehicle charging stations. The main purpose of this is to use wireless power transmission to power long-distance electric vehicles.

The space solar power station based on the principle of solar power generation is specially designed for power generation by making use of the advantages of no climate influence in the universe to achieve a higher utilization rate and the application of space advantages. Wireless power transmission technology is widely used in space solar power stations, mainly using microwave or laser to transmit power wirelessly. These two transmission methods have different requirements on the area of the receiving antenna, and the microwave transmission requirements are higher. Microwave transmission has become a research hotspot in space solar power stations due to its high conversion rate and transmission efficiency. Its cloud penetrability is very strong, and it can also achieve high-precision pointing control. But because the beam is relatively wide, the size of the receiving antenna and the transmitting antenna is difficult to achieve in engineering.

5. Conclusion
Wireless power transmission technology is a new type of power transmission mode, which has incomparable advantages in some special fields. For short-distance, low-power power transmission, because of its low requirements on efficiency, it has a wide range of applications and can serve people for bringing unexpected conveniences, such as getting the rid of the shackles of power cords for mobile devices, and providing wireless power to many places. However, for long-distance, high-power electrical energy transmission, the transmission efficiency is generally not higher than 20%, and improving transmission efficiency is a subject worthy of study. With the continuous development of human science and technology, there will definitely be a qualitative improvement in transmission efficiency and cost control. Once wireless power transmission technology matures, human life will change dramatically. In short, in the long run, wireless power transmission technology has great potential application value.

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