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Research on the development and application of radio transmission technology

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Abstract. Since the 21st century, radio energy transmission technology has entered a stage of rapid development, and relevant theoretical research, innovative experiments and application promotion have made great progress. With the proposal and construction of the global energy Internet, related technologies will have greater development potential and application value in the future. Through qualitative analysis and literature review, this paper introduces the development and classification of radio transmission technology, summarizes the advantages and disadvantages of the combination of radio transmission technology, as well as the prospects for development in the fields of transportation drones, health care, and other fields, and the main problems currently faced. And the research and development of wireless energy transmission technology in different fields will face many technical challenges, such as theory, devices, safety, and so on. Therefore, its R&D process needs to break through key technologies in stages and steps. However, with the development of technology and the increase in demand, wireless energy transfer also has a lot of possibilities.

Keywords: Radio transmission technology, magnetic field coupling, electromagnetic induction, microwave, technical issues

1. Introduction

Nowadays, with the development of technology, electrical equipment has been gradually popularized in all walks of life, accelerating the development of all walks of life by improving work efficiency. However, the energy problems brought about by society, the increasing demand for electricity, and the development of clean energy, forcing people to study and develop a more energy-efficient radio energy transmission technology, which can avoid some of the energy loss caused by the traditional wired transmission lines. With the maturity and application of technology, radio transmission technology has also experienced rapid development, with the types being gradually diversified. This has optimized traditional radio transmission technology to a large extent, thus greatly improving the quality and speed of radio transmission technology. People's quality of life has also seen a huge improvement as a result.

The field of radio power transmission was pioneered by the great electrical engineer Nikola Tesla. As early as 1895, Tesla successfully lit a light bulb through magnetic field coupling wireless energy transfer technology in the Fifth Avenue laboratory in New York, which was the world's first wireless energy transfer experiment [1]. In 1898, Tesla observed in Colorado Springs, United States, that the electrical signal generated by lightning can be transmitted over an extremely long distance and the attenuation is very small, which inferred that electric energy can be transmitted over a long distance, thus formally proposing the concept of radio energy transmission [1]. Until 1970, with the breakthrough of semiconductor devices, magnetic field-coupled radio energy transmission technology gradually received people's attention.

The development of magnetic field coupled wireless energy transmission technology in China is relatively late compared with other countries in the world, but in recent years, the government and enterprises in China have invested a lot of resources in the development and application of electric vehicles. Meanwhile, in order to ensure the standardization of this field, the government has also formulated relevant standards and policies. This has provided great support and help for the research of magnetic field coupled wireless energy transmission.

Therefore, this paper will summarize and analyze the optimization and development of wireless energy transmission technology, by means of literature review and theoretical analysis. It also analyzes the application of wireless energy transmission technology in different industries.

2. Principles of wireless power transmission

Radio transmission refers to the process of transmitting electrical energy through a solid line without having to contact it through a wire [2]. The current radio transmission technology is mainly based on electromagnetic induction, magnetic field coupling, and microwave mode. The principle of radio utilization is to use the transmitter to convert the electrical energy, so that the electrical energy becomes relay energy, such as microwave, electromagnetic field, etc., and then the non-contact transmission is carried out, and the receiver is received and then converted into electrical energy [3].

2.1. Wireless power transmission technology based on electromagnetic induction

2.1.1. Principle. Low frequency alternating current is input and stable direct current is obtained by shaping and filtering. Then you change the direct current to high frequency and you get high frequency alternating current. The high frequency alternating current now generates a high frequency magnetic field on the main side of the transformer. According to Faraday's law of electromagnetic induction, electrical energy is transferred to the secondary side of the separation transformer through magnetic field coupling and high-frequency alternating current is generated, which provides energy for the load after shaping and filtering [4].

2.1.2. Strengths and weaknesses. Advantages of wireless power transmission technology based on electromagnetic induction Contains a wide range of transmitted power and is efficient over short distances. In addition, the operating frequency is relatively low. This technology is relatively mature and has been partially put into production [4]. However, the transmission distance is very short, which leads to a significant reduction in cutting efficiency as the transmission distance increases. It is easier to reduce the transmission effect due to the intrusion of foreign objects [4].

2.2. Wireless power transmission technology based on magnetic coupling resonant mode

2.2.1. Principle. A high-frequency signal is generated by the oscillator, and after passing through the power amplifier of the resonant coil, the high-frequency signal is transmitted to the LC resonant coil at the transmitting end, generating a non-radiating magnetic field. The non-radiating magnetic field is coupled by the magnetic field, and the energy is transmitted to the coil at the receiving end to generate high-frequency alternating current, which provides electrical energy for the load after shaping and filtering [5].

2.2.2. Strengths and weaknesses. Wireless Power Transmission Technology Based on Magnetically Coupled Resonant Modes Compared with wireless power transmission technology based on electromagnetic induction, the transmission distance is far, the overall propagation efficiency is high, the penetration force is stronger, and the electromagnetic interference in the propagation process is

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smaller. However, this technology is still under development and is not mature enough to be widely used. In addition, its frequency is so high that the performance of the current electronic equipment cannot be fully matched [5].

2.3. Wireless power transmission technology based on microwave mode

2.3.1. Principle. The transmission system first converts electrical energy into microwaves of a certain frequency, and then transmits the microwaves through the antenna. After receiving the microwave signal, the receiver passes through the rectification device to convert the microwave into electrical energy [6].

2.3.2. Strengths and weaknesses. The advantages of wireless power transmission technology based on microwave mode include that it can be transmitted over long distances and can transmit large amounts of energy. However, the transmission efficiency is low due to its characteristics. There are some technical problems in high-power transmission due to the difficulty of electronic components meeting the technical requirements of the microwave frequency band. It is also not possible to open up specific application techniques [6].

3. Applications of wireless power transmission

3.1. Electric vehicle

The widespread use of electric vehicles also marks the arrival of the era of electric vehicles, and major domestic and foreign automobile manufacturers and scientific research institutions have actively carried out research on wireless charging technology for electric vehicles, which has accelerated the optimization and development of electric vehicles. Relevant research has been conducted and achieved remarkable results. Wireless charging design of electric vehicles by hiding the power supply and transformer in the underground way, completely avoiding exposed connectors and other security risks such as leakage and power run. And this charging method can meet the car in the parking place or on the street at the special charging point. The optimization of supporting infrastructure for electric vehicles is improved by setting up dedicated charging locations [7].

At present, the use of wireless charging technology in the electric vehicle industry is relatively mature, and the efficiency is very high. The electric bus that BYD sold to the University of Utah in July 2005, for example, can be fully charged by sitting on a charging mat for only a few minutes [8]. At present, wireless charging of electric vehicles is developing technologies such as barrier charging. For example, the electric car charger developed by Witricty can be charged in the air (a board embedded in the ground). And Fulton Technologies' technology can wirelessly charge electric vehicles through a few centimeters of marble or a garage floor [7].

The main methods for wireless charging of electric vehicles are electromagnetic coupling, photoelectric coupling, and electromagnetic resonance. However, both methods have obvious defects. Electromagnetic coupling charging must have a high-permeability core as a medium. Otherwise, the magnetic field lines will be seriously dispersed into the air, resulting in a significant reduction in transmission efficiency. So electromagnetic coupling is not suitable for high-power, long-distance wireless power supplies. Secondly, photoelectric coupling is limited to the propagation of light because there cannot be obstacles in the transmission path of light that cannot transfer energy, so the electromagnetic resonance formula is still imperfect and has great uncertainty [9]

3.2. Drone

Uav has the advantage of high flexibility and plays an important role in the fields of reconnaissance, survey and inspection, rescue and so on. Limited by the loading capacity, the UAV hit the battery capacity is limited, resulting in insufficient endurance, and the limited scope of inspection has become a bottleneck problem restricting the development of drones.

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Drones currently rely on manual wired charging, which reduces the efficiency and operational range of drones, while also unable to truly automate the line. The wireless charging technology avoids the direct contact of the wire, eliminates the step of manual plugging, and creates the possibility for the automatic charging process of the UAV [10].

Magnetic coupling resonant wireless charging is one of the main ways of UAV wireless charging. In order to improve the coupling ability, the City University of Hong Kong uses a receiving coil wrapped around the bottom end of the UAV landing gear to improve the coupling ability, but only for the UAV without a head or other operating equipment installed on the abdomen [11]. For the magnetic leakage problem, Maradei proposed a small plane coil at the lower end of the landing gear. This scheme is suitable for the UAV with operation equipment installed in the abdomen, and has high coupling capability, but low fault tolerance for dislocation. Therefore, the primary problem of drones is still to consider the magnetic leakage and dislocation tolerance rate [12].

Furthermore, the research of UAV wireless charging technology is multi-faceted. In 2015, the University of Colorado developed a wireless charging system for small drones based on microwave energy transmission, with a charging power of 5 W [13]. In 2020, Imperial College London designed and developed a wireless charging system for DJI's Matrice 100 quadcopter drone [13]. When the drone lands anywhere on the charging platform, even if there is a certain lateral offset or Angle deviation, the system is able to provide power to the drone at 100 W, the same power as the adaptive wired charger. In 2020, the Korea Advanced Institute of Science and Technology designed an electric-field-coupled drone wireless charging platform that provides 100 W of power to drones with 90% efficiency [13]. In 2021, Toshiba developed a magnetic field-coupled wireless energy transfer system for drones patrolling overhead transmission lines with a charging power of up to 400 W and an efficiency of 78% [13]. Tianjin University of Technology designed a two-way wireless charging system for drones based on magnetic field coupling, which can both transmit energy to sensors and receive energy from wireless charging piles [10].

3.3. *Medical field*

With the rapid development of medical technology, implantable medical devices can not only carry out drug positioning treatment for some diseases, long-term real-time monitoring, postoperative rehabilitation diagnosis, etc., but also can be used to replace some organs with loss of function or insufficiency. It mainly includes cardiac pacemakers, artificial hearts, cochlear implants, spinal cord electrical stimulators, implantable wireless sensing devices and atrial defibrillators [14].

Relevant research in the field of implantable medical devices is mainly based on four technologies: magnetic field coupling, electric field coupling, microwave, and ultrasound. Among them, the magnetic field coupling wireless energy transfer technology has a strong biological tissue penetration capability and can provide stable energy transfer through some human tissues.

However, magnetic field-coupled coils are difficult to integrate into microimplants due to issues with metallic components (e.g., batteries and hermetically sealed packaging). Therefore, it is necessary to increase the parasitic load of the implantable medical device, thus reducing its performance. In addition, the miniaturization of implantable devices means that the systems require higher power transfer densities while at the same time generating stronger electric and magnetic fields that affect the human body and the device [14]. In 2013, the National University of Singapore proposed an implantable wireless energy transfer system based on electric field coupling, which operates at 402 MHz and can transmit energy through 5 mm of skin, and the system efficiency reaches 67% [15]. Poon pioneered the research of implantable wireless energy transfer systems based on microwaves. The team designed a cross slot antenna by simulating the distributed current [15]. At the same time, the efficiency, magnetic field distribution and thermal effect of the system are studied. In addition, the ultrasonic radio energy transmission system hardly generates magnetic and electric fields, which is more in line with the safety requirements of the human body [15]. In 2011, Arizona State University proposed an ultrasonic wireless nerve stimulator, in the case of transmission power of 23 mW, the impact of ultrasound on the human body is far below the safety threshold [15].

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4. Conclusion

Wireless energy transfer technology has a broad application prospect and great comprehensive benefits for current social problems and future industry development. However, the research and development of wireless energy transfer technology is a gradual, systematic project and will face many technical challenges, such as theory, devices, security, and so on. The whole R&D process needs to break through the key technologies in phases and steps so as to explore the possibilities in different fields. Combined with the current status and trend of technology development, the future of wireless energy transmission is bound to develop in the direction of optimization, compatibility, and integration.

This paper summarizes the applications and problems of wireless energy transfer technology in different industries, but as a review type of article, it involves relatively little literature. At the same time, there is a lack of in-depth exploration of specialized theoretical knowledge. Afterwards, with the increase in professional knowledge and familiarity, we will combine more literature to explore the applications and problems of wireless energy transmission technology.

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