A view of research on wireless power transmission

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Abstract. Wireless power transmission is different from the traditional way of transmission, which can meet the needs of the development of science and technology. It can be widely used in electronic devices, implantable medical devices, industry and other fields, and has become a research hotspot at home and abroad. This paper introduces the development history and classification of wireless power transmission and the application field of it. Several methods of wireless power transmission were compared in this paper. This paper focuses on the current research status and the development trend of magnetic coupled resonance based wireless power transfer (MCR-WPT).

1. Introduction
With the development of science and technology, the traditional transmission has many defects and limitations, such as machinery and equipment aging affect the supply rate, the limits of wired transmission are not suitable for the body, underwater and other environments, adverse environmental changes affect power supply performance, potential safety hazards in the operation. What’s more, the power has two disadvantages: hard to storage and hard to transport. So people urgently need a new mode of power transmission. Wireless power transmission (WPT) which relieves the dependence of the wire has become a hotspot at home and abroad in recent years.

2. The development history of wireless power transfer
Wireless power transmission has undergone three stages from generation to development [1], as shown in table 1.

| Stage   | Time             | Achievements                                                                                                                                 |
|---------|------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Stage 1 | The end of the 19th Century | The Nicholas Tesla wireless energy transmission test carried out the transmission between the two coils and lit a light bulb in the air. Microwave power transmission (MPT); |
| Stage 2 | 1960s            | In 1975, the first MPT experiment was launched in Venus laboratory. The radio frequency 2.388GHz of 450kW can be transmitted to a distance of 1.6km, and its wireless transmission efficiency is 8.1%. Professor Marin Sorgasik of MIT proposed magnetic coupled resonant radio transmission [2] and achieved some experimental results. |
| Stage 3 | 2007             |                                                                                                                                               |
Wireless power transmission (WPT) also known as wireless energy transmission. It’s a technology that converts electricity into radio waves to specific receiving devices and then transmits them into load powers.

At the end of 19th Century, Nicola Tesla [3] who a famous inventor did experiments about wireless power transmission. In his experiment, he achieved the transfer of energy between the two Tesla coil and successfully used Tesla coils to light a wireless bulb which lay the foundation for the development of wireless power transmission.

3. Classification of wireless power transmission

According to the principle of electric energy generation [4-7], it is divided into four categories, as shown in figure 1.

According to the distance in the space, the wireless power transmission is divided into three types: short range, medium range and remote transmission[8].

The close range transmission is realized by the principle of electromagnetic induction, and the upper limit is 10cm. Electromagnetic induction based wireless power transfer generates current through primary and secondary coils, and its electromagnetic field can penetrate all non-metallic materials, so as to achieve the transmission of energy from the transmission end to the receiver side. The principle of electromagnetic induction is usually used for power supply of small electronic equipment because of the limit of transmission distance.

Medium range transmission is realized by using electromagnetic coupling resonance principle or electromagnetic wave radio frequency. The electromagnetic resonance takes place in the non radiation magnetic field by the receiving coil, and oscillates at the same frequency, and then effectively utilizes magnetic induction to realize the transmission of electric power. Compared with the electromagnetic induction based wireless power transfer, the magnetic field is weaker, the transmission power is higher, the transmission distance is longer, and the transmission distance is 2~4m. Radio frequency power transmission mainly transmit radio frequency signal through power amplifier, and then get direct current through demodulation and high frequency rectifier to realize transmission of power. Radio frequency power transmission distance is far, can reach 10m, but the transmission power is very small, it is 1mW ~ 100mW. Medium range transmission can provide power for mobile phones, MP3, auto parts, thermometers, hearing aids and human implant instruments.

Long distance transmission is realized by means of microwave or laser. Its transmission distance is 10m to 1000m. Microwave or laser are sent to the far end receiving antenna, and then processed through rectification and modulation. Remote transmission can be used to supply power to difficult areas, and it also has important strategic significance for space technology, such as artificial satellites, energy transmission between spacecrafts, and new energy development and utilization, such as space solar power stations. As shown in figure 2.
4. Analysis and comparison of wireless power transmission

4.1 Electromagnetic induction based wireless power transfer (EI-WPT)

The working principle of electromagnetic induction based wireless power transfer is that when the current passes through the coil, the coil generates magnetic field and induces induction electromotive force to the nearby coil, thus generating electric energy and realizing wireless power transmission[9]. The components of the WPT system include waves filtering rectifier, high frequency inverter, primary coil compensation, secondary coil compensation, separate transformer and power conditioning. As shown in figure 3.

![Figure 3. Basic structure schematic diagram of EI-WPT.](image1)

4.2 Magnetic coupled resonance based wireless power transfer (MCR-WPT)

MCR-WPT can reasonably transmit the parameters of the launcher and the receiving device, and transmit the electromagnetic resonance between the transmitting coil and the receiving coil reasonably. Under the drive of the resonant frequency power supply, the system can reach the state of the electric resonance and realize the efficient transfer of energy from the transmitter to the receiver. The system of MCR-WPT is mainly composed of high frequency power, impedance matching network, induction coil, resonance coil and load driving circuit[10-15]. The working principle of MCR-WPT is the high frequency power supply to output high frequency alternating current induction coil, the magnetic coupling resonance under the action of the induction coil and the transmitting coil resonant coupling occurs, so as to realize the power from the transmitter to the receiver, wireless transmission, and received power through the load driving circuit for rectifying and filtering processing, can be directly to load power. As shown in figure 4.

![Figure 4. Basic structure schematic diagram of MCR-WPT.](image2)
4.3 Microwave based wireless power transfer

Microwave based wireless power transfer transmits power through microwave. The working principle of Microwave WPT is electric energy into microwave, high emission emitted by transmitting antenna, the emission and radiation to the surrounding space, the free space propagation of microwave energy to the load through the receiving antenna, rectifier, microwave and then converted to DC to use[16]. The components of the microwave WPT system mainly include the microwave power source, the transmitting antenna and the receiving antenna. As shown in figure 5.

![Figure 5. Basic structure schematic diagram of WPT via microwave radiation.](image)

Analysis and comparison of electromagnetic induction, magnetic coupling resonance and microwave wireless power transmission[17-22] are shown in table 2.

| Method          | EI-WPT                                              | MCR-WPT                                             | Microwave WPT                                                                      |
|-----------------|-----------------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------------------------------|
| Advantage       | It can realize large transmission power, high near  | It can realize the transmission distance of 2        | Microwave has biological harmfulness, it has great interference to communication    |
|                 | distance transmission efficiency and low working   | ~ 4m, it is not sensitive to the dislocation of the | equipment, it can only achieve fixed point launch, high demand for transceiver and   |
|                 | frequency.                                         | transceiver position, the radiation energy is small,| low transmission efficiency.                                                       |
|                 |                                                     | the penetration ability is strong, and the influence of | Energy transmission between solar satellite, satellite and spacecraft.                |
| Disadvantage    | The transmission distance is short, generally      | The operation frequency is high, the frequency     |                                                                                     |
|                 | centimetre level, high requirement for the         | change has a great influence on the transmission    |                                                                                     |
|                 | receiving position, the foreign bodies will        | performance, the transmission power needs to be    |                                                                                     |
|                 | produce local heating[24], it is easily subject    | improved, the technology is not mature[25, 26].    |                                                                                     |
|                 | to electromagnetic interference.                    |                                                     |                                                                                     |
| Application     | Small electronic equipment charging, EV wireless   | Implantable medical equipment, wireless sensor,    |                                                                                     |
|                 | charging, traffic track power supply, etc.         | electronic equipment charging and so on             |                                                                                     |
From the above table, we can see that the magnetic coupled resonance based wireless power transfer has moderate transmission distance, high safety[27], transmission power and transmission efficiency, which can meet the needs of some electronic devices. It can be widely applied in daily life, and has good application prospects.

5. Research hotspots of WPT

5.1. Field of intelligent household appliances

In 2010, Haier group launched the world's first "tailless TV" without power lines [28], signal lines and network lines, causing a sensation. The TV can achieve long distance and high efficient wireless power transmission without the help of wires, which is a successful example of the combination of wireless power transmission and practical applications. In addition, portable electronic products, such as mobile phones and panel pc, can greatly improve the user experience through wireless power transmission technology, which is convenient to use.

5.2. Field of electric vehicle

The application of wireless power transmission to the field of electric vehicle[29] charging can greatly improve the scope of application of electric vehicles, increase the penetration rate of electric vehicles and reduce the number of charging piles, which is also conducive to the protection of environment and energy[30].

5.3. Implantable medical device

The power demand of implantable medical devices is very small. Through wireless power transmission technology, it can greatly improve its operation time in vivo, improve the accuracy of diagnosis and treatment, reduce the rate of misdiagnosis, and achieve permanent operation in vivo, so as to improve patient comfort. Such as cardiac pacemaker, gastrointestinal endoscopy[31] and so on[32-35].

5.4. Industrial application

Many environments in the industry cannot use the wired power supply, such as underwater and chemical environment. Wireless power transmission can overcome these shortcomings and drive the development of technology. Such as underwater detector, pipeline detection robot and so on.

6. Conclusions

The emergence of wireless power transmission has greatly promoted the development of science and technology. Magnetic coupling resonant based wireless power transfer(MCR-WPT) has wide application prospects, and it can be applied to the popular products such as implantable medical devices, electronic products, etc, and has good social effects. At present, our research on MCE-WPT is at an initial stage. We need to improve the research depth, solve problems and make the technology mature, which can be widely applied in scientific research and commercial products.

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