Analysis on the classification and research direction of wireless charging technology

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Abstract: Wireless charging technology is wireless power transmission through electromagnetic wave. Wireless charging technology can make the product design get rid of the shackles of cable and make the product design more compact and miniaturized. This paper introduces the wireless charging technology. In order to overcome the heavy charging cable, realize wireless charging anytime and anywhere; Electronic equipment has the trend of miniaturization, low power consumption and standardization of wireless charging; The application of Internet of things and the sensor of wireless sensor network do not need to connect, power supply and send and upload data through cable. As well as wireless charging, charging efficiency, its impact on the human body, ultra-low power sensors and commercial operation of wireless charging technology are the research focus of wireless charging technology.

1. Introduction
Wireless charging technology originated from Nicholas Tesla's idea of wireless power transmission, which uses electromagnetic wave to carry out wireless power transmission. Wireless charging technology can make the product design get rid of the shackles of cable and make the product design more compact and miniaturized. At present, the research focuses on the wireless charging technology of electric vehicles (Overcoming customers' feeling of heavy charging cables and realizing wireless charging anytime and anywhere), and the wireless charging of consumer electronics (standardization, miniaturization and low power consumption are the current development trend), Internet of things applications and wireless sensor networks (sensors do not need to be connected through cables for power supply and data transmission and upload), long-distance microwave and laser power transmission technology. Scholars at home and abroad have carried out a lot of research work[1].

2. Main Technology
Wireless charging technology can be divided into two categories according to the frequency band of electromagnetic wave used: Based on non radiation electromagnetic field (near-field frequency band) and based on radiation electromagnetic field (far-field frequency band). The technology based on non radiation electromagnetic field mainly includes: electromagnetic induction technology, magnetic resonance engagement technology, electric field engagement technology

Integration technology, near field communication (NFC); The technology of electromagnetic field based on radiation mainly includes UHF radio wave technology, microwave and laser technology.
2.1. non radiative electromagnetic fields

(1) Electromagnetic induction: through the principle of electromagnetic induction, the energy (AC) is transferred to the air. Electricity is transmitted wirelessly from the input (primary coil) to the output (secondary coil), and the two coils need to be in close contact. The technology is the most mature and has been commercialized and industrialized in low power electronic products. However, at present, the charging distance is short (the distance cannot exceed the coil radius, generally 10 cm), the primary coils need to be aligned, the charging power is low (currently widely used as 5 cm), and the data communication is one-way communication (only from the input to the output, using reverse modulation to realize data transmission), which affects the further application of this technology in other fields;

(2) Magnetic resonance coupling: through the energy sending device and the energy receiving device resonance at a specific frequency, so as to realize the exchange and transfer of energy. 2007, MIT successfully lit a 60 W light bulb two meters away using the principle of magnetic resonance engagement, and named the technology WiTricity. The self-engaging coil is a pair of $\varnothing 6$ mm copper wire wound for 5.25 turns, with a coil radius of 25 cm. The self-engaging coil is realized by the interaction of distributed inductance and distributed capacitance, and the resonance frequency is 9.9 MHz;

(3) Electric field coupling mode: electric field coupling mode uses the induced electric field generated by combining two groups of asymmetric dipoles along the vertical direction to transmit power. Because the voltage at the electrode is as high as 1.5 kV, the size of the power transmission module is 30-108 mm, the size of the power receiving module is 11.5-76.5 mm, and the transmission power is only 10 W, it cannot be miniaturized and built-in, so the application range is limited. At present, only Murata Manufacturing Institute in Japan adopts electric field coupling technology;

(4) Short range wireless communication technology, evolved from non-contact radio frequency identification (rf1d), is a short-range and high-frequency radio technology, with a working frequency of 13.56 MHz and a transmission distance of about 10 cm. NFC technology has the ability of energy transmission, but the current NFC standard does not include the content of wireless charging. Two thousand and twelve Eskostr of VTT technology research center in Finland $\ddot{O}$ Mmer tal The concept design of wireless charging technology based on NFC is proposed. The existing NFC antenna can be used to provide an integrated and low-cost wireless charging solution for small devices. In 2013, Renesas electronics proposed the first NFC wireless charging solution, which realized power transmission and data reception with a single antenna, widened the charging area to 10 cm, supported two-way communication, and had higher security.$^{[2]}$

2.2. Radiation electromagnetic field

Ultra high frequency radio wave: proposed by powercast company of the United States, the working frequency is 915 MHz, the maximum transmission distance (medium distance) is about 8 m, and the target application field is the sensor field. Its working principle is similar to the early ore radio, mainly composed of microwave transmitting device and microwave receiving device. The microwave receiving device can capture all kinds of radio waves from the transmitter and convert them into usable electric energy.$^{[3]}$. The transmitter also has the function of sending and receiving data, which can send the external input data to the sensor node.

Microwave and laser wireless power transmission: in 1968, glaser, an American scholar, proposed the idea of using electromagnetic wave receiver to convert solar energy into electric energy. In 2003, karaaia and others from the French National Center for scientific research conducted point-to-point wireless power supply to a village close to 1 km at the frequency of 2.45 GHz.

3. Main industrial standards

The current mainstream wireless charging standards are: Qi standard, PMA standard, a4wp standard. At present, electromagnetic induction technology and magnetic resonance technology are merging with each other. The two camps, a4wp and PMA, announced that they will be compatible with each other's wireless charging technology standards, and the wireless charging devices based on the two standards
can be compatible with each other's standard mobile phones. The magnetic resonance technology is also explicitly added to Qi standard in version 1.2.

Qi standard is an interconnection standard of short distance and low power wireless inductive power transmission developed by WPC, which is mainly used for wireless charging of low power equipment. WPC was first founded by eight companies and now has 212 member companies. Version 1.0 Qi standard adopts electromagnetic induction technology, adopts low-frequency non ionization frequency of 100-205 kHz, charging distance of 10 mm, supports only one device charging, primary coil alignment is required, energy conversion efficiency is about 85%, and power is 5 W. Qi standard version 1.2 adopts electromagnetic induction and magnetic resonance technology to expand the charging distance to 45 mm, supports multi terminal charging at the same time, and the maximum power can reach 2 kW\cite{4}.

PMA technology is also based on electromagnetic induction technology, which was founded by P & G and Powermat. It uses electromagnetic wave with frequency of 277-357 kHz, and others are similar to Qi standard.

A4wp magnetic resonance technology (rezence specification), developed by Samsung and Founded by qualcomm, the frequency range is 6.765-6.795 MHz (center frequency is 6.780 MHz), the power range is 10-15 W, the charging distance is long, the coil does not need to be aligned, but the efficiency is slightly lower than Qi.

4. The main research direction and prospect at present

(1) EV wireless charging technology for electric vehicles. The success of electric vehicles led by Tesla makes most automobile manufacturers accelerate the layout of electric vehicle industry, and also drives the research on EV wireless charging / wireless power supply technology in academic circles. WPT technology used in EV can be divided into two types: RF or microwave roar Pt and electromagnetic resonance roar Pt. In 2013, Naoki Shinohara of Jingdong University developed two kinds of electric vehicle microwave power transmission WPT systems, one is similar to inductive coupling and magnetic coupling short distance WPT system, and the other is medium distance WPT system without coupling. In 2011, Huang Xueliang of Southeast University and others studied the topology design of electric vehicle wireless power transmission based on magnetic resonance coupling. In 2012\cite{5}, heri rakouth of Delphi Automotive Systems Co., Ltd. and others based on the magnetic resonance coupled WiTricity technology achieved the transmission efficiency of 3.3 kW wireless charging station 90%. In 2013, Liao Chenglin and others of Chinese Academy of Sciences designed a medium distance wireless charging system for electric vehicles based on magnetic resonance and wireless energy transmission technology, and built a wireless charging system for electric vehicles with charging efficiency of 3300 W, transmission distance of 22 cm and end-to-end efficiency of 85% to verify its feasibility;

(2) Charging efficiency and topology. Topology structure has a great influence on the improvement of charging efficiency. In 2014, Liguang Xie of Virginia Tech proposed a cellular multi node wireless energy transmission technology, which optimizes the path, routing traffic and charging time, and solves the scalability problem of wireless charging technology. In 2013, Peng Wu and others from City University of Hong Kong Limited RF to the surface area of the charging board through a low-cost technology to improve charging efficiency. In 2012, Xia Chenyang and others from China University of mining and technology optimized the magnetic circuit mechanism of magnetic resonance coupled power transfer (cmrpt) system for power transmission and efficiency optimization. In 2015, Ding Zhao and others proposed a time-varying dynamic topology model for Rechargeable Wireless Sensor Networks, and optimized the model with the goal of maximizing the dwell time ratio of energy supply equipment;

(3) Analysis of the impact of wireless charging technology on human body. The development of wireless charging technology has been accompanied by doubts, mainly the impact of electromagnetic radiation on the human body. In 2014, Ping Ping Ding and others from sup-elec of France used the finite element method to evaluate the impact of electromagnetic field of electric vehicle wireless induction charging system on human body. The power of the charging system is 3 kHz and the frequency is 30 kHz. Research shows that even if the human body is very close to the emission coil, the level of
Electromagnetic radiation can meet the requirements of the standard. For high-power wireless charging technology, electromagnetic shielding measures must be taken to ensure that the electromagnetic radiation level of human body is in a safe range. In 2014, Dai Haipeng and Chen Guihai of Nanjing University studied the safe charging problem of wireless charging scheduling, in order to transmit more energy and ensure that the electromagnetic radiation at any position in the field is lower than the given threshold. The results were verified by using eight powercast tx91501 signal transmitters;

(4) Wireless charging technology puts forward higher requirements for sensor technology. Ultra low power consumption sensor, especially for radio wave RF mode, the transmission power is small. If the sensor consumes more energy, leading to a significant decline in charging efficiency, then the working cycle of the sensor belongs to the stage work, which can not give full play to the role of the sensor. In 2012, young Jun Hong of Samsung Electronics proposed an ultra-low power sensor platform for wireless charging system. RF transmitter and receiver consume 1.79 MW and 0.683 MW respectively, providing 1.2 MW of charging energy, extending the working time of sensor platform from 41 h to 168 h[6];

(5) The access authentication of wireless charging technology is particularly important for the commercialization of wireless charging technology, such as the authorization and charging of public charging facilities, such as parking lots, charging stations, etc. At present, Bluetooth 4.0 in 2.4 GHz band (currently adopted by rezone specification), NFC and rf1d are widely used.

5. Conclusion
The emergence of wireless charging technology makes Nicolas Tesla's idea come true. Electricity can be transmitted in the form of electromagnetic waves in the electromagnetic field. Electromagnetic induction technology and magnetic resonance coupling technology become the mainstream of wireless charging technology. Driven by the large demand of consumer electronics and electric vehicles, the development of wireless charging technology will enter a new stage.

Acknowledgments
Special Project of Science and Technology Innovation Venture Capital of Tiandi Co., Ltd. (Project No.: 2020-TD-MS013)

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