



Wireless Electricity

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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).

I. 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.

Wireless power techniques mainly fall into two categories: near field and far-field. In near field or non-radiative techniques, power is transferred over short distances by magnetic fields using inductive coupling between coils of wire, or by electric fields using capacitive coupling between metal electrodes. Inductive coupling is the most widely used wireless technology; its applications include charging handheld devices like phones and electric toothbrushes, RFID tags, induction cooking, and wirelessly charging or continuous wireless power transfer in implantable medical devices like artificial cardiac pacemakers, or electric vehicles.

Wireless power transfer may be used to power up wireless information transmitters or receivers. This type of communication is known as wireless powered communication (WPC). When the harvested power is used to supply the power of wireless information transmitters, the network is known as Simultaneous Wireless Information and Power Transfer (SWIPT); whereas when it is used to supply the power of wireless information receivers, it is known as a Wireless Powered Communication Network (WPCN).

For this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firms and relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

II. THE DEVELOPMENT HISTORY OF WIRELESS POWER TRANSMISSION

Wireless power transmission has undergone three stages from generation to development [1], as shown in table 1.

Table 1. The three stage of wireless power transmission.

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.
Stage 2	1960s	Microwave power transmission (MPT); 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%.
Stage 3	2007	Professor Marin Sorgasik of MIT proposed magnetic coupled resonant radio transmission [2] and achieved some experimental results.

. WPT research was initiated by Nicola Tesla at the end of the 19th century. He said “This energy will be collected all over the globe preferably in small amounts, ranging from a fraction of one to a few horse-power. One of its chief uses will be the illumination of isolated homes.” Tesla built a gigantic coil that was connected to a 200-ft high mast with a 3-ft diameter ball at its top. The device was called the Tesla Tower. Tesla fed 300 kW of power to the coil, which resonated at a frequency of 150 kHz. The radio frequency (RF) at the top sphere reached 100 MV. Unfortunately, the experiment failed because the transmitted power diffused in all directions using 150-kHz radio waves with a wavelength of 21 km. It was a wide-beam WPT similar to a broadcasting system.

After the first WPT trial by Tesla, the history of radio waves has been dominated by wireless communications and remote sensing. In the 1940s, Percy L. Spencer, engineer of Raytheon Company, found microwave (GHz-order radio wave) heating and developed the first microwave oven when he developed a microwave radar for remote sensing. Similar to the development of the microwave oven, the broadcasting system leads to energy harvesting from ambient radio waves. The most well-known application of energy harvesting from ambient radio waves is Germanium radio. No battery is required to use the radio. It receives radio waves both for broadcast and energy. Besides ambient radio waves, energy sources for energy harvesting can be vibration, heat, and electric light, which are ambient weak power around us. The number of scientific papers has increased in the 21st century and recently, some large-scale research projects are ongoing around the world. Recent advances in energy harvesting are led by Internet of Things (IoT) applications. An IoT device generally requires very small power, and the number of IoT devices is expected to increase to trillions. The characteristics of an IoT device is suitable for energy harvesting.

The University of Washington is one of the promoters of RF energy harvesting, and they propose the concept of wireless identification and sensing platform (WISP) [5]. WISP is a family of sensors that are powered and read by UHF RFID readers. WISPs use harvested power from the RF signal generated by the reader. Based on WISP technology, they developed a battery-free phone using RF energy harvesting, and it was operated by combining analog and digital approaches with a power of only 3.48 μ W [6].

The drawback of RF energy harvesting is its small power. For example, the measured power density of TV broadcasting waves and mobile phones in Japan is only dozens of μ W/m² [7]. The advantage of RF energy harvesting is that it obviates the need for a special power transmitter. However, if the user needs more power, it could be used as a far-field WPT system.

III. 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.

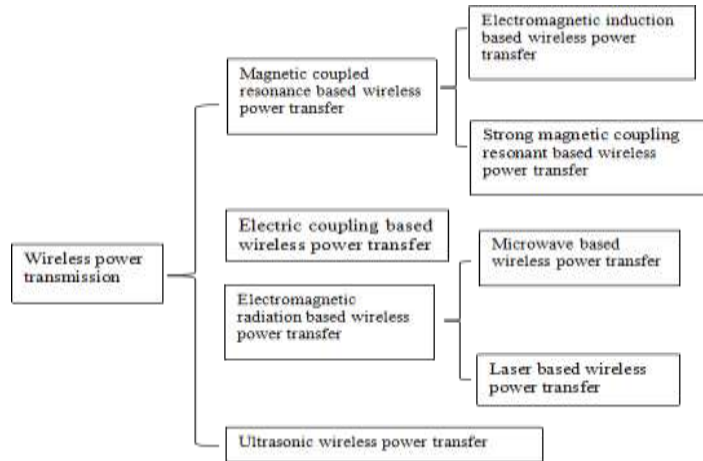


Figure 1. Wireless power transmission taxonomy.

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

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.

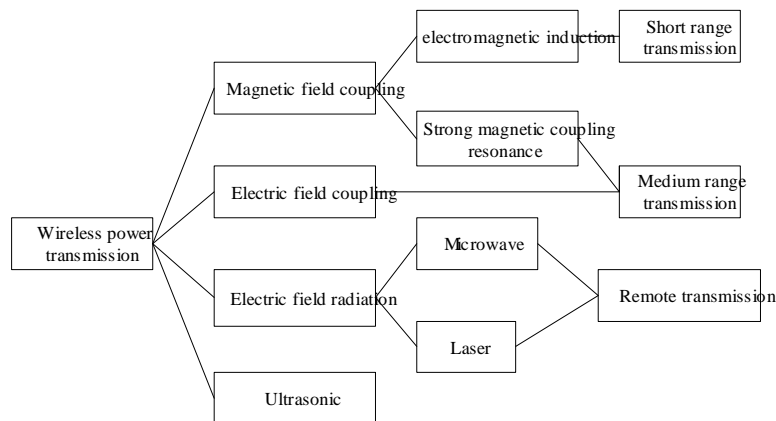


Figure 2. Wireless power transmission classification

IV. ANALYSIS AND COMPARISON OF WIRELESS POWER TRANSMISSION

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.

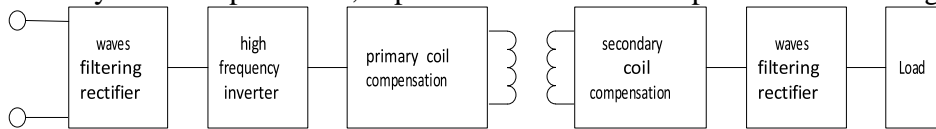


Figure 3. Basic structure schematic diagram of EI-WPT.

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.

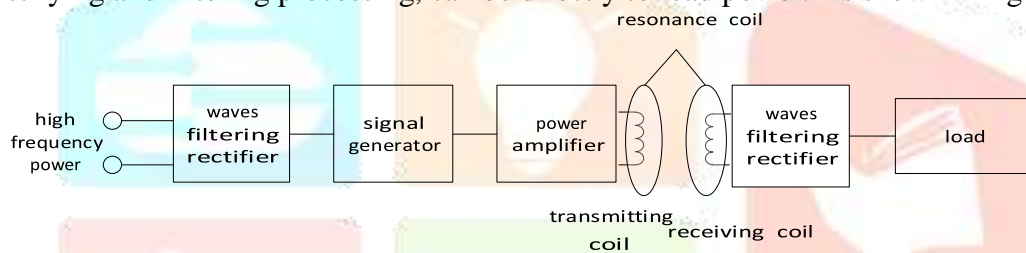


Figure 4. Basic structure schematic diagram of MCR-WPT.

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.

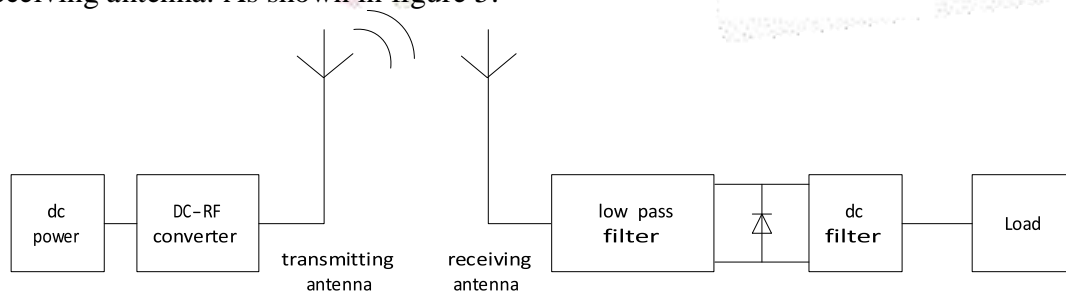


Figure 5. Basic structure schematic diagram of WPT via microwave radiation.

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

Table 2. Comparison of the advantages and disadvantages of three common wireless power transmission methods.

Method	EI-WPT	MCR-WPT	Microwave WPT
Advantage	It can realize large transmission power, high near distance transmission efficiency and low working frequency.	It can realize the transmission distance of 2 ~ 4m, it is not sensitive to the dislocation of the transceiver position, the radiation energy is small, the penetration ability is strong, and the influence of electromagnetic interference is small[23].	It can realize large distance transmission
Disadvantage	The transmission distance is short, generally centimetre level, high requirement for the receiving position, the foreign bodies will produce local heating[24], it is easily subject to electromagnetic interference.	The operation frequency is high, the frequency change has a great influence on the transmission performance, the transmission power needs to be improved, the technology is not mature[25, 26].	Microwave has biological harmfulness, it has great interference to communication equipment, it can only achieve fixed point launch, high demand for transceiver and low transmission efficiency.
Application	Small electronic equipment charging, EV wireless charging, traffic track power supply, etc.	Implantable medical equipment, sensor, equipment charging and so on	Energy transmission between solar satellite, satellite and spacecraft.

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.

CONCLUSION: 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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