WiTricity - Wireless Power Transfer by Non-radiative Method

Sivambika.K
UG Student
Department of ECE, Kathir college of Engineering, Coimbatore, India

***Abstract* - Nowadays Electricity has become a cup of life. The transmission of electricity without use of electrical wires is made possible by a method called "WiTricity" will facilitate to Transfer power without using wires. The efficient midrange power can be transmitted to any device which uses that range of power by the technique used in this WiTricity concept. The principle behind the working is Magnetic Resonance. Two resonant objects at 'strong coupled' regime tends to exchange their energy efficiently through this method. Two coils having same magnetic resonance one coupled to the source and other coupled to the device. The resonance transmitter emits a non–radiative magnetic field resonating at MHz frequencies and receiving unit loads resonating in that field. Midrange power implemented here is Omni directional, efficient irrespective of the environment. Nowadays there is a rapid influence of electronic devices rely on chemical energy storage (Battery). As they are becoming our daily needs wireless energy transfer would be useful for many applications.**

***Keywords* - WiTricity, Magnetic resonance, strong coupling, resonant wireless energy transfer.**

I. INTRODUCTION

Wireless electricity or WiTricity is the transfer of electric energy or power over a distance without the use of wires. In order for the energy to be transferred safely coupled resonators are used. Coupled resonators are two objects of the same resonant frequency that exchange energy efficiently without much leakage. Minimizing energy leakage is very important because the goal is to have as much energy as possible be transferred from one object to another. The first experiment to successfully wirelessly transfer energy consisted of two copper coils that were each a self-resonant system. One of the coils was connected to an AC power supply and acted as the resonant source. The second coil acted as the resonant capturing device and was connected to a 60-watt light bulb. The power source and the capturing device were about 2.5 meters apart and the light bulb was able to light up. This technology is very useful both in everyday life and for military usage. An example of a military usage includes sensors on a battlefield that can detect motion. The sensors would send their information to a base station and the soldiers can use this information to sense possible attacks. This could give them enough time to move or keep safe. This would be very beneficial, however; replacing batteries in the sensors can be dangerous and time consuming. Using WiTricity there would be no need to replace batteries because energy could be transferred from one sensor to another. Once a sensor has reached a predetermined threshold it would "shout" for help from a neighboring sensor. If the neighboring sensor had above the determined threshold it would transfer the necessary amount of energy to the sensor in need.

The wireless energy transmission was demonstrated by Nikola Tesla in the year 1890.It was demonstrated using resonant transformers called "Tesla coils". It provides undesirable electric fields which radiates energy in all directions. Various methods have been proposed to transfer energy through wireless methods. It involves methods like capacitive coupling, Microwave and Laser methods for far field region. Hence this technology uses magnetic resonance coupling has been found to be a viable technology for midrange energy transfer. Wireless energy transfer or WiTricity is currently extending its applications in also in medical applications undergoing operations to replace the lithium ion batteries used for pacemakers. Magnetic resonance is also being used for charging of electric vehicles while driving on a highway. Since this technology can work even in water. It is an alternative to the use of hazardous batteries. The most important distinctive structural difference between contactless transformers and conventional transformers is that the two 'coils' in the former are separated by a large air gap. Compared with plug and socket (i.e., conductive) charging, the primary advantage of the inductive charging approach is that the system can work with no exposed conductors, no interlocks and no connectors, allowing the system to work with far lower risk of electric shock hazards.

II. SYSTEM DESCRIPTION

The system is usually either wall power (AC mains) which is converted to DC in an AC/DC rectifier block, or alternatively, a DC voltage directly from a battery or other DC supply. In high power applications a power factor correction stage may also be included in this block. A high efficiency switching amplifier converts the DC voltage into an RF voltage waveform used to drive the source resonator. Often an impedance matching network (IMN) is used to efficiently couple the amplifier output to the source resonator while enabling efficient switching-amplifier operation as shown in figure 1. Class D or E switching amplifiers are suitable generally require inductive load impedance for highest efficiency. The IMN serves to transform the source resonator impedance, loaded by the coupling to the device resonator and output load, into such impedance for the source amplifier. The magnetic field generated by the source resonator couples to the device resonator, exciting the resonator and causing energy to build CE resonator to do useful work, for example, directly powering a load or charging a battery. A second IMN may be used here to efficiently couple energy from resonator the load. It may transform the actual load impedance into effective load impedance seen by the device resonator which more closely matches the loading for optimum efficiency.

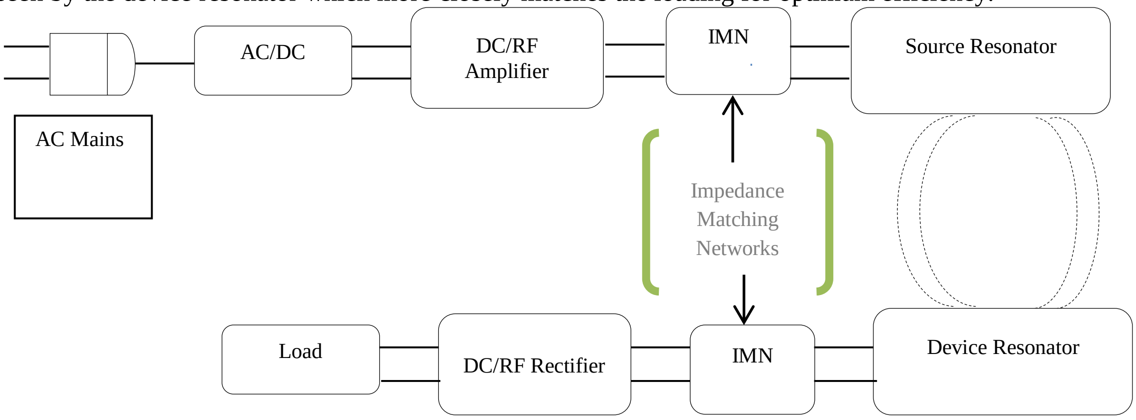

Figure 1: System Description

Presently, the most popular wireless transfer technologies are the electromagnetic induction and the microwave power transfer. However, the electromagnetic induction method has a short range [3], and the microwave power transfer has a low efficiency as it involves radiation of electromagnetic waves. Recently, a highly efficient mid-range wireless power transfer technology using magnetic resonant coupling, WiTricity, was proposed. It is a system that transfers power in between two resonating antennas through magnetic coupling. It satisfies all three conditions to make wireless charging possible as it has a high efficiency at mid-range (Approximately 90% at 1m and 50% at 2m [1] at 60W). Until now, this phenomenon was explained using mode coupling theory. However, this theory is this theory is often complicated and inconvenient when it comes to designing the circuits around the system.

III. CONDITIONS TO ACHIEVE WITRICITY

The following are the conditions for WiTricity charging:

- The first condition is that charging must be able to occur through physical objects. If the WiTricity cannot be passed through physical objects then the charging can only occur in a perfect unobstructed environment. This is not realistic because there are objects all around us that can interfere with the transmission of the energy. Research thus far has found that WiTricity can be transmitted through wood, gypsum wallboard, plastics, textiles, glass, brick and concrete.
- The second condition is that charging must be safe and not pose any sort of threat or safety hazard to humans or animals. Since this type of energy transfer is non-radioactive it is safe for humans and animals.
- The third condition necessary is that WiTricity charging must be able to provide electricity to remote objects without the use of wires. Therefore, the energy must be transferable from the transmitter to the capturing device over a certain distance.
- The fourth condition necessary is that the WiTricity is able to transfer a meaningful amount of energy, or else it would defeat the purpose of the energy transfer. WiTrcity.com states their technology is able to transfer energy ranging from miliwatts to several kilowatts of power.
- The fifth condition necessary is that the WiTricity technology should not use a lot of memory. In order for a program to be loaded on the sensors it cannot take a lot of memory, since the sensors have limited memory capacity.
- The final condition necessary is that the WiTricity charging technology should be affordable to be able to be a part of a sensor.

IV. COMPARISON WITH INDUCTIVE COUPLING

Traditional inductive coupling methods have limited transmission distance due to weak coupling between the source and loads. This occurs in the charging of conventional electric tooth brushes. The tooth brush with the receiving coil is placed on the source cradle for getting charged. The efficiency is as low as 1-2%. Using magnetic resonance the transmitting source coil frequency exactly matches the frequency of the receiving coils at resonance. Since the energy transfer is maximum at resonance, magnetic resonance coupling is found to have an efficiency of about 45% as shown in figure 2. Wireless power transfer (WPT) or wireless energy transmission is the transmission of electrical power from a power source to a consuming device without using discrete manmade conductors. It is a generic term that refers to a number of different power transmission technologies that use time-varying electromagnetic fields. Wireless transmission is useful to power electrical devices in cases where interconnecting wires are inconvenient, hazardous, or are not possible. In wireless power transfer, a transmitter device connected to a power source, such as the mains power line, transmits power by electromagnetic fields across an intervening space to one or more receiver devices, where it is converted back to electric power and utilized.[1]

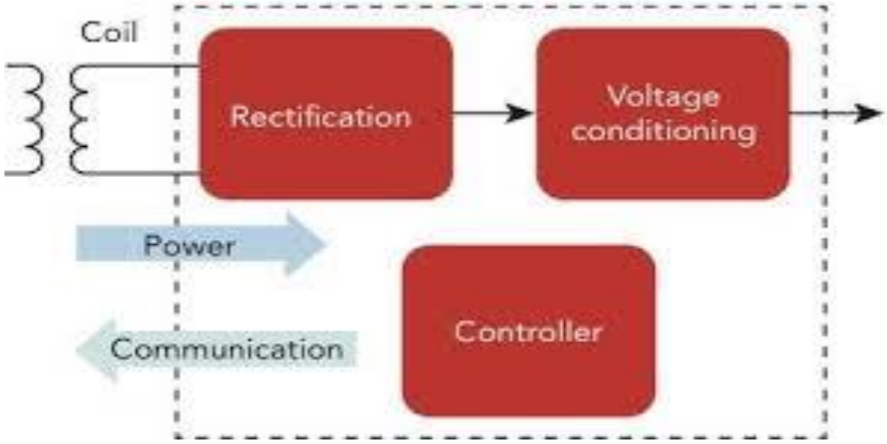

Figure 2: WiTricity Mechanism

There are various methods of transferring electricity wirelessly, basically they are classified as:

1) Near Field Transfer (Non-Radiative): These are wireless transmission techniques over distances comparable to, or a few times the diameter of the device(s).

a) Inductive Coupling: Inductive coupling is the action of electrical transformer is the simplest instance of wireless energy transfer. The primary and secondary circuits of a transformer are not directly connected. The transfer of energy takes place by electromagnetic coupling through a process known as mutual induction. The receiver must be very close to the transmitter or induction unit in order to inductively couple with it.

b) Resonance Coupling: The idea of such mid-range induction was given by Marin Soljacic for efficient wireless transfer. The reason behind it is that, if two such resonant objects are brought in mid-range proximity, their near fields (consisting of so-called 'evanescent waves') and can allow the energy to transfer from one object to the other within times much shorter than all loss times, which were designed to be long, and thus with the maximum possible energy-transfer efficiency. Electromagnetic resonance induction works on the principle of a primary coil generating a predominantly magnetic field and a secondary coil being within that field so a current is induced within its coils, when both of these are made to resonate at same frequency they become much efficient.

2) Far Field Transfer (Radiative): Far Field transfer refers to methods achieving longer range transfers, often multiple kilometer ranges, where the distance is much greater than the diameter of the device(s).

a) Laser/Microwave Transmission: Such power transmissions can be made effective at long range power beaming, with shorter wavelengths of electromagnetic radiation, typically in the microwave range. An antenna may be used to convert the microwave energy back into electricity. These provide 95% efficiency.

Currently, it achieves a maximum output of 6 volts for a little over one meter. Energy Transmission via laser is an efficient way for long range, except for it requires a proper line of sight for power beaming. In the case of light, power can be transmitted by converting electricity into a laser beam that is then fired at a solar cell receiver. With such laser beam efficiencies it is planned to build a solar panel grid in space & transferring the solar energy to earth receivers via laser methods.

V. RESONANT COUPLED SYSTEM

The resonant coupled system is formulated on the basis of coupled mode theory. A high frequency power source drives power through a transmitting antenna. The transmitting antenna sends power wirelessly using electromagnetic resonance coupling to the receiving antennas. Near field coupling using evanescent field drives the receiving antennas. The distance of transmission can be increased using coupled source antennas which work as resonators .This allows the transmission to follow a curved transmission path in space.

Magnetic coupling occurs when two objects exchange energy through their varying or oscillating magnetic fields. Resonant coupling occurs when the natural frequencies of the two objects are approximately the same. WiTricity power sources and capture devices are specially designed magnetic resonators that efficiently transfer power over large distances via the magnetic near-field. These proprietary source and device designs and the electronic systems that control them support efficient energy transfer over distances that are many times the size of the sources/devices themselves.

Features:

1. **Highly resonant strong coupling provides High efficiency over distance** - WiTricity mode of wireless power transfer is highly efficient over distances ranging from centimeters to several meters. In many applications, efficiency can exceed 90%. The WiTricity power source will automatically reduce its power consumption to a power saving idle state.
2. **Energy transfer through Magnetic near field makes it penetrate via obstacles -** Most common building and furnishing materials, such as wood, gypsum wall board, plastics, textiles, glass, brick, and concrete are essentially transparent to magnetic fields enabling WiTricity technology to efficiently transfer power through them.

VI. PROS AND CONS OF WiTricity SYSTEM DESIGN

- No manual recharging and changing batteries which reduces the usage of disposable batteries.
- Unaffected by the time and weather conditions and any other circumstances.
- Unsightly, unwieldy and costly power cords are eliminated.

- Reduce product failure rates by fixing the weakest link: flexing wiring and mechanical interconnects.
- It uses efficient electric grid power instead of battery charging. When a WiTricity powered device no longer needs to capture additional energy, the WiTricity power source will automatically reduce its power consumption to a power saving idle state.

As there exists many benefits over this system, it also has some drawbacks and limitations.

- The resonance condition should be satisfied and if any error exists, there is no possibility of power transfer.
- If there occurs, a very strong ferromagnetic material presence, then there may be a possibility of low power transfer due to radiation.

VII. APPLICATIONS OF WiTricity

The ability of our technology to transfer power safely, efficiently, and over distance can improve products by making them more convenient, reliable, and environmentally friendly.

1. Automatic Wireless Power Charging of mobile electronics (Laptops, mobile phones, game controllers etc.) in public places and in Wi-Fi hotspots.
2. Direct powering of stationary devices like flat screen TV's, home theatre accessories and wireless loud speakers eliminating wiring and unsightly cables. This comes under the category of consumer electronics.
3. In terms of Industrial perspectives-Direct wireless power and communication interconnections across rotating and moving joints (robots, packaging machinery, assembly machinery and machine tools) eliminating costly and failure-prone wiring. It provides Wireless power for wireless sensors and actuators, eliminating the need for expensive power wiring or battery replacement and disposal.
4. In the view of Transportation- Automatic wireless charging for existing electric vehicle classes: golf carts, industrial vehicles. Automatic wireless charging for future hybrid and all-electric passenger and commercial vehicles, at home, in parking garages, at fleet depots, and at remote kiosks. Direct wireless power interconnections to replace costly vehicle wiring harnesses and slip rings.
5. Medical Applications: Wireless charging systems are being developed for implanted medical devices including Left ventricular assist device (LVAD) heart assist pumps, pacemakers, and infusion pumps. The highly resonant wireless power transfer, such devices can be efficiently powered through the skin and over distances much greater than the thickness of the skin, so that power can be supplied to devices deeply implanted within the human body.
6. Wireless power transfer is essential for the spread of EVs as it provides a safe and convenient way to charge the vehicles. When wireless power transfer is achieved, the process the process of charging the devices will be made a lot more convenient as we do not have to plug the cord into the socket. Furthermore, as power can be constantly transferred to the vehicles, the battery size can be reduced. Also, the danger of being electrocuted due to the wear and tear of an old cord, or rain will be avoided as the process of handling the power cord is unnecessary, thus making the charging process safer. To achieve wireless charging, the wireless power transfer system must satisfy these three conditions: high efficiency, large air gaps, and high power.

VIII. CONCLUSION

As this wireless non radiative energy transfer scheme occurs in the mid-range even very simple design has promising performance and provides better efficiency with respect to distance. WiTricity is a powerful concept and hence it has wide range of applications in all over the fields. Standards Development Organizations (SDOs) are now developing interoperability guidelines for highly-resonant wireless power transfer to ensure that mobile devices from different vendors can charge anywhere in a common wireless ecosystem. Since the maximum power transfer efficiency occurs at the resonance frequency, the resonance frequency must match the frequency of the power source. When this is applied in the MHz range (which allows smaller size antennas), the usable frequency range is bounded by the ISM band.

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