# Issues And Challenges Of Witricity

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Abstract — This paper describes different methods of wireless electricity transmission. Wireless electricity is technology which transfer electric power without any physical contact (conductor) between source to load. It works based on the two principles: Faraday's law of electromagnetic induction & principle of electronic resonance. According to maximum power transfer theorem the maximum power is transmitted from source to load, when source impedance equals to load impedance, that is, impedance must be minimum as possible. The primary coil of the transmitter is subjected to high voltage and low alternating current to induce high density fluxes with high frequency. The wireless power transmission will always depends on strong coupled resonance between transmitter and receiver coils. Now a days more research and developments are taking place in this field. Moreover, this research paper explains the issues and challenges in the field of wireless electricity.

**Index Terms** — WiTricity, Electrical Resonance, Impedance, Electromagnetic Induction, Magnetic Resonance, Power Transfer, High Density Fluxes, High Frequency

## I. Introduction

The technology which transfers electrical energy from power source to an electrical load without using any cables or wires is called wireless electricity.

In 1899, the scientist named Dr. Nikola tesla who is also called " Father of wireless" , discovered the principles of wireless transmission and reception. The designed and constructed Wardenclyffe Tower (Tesla Tower) for mainly for wireless transmission of electrical power, rather than telegraphy. He explained with transmitting power by inductive and capacitive coupling using spark-excited radio frequency resonant transformers now called Tesla Coil., which generated high AC voltages[4]. In July 2007, a group of researchers at MIT presented a method of transmitting power wirelessly. Those members lit the bulb of 60W at the distance of 2 meters[5].

In WiTricity, energy efficiency is more significant parameter. A wireless system is said to be economical only when large energy transmitted through transmitters should arrive at the receivers. The most common method used for WiTricity is resonant magnetic induction[1]. The transmitting coil is strongly coupled with receiving coil at resonance. For maintaining the resonance we need higher frequency for transmitting coil which has large diameter, it also produces high density flux. Here parallel LC circuit is subjected for excitation by an AC high voltage. The receiving coil is also parallel LC with same resonance as the transmitter. As the LC gets excited in the transmitter, in the mean while voltage is induced in the receiving coil by the principle of electromagnetic induction. This method is done for maximizing the efficiency of the system for longer distances [3].

WiTricity consists of power AC power source, full wave rectifier, primary impedance matching circuit and two magnetically coupled coils, secondary impedance matching circuit, fast switching circuit and the load.[6] Block diagram is shown in the Fig.1.

An AC source is given to the high frequency rectifier to convert high frequency AC power to DC power. Due to high frequency there are some loss like reverse recovery time of normal diodes. Hence, Schottky diodes or ultrafast diodes are used in the rectifier circuit instead of normal diodes. The voltage regulator is used for stabilising and to control the DC voltage level according to the required load voltage. In high power applications, power factor correction stage is also included.

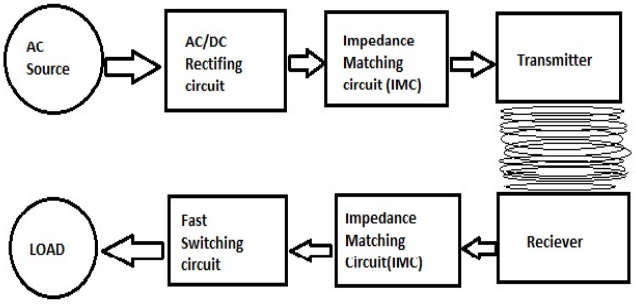


Figure.1. Block diagram of WiTricity

Impedance matching circuit is used here couples the primary coil and secondary coil effectively. It plays an important role by minimizing the reactance of input impedance and increases the power transfer efficiency which also reduces the volt-ampere rating of power source. A high frequency amplifier coverts dc power into RF voltage waveform that helps to excite the primary coil. The magnetic field is induced in the primary coil and gathered to the secondary coil to transfer the average load power. The fast switching circuit is a high frequency quasi resonant inverter consists of MOSFET, which has the capacity to operate at the frequencies up to MHz.[2]

The Section II describes principle of operation of the WiTricity, Section III explains WiTricity topology, Section IV presents review on experimental setup of WiTricity, Section V describes pros and cons of WiTricity, Section VI gives detail on issues and challenges of WiTricity, Section VII concludes the review paper.

## II. Principle Of Operation

### *A. Faraday's Electromagnetic Induction*

In Faraday's law, time varying magnetic field induces the voltage in the wire due to rate of change of magnetic field. This phenomena is adopted in tesla coil, where an oscillating current is made to flow in the coil to get the oscillating magnetic flux. Therefore, a sharp spike of voltage is induced.

$$\mathcal{E}=-N d\phi/dt \quad (1)$$

Where, $\mathcal{E}$ is the induced voltage or electromagnetic force (EMF), N is number of turns, dø rate of change of magnetic flux, dt refers to rate of change of time. A changing magnetic field induces an EMF even in empty space is called electromagnetic induction. The alternating current which is directed to flow in the

primary coil induces an EMF in the secondary coil, this phenomenon is called mutual induction [1].

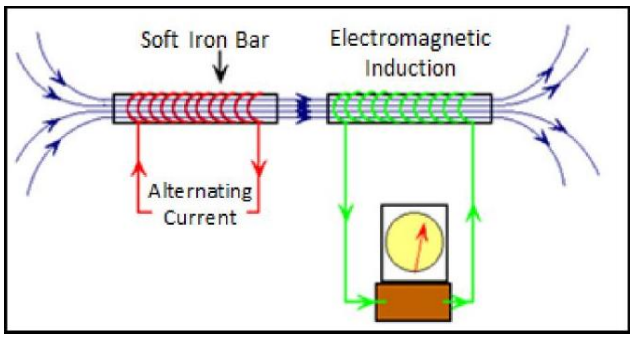


Figure.2.current is induced in secondary due to mutual induction

*B. Principle of Electric Resinance*

The circuit which has capacitors and inductors will cause a resonance by collapsing magnetic field of the inductor generates an electric current in its winding that charges the capacitor provides an electric current that builds the magnetic field in the inductor. This process is repeated continuously, for the process of mutual induction.

At, resonance, the series impedance of the two elements is at a minimum and the parallel impedance is at the maximum. Resonance is used for tuning and filtering, because it occurs at a particular frequency for given values of inductance and capacitance.

Parallel resonance or near to resonance circuits can be used to prevent the waste of electrical energy, which would otherwise occur while the inductor built its field or the capacitor charged and discharged. The use of the two types in parallel makes the inductor feed the capacitor, and vice versa, maintaining the same resonant current in the circuit, and converting all the current into useful work.

$$\omega L=1/\omega c \quad (2)$$

By the above equation we can say inductive reactance equal to capacitive reactance.

The resonant frequency is given by

$$f_r=1/2\Pi(LC)^{1/2} \quad (3)$$

Where, $f_r$ is the resonant frequency in hertz, L is the inductance in Henry, C is the capacitance in Farad.

*C. Analysis of wireless power transmission*

There are four types of impedance compensating network they are: Series-Series (SS), Series-Parallel (SP), Parllel-Series (PS) and Parallel-Parallel (PP).

The WiTricity operate on the Series-Series (SS) compensation technology, because to transfer maximum power, minimum impedance is necessary. This is obtain in SS technology.

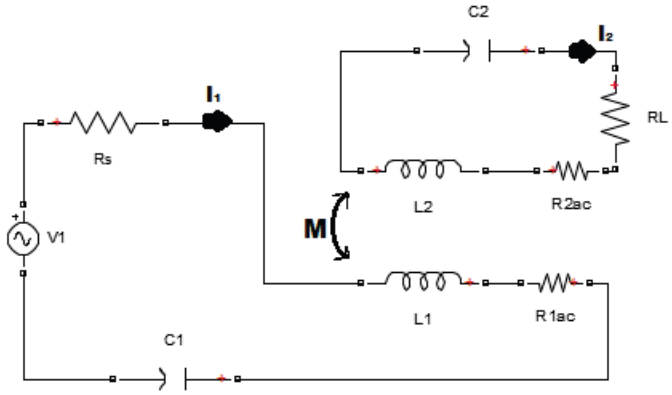


Figure. 3 Equivalent circuit Series-Series resonance for power transmission

The above figure shows the equivalent circuit series resonant circuit for WiTricity. The load power can be increased by three methods: 1.Increasing the frequency 2.by mutual inductance 3. By the magnitude of current source.

The loop equation of the equivalent circuit is given by:

$$V_1=Z_1I_1j\omega MI_2 \quad (1)$$

$$|I_2|=(\omega M/Z_2)I_1 \quad (2)$$

Where, $V_1$ will be the supply voltage, $I_1$ and $I_2$ are the passing current in the primary and secondary coils, respectively. $Z_1$ and $Z_2$ are the equivalent impedances of both primary and secondary circuit, M is the mutual coupling between two coils or it is also called as mutual induction and it depends on the coupling coefficient between the self-induction $L_1$ and $L_2$.

$$M=k(L_1L_2)^{1/2} \quad (3)$$

At resonance the equivalent impedances $Z_1$ and $Z_2$ can be approximated and simplified as,

$$Z_1=R_S+R_{1ac} \quad (4)$$

$$Z2=R_l+R_{2ac} \quad (5)$$

Where $R_{1ac}$ and $R_{2ac}$ are series resistance of the primary and secondary coils, Rs and Rl are the source and load resistances.

The resonant frequency ω is defined by

$$\omega=1/(l_1c_1)=1/(l_2c_2) \quad (6)$$

The load power can be deduced as

$$Pl=(\omega^2M^2I_1R_l)/(R_l+R_{2ac})^2 \quad (7)$$

The power transfer efficiency is given by

$$\eta=(\omega^2M^2R_l)/(\omega^2M^2)(R_l+R_{2ac})+(R_s+R_{1ac})(R_l+R_{2ac})^2 \quad (8)$$

Hence, from equation (7) and (8) we can say that the load power can be increased by mutual induction, increasing frequency and by the magnitude of the current source.

Therefore from equation (8), it is proved that by the efficiency can be increased by minimizing the parasitic resistance, increasing the frequency and the mutual inductance.

The losses due to the parasitic resistance R1ac and R2ac can be decreased by Litz wire in the coils design. Litz wire is used to mitigate the skin and the proximity effects. The more flux reaches the receiver; the better the coils are coupled. The degree of coupling is expressed by the coupling factor k. From equation (3), it is clear that the coupling coefficient depends on the medium between the two coupled coils and their parameters such as number of turns, cross sectional area and coils length. In WiTricity the relative permeability is one. [6]

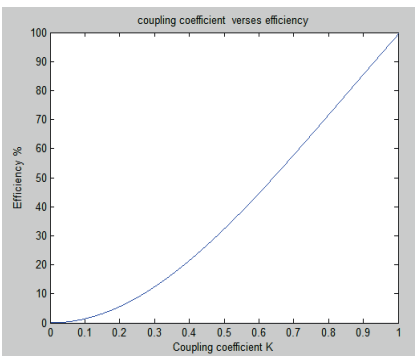


Figure.4. Relation between coupling coefficient and the power transfer efficiency in the simplified wireless charging model.

## II. WiTricity topologies

WiTricity has some different types, they are: a) Near-field techniques (short range): 1) Inductive coupling, 2) Resonant inductive coupling and 3) Air ionization. b) Far-field techniques (Long range): 1) Microwave power transmission (MPT) and 2) LASER power transmission

### *A. Near-field transfer techniques*

The wireless power transmission system which has the capability to transfer power in the short area or medium range is called near-field technique of WiTricity.

**Inductive coupling:** Induction coupling occurs when an energy source has a means of transferring energy to another object. One simple example is a locomotive pulling a train car- the mechanical coupling between the two enables the locomotive to pull the train, and overcome the forces of friction and inertia that keep the train still and, the train moves. Magnetic coupling occurs when the magnetic field of one object interacts with a second object and induces an electric current in or on that object. In this way, electric energy can be transferred from a power source to the powered device. In contrast to the example of mechanical coupling given for the train, magnetic coupling does not require any physical contact between the object generating the energy and the object receiving or capturing that energy.

$X_C = X_L$

$1/2\pi f = 2\pi f_L$ (4)

Figure. 5 Inductive coupling

**Resonant Magnetic Coupling:** Magnetic coupling occurs when two objects exchange energy through their varying or oscillating magnetic fields. Resonant coupling occurs when the natural frequencies of two objects are approximately the same.

**Atmospheric conduction method**: In this method a closed circuit is made using transmitter, ionized path between upper atmosphere and transmitter, second ionized path is connecting to receiver.

### *B. Far field transfer technique*

The power transmitted to long range by the help of wireless power transmission method is called far field transfer technique inn WiTricity.

**Microwave Transmission:** Power transmission via radio waves can be made more directional, allowing longer distance power beaming, with shorter wavelengths of electromagnetic radiation, typically in the microwave range. A Rectenna may be used to convert the microwave energy back into electricity. Rectenna conversion efficiencies exceeding 95% have been realized. Power beaming using microwaves has been proposed for the transmission of energy from orbiting solar power satellites to Earth and the beaming of power to spacecraft leaving orbit has been considered. Power beaming by microwaves has the difficulty that, for most space applications, the required aperture sizes are very large due to diffraction limiting antenna directionality.

**Laser power transmission:** The first method of transmission using a beam of laser which behaves as a source. In this technology, high intensity beam is transmitted through source to the load under a specific distance. The first experiment on WPT through laser is conducted by NASA “Marshall Space Flight Center” in which aircraft is powered by a laser beam.

This is very related to photovoltaic cell which used to convert solar energy into electricity when laser beam or sunlight strike the photovoltaic cell, then these cells convert it into electrical energy. Power can be transmitted through long distance, but losses occur due to scattering of light, it is also harmful to human being.

## III. Pros and cons of wirtricity

### *A. Advantages of WiTricity*

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. Multiple electronic devices can be simultaneously charged as posed to one[9].

No need of line of sight - In WiTricity power transmission there is any; need of line of sight between transmitter and receiver. That is power! Transmission can be possible if there are any obstructions like wood, metal, or other devices were placed in between the transmitter and receiver. Does not interfere with radio waves. Wastage of power is small - Electromagnetic waves would tunnel, they would not propagate through air to be absorbed or dissipated. So the wastage is small. Highly efficient than electromagnetic induction - Electromagnetic induction system can be used for wireless energy transfer only if the primary and secondary are in very close proximity. Resonant induction system is one million times as efficient as electromagnetic induction system.

Less costly - The components of transmitter and receivers are cheaper. So this system is less costly.[10]

### *B. Disadvantages of WiTricity:*

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. The magnetic field measured midway between the transmitter and receiver coils is about 14 time’s maximum value established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Electric field is about 7.5 times over the limit. The magnetic and electric fields closer to the coils has even higher readings [9].

Size: The copper rings which create resonance and energy are simply too big for them to be part of any wireless energy package. Range: The range of wireless energy transfer is just a few meters, which is a major hurdle. Efficiency: Wireless energy transfer ensures between 45% and 80% of the energy put in is transferred, which is much less efficient than regular

wired connections. Cost: The cost of developing and implementing wireless energy networks means that it would be too expensive for the end-user to afford at this point. [8]

## IV. APLLICATIONS

There are many applications of WPTT such as:

- Automatic wireless charging of mobile electronics
- Direct wireless powering of stationary devices, eliminating expensive custom wiring, unsightly cables and "wall-wart" power supplies.
- Robots, packaging machinery, assembly machinery and machine tools can take advantage of this technology.
- Direct wireless power for wireless sensors and actuators, eliminates the need for expensive power wiring or battery replacement and disposal.
- Automatic wireless charging for future hybrid and all electric passenger and commercial vehicles, at home or in parking garages. [6]
- WiTicity has many medical applications. It is used for electric power in many commercially available medical implantable devices. [5]

## V. ISSUES AND CHALLENGES OF WITRICITY

Flexibility for various usage environments: The magnetic resonance method is highly flexible in terms of transmission di-stance, position, coil space, and so on. Packaging technology: Manufacture of small, low profile, light weight WPT systems are required for consumer electronics. Prevention of heat generation is extremely important. Frequency band for WPT: No frequency band is designated for WPT. Clearer guidance is required concerning the choice of frequency bands for WPT under current radio regulations. Control system for WPT: A control system together with its protocol is necessary for highly efficient, highly safe power transmission. [11].

## CONCLUSION

By this paper we conclude that the electrical energy can be transmitted without wires to any distance. This system helps to get rid of wires and cables. Wireless power transmission is safe for animals and people. Consumer electronics and Electric vehicles they are capable of recharging themselves without plugging in. It makes our life easier. Another promising application area for wireless power transfer is in the medical arena. Development of world-wide standards for wireless power for the application and design of various products and brands, facilitate the deployment of wireless charging infrastructure and help to accelerate adoption of this technology. With a maturing technology base and a broad application space, wireless power transfer will become prevalent in many areas of life in the coming years.

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