

## A Comparative Study of Wireless Power Transmission Techniques

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### ABSTRACT

The advent of various wireless technologies have revolutionized the communication infrastructure and consequently changed the entire world into a global village. Use of wireless technology has also been made for transmission of electric power wirelessly. It can reduce heavy line losses; increase the portability of power systems. It also integrates the communication technologies and electric power to the same platform. This paper presents a comprehensive review and detailed analysis of various techniques used for wireless power transmission. Role of wireless power transmission in applications of smart grid like electric vehicle charging has also been covered. Feasibility, implementations, operations, results and comparison among different methods have been elaborated in order to identify the favourable and economical method for low power and small distance applications.

**KEYWORDS:** Power systems, Wireless power transmission, Magnetic resonance.

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### INTRODUCTION

Role of electricity in modern machine era is considered like circulation of blood in human body. Electrical energy has made human life easy and luxurious. Electricity is being distributed using the conventional grid which is in service for last hundred years. Conventional grid is characterized by out dated infrastructure, delayed communication and heavy transmission losses. One of the solutions of the heavy line losses is the transmission of electricity wirelessly which is called Witricity.

Goal of wireless power transmission is to transfer electricity from source to destination in order to reduce high transmission losses. Wireless power transmission increases the portability and convenience. It also fulfils the demand of recent devices and technologies which already use wireless technique for different operations and communications like Wi-Fi being used in laptops and cellular phones for the access to the internet. Transfer of electric power without using wires is possible by using three major methods.

Nicola Tesla is the pioneer of the wireless power transmission concept and he implemented his concept in 1902 with the technologies available at that time. Since then, many of the scientists involved in further extension of this idea and achieved positive results for the transmission at a close range [1]. In 2007, a team at the Massachusetts Institute of Technology (MIT), was successful in transferring the power wirelessly at a mid-range using magnetic coupling resonance by lighting a bulb of 60w at a range of 2m [2].

Smart grid is the concept of modernizing the conventional grid by integration of advanced digital communications. Wireless communications will play an important role for realization of smart grid. Witricity also helps in achieving the goals of 21st century power quality requirements and special applications. Electrical vehicles are supposed to replace the conventional internal combustion engines in smart grid. Wireless charging for electrical vehicles is an important application of Witricity [3].

There are three main methods of wireless power transmission. The first method is to transfer electric power by the phenomena of mutual induction between two coils operating at same resonant frequency; second method is by microwave transmitter and receiver while the third method is the transfer of electric power using laser technology [4].

A part of this work has been accepted as conference paper in [15]. Rest of the paper is organized as follows. Section II is dedicated for microwave power transmission methods and section III elaborates the advantages, disadvantages and applications associated with wireless power transmission. Conclusions are drawn in section IV.

### WIRELESS POWER TRANSMISSION TECHNIQUES

Several methods have been explored for Witricity. This section describes the different methods of wireless power transmission. Various methods are discussed in detail in subsequent subsections.

## WIRELESS POWER TRANSMISSION USING MICROWAVES

Microwave wireless power transmission is a wide range process in which long distance electric power transmission becomes possible. This process uses the microwave voltage source which emits the microwaves. The microwave source acts as a transmitting antenna and a microwave receiver is attached with the load which acts as receiving antenna. The received microwaves are then converted back in to electrical energy through which the load is driven. Different parts of the wireless power transmission through microwaves are briefed as following.

The microwave source antenna acts as transmitting antenna at the base station. It uses the microwaves of high frequency ranging from 1GHz to 1000 GHz [5]. There are many types of microwaves source antennas each of which has its own efficiency. Usually the slotted wave guide, micro strip patch and parabolic dish antennas are used for this purpose [6]. For high power applications the slotted waveguide antennas are used because of their high efficiency.

The microwave receiving antenna is mounted at the load end and due to high frequency of microwaves it could be used for large distance applications of wireless power transmission. At the load end the microwaves are received by microwaves receiving antenna and then the received microwaves are converted back into dc power. The unit which receives microwaves and then converts back to the dc power is called rectenna. The rectenna is mounted at the load end.

A typical rectifying antenna used to produce dc power from microwave energy is called rectenna. . These are extensively used in microwave wireless power transmission systems. As defined in [7], “simple rectenna consists of a dipole antenna with an RF diode connected across the dipole elements. The diode rectifies the AC current induced in the antenna by the microwaves, to produce dc power, which powers a load connected across the diode.”

## WIRELESS POWER TRANSMISSION USING LASER

The second technique is the wireless power transmission using laser beam which acts as a source. The laser beam of high intensity is thrown from some specific distance to the load end. Depending on the range and intensity of the beam this method is used for small distance applications. This process is similar to the solar cells photovoltaic generation which uses the solar energy of the sun light and converts it into electricity. At the load end highly efficient photo voltaic cells are used which receive the laser beam, energize laser light and finally convert light energy in to electrical energy.

Experiments have shown that the wireless power transmission through laser beam is 50 percent efficient with respect to other methods but by using advance technology of laser photovoltaic cells receivers the efficiency could be increased. Various stages of process are described as following.

The laser source transmits the laser beam through an efficient lens. The lens is used to converge the beam of the laser to the specific place where the receiver is present. The laser receiver consists of a series of highly efficient photovoltaic cells which receives the laser beam and then convert them into electrical energy. The load is attached with the photovoltaic cells which after being energized through laser beam convert light energy of laser beam into electrical energy [8]. Laser power transmission is shown in Fig. 1 as following.

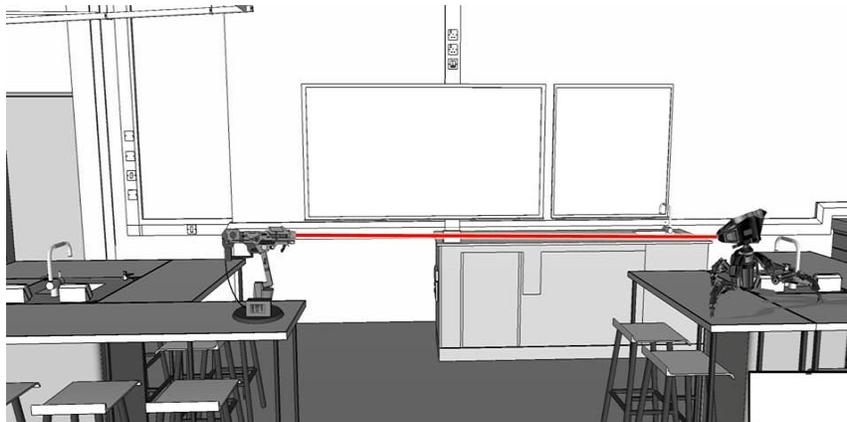


Figure 1. Wireless Power Transmission Through Laser

### WIRELESS POWER TRANSMISSION BY MAGNETIC RESONANCE

The mutual induction phenomena between two coils work on the principle that if there is a continuous varying current passes through one coil produces the magnetic field in the space around first coil called primary coil. As this varying magnetic field interacts with the secondary coil it produces an induced current in the secondary coil. This is also called magnetic resonance between two coils operating at a same resonance frequency. Principle of mutual induction is elaborated in Fig. 2.

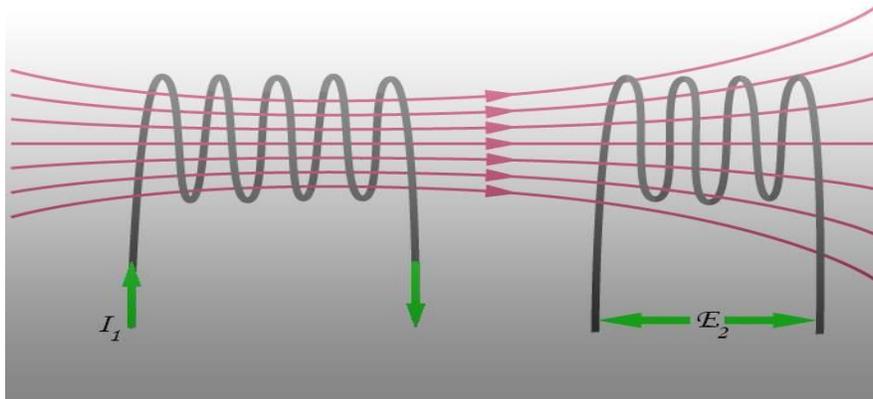


Figure 2. Mutual Induction Process

The frequency at which the amplitude of the waves produced in the system is maximum called resonance frequency. The resonance frequency is attained by varying different parameters affecting the gain of voltage produced within the coils [9]. The phenomena of wireless power transmission using mutual induction consist of primary and secondary coils which act as transmitting and receiving antenna respectively. The process is described in block diagram in Fig. 3.

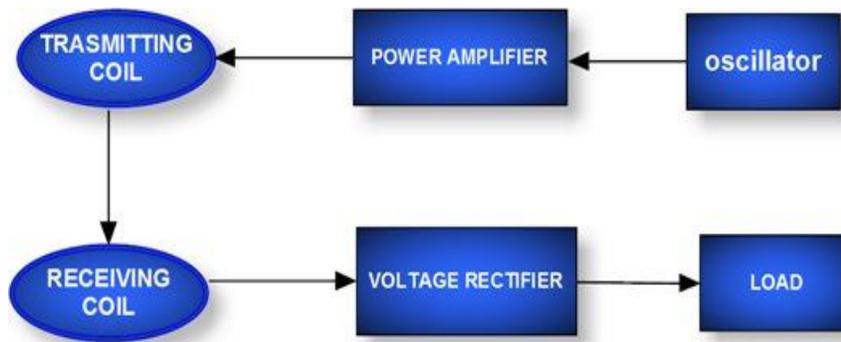


Figure 3. Magnetic Resonance Method

A set of copper wires is used which acts as transmitting and receiving coil. The number of turns of copper wires, resistance and diameter affects the mutual induction between them [10]. Important parameters of the system include: operating frequency of signal generator or source, voltage of the source, diameter and resistance of the coils and number of turns of coils.

We use oscillator for generation of a particular voltage signal at which we can get such a frequency where the mutual induction will be maximum. Such frequency is called resonance frequency. There are many types of oscillators. Voltage control oscillator is one of them. The voltage control oscillator consist of some resistors , capacitors , inductors transistor and a varying voltage source joined together in a manner to get the required voltage signal having some specified value of frequency where the mutual induction between the coils would be maximum i.e at resonance frequency.

The amplifiers are used for the amplification of the voltage signal so that a high power voltage signal should be fed to the primary coil acting as transmitting antenna. There are many types of amplifiers like class A, B,

and C amplifiers each having its own properties. Normally parallel combination of transistors is used in power amplifiers. As our load operates at direct current because devices like cellular phones and laptops use direct current for the charging purpose. So rectification is done at the load end. The rectification is done through bridge rectifier.

**COMPARISON OF WIRELESS POWER TRANSMISSION METHODS**

Methods presented in above subsections are compared briefly in this subsection. Each and every method has its own advantages and disadvantages regarding cost, range and health hazards. Comparison is summarized in table 1.

Table 1. Comparison of Different Methods

<b>Magnetic Resonance Method</b>	<b>Microwaves Method</b>	<b>Lasers Method</b>
<b>It is economical as the equipment used is cheap and easily available</b>	Relatively expensive as compared to other methods	Implies same economic conditions of mutual induction
<b>Useful for implementation of the small distance applications</b>	This method implies for long distance applications	Used for small distance but could be used for longer distances when high intensity beam is involved
<b>It is safe from biological point of view.</b>	Injurious for health because of high frequency rays (1GHz to 1000 GHz)	The laser method is also injurious to human health

**ADVANTAGES, DISADVANTAGES AND APPLICATIONS**

Wireless power transmission is the only process through which we could eliminate the existing system of high power transmission lines, towers and substations, which is inefficient and costly way of energy transmission. This will lead to a globally efficient and cheap transmission system. The cost of the transmission and receiving power would lower for the daily users and the large scale reduction of power tariff would be easily visible. The loss of transmission will be decreased and the power could easily be transferred to any place irrespective of the geographical situations. Power failures minimization will become possible which are caused by short circuit and faults [11]. It will make the system more efficient and environment friendly system. The natural disasters such as floods, earthquakes, landslides or tornados would not become the reason for power cuts and damages to the system. The usage of land for the installment of the system would completely be eliminated. As Dr. Neville of NASA states “You don’t need cables, pipes, or copper wires to receive power. We can send it to you like a cell phone call where you want it, when you want it, in real time” [14].

In terms of portability, this system is very superior to any other existing system. However, the most important concern remains the biological impacts. But according to the safety studies and research it indicates clearly that the radiation level achieved by the wireless power transmission is very close or slightly higher than the radiation of cellular phones or never greater than microwave oven exposure. Therefore, public exposure of wireless power transmission will be within the acceptable limits [12].

Disadvantages of the system include very high initial cost for the system's practical installation. Since microwaves are used for the transmission then the line of sight becomes the basic need. Any sort of interference in the line of sight could actually stop the transmission. The microwave power transmission can cause high interference problems for telecommunication infrastructure. As the energy will be available freely in the air energy; chances of the theft will be increased [13]. Applications of the wireless power transmission are elaborated as following.

Due to the advent of different recent technologies like cellular phones, laptops automated systems and robotics, the portability and convenience has become main objective of scientific research and development. To achieve portability, convenience and the demand of recent developing technologies; wireless power transmission can play an important role. It has vast applications which will decrease the cost of power systems by reducing the wires and towers. It will save the cost of equipments and labor. System complexity will be reduced and efficiency will be enhanced. There are many applications of Witricity in context of smart grid like electrical vehicle charging etc. Applications of wireless power transmission are depicted in Fig. 4.

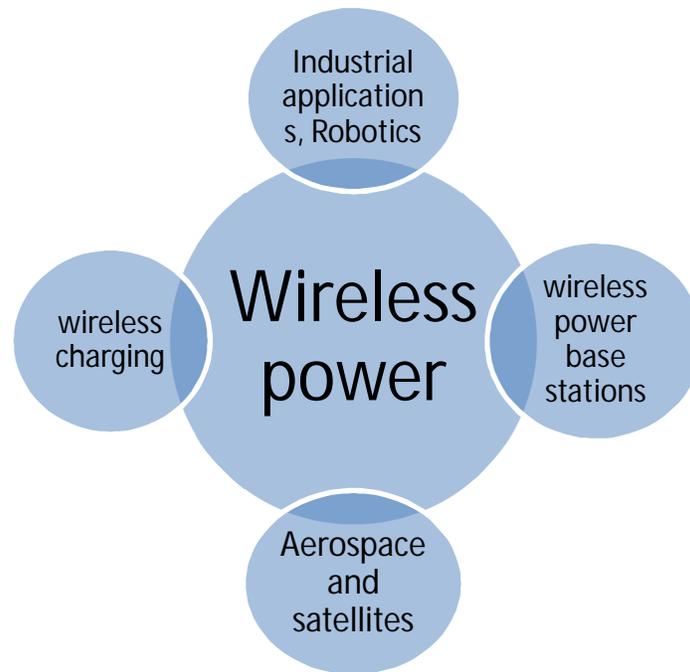


Figure 4. Applications of Wireless Power Transmission

#### **CONCLUSION AND FUTURE WORK**

The wireless power energy concept is indeed a great and a noble one. It has entirely changed the concept of power transmission. It has the potential to bring complete revolution in scientific development. Ranging from charging of the handset up to the reduction in global warming; wireless power transmission has many applications and solutions. It could reduce the human dependency on the fossil fuels and other petroleum products due to its efficiency in order to achieve sustainable development. We have reviewed and compared different methods of wireless power transmission. Different applications in context of smart grid have also been covered. Researchers are trying to make this technology more efficient and to overcome the challenges being faced. Though the practical implementation of this technology is quite limited due to the technological barriers but this could be the biggest breakthrough in the field of power transmission. In future, we are interested to carry out a detailed regional survey of energy management system including residential, home and industrial energy management systems, as done in [16-22].

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