

Wireless Power Transmission – The Future of Power Transmission System.

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ABSTRACT

Electricity is a basic requirement in modern era & fuel for technological development. The conventional use of electricity is through use of wires. Presently we are using wire system for power transmission but in today's modern life everyone needs wireless system for flexibility or mobility. The primary goal of this research work is to give a brief overview of most recent researches and development in the field of wireless transmission of electrical power transmission. By deploying Wireless power transmission we can reduce the transmission and distribution losses & increase efficiency to some extent. The techniques used for wireless power transmission are Induction, Electromagnetic transmission, Evanescent wave coupling, Electrodynamics induction, Radio, microwave Electrostatic Induction, Laser etc. This paper also put focus on Basic Design, Implementation, feasibility, economic aspects, limitations advantages, disadvantages, biological impacts and applications of WPT systems.

Keywords:

WPT-Wireless Power Transmission, Induction, Electromagnetic, Laser.

1. INTRODUCTION

One of the major concern in power system is that the losses occurring during the transmission and allocation of electrical power. Our existing transmission system is only 70-74% efficient this means about 1/3 of our generated power is waste in distribution [1]. The resistance of the wire used in the electrical grid distribution system causes a loss of 26-30% of the energy generated. According to the World Resources Institute, India's electricity grid has the highest transmission and distribution losses in the world – a whopping 27%. Wireless Power transmission is useful to power electrical devices as well as in communication system case where interconnecting wires are inconvenient, hazardous is not

possible [2]. There is a variety of technique of wireless power transmission which include Electromagnetic Induction, Electric Induction & Magnetic Induction used for different ranges e.g. short, moderate & Long transmission.

The definition of Wireless Power Transmission (WPT) can be given as a way of efficient transmission of power from one point to another through vacuum or an atmosphere without the use of wire.

In 1891 Nicola Tesla ("Father of Wireless") carried out the first WPT experiment and it still has been underdeveloped technology. Tesla had always tried to introduce wireless power distribution system worldwide. Then onwards this technology has not been developed up to the level which it would be completely applicable for practical purpose. Despite of its little advances WPT has not been adopted for commercial use. Research has been going on to explore present electrical wpt system for large scale commercial use & some developments have been observed in this field. Some exist only as theories or prototypes, but others are already in use. This article explores the advances in wireless power technology enabled by the use of highly resonant wireless power transfer, how those advances are being applied across a broad spectrum of applications, and how they address the safety concerns in typical applications.

2. Brief History of WPT

In 1864, James C. Maxwell predicted the existence of radio waves by means of mathematical model. In 1884, John H. Poynting realized that the Poynting Vector would play an important role in quantifying the electromagnetic energy.

In 1888, bolstered by Maxwell's theory, Heinrich Hertz first succeeded in showing experimental evidence of radio waves by his spark-gap radio transmitter.

In 1891 Nicola Tesla ("Father of Wireless") carried out the first WPT experiment in his "experimental station" at Colorado and demonstrated "the transmission of electrical energy without wires" that depends upon electrical conductivity. In

1893, Tesla demonstrated the illumination of vacuum bulbs by means of a resonant circuit without using wires for power transmission at the World Columbian Exposition in Chicago. The receiver works on the same principle as radio receivers where the device has to be in the transmitter.



Fig2.1 warden clyffe tower.

Wardenclyffe tower shown in Figure 1. was designed and constructed by Tesla mainly for wireless transmission of electrical power rather than telegraphy [3]. This was to be the first broadcasting system in the world. Tesla wanted to transmit electricity from this Tower to the whole globe without wires using the Ionosphere.

William C. Brown, the pioneer in wireless power transmission Technology, has designed, developed a unit and demonstrated to show how power can be transferred through free space by microwaves. In 1961, Brown published the first paper proposing microwave energy for power transmission, and in 1964 he demonstrated a microwave-powered model helicopter that received all the power needed for flight from a microwave beam at 2.45 GHz [5] from the range of 2.4GHz – 2.5 GHz frequency band which is reserved.[4].

3. Classification of WPT system

Wireless power transfer systems can be classified mainly into two types based on radiation pattern

(a) Radiative (b)Non radiative pattern.

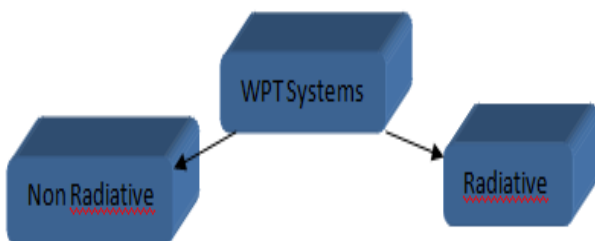


Fig.3.1Classification of WPT system

(a)Non- radiative (Near –field techniques)This means the area within about wavelength (λ) of the antenna. These fields are not *radiative*, meaning the energy stays within a small distance of the transmitter.[8] The power transmitted, decrease *exponentially* with distance,[5][6][7].The range of near-field devices is conventionally separated into two categories:

Short range– up to about one antenna diameter: $D_{range} \leq D_{ant}$. [8][9][10] This is the range over which ordinary non resonant capacitive or inductive coupling can transfer practical amounts of power.

Mid-range– up to 10 times the antenna diameter: $D_{range} \leq 10 D_{ant}$. [9][11][10][12] This is the range over which resonant capacitive or inductive coupling can transfer practical amounts of power.

(B) Far-field or radiative techniques(Far-field techniques)

Far-field or radiative region also called power beaming. Beyond about 1 wavelength (λ) of antenna, the electric and magnetic fields perpendicular to each other and propagate as an electromagnetic radiation wave; example are radio waves, microwave, or light waves. These techniques can transport energy longer distances but must be aimed at the receiver. Proposed application for this type is solar power satellites, and wireless powered drone aircraft.

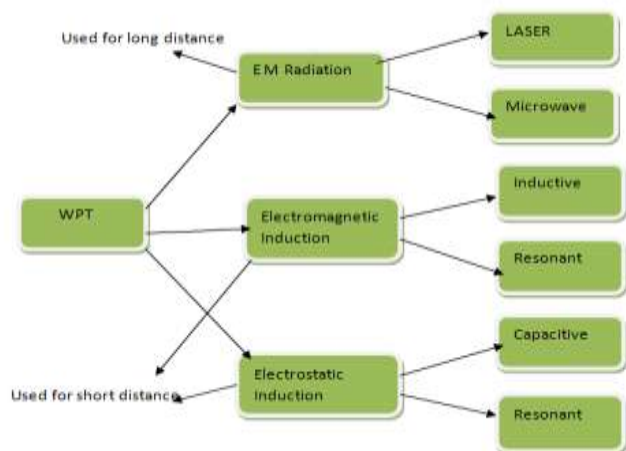


Fig.3.2 different types of technique on wpt

3.1.Near-field(nonradiative) techniques

The range of these fields is short, and depends on the size and shape of the “antenna” devices, which are usually coils of wire. The fields decrease exponentially with distance, The power is proportional to the square of the field strength, the power transferred decreases as (D_{range}/D_{ant}) . [18][7][15][16] or 60dB per decade. Inductive and capacitive coupling only

can be used for short-range power transfer, within a few times the diameter of the antenna device D_{ant} .

3.1.1. Short distance Magnetic induction.

A coil (loop) conductive material like copper is used for making coil. If this conductive loop is connected to an AC power source, it will generate an oscillating magnetic field in the vicinity of the loop. A second conducting loop, brought close enough to the first, may "capture" some portion of that oscillating magnetic field, which in turn, generates or induces an electric current in the second coil. The current generated in the second coil may be used to power devices. This type of electrical power transfer from one loop or coil to another is well known and referred to as magnetic induction.

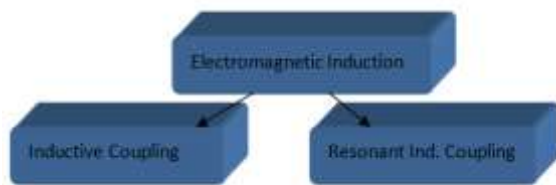


Fig.3.3 Electromagnetic Induction

(a). Inductive coupling. Electromagnetic Inductive Power Transfer (IPT) or inductive coupling is a popular technique of transferring power wirelessly over a short range. This technique of transferring power derives its capability from the two fundamental laws of physics: Ampere's law and Faraday's law. The functioning of such IPT systems is based on the changing magnetic field that is created due to alternating currents through a primary that induce a voltage onto a secondary coupled by means of air. The power transferred increases with frequency [17] and the mutual inductance M between the coils, [5] which depends on their geometry and the distance D between them. Energy gets transferred from the source to the device when the magnetic fields of the two interact.

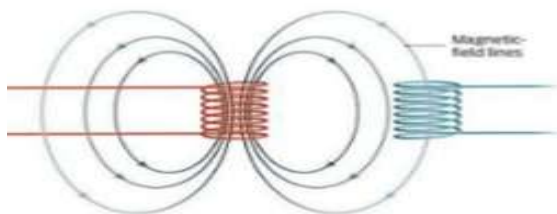


Fig.3.4 Inductive coupling

(B) Resonant inductive coupling. In order to increase range of Inductive WPT, Resonance inductive coupling is used. Resonance is a property that can be explained as a natural frequency of the system at which if the system oscillates maximum energy transfer takes place. This property when incorporated in WPT systems increases the transfer efficiency. Frequency tuning and impedance matching both enhanced the efficiency of power transfer. Resonant coupling is used for Mid range power transfer i.e. up to 10 times the antenna diameter. [13][18][19][20][21]

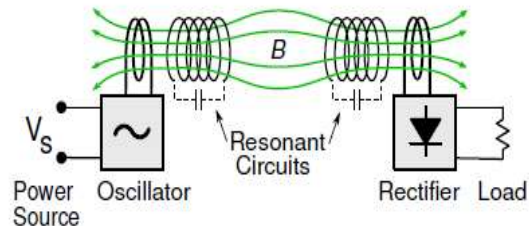


Fig.3.5 Resonant inductive coupling

3.1.2 Electrostatic Induction

Electric induction In Capacitive Power Transfer (CPT) the energy is transmitted between the two electrodes of a capacitor assembly. Based on the fact that when high frequency AC voltage source is applied to the plates of the capacitor that are placed close to each other, electric fields are formed and displacement current maintains the current continuity. Transmitter and receiver electrodes form a capacitor which can hold a charge, attaches to each end of the coil. This is referred to as electric induction. Some of the features that CPT has compared to IPT are [6].

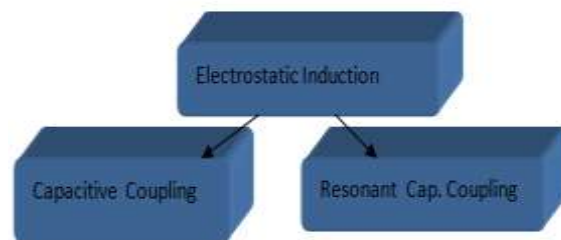


Fig.3.6 Electrostatic Induction

(a) Capacitive coupling .

In capacitive coupling, the energy is transmitted by electric fields between electrodes such as metal plates. Transmitter and receiver electrodes form a capacitor which can hold a charge, attaches to each end of the coil. An alternating voltage created by the transmitter is given to the transmitting plate, and by electrostatic induction the oscillating electric field induces an alternating potential on the receiver plate, [10] which turns into

alternating current flow in the load circuit. The amount of power transferred increases with the frequency [22] the square of the voltage, and the capacitance between the plates, which is proportional to the area of the smaller plate and (for short distances) inversely proportional to the separation. Capacitive coupling used in low power application, because the very high voltages on electrodes required transmitting significant power can be hazardous and can cause unpleasant side effects such as noxious ozone production.

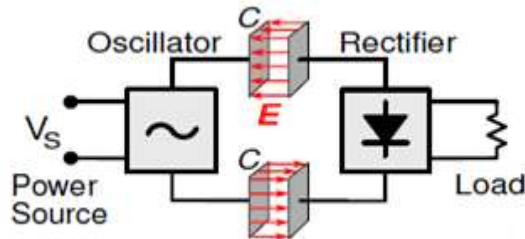


Fig.3.7 Capacitive coupling

(b) Resonant capacitive coupling

Resonance can also be used with capacitive coupling to extend the range. At the turn of the 20th century, Nikola Tesla did the first experiments with both resonant inductive and capacitive coupling. Used in order to increase large range.

4. Long-distance Wireless Power. Far-field methods are used for achieving WPT for distances longer than one wavelength by the use of propagating electromagnetic fields. Far-field or radiative region also called power beaming. In general, visible light (from lasers) and microwaves (from purpose-designed antennas) are the forms of electromagnetic radiation best suited to energy transfer. Electromagnetic radiation experiences less diffraction at shorter wavelengths.

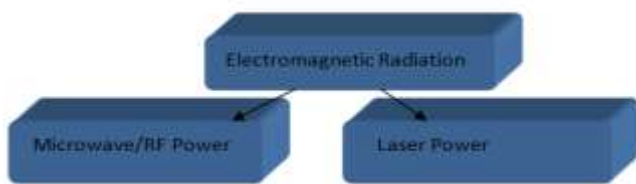


Fig.4.1 Electromagnetic Radiation

4.1 Microwave power transmission technology transfers high power from the base station to the receiving station or mobile devices with two places being in line of sight via radio waves whose wavelength are conveniently measure in small number of centimeter. This part of radio spectrum range across frequencies of roughly 1.0 GHz to 30 GHz. The most common transmitters used for microwaves is magnetron. Magnetron is used because they are cheap, efficient & power transmission is

more lenient to frequency fluctuations than communication systems are. AC needs to be converted to Direct Current (DC) first and then DC is converted to microwaves by using magnetron. Transmitted waves are received at rectenna and then rectify microwaves into electricity with more efficiently. It will give DC as the output. In the final step, DC will be converted back to AC. Lack of strong coupling leads to much lower efficiencies. This technique demands commitment of line of sight and beam approaches focusing. At present an efficiency of 76% is possible using current technology for microwave power transmission.

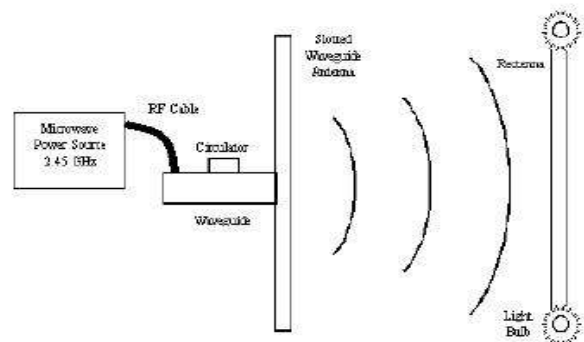


Fig.4.2 Microwave system

MPT provides the efficiency in energy conversion but it is slightly difficult to focus the beam in a small region. Power beaming using microwaves has been proposed for the transmission of energy from orbiting solar power satellites (SPS) to Earth and the beaming of power to spacecraft leaving orbit has been considered. [23][24] 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.

4.2 Laser Power Transmission: This technology the power concentrated in a small area by utilizing the mirror. This technology also produces high powers that are coherent and not dispersed for very long. But gets attenuated when it propagates through atmosphere. In addition, this technology has been used to apply to a rover to explore the presence of ice in the bottom of craters of the moon where no sunlight is available. On the other hand, the solar energy generated by the radiation is converted into the electric energy. This energy next will be converted to the laser light and then transmitted to the rover working at the bottom of the crater [25] [26].



Fig. 4.3Laser diagram of WPT

5. Advantages, Disadvantages & Biological Impacts of WPT

5.1 Advantages

- Can transfer electricity anywhere without wires i.e. Reduction of E-waste by eliminating the need of power cords.
- More reliable ,flexible & convenient.
- Short circuit and fault on cables would never exist in transmission.
- Automatic wireless charging for cordless for instruments.

5.2Disadvantages

- The particle implementation of WPT system cost seems very high.
- If proper flux linkage not possible, no power supply takes place. WPT systems can cause interference

communication systems which using microwaves or radio waves.

- This approach is good but up to certain level if transmitter and receiver antenna is high in gain so that is too much dangerous for human life may be generated radiation will create cancer
- Less efficiency compared to traditional charging

5.3Applications of WPT

- Most wide application of WPT by using satellites with giant solar arrays placed in Geosynchronous Earth Orbit. These satellites used to generate and transmit the power as microwaves to the earth known as Solar Power Satellites (SPS)
- Application of wpt Ubiquitous Power Source (or) Wireless Power Source, Wireless sensors and RF Power Adaptive Rectifying Circuits (PARC).
- Mobility -. Moving targets such as fuel free airplanes, Electric vehicles, moving robots etc.
- Used in remote controls, computer headsets sensors, wireless thermostats, smoke detectors, smart phone accessories, laptops etc.

5.4.Biological Impacts : The studies in this field shown and prove that the microwave radiation level would be never higher than the dose received while opening the door microwave oven .Also the magnetic rays will not interact with the living tissues so strong and can be easily passed through the humans or other living organisms

Comparison chart of Different Wireless Power Transmission system .

Method	Range	Directivity	Frequency	Antenna devices	Current and or possible future applications
Inductive coupling	short	Low	Hz - MHz	Wire coils	Electric tooth brush and Razor Battery charging, induction stove
Capacitive coupling	Short	Low	kHz – MHz	Electrodes	Charging portable devices, power routing in large scale integrated circuits, Smartcards.
Resonant inductive coupling	Mid	Low	MHz –GHz	Tuned wire coils, lumped element resonators	Charging portable devices (WiTricity), biomedical implants, electric vehicles

Microwaves	Long	High	GHz	Parabolic dishes, phased arrays, rectennas	Solar power satellite, powering drone aircraft
Light waves	Long	High	$\geq$ THz	Lasers, photocells, lenses, telescopes	Powering drone aircraft, powering space elevator climbers

6.Future scope of WPT

Some of the following Issue which needs for making WPT system more general and effective are

- (i) Reduce Radiation Issue.
- (ii) Improve Distance Issue.
- (iii) Improve voltage Issue.
- (iv) To develop Multiple Transmitters and Receivers System.

7.Conclusion

WPT is most wide area of research area .Wireless power transmission offers greater possibilities for transmitting power with negligible losses. WPT is certainly a promising solution to the problems aroused by the existing technology There recent technological applications that make the human life more beneficial in the present world have been discussed. Despite this the technology has not been publicly accepted due to limitation of range and safety considerations. The focus of this paper has been an overview of various methods, application that are under research, biological impacts etc.of WPT systems as well as put focus on Solar power satellites,the future of supplying non conventional energy. The brief detail of several aspects relating to history of wireless power transmission systems &recenttechnology as well as its future trends are also mentioned.

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