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# Wireless Power Transmission

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**ABSTRACT-** The technology for wireless power transfer (WPT) is a varied and a complex process. The demand for electricity is much higher than the amount being produced. Generally, the power generated is transmitted through wires. To reduce transmission and distribution losses, researchers have drifted towards wireless energy transmission. The present paper discusses about the history, evolution, types, research and advantages of wireless power transmission. There are separate methods proposed for shorter and longer distance power transmission; Inductive coupling, Resonant inductive coupling and air ionization for short distances; Microwave and Laser transmission for longer distances. The pioneer of the field, Tesla attempted to create a powerful, wireless electric transmitter more than a century ago which has now seen an exponential growth. This paper as a whole illuminates all the efficient methods proposed for transmitting power without wires.

## INTRODUCTION

Wireless power transfer involves the transmission of power from a power source to an electrical load without connectors, across an air gap. The basis of a wireless power system involves essentially two coils – a transmitter and receiver coil. The transmitter coil is energized by alternating current to generate a magnetic field, which in turn induces a current in the receiver coil (Ref 1). The basics of wireless power transfer involves the inductive transmission of energy from a transmitter to a receiver via an oscillating magnetic field. To achieve this Direct Current (DC), supplied by a power source, is converted into high frequency Alternating Current (AC) by specially designed electronics built into the transmitter. The alternating current energizes a copper wire coil in the transmitter, which generates a magnetic field. Once a second (receiver) coil is placed within proximity of the magnetic field, the field can induce an alternating current in the receiving coil. Electronics in the receiving device then converts the alternating current back into direct current, which becomes usable power.

According to the Department of Energy, California lost about 19.7 x $10^9$ kWh of electrical energy through transmission/distribution in 2008.This amount of energy loss was equal to 6.8% of total amount of electricity used in the state throughout that year (Ref 2). At the 2008 average retail price of $0.1248/kWh, this amounts to a loss of about $2.4B worth of electricity in California, and a $24B loss nationally (Ref 3). This loss is mainly due to resistive loss and corona loss during transmission of current through wires. The power is dissipated in the form of useless heat as the current attempts to overcome the ohmic resistance of the line, and is directly proportional to the square of the rms current traveling through the line and the resistance of the conductor (Ref 4). A corona discharge is an electrical discharge brought on by the ionization of a air surrounding a conductor that is electrically energized which results in power loss from the system(Ref 5). To avoid these losses, scientists are now-a-days lured towards wireless energy transfer that has a non-resisitance condition.

## TESLA'S INCEPTION OF WIRELESS ENERGY TRANSFER

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Tesla spent his funds from invention of AC current on his other inventions and culminated his efforts in a major breakthrough in 1899 at Colorado Springs when he propounded to have transmitted 100 million volts of high-frequency electric power wirelessly over a distance of 26 miles at which he had lit up a bank of 200 light bulbs and ran one electric motor. With this Tesla coil, Tesla claimed that only 5% of the transmitted energy was lost in the process. But broke of funds again, he looked for investors to back his project of broadcasting electric power in almost unlimited amounts to any point on the globe. The method he would use to produce this wireless power was to employ the earth's own resonance with its specific vibrational frequency to conduct AC electricity via a large electric oscillator. When J.P. Morgan agreed to underwrite Tesla's project, a strange structure was begun and almost completed near Wardenclyffe in Long Island, N.Y. Looking like a huge lattice-like, wooden oil derrick with a mushroom cap, it had a total height of 200 feet. Then suddenly, Morgan withdrew his support to the project before completion and Wardenclyffe was shut down by 1905 (Ref 6). Though the project had not meet its needs, the commencement of this research by Tesla has illuminated the scientists and the field has now achieved greater heights with good results.

## WIRELESS POWER TRANSFER FOR SHORT AND LONG DISTANCES

All the wireless power transfer systems require a transmitter to send signals, a receiver to receive the signals and a medium. Power can be transmitted over short as well as long range. For short range transmission there are three methods available so far:

**1. Inductive coupling** : To transmit power by electromagnetic induction.
**2. Resonant Inductive Coupling** : To transmit power by induction between coils at resonance.
**3. Air Ionization** : To transmit power by ionising the medium i.e air.

For long range transmission there are two methods proposed:
1. **Microwave transmission** : To transmit power by long distance power beaming with shorter wavelengths,in microwave range.
2. **Laser transmission** : To transmit power by converting electricity into a laser beam that is then pointed at a photovoltaic cell.

## NEAR FIELD TECHNIQUES

### INDUCTIVE COUPLING

Two conductors are referred to as mutual-inductively coupled when they are configured such that change in current flow through one wire induces a voltage across the ends of the other wire through electromagnetic induction. In wireless transfer, a portion of the magnetic flux established by one circuit interlinks with the second circuit, then two circuits are coupled magnetically and the energy is transferred from one circuit to the another circuit The basics of this process is that the transmitter and receiver coils are inductively coupled. Oscillators are used in transmitters to convert DC current to AC current. The AC current passed in the transmitter coil generates magnetic field, which induces a voltage in receiver coil. Magnetic Field is concentrated in small volume between transmitter and receiver (Ref 1).The receiver has a rectifier that converts

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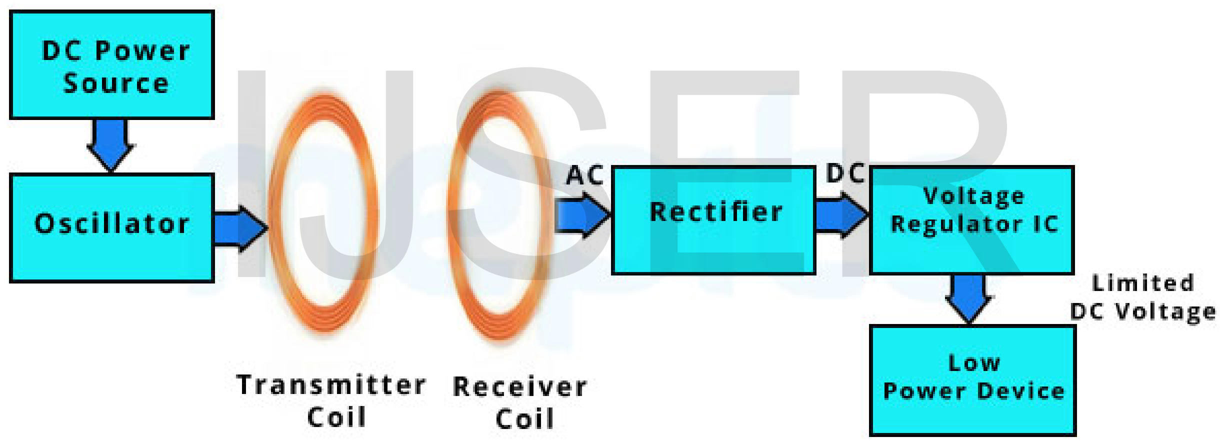
AC back into DC for use. The voltage regulator is meant to maintain a constant voltage. The effect of inductance can be magnified or amplified through coiling the wire. Inductive coupling energy transfer carries a far lower risk of electrical shock, when compared with conductive charging, because there are no exposed conductors. The main disadvantages of this method is its lower efficiency and increased resistive heating in comparison to direct contact.Inductive charging also requires drive electronics and coils that increase manufacturing complexity and cost (Ref 7). Wireless charging pad, electric brush, transformer work based on this concept.

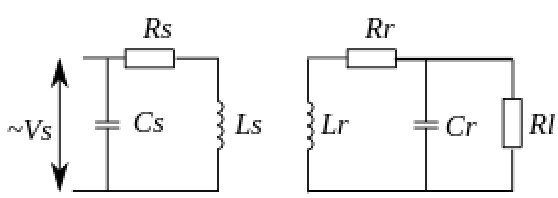
## RESONANT INDUCTIVE COUPLING

Resonant inductive coupling is transmitting power between two coils that are tuned to resonate at the same frequency. Resonance occurs when the self-resonant frequency of coils equal to the frequency of AC power supply, when the equivalent circuits of coils in high frequency have the minimum impedance. Then, the most energy will be transferred from the resonant path (Ref 8). Resonant transfer works by making a capacitively loaded primary coil *ring* with an oscillating current. This generates an oscillating magnetic field. Because the coil is highly resonant, any energy placed in the coil dies away relatively slowly over very many cycles; but if a second coil is brought near it, the coil can pick up most of the energy before it is lost, even if it is some distance away. The fields used are predominately non-radiative (Ref 1). Magnetic resonant coupling can also be used to deliver power from a large source coil to one or many small load coils with lumped capacitors at the coil terminals providing a simple means to match resonant frequencies for the coils (Ref 9).In this method, losses occur due to ohmic resistance and




radiation. Some of these wireless resonant inductive devices operate at low milliwatt power levels and are battery powered. Others operate at higher kilowatt power levels. Current implantable medical and road electrification device designs achieve more than 75% transfer efficiency at an operating distance between the transmit and receive coils of less than 10 cm (Ref 1). Deployed systems already generate magnetic fields, for example induction cookers and contactless smart card readers.

## AIR IONISATION




Ionisation of air is the toughest technique of energy transfer. When the electric field becomes very strong around 2.11MV/m, conditions are ripe for the air to begin breaking down. The electric field causes the surrounding air to become separated into positive ions and electrons -- the air is ionized.The ionization does not mean that there is more negative charge (electrons) or more positive charge (positive atomic nuclei / positive ions) than before. This ionization only means that the electrons and positive ions are farther apart than they were in their original molecular or atomic structure. The importance of this separation/stripping is that the electrons are now free to move much more easily than they could before the separation. So this ionized air is much more conductive than the previous non-ionized air. Incidentally, the ability or freedom of the electrons to move is what makes any material a good conductor of electricity (Ref 10). The advantages of adopting this technique include no e-waste, harmless if the field strength is within limits and less maintenance cost. However this system has its own disadvantages. The distance constraint is the main drawback since ionization cannot lit up receiver at long distances. The initial cost is very high and the feasibility of the system is not assuurable.

## FAR FIELD ENERGY TECHNIQUE

### MICROWAVETRANSMISSION

Microwave transmission refers to the technology of transmitting information or energy by the use of electromagnetic waves whose wavelengths are conveniently measured in small numbers of centimetre; they are called microwaves. The wireless energy transfer with microwaves need a source of electromagnetic radiation, and a microwave receiver with a DC rectifier to transform the microwave energy into DC electrical power(Ref 11). The transmitting and receiving units has to be in line of sight. Line of sight (LoS) is a type of propagation that can transmit and receive data only where transmit and receive stations are in view of each other without any sort of an obstacle between them (Ref 12). The electrical energy is first converted into microwave energyin the transmitter which is transmitted over distance to receiver which has rectenna that converts these microwaves back into electrical energy. AC cannot be converted directly to microwave in a transmitter. First it has to be converted to DC using oscillator.In the receiver, the ouput DC from rectenna is converted to AC for use. 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. Wireless high power transmission using microwaves is well proven. Experiments in the tens of kilowatts have been performed at Goldstone in California in 1975 and more recently (1997) at Grand Bassin on Reunion Island. These methods achieve distances on the order of a kilometer.Under experimental conditions microwave conversion efficiency was measured to be around 54% (Ref 1).

### LASER TRANSMISSION

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. A laser differs from other sources of light because it emits light *coherently*. Spatial coherence allows a laser to be focused to a tight spot. The mechanism of producing radiation in a laser relies on stimulated emission, where energy is extracted from a transition in an atom or molecule (Ref 13). Power can be transmitted by converting electricity into a laser beam that is then pointed at a photovoltaic cell.This mechanism is generally known as "power beaming" because the power is beamed at a receiver that can convert it to electrical energy(Ref 13 &14 ).There are lot of advantages in this system It allows narrow beam cross-section area for transmission over large distances; Compact size; No radio-frequency interference to existing radio communication. There are various disadvantages too.Laser radiation is hazardous. Conversion between electricity and light is inefficient. Photovoltaic cells achieve only 40%–50% efficiency. Atmospheric absorption, and absorption and scattering by clouds, fog, rain, etc .It requires a direct line of sight with the target (Ref 14).This method has been used in military and aerospace applications.

The near field techniques find its application in electric automobile charging, consumer electronics and electric purposes.Far field techniques are proposed to be used to transfer energy to remote areas, solar power satellites and to broadcast energy globally. Thus transmission without wires has become reality and is highly efficient. Though the initial cost is high, the maintenance cost is low and is worthy. Losses due to wires are reduced considerably and reduction in energy crisis can be achieved. In a few years, entire power transfer would be wireless striving to achieve 100% efficiency.

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