Scholarly Research Journal for Interdisciplinary Studies,
Online ISSN 2278-8808, SJIF 2018 = 6.371, www.srjis.com
PEER REVIEWED JOURNAL, NOV-DEC, 2018, VOL- 6/48

WIRELESS POWER TRANSFER (WPT): REVIEW PAPER & A PRODUCT DESIGN

Raghav Bansal

Electrical and Electronics engineering, University Institute of Engineering and Technology, Panjab University, Chandigarh, raghavp36@gmail.com

Abstract

In this review paper we will see an overview of wireless transmission of electrical energy, its recent researches and developments in the field. We will discuss the challenging issues, its merits and demerits. Distinguish WPT on basis of distance and different methods applied to achieve the same. Discuss an original product design based on WPT.

Keywords: *Wireless power transfer, Induction, Electromagnetic transmission, Evanescent wave coupling, Electrodynamic induction, Radio waves, microwaves, Electrostatic Induction.*

I. Introduction:

Nikola Tesla was the first person to envision power supply to the world without the need of wires. In 1890 he experimented with transmitting power by inductive and capacitive coupling using spark-excited radio frequency resonant transformers, now called Tesla coils, which generated high frequency AC voltages. From then scientists have been implementing different techniques to improve the technology which could lead to clean sources of electricity. These techniques can be classified according to the different field regions (Near-Field and Far-Field). These include methods like inductive coupling, resonant inductive coupling, electrostatic induction, laser power beaming, microwave power transfer (MPT) etc. Challenges like initial cost, health hazard, environmental effect and efficiency of wireless transmission (it gets reduced for long distance because of diffraction of EM signal) are still under research. This paper discusses all these issues and survey research publications to find the feasibility of wireless power transmission in practical for coming days.

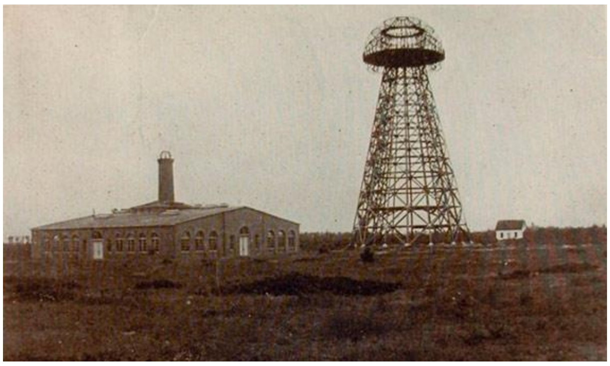

Fig. 1. Wardenclyffe Tower also known as the Tesla Tower built by Nikola Tesla in 1901-1902

Fig. 2. Wireless power transfer in practical

Field Regions:

A steady current (DC) flowing through some conductor produces an electric field. This electric field does carry energy but can't carry power as it is static. We need time varying field to carry power such as found in an alternating current (AC) which creates time-varying electric and magnetic fields in the space around them. These oscillating electric and magnetic fields can be divided into two regions, depending on the transmitter distance from the antenna. The fields have different characteristics in these regions, and different technologies are used for transferring power:

Near-Field or Nonradiative Region (Evanescent wave coupling): This means the area within about 1 wavelength (λ) of the antenna. In this region the oscillating electric and magnetic fields are separate and power can be transferred via electric fields or via magnetic fields. These fields are not radiative, meaning the energy stays within a short distance of the transmitter. If there is no receiving device or absorbing material within their limited range to couple to, no power leaves the transmitter. The power transmitted decreases exponentially with distance. Therefore, these techniques cannot be used for long range power transmission.

- **Short range** – Range is up to about one antenna diameter. This is the range over which ordinary non-resonant capacitive or inductive coupling can transfer practical amounts of power.
- **Mid-range** – Range is up to about ten times the antenna diameter. This is the range over which resonant capacitive or resonant inductive coupling can transfer practical amounts of power.

Far-field or radiative region – Beyond about 1 wavelength (λ) of the antenna, the electric and magnetic fields are perpendicular to each other and propagate as an electromagnetic wave; examples are radio waves, microwaves, or light waves. This part of the energy is radiative, meaning it leaves the antenna whether or not there is a receiver to absorb it. The portion of energy which does not strike the receiving antenna is dissipated and considered as a loss. Electromagnetic radiation can be focused by reflection or refraction into beams. By using a high-gain antenna or optical system which concentrates the radiation into a narrow beam aimed at the receiver, it can be used for long range power transmission.

II. Techniques and Development:

Nonradiative techniques:

- **Inductive coupling:**

Inductive coupling is the oldest and most widely used wireless power technology and virtually the only one so far which is used in commercial products. In inductive coupling the power transfer happens between coils of wire by magnetic field. The simplest example of this is transformer. The primary and secondary circuits of a transformer are electrically isolated from each other. The transfer of energy takes place by electromagnetic coupling through a process known as mutual induction (An added benefit is the capability to step the primary voltage either up or down). The electric toothbrush charger is an example of how this principle can be used. A toothbrush's daily exposure to water makes a traditional plug-in charger potentially dangerous. Ordinary electrical connections could also allow water to seep into the toothbrush, damaging its components. Because of this, most toothbrushes recharge through inductive coupling. However the fastest growing use is wireless charging pads to recharge mobile and handheld wireless devices such as laptops, tablet computers, cell phones, digital media players, and video game controllers.

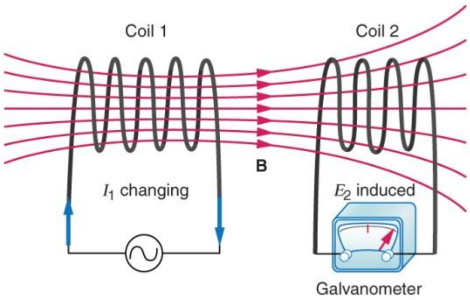

Fig.3. Two coils linking through magnetic field and transferring power wirelessly

Fig. 4. A device by Powerbyproxi, charging multiple mobiles wirelessly simultaneously

- **Resonant inductive coupling (Electrodynamic Coupling):**

Nikola Tesla first discovered resonant coupling during his pioneering experiments in wireless power transfer around the turn of the 20th century, but the possibilities of using resonant coupling to increase transmission range has only been explored recently. Resonant inductive coupling is a form of inductive coupling in which power is transferred by magnetic fields between two resonant circuits (tuned circuits), one in the transmitter and one in the receiver. Each resonant circuit consists of a coil of wire connected to a capacitor, or a self-resonant coil or other resonator with internal capacitance. The two are tuned to resonate at the same resonant frequency. The resonance between the coils can greatly increase coupling and power transfer. Resonant technology is currently being incorporated in modern inductive wireless power systems. One of the possibilities envisioned for this technology is that a coil in the wall or ceiling of a room might be able to wirelessly power lights and mobile devices anywhere in the room, with reasonable efficiency. An environmental and economic benefit of wirelessly powering small devices such as clocks, radios, music players and remote controls is that it could drastically reduce the 6 billion batteries disposed of each year, a large source of toxic waste and groundwater contamination.

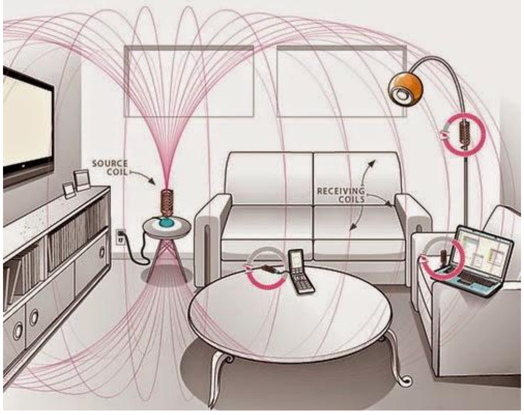

Fig. 5. Pictorial representation of how multiple devices can be powered through a single coil

- **Capacitive Coupling (Electrostatic Induction):**

Capacitive coupling is the conjugate of inductive coupling; energy is transmitted by electric fields between electrodes such as metal plates. The transmitter and receiver electrodes form a capacitor, while treating the intervening space as the dielectric. An alternating voltage generated by the transmitter is applied to the transmitting plate, and the oscillating electric field induces an alternating potential on the receiver plate by electrostatic induction, which causes an alternating current to flow in the load circuit. The amount of power transferred increases with the frequency, 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 has recently been applied to charging battery powered portable devices as well as charging or continuous wireless power transfer in biomedical implants, and is being considered as a means of transferring power between substrate layers in integrated circuits. **Resonant capacitive coupling** can be used to extend the range. At the turn of the 20th century, Nikola Tesla did the first experiments with both resonant inductive and capacitive coupling.

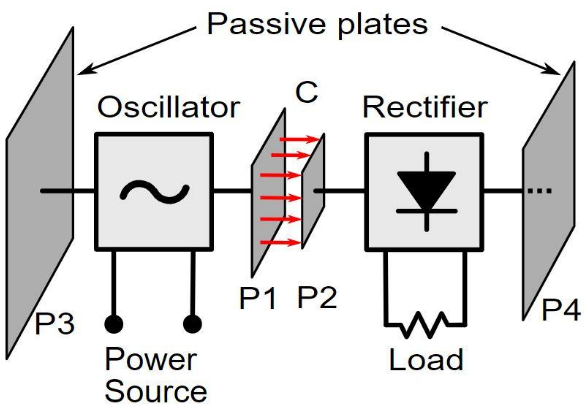

Fig. 6. Representation of power transfer between two metal plates P1 and P2

Radiative techniques:

Far field methods are used for longer ranges, often multiple kilometer ranges, where the distance is much greater than the diameter of the device. In general, visible light (from lasers) and microwaves (from purpose-designed antennas) are the forms of electromagnetic radiation best suited to energy transfer.

- **Microwaves:**

The Microwave Power Transfer (MPT) system works by converting power to microwaves through a microwave generator and then transmits that power through free space where it is received and converted back to power at a special device called a rectenna. A complete microwave transmission system consists of three essential parts:

- Electrical power to microwave conversion
- Absorption antenna that captures the waves
- (Re) conversion to electrical power

The challenges faced by Microwave power transmitter are with respect to some factors like antenna design, diffraction, interference, cost of the system, health hazard, and environmental issues. For transmission efficiency the waves must be focused so that all the energy transmitted by the source is incident on the wave collection device (rectenna). Microwave transmissions are not particularly hindered by significant attenuation loss due to Rayleigh scattering because the transmitted wavelengths tend to be long enough to mitigate this effect. However the Rayleigh criterion necessitates a receiving antenna proportional to the longer wavelength and thus system must account for large transmitting and receiving antennas. Lower the frequency larger the antenna is required hence the frequency chosen for MPT is in the range of2.45 GHz and 5.8GHz. A general public perception that microwaves are harmful has been a major obstacle for the acceptance of power transmission with microwaves. A major concern is that the long-term exposure to low levels of microwaves might be unsafe and even could cause cancer. Since 1950, there have been thousands of papers published about microwave bio-effects. The scientific research indicates that heating of humans exposed to the radiation is the only known effect. There are also many claims of low-level non-thermal effects, but most of these are difficult to replicate or show unsatisfying uncertainties. Public acceptance of wireless power transfer by microwaves is needed for the success of WPT. More number of practical projects should validate the safe limits of MPT which encourages the public and government in implementing such projects.

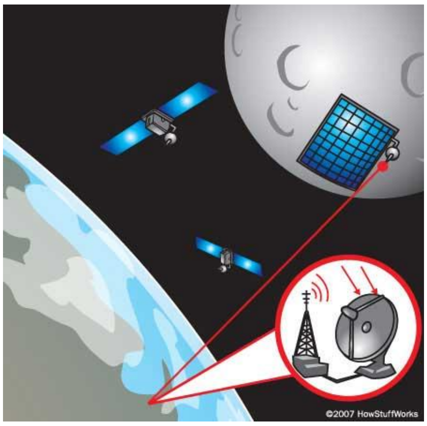

Fig. 7. Wireless power transfer from space through microwaves using solar power generating satellites

Current technology under development on MPT is regarding **solar power generating satellites.** These are planned to be launched into space and transmit power to Earth stations. This idea was first proposed in 1968 and all of the experiments have only been carried out in terrestrial laboratories. The SPS satellites would be put in high earth orbit at geosynchronous location. This would allow them to receive light 99% of the year. A large rectenna array facility will be built on the Earth to collect the incoming microwaves. To maintain a good lock on the rectenna the satellite will need to be built with a retrodirective transmitter which locks on to a pilot beam emanated from the ground station. Since most of the research is done in the 2.4 GHz to 5.8 GHz range there are some spectrum regulatory issues to deal with. Also since the retro directive antenna system is unproven. There is the health concern that the microwave beam could veer off target and microwave some unsuspecting family. However, a Japanese government agency is planning to send up 10 to 100 kW low earth orbit satellite to prove its feasibility.

Fig. 8. Stationary High Altitude Relay Platform (SHARP) airplane, having a large rectenna behind the wings, allowing for power to be transmitted to it from the earth, and thus is able to stay in the air for long periods of time, potentially months

- **Lasers (Power Beaming):**

In the case of electromagnetic radiation closer to the visible region of the spectrum, power can be transmitted by converting electricity into a laser beam that is then pointed at a photovoltaic cell. This mechanism is known as power beaming because the power is beamed at a receiver that can convert it to electrical energy. At the receiver, special photovoltaic laser power converters which are optimized for monochromatic light conversion are applied. Lasers can be used for long distance power transmission. Small size products can produce high power laser which gives them a advantage over other long power transmission techniques. But like with every other electromagnetic wave transmission technique lasers are hazardous. Low level lasers can blind humans and animals whereas high power can kill through localized spot heating. Lasers lose their intensity due to absorption and scattering, moreover the efficiency of converting laser light into electricity is only 40% - 50%. Laser power beaming is being explored in military weapons and aerospace applications. NASA Dryden flight Research Centre demonstrated a lightweight unmanned model plane powered by a laser beam to show the proof-of-concept.

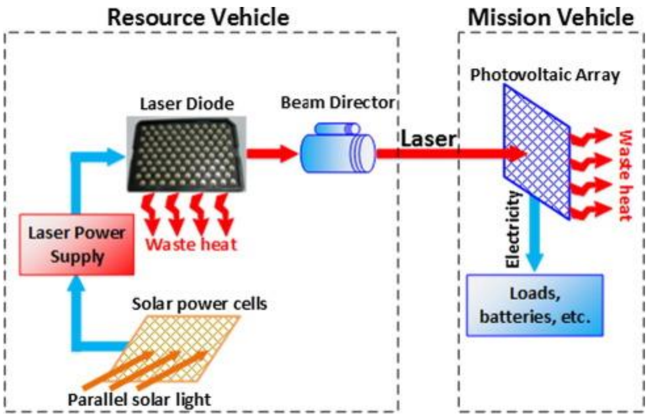

Fig. 9. Process of WPT through power beaming

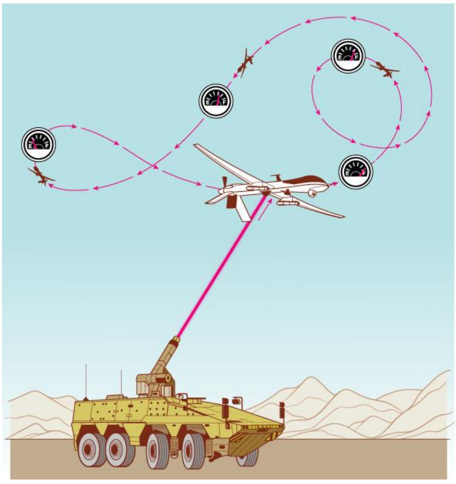

Fig. 10. Pictorial representation of powering an airplane through lasers

III. Advantages & Disadvantages:

Advantages

- An electrical transmission system based on WPT will reduce the cost of transmission system drastically.
- It'll remove all the wires, substations, poles, overhead lines etc from the system. Just plain generation, transmitter and a receiver will be there
- The system will become efficient. Line losses will be removed
- As there are no wires thus problems like faults (short circuits, breaking of lines from high tension points etc.), formation of capacitance and inductance between wires, sag problems etc will be simply removed
- The distance to which electrical energy has to be transmitted will not be a problem anymore as no transmission system is required now. Energy could be transmitted through air only.

Disadvantages:

- The initial cost of setting up the system will be very high
- Interference of microwaves with current communication system
- Fear in common man of exposure to microwaves

IV. Conclusion:

The discussion began by what is wireless power transfer and different practical and theoretical methods to make it work. Advantages, disadvantages and development in WPT are discussed. WPT is commercially been implemented in many short distance power transfer applications; whereas for long distance only test experiments and theoretical data exists. Microwave power transfer method is considered a better option than laser power beaming for the current technology available. WPT has the potential to completely disrupt and revolutionize existing and future technologies. It has been a topic of interest in past and will continue to be in future.

V. Original Product Design Based On WPT:

In today's world everyone has a cell phone. Mobile phones are getting new technology every day, bigger and better screens to view and a lot of advanced internal hardware to perform all your daily tasks you put on them; and to power all that we need a battery. Many methods have come in market to charge the battery, broadly divided into two types: wired charging & wireless charging. Wired charging methods like turbo charging, quick charging, fast charging etc. but still they all need a cable to supply the power to the battery; whereas in wireless charging, the power is transferred directly to the phone without any wires. The WPC's Qi standard is the most popular standard being adopted by companies to make their wireless charging pads.

Fig. 11. Mobile phone being chargen on a wireless charging pad

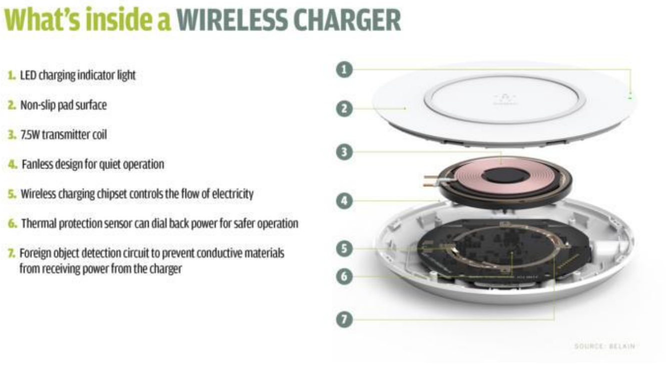

Fig. 12. Inside look of a wireless charging pad

Fig. 13. Inside look of a phone enabled for wirelss charging

To keep the aesthetic look and feel of the phone battery size has to be kept in a limit so that it doesn't get too bulky nor does it drain very quickly. So with all the new applications and advancement in software of the phones, the battery still has to be kept in the very same limits. With all the new methods of charging they still can't be used on the move.

Battery power banks are in the market but they are difficult and bulky to carry. Everyone uses a cover on their phone to protect it from accidental drops and scratches. So why not integrate the two and make a mobile phone cover which has integrated wireless charging pad and a battery. Which you can directly put on your phone as a normal cover and it will charge your phone on the go.

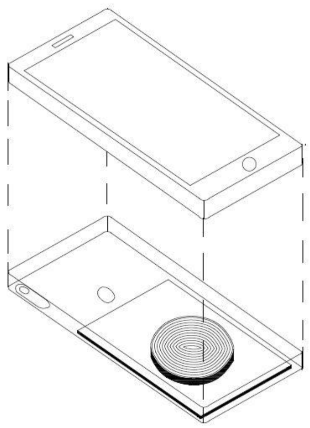

Fig. 14. Representation of design

The wireless charging phone cover can be charged through any wireless charging pad and then can be put on the phone to act as a portable battery source.

VI. References:

Sagolsem Kripachariya Singh, "Wireless Transmission of Electrical Power Overview of Recent Research & Development"

R Rajalakshmi, "An overview of the current state-of-an-art in the field of wireless power transmission"

ER. Upendra Pal Singh, "Charging on the move (through wireless)"

Paramanand.S.Patil, Satyanarayan.K.Padaganur, "Challenging Issues In Wireless Power Transmission Methods A Survey"

Dylan Jorgensen, Chris Loadman and Zhizhang (David) Chen, "Retrodirective Antenna Systems for Wireless Communications"

Adarsh Gawai, Pranshu Umale, Sayali Urkude, "Wireless Transmission of Electrical Power"

Vikash Choudhary, Satendar Pal Singh, Vikash Kumar and Deepak Prashar, "Wireless Power Transmission: An Innovative Idea"

Jayshree Sonawane , Sonal Benare, "Wireless Power Transmission Using Microwaves"

Wireless power transfer, https://en.wikipedia.org/wiki/Wireless_power_transfer

Beaming Up, https://www.seattlebusinessmag.com/article/beaming

Wireless transmission of energy, https://teslaresearch.jimdo.com/wireless-transmission-of-energy-1/

Stanford Scientists Are Making Wireless Electricity Transmission a Reality, https://futurism.com/stanford-scientists-are-making-wireless-electricity-transmission-a-reality

Wireless charging explained: What is it and how does it work? , https://www.computerworld.com/article/3235176/mobile-wireless/wireless-charging-explained-what-is-it-and-how-does-it-work.html

The basics of power banks, https://www.xtpower.de/Technology-The-Basics-of-Power-Banks-and-Solar-Panels

Making Wireless Energy for the Entire Planet—Nikola Tesla's Wardenclyffe Tower, https://www.youtube.com/watch?v=KIR7tcS5d8A

How Does Wireless Charging Work? || Crude Wireless Energy Transfer Circuit, https://www.youtube.com/watch?v=ExU32UyGX6w