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Review Paper on Wireless Power Transmission for Energy Harvesting System

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Abstract: ***According to current stage every human being wireless system as we know there is lots of systems are there which are use for wireless communication like GSM, WiFi, BLE, Bluetooth etc. Now if we are talking about wireless power transmission so this is still a current research area for all researchers. Right now we are using wire system for power transmission but everyone demand wireless system. Right now there is lots of commercial and non commercial sector where everyone need wireless power transmission system, those sector like WSN networking, Remote Location based industries etc. These applications are currently using battery system or direct wired system now if we are talking about WSN network system so those system are require less power and working on battery but lifetime of battery is limited so that's why there is need of wireless power system. In this paper basically we did comparative study about the previous existing wireless power transmission system and find out some research issue which can be treating like a future research objective for this area.***

Keywords: Induction, Electromagnetic, Laser, wireless sensor network, Wireless power transmission (WPT)

1. Introduction

Wireless Power Transfer (WPT) is the process of transferring power from one circuit onto another without passing through any manmade conductive elements interconnecting them. Several schemes for wireless power transfer exists – Inductive, Capacitive, Laser, Microwave etc. Of these, Inductive Power Transfer (IPT) is the most popular and is being extensively studied particularly from the last two decades. The area of wireless power transmission is very interesting. The technology is in its infancy but the overall benefits from its maturation could be significant to society as a whole. World population is expected to continue to grow exponentially. Five sixths of the world's population lives in developing nations. Most developing nations such as China, India, and Pakistan are rapidly improving their standard of living.

All of these trends point to an energy demand that will grow at even a larger rate. Wireless power transmission could one day allow us to generate solar power on a satellite and beam it down to Earth, transmit power to a water treatment plant for a disaster relief operation or power a flying communication relay station from a terrestrial station. In current stage there are lots of researches who are working on this are and they have developed several techniques for moving electricity over long distances without wires. Some exist only as theories or prototypes, but others are already in use.

As we know there is lots of approaches for power transmission those are divided in two part:
1) Wire power Transmission
2) Wireless power transmission
Now if we are talking about Wireless power transmission system so again this system is divide in three sub part those are like:
1) Electromagnetic
2) Induction
3) Magnetic

Now again each sub part is divide in there sub part which are like:
1) Microwave
2) Laser
3) Capacitive
4) Resonant
5) Inductive

This division of wireless power transmission system is show in fig. 1.1, this figure give the details about the classification of WPT system

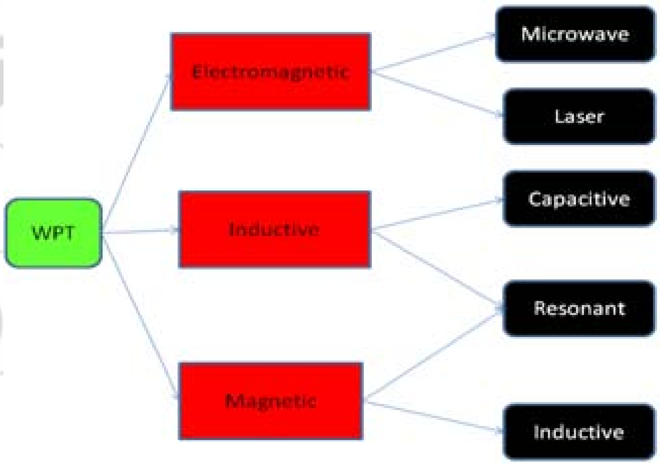

Figure 1.1: Classification of wireless power transmission

According to This paper we provides the multiple existing techniques which is used for the wireless power transmission which already we discuss previously. Wireless transmission is useful to power electrical devices in cases where interconnecting wires are inconvenient, hazardous, or are not possible. For example the life of WSN is its node which consists of several device controllers, memory, sensors/actuators,

1.1 Overview of an inductive power transfer system

Ampere's circuital law and Faraday's law of induction are the two key principles behind the operation of every magnetic induction wireless power transfer (WPT), or inductive power transfer (IPT), system. Ampere's circuital law states that a magnetic field is produced around a conductor carrying electric current with a strength proportional to the current. On the other hand, Faraday's law of induction states that an alternating magnetic field can induce an electromotive force (EMF) in a conductor that is proportional to the magnetic field's strength and its rate of change. Fig. illustrates how these two laws can be applied together to transfer power wirelessly. An alternating current is passed into a coil, referred to as the primary or transmitting coil, producing an alternating magnetic field. If a second coil, referred to as the secondary or receiving coil, is placed in close proximity with the transmitter, then the alternating magnetic field will induce an electromotive force in the receiver's coil and current will flow if a load is connected to the coil. Thus, power is being transferred from the transmitter's coil to the receiver's coil.

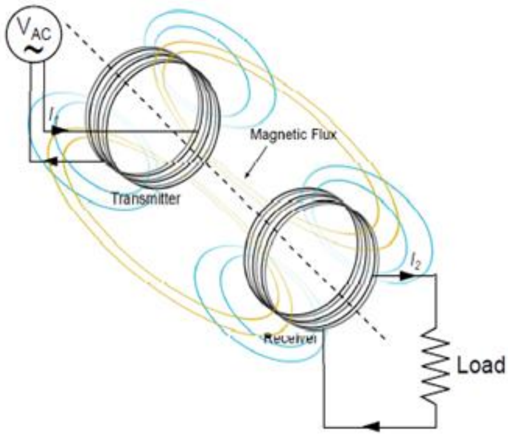

Figure 1.2: Principal of Operation of IPT System

The block diagram of a basic modern IPT system is shown in Fig.1.2. The major sections of the system that implement Ampere's and Faraday's laws are the transmitting and receiving coupled coils pair, and the DC/AC inverter. The transmitting and receiving coupled coils are referred to as the 'inductive link' section of the IPT system.

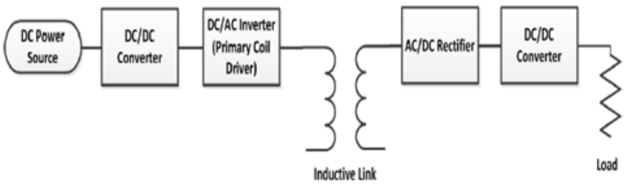

Figure 1.3: Block of IPT System

1.2 Wireless Power Transfer Systems

The history of wireless power transmission dates back to the late 19th century with the prediction that power could be transmitted from one point to another in free space by Maxwell in his "Treatise on Electricity and Magnetism". Heinrich Rudolf Hertz performed experimental validation of Maxwell's equation which was a monumental step in the direction. However, Nikola Tesla's experiments are often considered as being some of the most serious demonstrations of the capability of transferring power wirelessly even with his failed attempts to send power to space [6].

- **Classification of wireless power transfer systems**

Wireless power transfer systems can be classified into different types depending on various factors. On the basis of the distance from the radiating source, the characteristics of the EM fields change and so are the methods for achieving wireless power transfer. They can be categorized as:
1) Near field
2) Mid field
3) Far field

1.2.1Non-radiative(Near-field techniques)

In near-field or non-radiative techniques, power is transferred over short distances by magnetic fields using inductive coupling between coils of wire or in a few devices by electric fields using capacitive coupling between electrodes[5][8].

A current focus is to develop wireless systems to charge mobile and handheld computing devices such as cellphones, digital music players and portable computers without being tethered to a wall plug. Applications of this type are electric toothbrush chargers, RFID tags, smartcards, and chargers for implantable medical devices like artificial cardiac pacemakers, and inductive powering or charging of electric vehicles like trains or buses.

1.2.2 Radiative (Far-field techniques)

In radiative or far-field techniques, also called power beaming, power is transmitted by beams of electromagnetic radiation, like microwaves or laser beams. These techniques can transport energy longer distances but must be aimed at the receiver. Proposed applications for this type are solar power satellites, and wireless powered drone aircraft.

In case of near field radiation, the boundary between the regions is restricted to one wavelength. In the transition zone, the boundary between the regions is between one to two wavelengths of electromagnetic radiation. In case of far field, the distance between the radiating source and the receiver is more than twice the wavelength of the radiation. Based on the mode of coupling between the transmitter and the receiver, wireless power transfer techniques can be classified into the following:
1) Electromagnetic induction (Resonant Inductive Power Transfer)
2) Electrostatic induction (Resonant Capacitive Power Transfer)
3) Far field transfer techniques (Laser and Microwave Power Transfer)

1.2.3 Electromagnetic induction

Electromagnetic Inductive Power Transfer (IPT) 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.

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In order to improve the efficiency of power transfer, resonant mode coupling of the coils is established by means of capacitive compensation. This technique is one of the most popular for wireless power transfer and has found vast applications including powering consumer devices, biomedical implants, electric mobility, material handling systems, lighting applications and contactless underwater power delivery among many others.

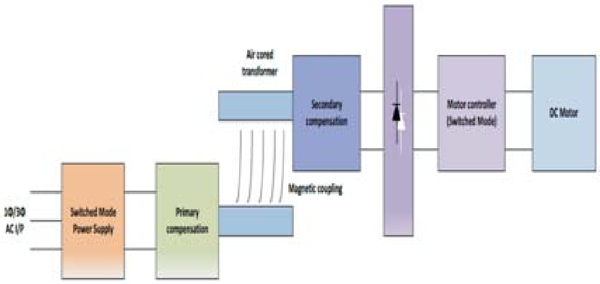

Figure 1.3: Powering system of IPT

1.2.4 Electrostatic Induction

Capacitive Power Transfer (CPT) is a novel technique used to transfer power wirelessly between the two electrodes of a capacitor assembly [6]. It is 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. Thus, in this case the energy carrier media is the electric field and hence the dual of IPT. Some of the features that CPT has compared to IPT are [6]:

1) Energy transfer can still continue even on the introduction of a metal barrier as it would result in a structure consisting of two capacitors in series.
2) Most electric fields are confined within the gap between the capacitors and hence EMI radiated and power losses are low.
3) The requirement for bulky and expensive coils doesn't exist and hence, the circuit can be made small.

In every WPT system there is need of Transceivers and battery. The transceiver can operate in four states, i.e. 1) Transmit 2) Receive 3) Idle and 4) Sleep. The major energy problem of a transmitter of a node is its receiving in idle state, as in this state it is always being ready to receive, consuming great amount of power.

However, the battery has a very short lifetime and moreover in some deployments, owing to sensor location, battery replacement may be both practically and economically infeasible or may involve significant resists to human life. That is why energy harvesting for WSN in replacement of battery is the only and unique solution. In wireless power transfer, a transmitter device connected to a power source, such as the mains power line, transmits power by electromagnetic fields across an intervening space to one or more receiver devices, where it is converted back to electric power and utilized. In communication the goal is the transmission of information, so the amount of power reaching the receiver is unimportant as long as it is enough that the signal to noise ratio is high enough that the information can be received intelligibly. In wireless communication technologies, generally, only tiny amounts of power reach the receiver. By contrast, in wireless power, the amount of power received is the important thing, so the efficiency (fraction of transmitted power that is received) is the more significant parameter.

1.3 Issues in WPT

One of the major issue in power system is the losses occurs during the transmission and distribution of electrical power. As the demand increases day by day, the power generation increases and the power loss is also increased. The major amount of power loss occurs during transmission and distribution. The percentage of loss of power during transmission and distribution is approximated as 26%[1]. The main reason for power loss during transmission and distribution is the resistance of wires used for grid. The efficiency of power transmission can be improved to certain level by using high strength composite over head conductors and underground cables that use high temperature super conductor. But, the transmission is still inefficient. According to the World Resources Institute (WRI), India's electricity grid has the highest transmission and distribution losses in the world – a whopping 27%. Numbers published by various Indian government agencies put that number at 30%, 40% and greater than 40%. This is attributed to technical losses (grid's inefficiencies) and theft [4].

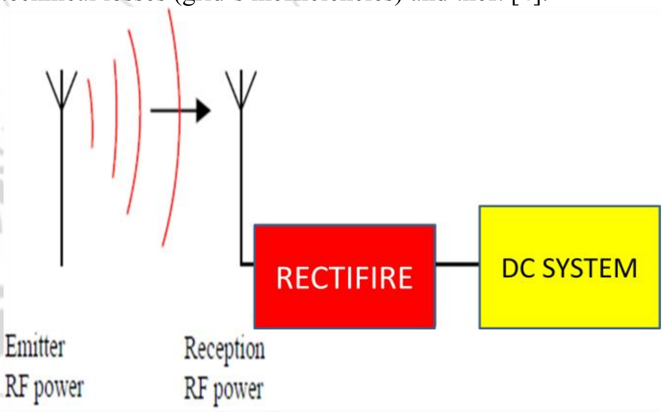

Figure 1.4: Conceptual view of the WPT system.

wavelength (λ) of the antenna. In this region the oscillating electric and magnetic fields are separate and power can be transferred via electric fields by capacitive coupling (electrostatic induction) between metal electrodes, or via magnetic fields by inductive coupling (electromagnetic induction) between coils of wire[5][6][7].If there is no receiving device or absorbing material within their limited range to "couple" to, no power leaves the transmitter. 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, and thus the power transmitted, decrease exponentially with distance, so if the distance between the two "antennas" Drange is much larger than the diameter of the "antennas" Dant very little power will be received. Therefore, these techniques cannot be used for long distance power transmission. Resonance, such as resonant inductive coupling, can increase the coupling between the antennas greatly, allowing efficient transmission at somewhat greater distances, although the fields still decrease exponentially. Therefore the range of near-field devices is conventionally divided into two categories: Short range – up to about one antenna diameter: Drange ≤ Dant. This is the range over which ordinary nonresonant capacitive or inductive coupling can transfer practical amounts of power. Mid-range – up to 10 times the antenna diameter: Drange ≤ 10 Dant. This is the range over which resonant capacitive or 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 lost to the system. The amount of power emitted as electromagnetic waves by an antenna depends on the ratio of the antenna's size Dant to the wavelength of the waves λ, which is determined by the frequency: λ = c/f. At low frequencies f where the antenna is much smaller than the size of the waves, Dant << λ, very little power is radiated. Therefore the near-field devices above, which use lower frequencies, radiate almost none of their energy as electromagnetic radiation. Antennas about the same size as the wavelength Dant ≈ λ such as monopole or dipole antennas, radiate power efficiently, but the electromagnetic waves are radiated in all directions (omnidirectionally), so if the receiving antenna is far away, only a small amount of the radiation will hit it. Therefore, these can be used for short range, inefficient power transmission but not for long range transmission. However, unlike fields, 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. From the Rayleigh criterion, to produce the narrow beams necessary to focus a significant amount of the energy on a distant receiver, an antenna must be much larger than the wavelength of the waves used Dant >> λ = c/f. Practical beam power devices require wavelengths in the centimeter region or below, corresponding to frequencies above 1 GHz, in the microwave range.

2. Literature Review

2.1 HISTORY

The literature review of WPT technologies will include the theoretical background and system concept. There are three basic methodologies to achieve wireless power transmission. They are longitudinal acoustic compression wave, inductive resonance coupling and electromagnetic propagation coupling. WPT by longitudinal acoustic compression wave was discontinued, therefore only a brief description is available as follows. The inductive resonance coupling and electromagnetic propagation coupling are modern methodology to achieve wireless power transmission. Both technologies will be described in detail latter.

In 1826 André-Marie Ampère developed Ampère's circuital law showing that electric current produces a magnetic field. Michael Faraday developed Faraday's law of induction in 1831, describing the electromagnetic force induced in a conductor by a time-varying magnetic flux. In 1862 James Clerk Maxwell synthesized these and other observations, experiments and equations of electricity, magnetism and optics into a consistent theory, deriving Maxwell's equations. This set of partial differential equations forms the basis for modern electromagnetics, including the wireless transmission of electrical energy.[9] The capital cost for particle implementation of WPT seems very high WPT may cause interference with present communication systems. Biological Impacts Common beliefs fear the effect of microwave radiation. But the studies proven that the microwave radiation level would be never higher than the dose received while opening the microwave oven door, meaning it slightly higher.

2.1.1Tesla's experiment

Tesla demonstrating wireless power transmission in a lecture at Columbia College, New York, in 1891. The two metal sheets are connected to his Tesla coil oscillator, which applies a high radio frequency oscillating voltage. The oscillating electric field between the sheets ionizes the low pressure gas in the two long Geissler tubes he is holding, causing them to glow by fluorescence, similar to neon lights. Experiment in resonant inductive transfer by Tesla at Colorado Springs 1899. The coil is in resonance with Tesla's magnifying transmitter nearby, powering the light bulb at bottom. (right) Tesla's unsuccessful Wardenclyffe power station. Inventor Nikola Tesla performed the first experiments in wireless power transmission at the turn of the 20th century, and may have done more to popularize the idea than any other individual. In the period 1891 to 1904 he experimented with transmitting power by inductive and capacitive coupling using spark-excited radio frequency resonant transformers, now called Tesla coils, which generated high AC voltages. With these he was able to transmit power for short distances without wires. In demonstrations before the American Institute of Electrical Engineers and at the 1893 Columbian Exposition in Chicago he lit light bulbs from across a stage. He found he could increase the distance by using a receiving LC circuit tuned to resonance with the transmitter's LC circuit. using resonant inductive coupling. At his Colorado Springs laboratory during 1899–1900, by using voltages of the order of 10 megavolts generated by an enormous coil, he was able to light three incandescent lamps at a distance of about one hundred feet. The resonant inductive coupling which Tesla pioneered is now a familiar technology used throughout electronics and is currently being widely applied to short-range wireless power systems.[1][2] Here we presents some of the research on this area.

Kavuri 2012[11] presents an optimization of the voltage doubler stages in an energy conversion module for Radio Frequency (RF) energy harvesting system at 900 MHz band. The function of the energy conversion module is to convert the (RF) signals into direct-current (DC) voltage at the given frequency band to power the low power devices/circuits. The de- sign is based on the Villard voltage doublers circuit. A 7 stage Schottky diode voltage doublers circuit is designed, modeled, simulated, fabricated and tested in this work.

Gianfranco[12] presntes an idea according to that designing, measuring and testing an antenna and rectifier circuit (RECTENNA) optimized for incoming signals of low power density. The rectenna is used to harvest electric energy from the RF signals that have been radiated by communication and broadcasting systems at ISM band centred in 2.45 GHz.

Venkateswara 2013[13] present the concept of transmitting power without using wires i.e., transmitting power as microwaves from one place to another is in order to reduce the cost, transmission and distribution losses. This concept is known as Microwave Power transmission (MPT). They also discussed the technological developments in Wireless Power Transmission (WPT).

Allen[14] presents a design and experimental implementation of a power harvesting metamaterial. There proposed design is working in the frecquency of 900MHz. Tamal[15] presents a simulated and designed 1,7 & 9-stage voltage multipliers which led to the final statements that :1) Higher voltage can be achieved by increasing the number of circuit stages; and 2) Voltage gain decreases with increasing number of stages. Zahriladha[16] presents an overview and the progress achieved in RF energy harvesting, which involves the integration of antenna with rectifying circuit. Different combinations of antenna and rectifier topologies yield diverse results. Therefore, this study is expected to give an indication on the appropriate techniques to develop an efficient RF energy harvesting system.

Nahida[17] presents an optimization of the voltage doublers stages in an energy conversion module for Radio Frequency (RF) energy harvesting system at 950 MHz band is presented.Two 10 stage voltage multipliers were designed and the Agilent diode HSMS-2850 and HSMS-2822 were compared, Agilent's HSMS-286x family of DC biased detector diodes have been designed and optimized for use from 915 MHz to 5.8 GHz.

Prusayon[18] presents a twofold contribution. First, they propose a dual-stage energy harvesting circuit composed of a seven-stage and ten-stage design, the former being more receptive in the low input power regions, while the latter is more suitable for higher power range. TARIS [19] presents a guideline to design and optimize a RF energy harvester operating in ISM Band at 902 MHz. The circuit is implemented on a standard FR4 board with commercially available off-the-shelf devices. The topology of the impedance transformation block is selected to reduce the losses which improves the overall performances of the system.

3. Previous Research Issue

Wireless power transmission is new and progressive area. As we are living in the era of wireless communication. So there is need of wireless power transmission system. But previous existing wireless power transmission is have some limitations are problem. According to previous coil based magnetic induction is very dangerous for human life. But still with some good efficiency & modification there is some PAD based charger is available which is based on magnetic induction. But those charger have the limitation of distance. Now for complete wireless power transmission is under research area. Some researchers are present there model which is based on WPT (wireless power transmission) but those approach are having the issue with distance, efficient power generation, radiation issue & costing issue

4. Future Objective on WPT

As we already see there is lots of issues in previous existing approaches. So in this thesis our objectives are to reduce previous existing problems. So our thesis objectives are followings:

- **Reduce Radiation Issue.**
- **Improve Voltage Issue.**
- **Improve Distance Issue.**
- **Useful for human beings**

So basically these are my thesis objective which I will try to reduce by my propose technique.

5. Application of WPT

Moving targets such as fuel free airplanes, fue free electric vehicles, moving robots and fuel free rackets. The another application of WPT are solar power satlites, energy to remote areas, broadcast energy globally. The another application of WPT ARE Ubiquitous power source, RF power Adaptive Rectifying Circuits(PARC).

6. Benefits & Limitations of WPT

Here we presents the benefits and limitations of WPT approach.

Benefits

It make devices more convenient and thus more desirable to purchasers, by eliminating the need for a power cord or battery replacement. The power failure due to short circuit and fault on cables would never exist in transmission.

Limitations :

This approach is good but upto 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.

7. Conclusion

As we already know now a days WPT is most important research area. This concept will change human life in very simple Way. The concept of wireless power transmission offers greater possibilities for transmitting power with negligible losses. In the long run, this could reduce our society's dependence on batteries, which are currently heavy and expensive.

So in this paper we did the comparative study on the previous existing wireless power transmission approach and according to our study we can say that there is lots of scope on this area.

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