WIRELESS POWER TRANSMISSION

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ABSTRACT

The main objective of this project is to develop a device for wireless power transfer. The concept of wireless power transfer was realized by Nikolas Tesla. Wireless power transfer can make a remarkable change in the field of the electrical engineering which eliminates the use conventional copper cables and current carrying wires. Based on this concept, the project is developed to transfer power within a small range. This project can be used for charging batteries those are physically not possible to be connected electrically such as pace makers (An electronic device that works in place of a defective heart valve) implanted in the body that runs on a battery. The patient is required to be operated every year to replace the battery.

This project is built upon using an electronic circuit which converts AC 230V 50Hz to AC 12V, High frequency. The output is fed to a tuned coil forming as primary of an air core transformer. The secondary coil develops a voltage of HF 12volt. Thus the transfer of power is done by the primary (transmitter) to the secondary that is separated with a considerable distance (say 10cm). Therefore the transfer could be seen as the primary transmits and the secondary receives the power to run load.

Moreover this technique can be used in number of applications, like to charge a mobile phone, iPod, laptop battery, propeller clock wirelessly. And also this kind of charging provides a far lower risk of electrical shock as it would be galvanically isolated. This concept is an Emerging Technology, and in future the distance of power transfer can be enhanced as the research across the world is still going on.

Keywords- **Wireless Power Transmission (WPT), Resonance, Witricity, Nikola Tesla etc.**

I-INTRODUCTION

Wireless power transmission (WPT) is an efficient way for the transmission of electric power from one point to another through vacuum or atmosphere without the use of wire or any substance. By using WPT, power can be transmitted using inductive coupling for short range, resonant induction for mid-range and Electromagnetic wave power transfer. By using this technology, it is possible to supply power to places, which is hard to do using conventional wires. Currently, the use of inductive coupling is in development and research phases. The most common wireless power transfer technologies are the electromagnetic induction and the microwave power transfer. For efficient midrange power transfer, the wireless power transfer system must satisfy three conditions: (a) high efficiency, (b) large air gap, (c) high power. The microwave power transfer has a low efficiency. For near field power transfer this method may be inefficient, since it involves radiation of electromagnetic waves. Wireless power transfer can be done via electric field coupling, but electric field coupling provides an inductively loaded electrical dipole that is an open capacitor or dielectric disk. Extraneous objects may provide a relatively strong influence on electric field coupling. Magnetic field coupling may be preferred, since extraneous objects in a magnetic field have the same magnetic properties as empty space. Electromagnetic induction method has short range. Since magnetic field coupling is a non radiative power transfer method, it has higher efficiency. However, power transfer range can be increased by applying magnetic coupling with resonance phenomenon applied on. A magnetic field is generated when electric charge moves through space or within an electrical conductor. The geometric shapes of the magnetic flux lines produced by moving charge (electric current) are similar to the shapes of the flux lines in an electrostatic field. WPT can be divided into 3 parts components. First transceiver, the transceiver electromagnetically transfers power via inductive coils which supply a wireless transfer of power to receiver units.

II-WIRELESS TECHNOLOGY

2.1 The Basics

Wireless power transmission involves the transferring of electrical energy or power over the distance without wires. Thus the basic technology lies on the concept on electricity, magnetism and electromagnetism.

2.2 Electricity

The flow of electrons (current) through a conductor (a wire), or charges though the atmosphere.

2.3 Magnetism

It is a fundamental force of nature, which causes certain types of material to attract or repel each other. Permanent magnets like in our refrigerator and the earth's magnetic field are example of objects having constant magnetic fields. Figure 2.a As a current I flow in the circuit it generates Oscillating magnetic fields vary in respect to time, which can be used to generate alternating current (AC).

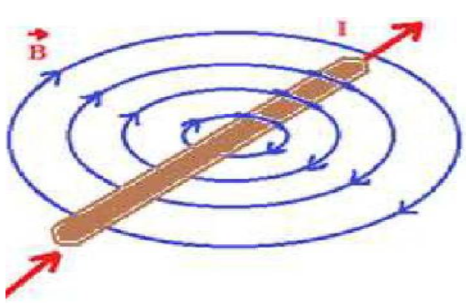

Figure 2.a: The strength, direction and extend of magnetic fields are visualized by drawing of magnetic field lines.

2.4 Electromagnetism

It is a term for the interdependence of time- varying electric and magnetic fields. The oscillating magnetic field produces a magnetic and electric field.

2.5 Magnetic induction

If a conductive loop is connected to an AC power source, it will generate an oscillating magnetic field in and around the loop. If a second conducting loop is brought near enough, it will capture portion of that oscillating magnetic field, which in turn generates or induces an electric current in the second coil. Thus the electrical power transfer from one loop or coil to another is known as magnetic induction .Examples of such phenomenon are used in electric transformer and electric generators. This concept is covered by the laws of electromagnetic induction by Faraday. Where he states that whenever there is change in magnetic flux linking with the coil an emf is induced in the coil. And the magnitude of the same is equal to the product of number of turns of the coil and the rate of change of flux.

$$e = \frac{N(\emptyset_2 + \emptyset_1)}{t} volts$$

Where,

e= induced emf

N= number of turns

$\Phi 2$= final value of flux

$\Phi 1$= initial value of flux

t= time duration during which the change in flux takes place.

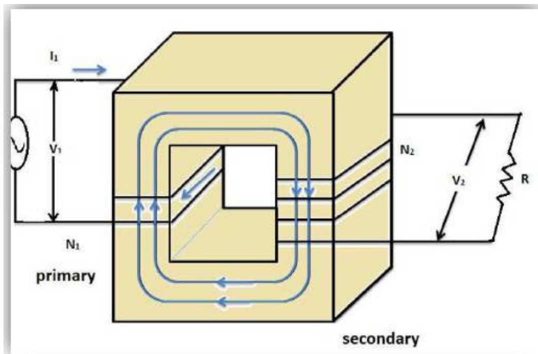

Figure 2.b: Transformer Diagram

This phenomenon occurs when one device is able to transfer energy to another deice. Magnetic coupling occurs when one object's magnetic field is able to induce an electric current to the other devices on its vicinity.

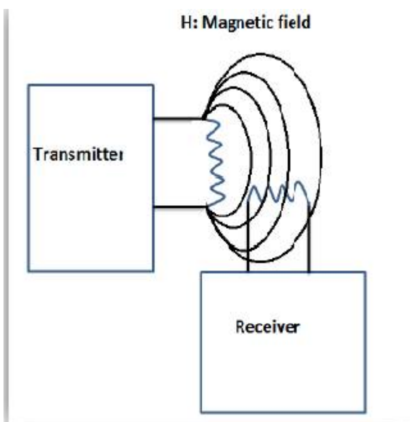

Figure 2.c: Magnetic coupling

2.6 Resonance

Resonance is the phenomenon in which magnetic systems that possesses both magnetic moments and angular momentum. It is the natural frequency at which energy can most efficiently be added to an oscillating system. It exists in most of the physical systems. When the resonant frequency is found it vibrates with higher energy.

2.7 Resonant Magnetic Coupling

As stated under section earlier magnetic coupling occurs when there is energy exchange between two objects through their varying magnetic fields. But the resonant coupling occurs when the natural frequencies of the two becomes approximately equal.

III-HISTORY

3.1 Contributions to Wireless Power Transmission

3.1.1 Nikola Tesla

Nikola Tesla, who is seen by mostly American as the "Father of Wireless", is also credited for his remarkable AC generation became the first person to conceive the idea of wireless power transmission and successfully demonstrated the transmission of electricity without wires as early as 1891. Tesla constructed the tower as shown below in figure 3.a, for wireless power transmission of electrical power rather than telegraphy .Tesla conducted his experiments in Colorado Spring in 1899.

Figure 3.a: Teslas's Wardenclyffe Tower for Wireless Power Transfer

3.1.2William C. Brown

William C. Brown is credited for modern research and father of microwave power transmission. In 1961 he published his first paper proposing microwave energy for power transmission.

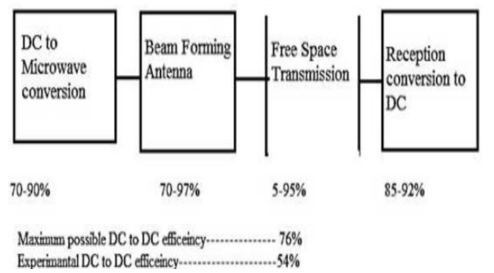

Figure 3.b: Schematic Diagram of element of beam Microwave Power Transmission

3.1.3 Prof. Marin Soljacic

A physics research group led by Prof. Marin Soljacic at the Massachusetts Institute of Technology (MIT) demonstrated wireless powering of 60W light bulb with 40% efficiency at 2m (7ft) distance using two 6ocm -diameter coils in 2007 . They used resonant induction to transmit power wirelessly. The group is also working to improve the technology. This came as a chance when Prof. Soljacic's phone beeped in the kitchen letting him know that he forgot to charge. Soon after the success of the experiment the term for the technology was given as WiTricity and to carry out this technology forward from the MIT laboratories, WiTricity Corp was launched.

IV-VARIOUS TECHNOLOGIES

4.1 Near Field Techniques

4.1.1 Inductive Coupling

Two devices are said to be mutually inductively coupled or magnetically coupled when they are configured such that change in current though one wire induces a voltage across the ends of the other wire by electromagnetic induction. This is due to the mutual inductance.

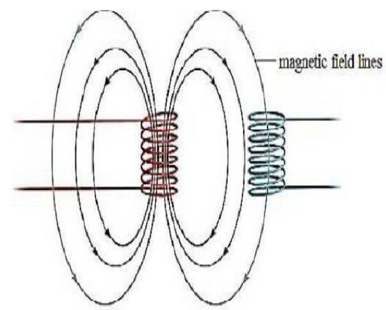

Figure 4.a: Inductive coupling

Transformer is an example of inductive coupling. Inductive coupling is preferred because of its comfortable, less use of wires and shock proof.

4.1.2Resonance Inductive Coupling (RIC)

RIC is the combination of both inductive coupling and resonance. Using the concept of resonance it makes the two objects to interact each other very strongly.

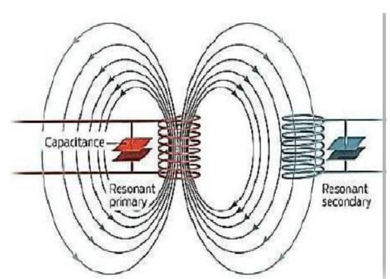

Figure 4.b: Concept of Resonance Inductive Coupling

Inductance induces current in the circuit. The coil provides the inductance. The capacitor is connected in parallel to the coil. Energy will be shifting back and forth between magnetic field surrounding the coil and electric field around the capacitor.

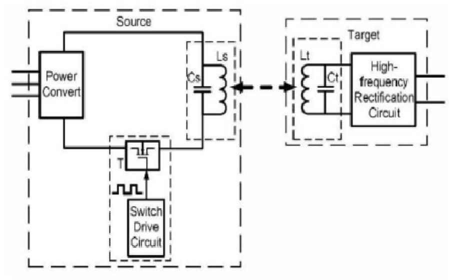

Figure 4.c: Block diagram representation of RIC

a) Comparison between RIC and Inductive Coupling

1. RIC is highly efficient.
2. RIC has greater range than inductive coupling.
3. RIC is directional when compared to inductive coupling.
4. RIC can be one- to- many whereas inductive coupling is one-to-one.
5. Device using RIC technique is highly portable.

4.1.3Air ionization

The concept here is the ionization of air due to field produced. This technique in exist in nature but there is hardly any feasibility of its implementation because it needs high field like 2.11MV/m. Several experiments are on the way. Richard E. Vollrath, a California inventor has developed an ingenious sand-storm generator, which sends blasts of dustladen air through copper tubes, generating electricity which can be stored in sphere and used later. Example of this technique is seen in nature lightning.

4.2 Far Field Techniques

Far Field Energy transfer technique is mainly dependent on radiative techniques. Here wave are either broadcasted in the form of narrow beam transmission of radio, or light waves. This is solely for high power transfer. Tesla already gave the concept to the world on his paper: “Truly Wireless” long time by late 1980s. He constructed large Wardenclyffe Tower to mainly transfer the energy for large distance.

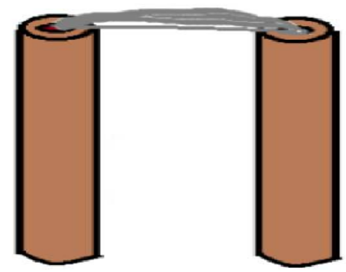

Figure 4.d: Air ionization between two wires due to high field

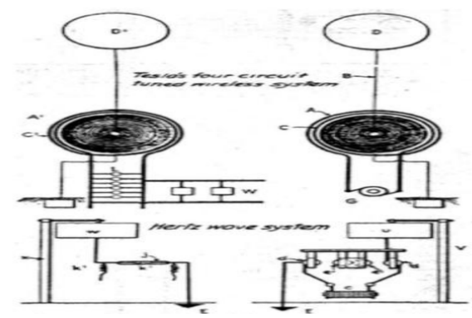

Figure 4.e: The basics for system for the wireless transmission of electrical power

There are basically two methods for WPT: the microwave power transmission and the power transmission using LASER.

4.2.1Microwave Power Transmission (MPT)

This technique involves the conversion of energy into microwave and then transfers the wave through the rectenna (rectifier and antenna) from the transmitter and received at the receiver which will be converted into the conventional electrical power.

The steps involved are:

1) Conversion of electrical energy to microwave energy
2) Receiving microwave energy using Rectenna
3) Conversion of microwave energy to electrical energy

The basics blocks of elements in wireless power transmission is shown in figure 4.f.

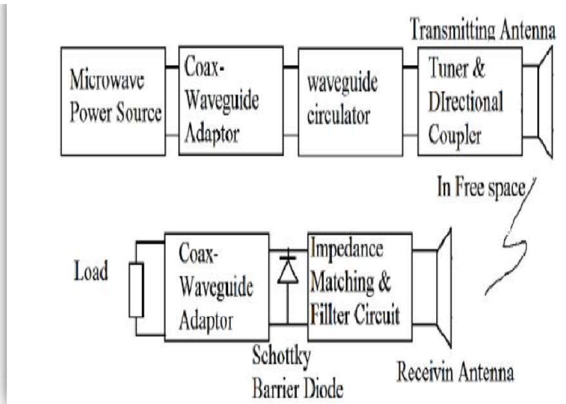

Figure 4.f: Functional Block Diagram of Wireless Power Transmission System

In the transmission side, the microwave power source generates microwave power and the output power is controlled by the electronic control circuits. The wave guide ferrite circulator which protects the microwave power source from reflected power is connected with the microwave power source through the Coax-waveguide adaptor. The tuner matches the impedance between the transmitting antenna and the microwave source. The attenuated signals will be then separated based on the direction of signal propagation by directional coupler. The transmitting antenna radiates the power uniformly through free space to the antenna.

In the receiver, an antenna receives the transmitted power and converts the microwave in DC power. The impedance matching circuit and filter is provided to set the output impedance of a signal source equal to the rectifying circuit. The rectifying circuit consists of schottky barrier diodes which convert the received microwave power into DC power.

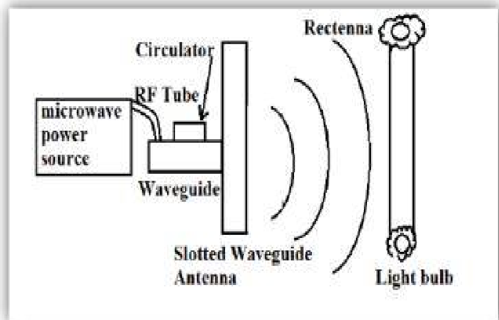

Figure 4.g: Microwave Power Transmission

For the wireless power transmission on the surface of the earth, a limited range of transmission frequencies are availably suitable. Due to atmospheric attenuation and absorption frequencies above 6 GHz, it is not efficient. The frequencies below 2 GHz require excessively large apertures for transmission and reception. Therefore, the suitable ranges of frequencies are in the range of 2GHz to 6 GHz. Efficient transmissions requires that the beams have Gaussion power density. Transmission efficiency for Gaussian beams is related to the aperture sizes of the transmitting and receiving antennas by:

$$\eta_b \sim 1 - e^{(-\tau^2)}$$

$$\eta_b = \frac{\pi D_t D_r}{4 \lambda R}$$

Where,

D_t is the transmission array diameter,

D_r is receiving array diameter,

A is the wavelength of transmission R is the range of transmission

Followings are the components required for generating frequencies of transmitting the power.

(a)Microwave Generator

Microwave transmitting devices are

classified as Microwave Vacuum Tubes (magnetron, klystron, travelling wave tube), and microwave power module (MPM) and Semiconductor Microwave transmitters (GaAs MESFET, GaN, pHEM, SiC MESFET, AlGaN/GaN HFET, and InGaAs). The microwave transmitter often uses 2.45 GHz or 5.8 GHz of ISM band. The other frequencies are 8.5 GHz, 10GHz and 35 GHz. The highest efficiency over 90% is achieved at 2.45 GHz.

(b)Transmitting Antenna

Micro-strip antenna and parabolic dish antenna are the most used amongst the others. The slotted waveguide antenna is considered to be ideal with the efficiency greater than 95% and high power handling capacity.

(c)Rectenna

The name rectenna comes from William C. Brown (Raytheon) in the early 1960s. It is the term given to the combination of rectifying diode and antenna. The rectenna is passive element and consists of antenna, rectifying circuit with a low pass filter between the antennas and rectifying diode. The antenna used may be dipole, Yagi-Uda, micro-strip or parabolic dish antenna. The patch dipole antenna is best with highest efficiency.

4.2.2 LASER Technology

The LASER Technology is another efficient way of wireless power transmission. It uses the same possibility as microwave wireless transmission but here energy emission is of high frequency and is coherent. Research organisations like NASA, ENTECH, and UAH have been working on this project as a means to transmit power wirelessly. The other great advantage of LASER power transmission is the aperture collection efficiency which is that antenna can be made small sized as these are the calumniated beams.

LASER transmission does not get dispersed for long distance but it gets attenuated when it propagates though atmosphere. During the design the receiver used can be simple like photovoltaic cell. Due to the simplicity in its construction it is cost efficient than he microwave power transmission. Developing photovoltaic cells which are capable of efficiently converting the multiple sun intensity coherent monochromatic light in to electricity have been under the belt of many researchers and scientist. Maximum efficiency for photovoltaic cell with monochromatic light has been achieved at a wavelength that is just short of cut-off wavelength for the semiconductor. The cut-off wavelength is given as:

$$\Lambda c = \frac{1.24}{Eg}$$

Where E_g is the semiconductor band gap energy in eV.

V-CIRCUIT DESIGN

5.1 Oscillator

This is the heart of the wireless power transmission module. The oscillator should be able to produce high frequency pulses of required power so that it can excite the transmitter coil at its resonant frequency. We tried many different methods using power MOSFETS and finally our search came to an end with **Royer push pull oscillator**.

The circuit of the royer oscillator is shown in figure 5.a.The royer oscillator consists of two cross coupled MOSFETs connected to a resonant circuit (resonant transmitter) formed by the centre tapped inductor and the capacitor C1.This resonator acts as a primary side link coil of the power system and is coupled to a second identical resonant circuit formed by L1 and C2 which is connected to a DC rectifier and battery charging circuit.

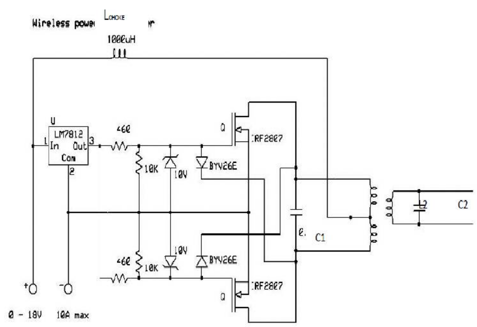

Figure 5.a: Circuit diagram wireless power transfer comprised of Royer push pull oscillator

In order to refer to the principle of operation of the oscillator we refer to the simplified scheme where the MOSFETs are replaced by voltage controlled ideal switches. Owing to the connection structure, when either one of the switches is in the “on” state it forces to zero the control voltage of the other one, which is thus set into the “off” state.

The voltage across the capacitor is assumed to be sinusoidal if the quality factor of the circuit is sufficient (here we have a quality factor of 68 and that is sufficient). Let us assume that at t=0,s1 is OFF and S2 is ON as shown in figure 4.This implies that during the first half period of capacitor voltage Vc1 ,the voltage at node1 is equal to Vc1 and is positive, so that S2 is held in the ON state. As a consequence the voltage across S2 remains zero, and S1 is kept OFF. At t=1/f, Vc1 becomes equal to zero and S1 turns OFF, thus voltage at node 2 starts increasing. Hence in the subsequent half period S1 is held ON and the voltage at node 1 is kept to zero. This situation continues until Vc1 crosses zero again at t= 2/f and the cycle restarts.

The inductance LCHOKE is chosen such a way that its impedance is very large at the resonant frequency so that the capacitor current can circulate only in the loop formed by C1 and L1. The DC voltage source and LCHOKE thus behave as a DC current source .Thus the current injected in the central tap of L1 can only flow in the switch that is on.

Here we have used IRF2807 power MOSFET as the switch because it has sufficient current capacity along with high switching frequency. The diodes used are BYV26E because of its high switching frequency .Also we used a 1mH inductor as LCHOKE.

5.1Coil Design

Once we decided about using royer oscillator, now we had to fix the resonant frequency of the coil and design it. We chose a frequency of 30kHz and a capacitance of 0.44gF. Now we tried out different materials and different coil forms. We tried PVC insulated copper wires and varnished copper wires used in transformer wires. At the end we decided to use PVC insulated copper wires wound in concentric helix as the transmitter coil. Using this coil we got an inductance of .050mH (required is 0.64mH as per equation).

The receiver coil is also wound in the same way with the same resonant frequency.

5.2 Realization of the Wireless Power Transmitter

In the next step we realized the wireless power transfer system for the WI-EV with the royer oscillator using the above designed transmitter and receiver coils. A 30V, 5A variable DC supply was used to energize the wireless power transfer system. We used this set up to light a 12V bulb at a distance of about 15cm.

VIII-FUTURE SCOPE

With such a wide-ranging application space, we feel that the use of resonance to enhance wireless power transfer will be prevalent in many areas of life in the coming years. Electronics companies are already developing the necessary core components that will help speed the introduction of the technology into more cost constrained applications. This will stimulate additional creative ways in which to apply the technology, not only bringing convenience to some everyday tasks such as battery charging, but also enabling uses in ways only limited by one's imagination.

CONCLUSION

The transmission of power without wires is not a theory, it is now a reality. The electrical power can be economically transmitted without wires to any terrestrial distance. Wireless transmission of electricity have tremendous merits like high transmission integrity and Low Loss (90 - 97 % efficient) and can be transmitted to anywhere in the globe and eliminate the need for an inefficient, costly, and capital intensive grid of cables, towers, and substations. The system would reduce the cost of electrical energy used by the consumer and get rid of the landscape of wires, cables, and transmission towers. It has negligible demerits like reactive power which was found insignificant and biologically compatible. It has a tremendous economic impact to human society.

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