A Study of Wireless Electricity-An Emerging Technology

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***Abstract*-Wireless Electricity is an Emerging technology which is used to transmit an Electrical energy from one object to another without using wires. It is also known as WiTricity.The concept of a WiTricity is a little complex. This technology is based on "Father of the wireless"Dr.Nikola Tesla's Research work. His theory is based on "Wardenclyffe Tower" known as Tesla Tower would permit wireless transmission and reception across large distances. He made lot of research to produce high quality wireless transmission of electricity and also he used conduction based systems instead of resonance magnetic field.WiTricity is used in many applications like automobile, wireless charging for implantable medical devices in biomedical fields. Generally it provides a technology to transfer power efficiently, reliable and environment friendly. In this paper, literature survey of the wireless power transmission is discussed. A proposed wireless power transfer circuit is simulated using MULTISIM software and also implemented in hardware.**

Keywords: WiTricity, MULTISIM, Hardware Implementation.

I. INTRODUCTION

WiTricity is based on coupled magnetic resonance which permits a power to be transmitted in several meters. Nowadays increase in laptops, cell phones, Robots, Medical implantable cardiac pacemakers, deep brain stimulators, cardiac defibrillators, drug infusion pumps. Insulation pumps. All these devices needs and also run with rechargeable batteries. It should be constantly recharged for their day by day use. By using WiTricity we can transfer the power to distance objects without using wires.Mid range power transfer is achieved by Separating the objects with affecting the transfer should be order of few times the characteristic sizes of the objects. Power is transferred between mutually coupled coils that are tuned to a specific resonant frequency .The energy is transferred among resonators at a resonant frequency.This principle says that one power source can be used to recharge or power the devices in a room. This technology can be established in a same way as Wi-Fi technology. WiTricity is Green energy alternative to conventional plug in charging methods. For an example of Electromagnetic induction, in a transformer an electric current is given to the primary winding and it generates a magnetic field, hence electric current is induced in secondary winding. The distance between this coils are smaller, they never make electrical contact even the two coils are overlap. However if the distance between the coils are large, the magnitude of power transfer will be reduced. In similar way, magnetic fields are generated for a long distance by "Resonant coupling process" [2],[3].Mid range power transfer can be implemented in this process. It is more efficient, safer and losses are minimum.

In this paper, literature survey on wireless power transmission is presented in part II. Simulation model and results are obtained using MULTISIM software and Hardware implementation and experimental results are compared with simulation results are presented in part III.

II. LITERATURE SURVEY ON WIRELESS POWER TRANSMISSION

In 1980's Nikola Tesla was the first to demonstrate the idea of power transfer with his well known electromagnetic induction theory. He demonstrated a midrange wireless power transfer using resonant circuits which produces high output voltage-Low output current with a high frequency alternating input current. The Tesla coil is resonant electrical transformer invented in 1891[1],[22].The schematic representation of Tesla's power transfer experiments is shown in Fig.1.

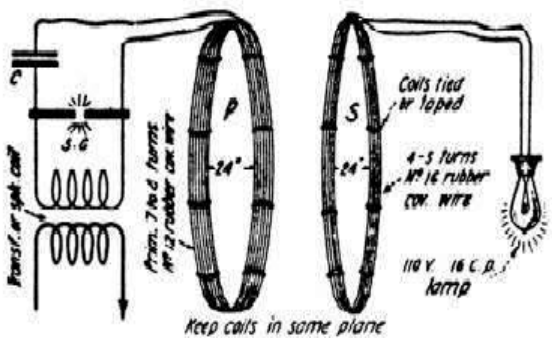

Fig.1.A diagram of one of Tesla's wireless power transfer experiments [1]

The above given Fig.1 describes that primary winding (P) is connected to transformer or condenser and spark gap (S.G).When spark breaks the gap, primary winding will absorb the power and it will glow the 110V, 16 candle power (40 watts) bulb which is connected in secondary winding(S) even when coils are separated at high frequency currents under resonance condition [4].After some years he proved that these high frequency currents could be used in medical applications. High frequency currents below significantly high limit of current can be passed through human body without causing any pain to burn out tissues [5].The Fig.2 shows a drawing from the patent of Tesla's wireless energy transmission [6] granted in 1990.

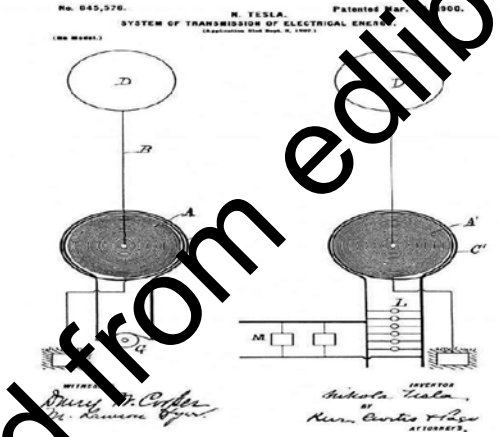

Fig.2.A drawing from the patent of Tesla's wireless energy transmission

It consists of transmission and receiver part Coils C and A forms a transformer which belongs to transmission part. In winding A, secondary of transformer has many turns and large diameter spiral structure. In winding C, primary of transformer has much shorter length and larger cross section conductor. Coil C is wound around A and it is connected to a source of current G which is a generator. One of the terminals of secondary winding A is at the center of the spiral of the coil and from this terminal the current is led by conductor B to a terminal D to transmit a power to receiver part. The terminal of the secondary winding A is connected to ground. At the receiver part similar construction of a transformer is used with coil A' as the primary winding and coil C' as the secondary winding of the transformer. Elevated terminal was used to receive power; it was connected to center of primary coil A' while the other end of A' is connected to ground. L and M are the loads connected to the secondary coil C'.

In the year 1892, Tesla demonstrated the principle of wireless power transfer. After this, he focused his vision on development of a proto type. He constructed a research facility [7] known as "Wardenclyffe" tower (187-ft) is shown in fig.3.

Fig.3. Wardenclyffe tower located in Shoreham, New York [7]

He demonstrated and proved a concept of transmission of electrical power from the tower to loads without wires.Tesla's transmitter's energy was concentrated near the surface of ground. The giant transmitter was resonant at 150 kHz and was fed by 300KW of low frequency power [8],[9]. There are no clear records about efficiency and power delivered of this tower; However, Tesla demonstrated by lighting the 200 incandescent lamps simultaneously while transmitting sides and receiving sides of the system's are separated at a distance of 26 miles (42km).In the year 1950's ,wireless power transmission has become active topic of research.

In the year 1959,a wireless monitoring system using radio pills was developed to study internal conditions of human body[10],[11].In the year 1962, an echo capsule(swallowable radio transmitter) was developed, it is energized from outside the human body to transmit information and temperature, acidity or other condition of digestive tract[12]. Early in 21st century, lots of experiments were done to develop a new application of Wireless power transmission. In the year 1964, Brown demonstrated on CBS News with Walter Cronkite, a model helicopter that received all the power needed for flight from a beam. In the year 1968, wireless transfer of solar energy was captured in space using "Power beaming technology" was proposed by Peter Glaser. Enhancing of flux coupling between magnetically coupled coils by distribution of coils across the diameter instead of concentrate it at their circumference [13].

Transferring of power between a air gap of 200mm at a frequency of 15.9MHz of 100W for an Electric vehicles with helical antennas was demonstrated[14].In the year 2010,Power of 32W is delivered to a Laptop computer with a maximum efficiency of 66% at a frequency of 240KHz demonstrated by Taylor et.al[15].Multi-Kw transfer of wireless power transfer system over a large air gap using loose couple coils was demonstrated by Lee and Lorenz[16].Optimal design of wireless power transfer system for an LED TV based on multi resonators was demonstrated by Kim et al.[17].They used a frequency of 205KHz to transfer the power of 150W for a 47 inch LED TV with an efficiency of 80%. 20cm of separation was made between transmitter and receiver.

In the year 2011, Matlab based computational tool for Calculation of self and mutual inductance of arbitrary shape and orientation in free space based on magnetic vector potential was described by Beams and Annam [18].Sequential application of reflected impedances through mutual inductances to design a simplified method for the four coil resonant wireless power transfer network [19].A Theoretical design of four coil MCRC wireless power transfer system was investigated by Beams and Nagoorkar.This system can transfer power over a distance of 2 meters with more than 70% efficiency[1],[20].

III. Simulation And Experimental Results

WiTricity can be designed for midrange distances, from centimeters to several meters. But the actual range in practical is determined by power supply, receiving device, size, efficiency and transfer of amount of power. In order to get resonance condition, the resonant frequency of the transmitter coil and the receiver coil must be same to transmit the electrical energy. The parameters of the wireless transmitter and Receiver system is calculated by the following equation [21].The inductance of the loop can be obtained by equation (1) and (2).

3.1 Inductance of the coil((L)

$$L=N^2\times R\mu_o\times (\ln(8\times R/r)-1.75) \quad (1)$$

Where,

L is inductance of the coil
N is the number of the turns in the coil
R is radius of the coil
r is coil conductor radius
μ_o is permeability of vacuum

In order to get a desired wireless power transfer, the transmitting coil and receiving coil must be tuned with the same resonant frequency(ω_o).This tuning can be made by connecting series capacitor with both the transmitting and receiving coils. The Equation (2) determines the capacitor value [24] to generate the resonant circuit with the inductor is given below.

3.2 Capacitance to generate resonant circuit (C)

$$C=1/(\omega_o^2\times L) \quad (2)$$

Where,

C is the capacitance required
ω_o is frequency of oscillation(rad/sec)
L is inductance of the coil

Specifications of the wireless power transmitting and receiving coils are shown in Table I.

TABLE I
Specifications Of Wireless Power Transmitting coil and receiving coils

Description	Number of turns	Diameter of Coil	Diameter of copper wire
Transmitting coil	25	7cm	0.15cm
Receiving coil	15	7cm	0.15cm

Specifications of the wireless power transmitting and receiving circuits are shown in Table II.

Transmitting circuit	
Description	Specifications
Bipolar Junction Transistor(NPN)	BD139
Capacitors	470pF,4.7Nf,33nF
Electrolytic Capacitors	2200 µF/25V, 10 µF/25V
Voltage Regulator	LM7805

Diode	1N 4007
Resistors	15KΩ
Transformer	230V/12-0-12V/2A
Receiving circuit	
Electrolytic Capacitors	10 µF/25V
Diode	1N 4148
LED	Red Colour

The whole circuit of wireless power transfer system is shown in Fig.4.The transmitter circuit consists of centre tapped step down transformer, Rectifier, Filter, Voltage Regulator, Oscillator circuit with circular transmitting coil. Resonant frequency of 114.45Hz is used in this circuit. The transmitting circuit is excited by 5V DC supply with help of transformer, Rectifier, Filter and Regulator. In MULTISIM software, there is no provision to couple or separate a coil [23], and hence receiver coil is assumed to have a separate AC source voltage.

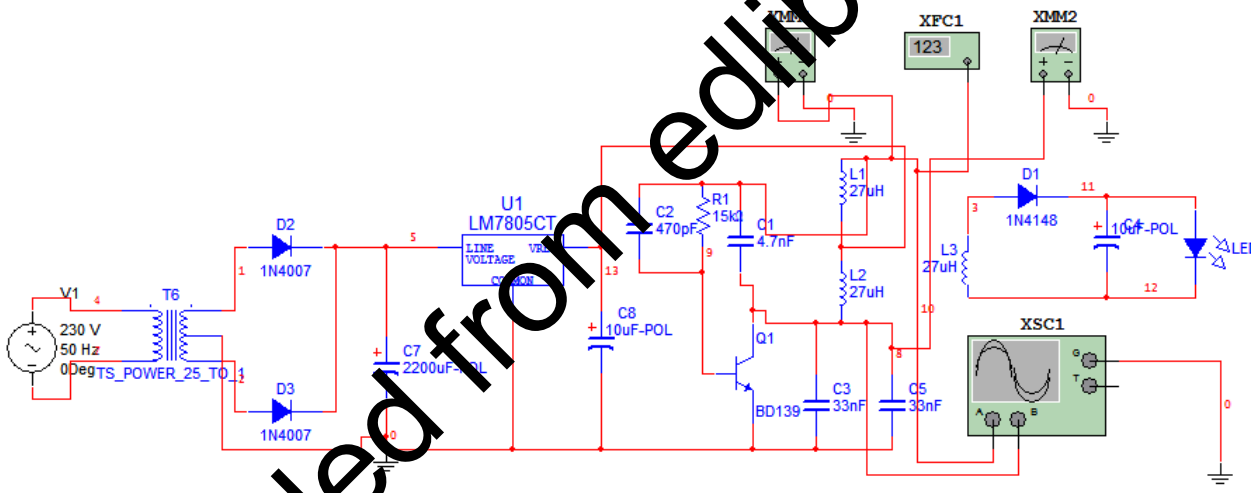

Fig.4.Circuit Diagram of Wireless power transfer system

That is simulation for Receiving coil circuit was carried out separately with an assumption of AC voltage which will be the expected output from Transmitter coil. Output simulation results of transmitting and receiving units are shown in fig.5

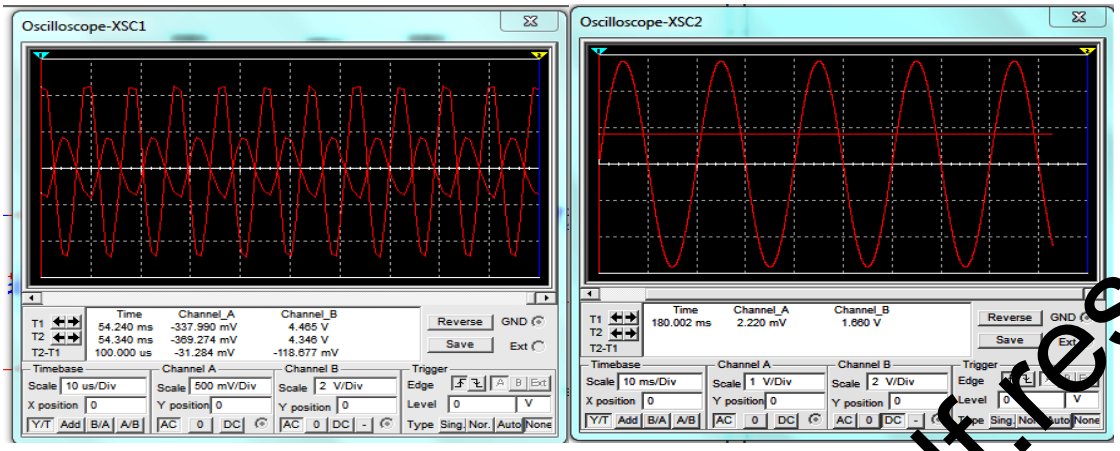

Fig.5.Output Results of Transmitter and Receiver of Wireless power transfer system

The wireless power transmission system is implemented in Hardware is shown in Fig.6. The Performances of the circuit is tested in simulation as well as hardware. In practical, Digital multimeters is used to measure the receiving coil voltage. The hardware circuit provides minimum transfer of DC voltage of 0.10 volts at 12 cm distance between the coils and maximum transfer of DC voltage of 2.13 volts at 0.5 cm distance between the coils. The coils are separated by non conductive material while doing practical implementation. LED is used to test the output condition of the receiving circuit. It was observed that the LED glow brighter at minimum distance of 0.5cm between the coils.

Fig.6.Hardware Implementation of Wireless power transfer system

The transmitting and receiving coil are separated up to 12cm distance. Depending upon on the distance between the coils; the transfer of power from transmitter to receiver can be varied. The voltage received at the receiving coil is AC.The voltage is converted to DC by connecting Diode 1N4148 in series and Capacitor in parallel with receiving coil. Comparison of performance of simulation and hardware results is shown in Table.III.

TABLE III
COMPARISON OF PERFORMANCE OF SIMULATION AND HARDWARE RESULTS

Distance between the coils in centi	Simulation Output at receiver coil in Volts	Hardware Output at receiver coil in Volts

meter	Vdc in volts	Vac in volts	Vdc in volts	Vac in volts
0.5	1.66	2.23	2.13	2.42
1	1.61	2.01	1.97	2.14
3	1.55	1.62	1.47	1.78
6	1.19	1.21	1.17	1.23
9	0.26	0.57	0.59	0.68
12	0.05	0.25	0.10	0.15

CONCLUSION

A proposed wireless power transfer circuit was simulated using MULTISIM software. The simulated output results of the wireless power transfer system were compared with hardware results. Simulated output voltages and hardware results of the wireless power transfer system almost agree with each other. The overall power transfer efficiency is 40.0%.It has been observed that the wireless power transfer system provides, maximum transfer Voltage of 2.13 Volts at 0.5 cm distance between the coils ,when transmitting coil is excited by 5V supply with resonant circuit . This system can be used for low voltage applications such as wireless battery charger for mobile phones.

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