Investigation To Increase Transmission Distance Of Wireless Power System

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***Abstract*-**Wireless power transmission (WPT) has the potential to be a common source of utilizable energy, but it will only receive serious consideration if the transmit and receive systems are extremely efficient and capable of delivering usable amounts of power. Today, the limit of wireless devices lays in the way they are powered. The aim of this paper, to investigate how to increase the transfer distance of a wireless power system, WPS, purposed to charge low power electronic devices. MATLAB is used for implementing the expression by creating a simulator, which finds optimal values of geometrical and material properties that maximizes the transfer distance. The simulator is set up and ran for each system 2 and 3 coils system, this is because each system behaves differently and all have some desirable properties. The results from MATLAB is similar and shows that a 2-coil system can transfer power with 90% efficiency over a distance of ~500micrometer. While 3- coil systems significantly improve the transfer distance and can transfer power with the same efficiency over a distance of ~1500micrometer. The efficiency of the complete system can be calculated from the measurements made are the power delivered to the amplifier and the power delivered to the load.

Keywords- *Wireless Power Transmission(WPT), WPS, Power electronic devices, Simulator, Material properties MATLAB, Efficiency.*

I. Introduction

Wireless communication is the transmission of the energy over a distance without, the usage wires or cables, where in distances involved may be short or long. Wireless operations allows services, such as long-range communications, that are unfeasible using wires. Wireless power transmission is the transmittance of electrical energy from a power source to an electrical load without connection of wires. Wireless power transmission is useful in occurrence where connection of wires are difficult, risky or impossible. The problem of wireless power transmission differs from that of wireless telecommunications. The proportion of energy received becomes critical only if it is too low for the signal to be distinguished from the noise[1]. Efficiency is more important parameter in wireless power. Maximum part of the energy sent out by the generating plant must arrive at the receiver to make the system inexpensive. The most common form of wireless power transmission is carried out using direct induction followed by resonant magnetic induction. Wireless communication is generally a branch of telecommunications. It covers various types of fixed, mobile, and movable two-way radios, cellular telephones, personal digital assistance (PDAs), and wireless networking.

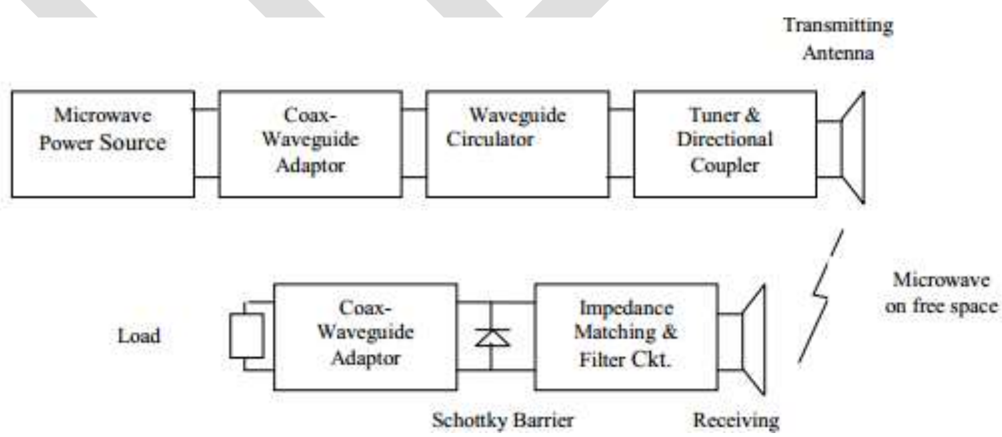

Figure 1 : Basic Design of Wireless Power Transmission System[2]

Wireless Power Transmission System is explained with block diagram as shown in figure. Microwave power is produced by microwave power source in the transmission side and output power is controlled by electronic control circuits. The waveguide circulator which protects the microwave source from reflected power is connected with the microwave power source through the

Coax-Waveguide Adapter. The tuner is used for matching the impedance between the microwave source and the transmitting antenna. Based upon the direction of signal propagation the attenuated signals will be separated by Directional Coupler.

The transmitting antenna radiates the power uniformly to the rectenna. A rectenna receives the transmitted power and converts microwave power into DC power in the receiving side[3]. The Impedance matching circuit and filter is provided to setting the output impedance of a signal source equal to the rectifying circuit. The rectifying circuit made up of Schottky barrier diodes converts the received power into DC power.

II. LITERATURE SURVEY

Nikola Tesla, he is who invented radio and is referred to as "Father of Wireless". The objective of Wireless Power Transmission is designed by Nikola Tesla, he demonstrated "the transmission of electrical energy without wires" that depends upon electrical conductivity as early as 1891. In 1893, Tesla validated the illumination of vacuum bulbs without using wires for power transmission at the World Columbian Exposition. The Wardenclyffe tower was proposed and constructed by Tesla mainly for wireless transmission of electrical power rather than telegraphy[6]. Wardenclyffe Tower, including the partially-complete cupola. The world's first fuel free airplane powered by microwave energy from ground was reported in 1987 at Canada. This system is called SHARP (Stationary High – Altitude Relay Platform). A physics research group at the Massachusetts Institute of technology (MIT) demonstrated wireless powering of a 60W light bulb with 40% efficiency at a 2m (7ft) distance using two 60cm-diameter coils in 2007. In 2008, Intel reproduced the MIT group's experiment by wirelessly powering a light bulb with 75% efficiency at a shorter distance[7]. MIT team experimentally demonstrates wireless power transfer, likely useful for charging cell phones, laptops without using wires.

Figure 2 : 187-foot Wardenclyffe (Tesla) Power[8]

Imagine a future in which wireless power transfer is practicable. Household robots, cell phones, mp3 players, laptop computers and other movable electronics capable of charging themselves without ever being plugged. Some of these devices might not even need their large batteries to operate. A team from Massachusetts Institute of technology's Department of Electrical Engineering, Physics and Computer Science and Institute for Soldier Nanotechnologies has experimentally demonstrated an important step toward accomplishing this vision of the future. They were able to light a 60W light bulb from a power source seven feet (more than two meters) away and there was no physical connection between the source and the appliance. The Massachusetts Institute of technology team refers to its concept as "WiTricity" (as in wireless electricity). Sony Corporation in 2009 announced the development of a highly efficient wireless power transfer system that eliminates the use of power cables from electronic products. Using this system, up to 60 Watts of electrical energy can be transferred over a distance of 50cm (at an efficiency of approximately 80%, approximately 60% including rectifier)[9]. This new wireless power transfer system consolidates a form of contactless electrical energy transmission technology based upon magnetic resonance. In magnetic resonance, electromagnetic energy is only transferred to recipient devices that share the identical resonant frequencies as the energy source, so energy transfer efficiency is conserved, even when misalignment occurs[10]. Furthermore, even if there are metal objects located between the transmitter and receiver, no heat induction occurs. The growth in networked products, lead to the number of cables used to connect these products. Data cables are quickly being replaced with wireless communication systems, the requirement for wireless power transfer systems is also continuing to grow. Sony will proceed with its attempts to develop further technologies that meet customer requirements for the wireless transfer of power across a wide range of products, energy levels and distances.

III. FRAMEWORK OF WPT

Framework of WPT can be explained by different properties of material.

A. Resistance- Resistance is defined as the opposition to pass current through a conductor. Losses will always be present when a current moves through a conductor. The power dissipated by the resistor will mainly be in the form of heat and is given by

$$P_{diss} = V*I \quad (1.1)$$

1)Resistance in a wire- The resistance of a wire for DC or low frequencies is given by the resistivity of the material ρ, the cross section area A and the length of the wire l

$$R_{dc} = \rho l / A \tag{1.2}$$

Two types of wires are used in transmission of wireless power, Litz and Magnet wire

B. Model of lossy 2-coil coupled system-

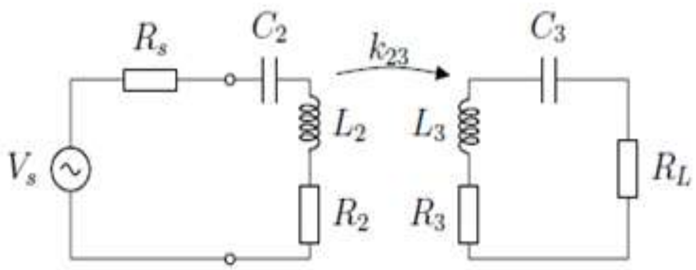

Figure 3: Circuit Diagram of 2-coil system

A resonant circuit is added as a load to the system, Figure 3, the transmitting circuit is denoted by the index 2 and receiving by 3. The two circuits are coupling to each other by the term k and the load resistor is taken into account by r_L. The complete system can now be described by

$$\frac{da_2(t)}{dt} = -(j\omega_2 + \Gamma_2)a_2(t) + F_S(t) + jka_3(t) \tag{1.3}$$

$$\frac{da_3(t)}{dt} = -\left(j\omega_3 + \Gamma_3 + \Gamma_L\right)a_3(t) + jka_2(t) \tag{1.4}$$

C. Wireless Power Transfer Efficiency-

In order to calculate the efficiency of the power transfer, the theory of energy conservation is applied. If the radiated power in the near field is neglected the following statement can be made

$$P_S = P_2 + P_3 + P_L \tag{1.5}$$

where the average power in each circuit, coil and capacitor, is

$$P_i = 2\Gamma_i \, |a_i|^2 \tag{1.6}$$

and in the load

$$P_L = 2\Gamma_L \, |a_L|^2 \tag{1.7}$$

With Eq. 1.5, the efficiency can be stated as

$$\eta_{2-coil} = \frac{P_L}{P_S} = \frac{1}{1 + \frac{\Gamma_3}{\Gamma_L}\left[1 + \frac{\Gamma_2\Gamma_3}{K_{23}^2}\left(1 + \frac{\Gamma_L}{\Gamma_3}\right)^2\right]} \tag{1.8}$$

where K_{23} is the coupling rate[11].

D. WPT expanded to 3-coil system-

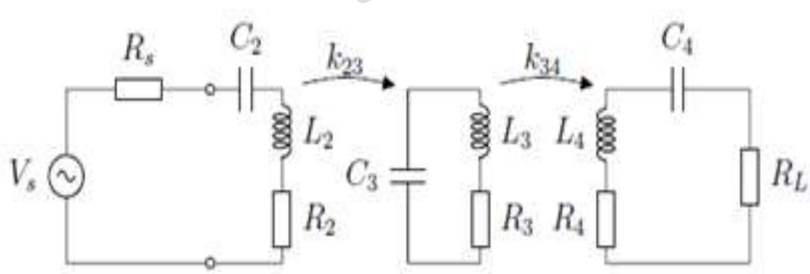

Figure 4: Circuit diagram of 3-coil system

The efficiency can be significantly improved at larger distances by using more than two coils. The law of energy conservation can be stated for an arbitrary number of coils

$$P_S = \sum_{i=1}^{m} P_i + P_L \tag{1.9}$$

An expression of the efficiency for a m-coil system can be derived in a similar way as for the 2-coil system[12]

$$\eta_{m-coil} = \frac{P_L}{P_S} = \frac{\Gamma_L}{\Gamma_m + \Gamma_L + \sum_{i=1}^{m-1} \Gamma_i \left| \frac{A_i}{A_m} \right|^2} \tag{1.10}$$

In the 3-coil system an extra load circuit is added for impedance matching, the 3-coil efficiency given by

$$\eta_{3-coil} = \frac{K_{23} K_{34} \Gamma_L}{\Gamma_2 \left[K_{34}^2 + \Gamma_3 \left(\Gamma_4 + \Gamma_L \right)^2 + K_{23}^2 \left[\Gamma_3 \left(\Gamma_4 + \Gamma_L \right)^2 \right] + K_{23}^2 K_{34}^2 \left(\Gamma_4 + \Gamma_L \right) \right]} \tag{1.11}$$

IV. MATLAB SIMULATIONS

There are comparison of power transmission efficiency using two coils made of magnet- and litz-wire. The MATLAB simulator plots PTE vs distance curve with optimal parameter set. Figures 5-7 shows the optimal PTE for each case and system.

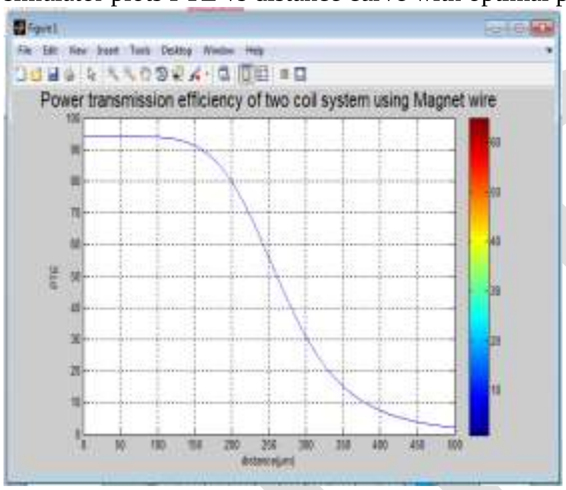

Figure 5: PTE for two coil system using Magnet wire

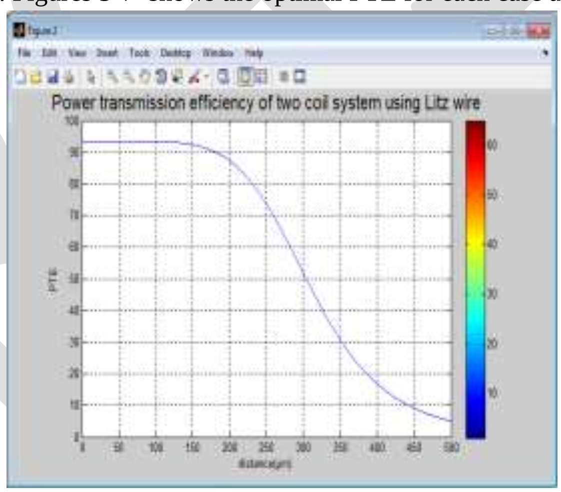

Figure 6: PTE for two coil system using Litz wire

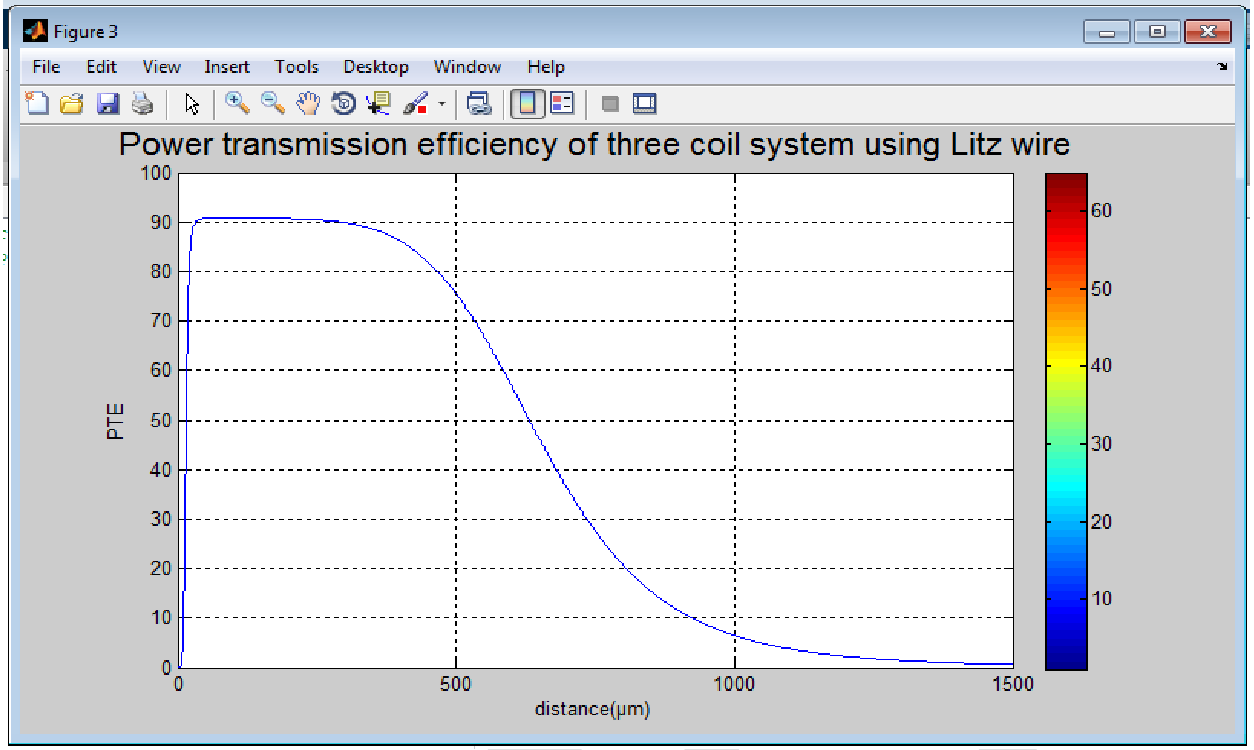

Figure 7: PTE for the Litz wire 3 coil system

V. CONCLUSIONS

Following conclusion summarizes the work done in this project. The key parts are as follows:

- Litz wire is better than Magnet wire implemented as MATLAB models[13].
- The WPS models for 2 and 3 coils are extended with the theory of the individual components, implemented as MATLAB models with actual material and geometrical properties as input parameters. An optimization technique is defined and a simulator is created that finds the optimal set of input parameters in MATLAB which results in the best PTE curve. As the coil system is increased PTE curve gives the best result.

VI. FUTURE SCOPE

Result of simulation tell us about which type of wire should be used in transmission to get the best output result and it also proved that 3 coil system is giving better result in comparison with 2 coil system. That means if we are increasing order of coil system for better transmission of power then we achieved better efficiency and it will transfer the power at longer range than low order coil system.

But as the order of coil system is increased then complexity of our system will increased and it will also effect the cost of the system. So in future we can think about new techniques which increases the transmission distance as well as it will not effect its cost and complexity of the system.

REFERENCES:

[1] http://en.wikipedia.org/wiki/Microwave_transmission.

[2] Nikola Tesla, My Inventions, Ben Johnston, Ed., Austin, Hart Brothers, p. 91,1982.

[3] Nikola Tesla, "The Transmission of Electrical Energy Without Wires as a Means for Furthering Peace," Electrical World and Engineer. Jan. 7, p. 21, 1905.

[4] HISTORY OF WIRELESS Tapan K. Sarkar Robert J. Mailloux Arthur A. Oliner Magdalena Salazar-Palma Dipak L. Sengupta.

[5] J.J. Schelesak, A. Alden and T. Ohno, A microwave powered high altitude platform, IEEE MTT-S Int. Symp. Digest, pp - 283- 286, 1988.

[6] http://cleantechindia.wordpress.com/2008/07/16/indiaselectricity-transmission-and-distribution-losses/

[7] Nikola Tesla, My Inventions, Ben Johnston, Ed., Austin, Hart Brothers, p. 91,1982.

[8] S. Sheik Mohammed, K. Ramasamy, T. Shanmuganantham,‖ Wireless Power Transmission – A Next Generation Power Transmission System‖, International Journal of Computer Applications (0975 – 8887), Volume 1 – No. 13, Pg. No. 100-103.

[9] W.C. Brown, J.R. Mims and N.I. Heenan, "An Experimental Microwave-Powered Helicopter", 965 IEEE International Convention Record, Vol. 13, Part 5, pp.225-235.

[10] J.J. Schelesak, A. Alden and T. Ohno, A microwave powered high altitude platform, IEEE MTT-S Int. Symp. Digest, pp - 283- 286, 1988.

[11] B. Wang, K. H. Teo, T. Nishino, W. Yerazunis, J. Barnwell and J. Zhang, \Experi-ments on wireless power transfer with metamaterials," 2011.

[12] M. Kiani and M. Ghovanloo, \The circuit theory behind coupled mode magnetic resonance based wireless power transmission," 2012.

[13] A. P. Sample, D. A. Meyer and J. R. Smith, \Analysis, experimental results, and range adaptation of magnetically coupledresonators for wireless power transfer," 2011