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Analysis and Study on Technique for Wireless Power Transfer depending upon Application Requirements

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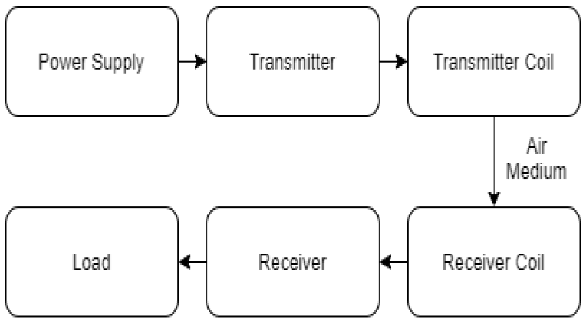
Abstract:
The purpose of our study is to design an efficient method for wireless power transfer (WPT) with high efficiency and low losses. In it we are working on a prototype based on mutual inductance and Tesla coil methods to calculate the parameters of wireless power transfer such as [i.e. Transmission efficiency, Transmission air Losses, Transmission Power losses, Transmission Distance, Impedance Losses]. The Research of wireless power transfer started in the year 1891 by Nicolas tesla father of wireless power transfer technology this journey continued till today having a lot of research opportunities and challenges in the field of WPT. We discuss the challenging issues with respect to various parameters of wireless power transfer like Cost of transmission.

Keywords : **Mutual Inductance, Wireless power Transfer, Electricity, Power, Tesla, WPT, Efficient power transfer system, Prototype, Cost effective method, Tesla Coil vs Mutual Inductance.**

I. Introduction:

Wireless power transfer (WPT) has recently started to gain traction. This recent interest stems from the idea of smart cities, electrical cars and lack of power sockets. This system has no rigidity and can be stimulated to be used in any situation required. Inductive coupling is a method through which this can be carried out. Inductive coupling involves transfer of power without the use of the conventional wire system. A study carried out at the Massachusetts Institute of Technology involved conducting experiments on mid range distances and they finally arrived at a non radiative method to increase its efficiency. The idea of WPT began when Nikola Tesla proposed to use the Earth's ionosphere to wirelessly transfer power over long distances.



[Fig: A:] Mutual inductance based wireless power transfer Method

Our concept is to suggest which method works best in a certain scenario, the tesla coil method or the mutual inductance method.

Scenarios: powering automobiles, fans, televisions, phones, bulbs,

There are many benefits such as lower cost, saving on resources, greater efficiency, longer transmittable distance, saving space and more durability to name a few.

II. Literature Survey:

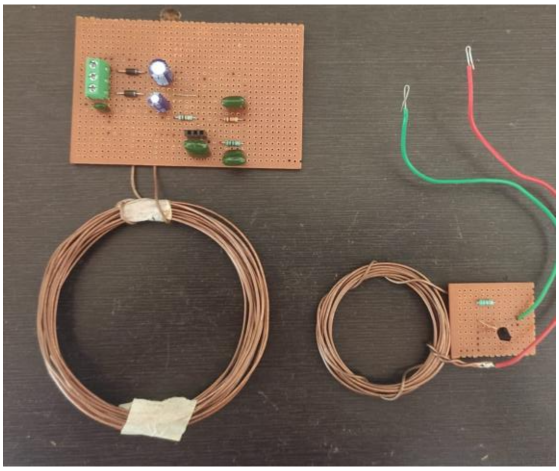
Wireless Power Transfer is a field where there is a humongous amount of ongoing research; its cause being the need to reduce wire usage and transfer power more efficiently, in doing so we can cut down massively on costs and resources used and have a cleaner and greener future.

There are a wide number of resources available through which one can understand the sheer amount of work done in this field and its ongoing and exponential growth. One such paper is "Design of WPT System using Inductive Coupling and MATLAB Programming", published in the International Journal in the Recent and Innovation Trends in Computing and Communication in June 2015 by Apoorva P. The purpose of this paper was to describe how interconnecting wires are difficult, hazardous or non-existent. An alternative method used here was the inductive coupling method, a form of WPT; the results showed that WPT was the best alternative despite a few drawbacks such as high installation costs.

Another work in this field is, "Design and Optimization of Switched-Mode Circuits for Inductive Links", a PhD thesis published by Cranfield University. The problem statement discussed was the limitations and the design challenges in WPT systems such as low efficiency and a short transmission range. To solve this problem, Cranfield University used techniques such as mathematical modeling and analysis. The conclusion they arrived at was that if the inductive link is operated at its resonant frequency, the reflected impedance is maximised.

In addition to these works, a biomedical application was discussed by Shawon Senjuti and submitted as a PhD thesis to the University of West Ontario, London, Ontario, Canada. The project titled as, "Design and Optimization of Efficient WPT for Implantable Biotelemetry Systems".aimed to develop a resonance-based inductive coupling technique in order to develop a design and optimization procedure for the inductors. The optimization process should be done as per specific application requirements was the conclusion she arrived at.

III. Design and Mathematics:



[Fig: B:] Mutual inductance based wireless power transfer Circuit

To operate the vehicle through wireless power transfer, a set of transmitter and receiver is required. One will be at the vehicle end and the other is planned to set at the road end. To transfer the power wirelessly from the transmitter to receiver coil is used. It uses the basic concept of Ampere's Circuital law and Faraday's Law of induction. The transmitter side is powered with a DC supply. When the primary coil (transmitter coil) gets supply, the current starts flowing through it and a field is generated. This field is received by the receiver coil and then the load connected to the output side of the receiver will get supplied and it will start working. Here in this project, the load is the motor of the vehicle to be driven.

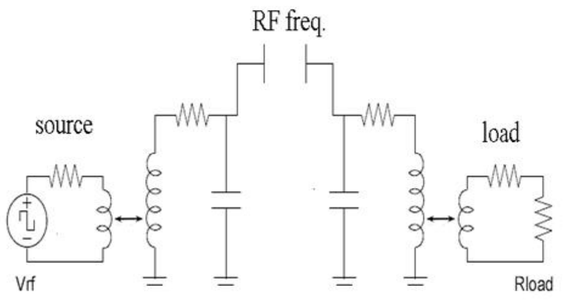


Fig. [C] Concept circuit for WPT

In the above circuit, the source is supplied to the transmitter which then excites the transmitter coil. With RF the field is transmitted to the receiver coil. The receiver coil is then excited and transfers that power with maximum possible efficiency to the load.

The basic concept used here is resonance, so we need to know what resonance is.

Fig. [D] Concept circuit for WPT

Resonance is a phenomenon that occurs in nature in many different forms. In general resonance involves energy oscillating between two modes. In a system at resonance, it is possible to have a large build-up of stored energy while having only a weak excitation to the system. The build-up occurs if the rate of energy injection into the system is greater than the rate of energy loss by the system.

The behavior of an isolated resonator can be described by two fundamental parameters, its resonant frequency ωo and its intrinsic loss rate Γ. The ratio of these two parameters defines the quality factor Q of the resonator (Q=(ωo)/2Γ) a measure of how well it stores energy. An example of resonator circuit is as shown in figure 2.3.1 below

Resonant frequency $\omega o = 1/\sqrt{LC}$

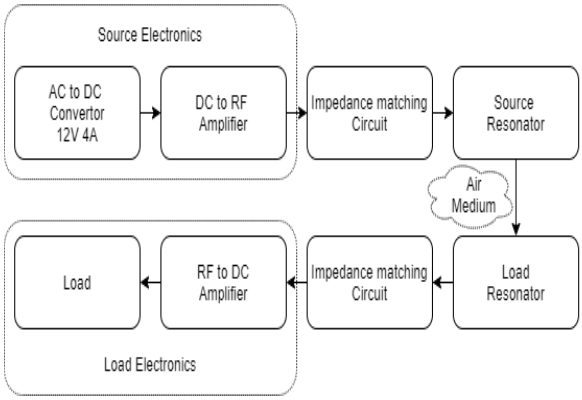
Quality factor $Q = (\omega o)/2\Gamma$

$= (\omega o\ L)/R$

Coupled Resonators:

If two resonators are placed in proximity to one another such that there is coupling between them, it becomes possible for resonators to exchange energy.

IV. Working Principle



Fig[F]: Block diagram of working principle of WPT

The above figure consists of two parts, the transmitter as well as the receiver. The transmitter will be at the road end and the receiver will be at the vehicle end.

Progressing from left to right on the top line of the diagram, the input power to the system is usually either wall power (AC mains) which is converted to DC in an AC/DC rectifier block, or alternatively, a DC voltage directly from a battery or other DC supply. In high power applications a power factor correction stage may also be included in this block. A high efficiency switching amplifier converts the DC voltage into an RF voltage waveform used to drive the source resonator. Often an impedance matching network (IMN) is used to efficiently couple the amplifier output to the source resonator while enabling efficient switching-amplifier operation. Class D or E switching amplifiers are suitable in many applications and generally require inductive load impedance for highest efficiency. The IMN serves to transform the source resonator impedance, loaded by the coupling to the device resonator and output load, into such an impedance for the source amplifier. The magnetic field generated by the source resonator couples to the device resonator, exciting the resonator and causing energy to build up in it. This energy is coupled out of the device resonator to do useful work, for example, directly powering a load or charging a battery. A second IMN may be used here to efficiently couple energy from the resonator to the load. It may transform the actual load impedance into an effective load impedance seen by the device resonator which more closely matches the loading for optimum efficiency. For loads requiring a DC voltage, a rectifier converts the received AC power back into DC. The source resonator is the transmitter coil whereas the device resonator is receiver coil.

A. Mutual Inductance:

The simulation of this project is done on NI Multisim 11.0

The simulation diagram is as shown in the figure below.

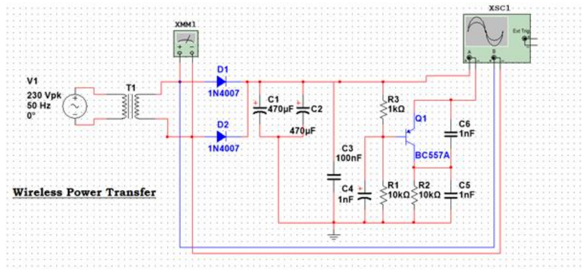


Fig. [G] Simulation on Multisim

Waveforms:

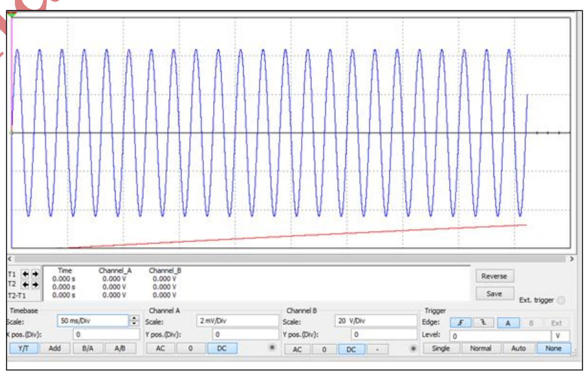


Fig. [H] Waveforms

B. Tesla Coil

All it takes to transmit electricity wirelessly is a system that converts a low voltage to a high voltage and simultaneously turns itself on and off very quickly.

That's what we're building. A few volts of electricity are passed to one side of a coil of wire and to a grounded capacitor connected to the negative side of the power supply. The other side of the coil is connected to the collector of a transistor. When connected to a power source, the capacitor begins to charge while the coil begins to radiate an electromagnetic field. This coil is then placed around a second coil with many more windings of a smaller gauge wire which creates a transformer, converting a low input voltage to a very high voltage in the second coil. This secondary coil is then connected to both a resistor connected to the power source and the base of the transistor, which then shuts off the flow of current to the first primary coil.

This circuit configuration creates a feedback loop that automatically turns on and off hundreds of times per second, creating a high voltage, high frequency electric field capable of transmitting wireless electricity.

V. Study and Analysis:

The following table shows the final result in terms of voltage and distance for the specified transmitter and receiver coils

Distance (in cm)	Voltage (in volts)
0 (approx.)	2.13
1	2.03
2	1.94
3	1.86
4	1.74
5	1.58
6	1.46
7	1.42
8	1.35
9	1.31
10	1.26
11	0.7 (LED threshold)

Table[A] Results

VI. Future Scope:

The main consideration of any application is its efficiency. The efficiency of the proposed model can be further improved if the design is optimized so that loss due to interference is reduced. The power level is also an issue in industrial applications. Work can be done to fulfill the demand for high power levels and efficiency. Resonance phenomenon can be studied in depth and applied to enhance wireless power transfer systems in the coming years. The areas in which applications can be developed are consumer electronics, medical devices, electric vehicles, defense systems etc.

VII. Conclusion:

This project leads to conclusions in different regions. Some of the important regions are considered here. Different coils are used to show the change in transmitted power. Wireless Power Transfer emerges as a suitable alternative to replace the conventional wired systems. As automobile application is considered, the fuel requirement will also reduce which will in turn reduce the cost and save the fuel reserves. Despite the large installation cost the wireless power transfer can be used for a large number of applications. The circuit is very simple to implement, so circuit complexity is also less as compared to wired systems.

VIII. Acknowledgement:

I would like to thank my mentors and On My Own Technology (OMOTEC) for providing me with the opportunity to work on this project. It allowed me to research numerous topics, through which I gained immense knowledge.

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