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Analysis and design of noncontact charger using lc load resonant coupling for electrical vehicle system

[1,] N.Ravishankar, (M.E AE), [2,] N.M.Anandhan, M.E,
[1,] Student/Dept of ECE, Anna University Chennai,
Jayam College of Engineering and Technology, Dharmapuri DT, India.
[2,] Assistant Professor/Dept of ECE, Anna University Chennai,
Jayam College of Engineering and Technology, Dharmapuri DT, India.

ABSTRACT

A wireless power transfer system for roadway powered electric vehicles (EVs) is presented. The system concept is using resonant inductive coupling of primary coils arranged in a linear array in the roadway to secondary coils in each EV. Due to the convenience of using electronic devices, contactless energy transfer (CET) systems have garnered interest in various fields of industry. In this system, a new design approach that uses antiparallel resonant loops for CET systems is presented. Forward and reverse loops forming an antiparallel resonant structure stabilize the transfer efficiency and therefore prevent it from dramatic distance-related changes, a phenomenon that can occur in CET systems with non-radiative methods (or resonant methods). This paper proposes frequency-insensitive antiparallel resonant loops and the optimal design of these loops for uniform transfer efficiency according to the distance. The proposed technique achieves frequency variation that is one-sixth that of conventional unidirectional loops, thus improving the power efficiency to a maximum of 87%. The improved performance of data transmissions for near-field communication is also verified. Effectiveness of the proposed approaches is demonstrated by using a dual-band (1.83/3.36 GHz) antenna of only $0.01\lambda^2$ in size. Power conversion efficiency (PCE) represents a major challenge for WPT, especially at low input power levels. Our results indicate that PCE is related to the distributions and the combinations of input power spectrum. Therefore, a novel multitone powering system is developed to achieve a high output voltage.

KEYWORDS - *Electrical vehicle system, Wireless power transmission, IGBT, OLEV.*

I. INTRODUCTION

Since a few years electric powered vehicles are available on the market. At the present time, most EVs are battery powered and the cars suffer from short cruising range, long charging times or the need to exchange the depleted battery for a charged one, high cost and the heavy weight of the battery. Wireless inductive power transfer offers an interesting option for powering EVs. Recently, wireless power supply devices which supply electric power wirelessly (in the medium of air) to apparatuses without power cables or the like have come to be in practical use. The principles upon which wireless electric power transmission is realized are generally categorized into three types there are Electromagnetic induction type, Radio reception type and Resonance type.

Electromagnetic induction non-contact power transmission employs the phenomenon in which application of an electric current to one of adjacent coils induces an electromotive force in the other coil with magnetic flux as the medium. Wireless power transfer (WPT) is a breakthrough technology that provides energy to communication devices without the power units. With the remarkable progress being made recently, this technology has been attracting a lot of attention of scientists and R&D firms around the world. Recently, the usage of mobile appliances such as cell phones, PDAs, laptops, tablets, and other handheld gadgets, equipped with rechargeable batteries has been widely spreading.

The design and implementation of a wireless power transfer system for moving electric vehicles along with an online electric vehicle system are presented. Electric vehicles are charged on roadway by wireless power transfer technology.

A WPT system for moving Electric Vehicles with linearly arranged array of primary power transfer coils which power the secondary power pick up coils in EVs. The system is geared to minimize loss of the stored energy in the primary coils and compensation capacitors by passing the energy on to the subsequent coil and capacitor of the linear array by sensing the vehicle location and presence.

II. PROPOSED SYSTEM

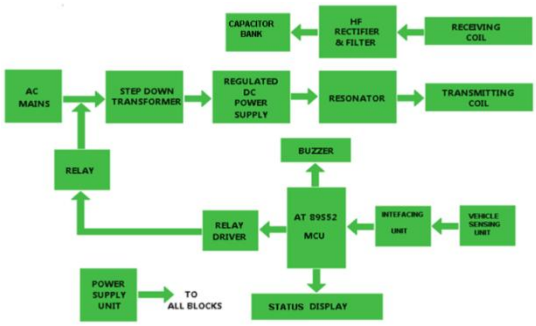

Fig 1: Block Diagram of Proposed system

The receiving coil is received the electrical energy from the transmitting coil. When the resonance frequency is identically the transmitting coil transmits the energy, otherwise not transmitting the energy from the transmitter. In receiver section, the transmitting frequency is observed by the coil and it converts the resonant frequency into voltage form. This voltage can be rectified and stored in battery bank. The vehicle system utilized the energy from the battery bank.

III. WIRELESS POWER TRANSMISSION

Wireless power in history

Wireless power transmission is not a new idea. Nickola Tesla demonstrated transmission of electrical energy without wires in early 19th century. Tesla used electromagnetic induction systems. William C Brown demonstrated a micro wave powered model helicopter in 1964. This receives all the power needed for flight from a micro wave beam. In 1975 Bill Brown transmitted 30kW power over a distance of 1 mile at 84% efficiency without using cables. Researchers developed several technique for moving electricity over long distance without wires. Some exist only as theories or prototypes, but others are already in use.

Consider an example, in this electric devices recharging without any plug-in. The device which can be recharged is placed on a charger. Supply is given to the charger and there is no electrical contact between charger and device.

Previous schemes for wireless power transmission included attempts by the late scientist Nikola Tesla and the Microwave power transmission. Both Tesla's design and the later microwave power were forms of radiative power transfer. Radiative transfer, used in wireless communication, is not particularly suitable for power transmission due to its low efficiency and radiative loss due to its Omni directional nature.

Theoretical background

The principle of Evanescent Wave Coupling extends the principle of Electromagnetic induction. Electromagnetic induction works on the principle of a primary coil generating a predominantly magnetic field and a secondary coil being within that field so a current is induced within its coils. This causes the relatively short range due to the amount of power required to produce an electromagnetic field. Over greater distances the non-resonant induction method is inefficient and wastes much of the transmitted energy just to increase range. This is where the resonance comes in and helps the efficiency dramatically by "tunneling" the magnetic field to a receiver coil that resonates at the same frequency.

Theoretical analysis shows that by sending electromagnetic waves around in a highly angular waveguide1, evanescent waves are produced which carry no energy. If a proper resonant waveguide is brought near the transmitter, the evanescent waves can allow the energy to tunnel to the power drawing waveguide, where they can be rectified into DC power. Since the electromagnetic waves would tunnel, they would not propagate through the air to be absorbed or be dissipated, and would not disrupt electronic devices or cause physical injury.

Methods of wireless power transmission

i. Inductive coupling
ii. Transformer coupling
iii. Resonant Inductive Coupling
iv. Radio and Microwave Energy Transfer

The inductive coupling is the resonant coupling between the coils of two LC circuits with the same resonant frequency, transferring energy from one coil to the others.

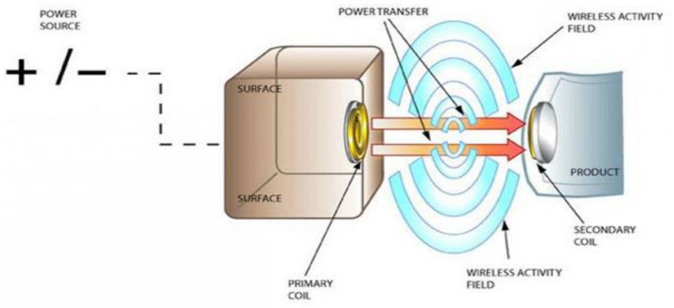

Fig 2: Resonant Inductive Coupling

With inductive resonance, electromagnetic energy is only transferred to recipient devices that share the identical resonant frequencies as the energy source, so energy transfer efficiency is maintained, even when misalignment occurs.

IV. CONCEPT OF RESONANT WIRELESS POWER TRANSFER

Resonance

Resonance is a phenomenon that occurs in nature in many different forms. In general, resonance involves energy oscillating between two modes, a familiar example being a mechanical pendulum in which energy oscillates between potential and kinetic forms. 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 behaviour of an isolated resonator can be described by two fundamental parameters, its resonant frequency and its intrinsic loss rate, Γ. The ratio of these two parameters defines the quality factor or of the resonator () a measure of how well it stores energy.

An example of an electromagnetic resonator is the circuit shown in Figure, containing an inductor, a capacitor and a resistor.

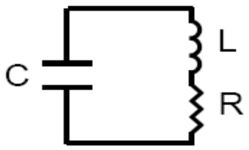

Fig 3: Electromagnetic Resonator

In this circuit, energy oscillates at the resonant frequency between the inductor (energy stored in the magnetic field) and the capacitor (energy stored in the electric field) and is dissipated in the resistor. The resonant frequency and the quality factor for this resonator are

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

and

$$Q = \frac{\omega_0}{2\Gamma} = \sqrt{\frac{L}{C}}\frac{1}{R} = \frac{\omega_0 L}{R}$$

The expression shows that decreasing the loss in the circuit, i.e., reducing, increases the quality factor of the system.

In highly-resonant wireless power transfer systems, the system resonators must be high-Q in order to efficiently transfer energy. High-Q electromagnetic resonators are typically made from conductors and components with low absorptive (also sometimes referred to as ohmic, resistive, series resistive, etc.) losses and low radiative losses, and have relatively narrow resonant frequency widths. Also, the resonators may be designed to reduce their interactions with extraneous objects.

Coupled Resonators

If two resonators are placed in proximity to one another such that there is coupling between them, it becomes possible for the resonators to exchange energy. The efficiency of the energy exchange depends on the characteristic parameters for each resonator and the energy coupling rate, κ, between them. The dynamics of the two resonator system can be described using coupled-mode theory, or from an analysis of a circuit equivalent of the coupled system of resonators. One equivalent circuit for coupled resonators is the series resonant circuit

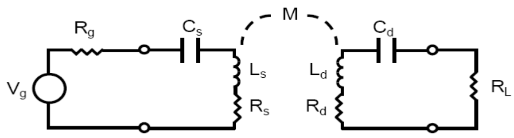

Fig 4: Equivalent circuit for the coupled resonator system

Here the generator is a sinusoidal voltage source with amplitude at frequency with generator resistance. The source and device resonator coils are represented by the inductors and, which are coupled through the mutual inductance M, where.

$$M = k\sqrt{L_s L_d}$$

Each coil has a series capacitor to form a resonator. The resistances and are the parasitic resistances (including both ohmic and radiative losses) of the coil and resonant capacitor for the respective resonators.

Where

$$U = \frac{\omega M}{\sqrt{R_s R_d}} = \frac{\kappa}{\sqrt{\Gamma_s \Gamma_d}} = k\sqrt{Q_s Q_d}$$

We have the ability to choose the generator and load resistances which give the best system performance (or use an impedance transformation network to match to other resistance values). If we choose

$$\frac{R_g}{R_s} = \frac{R_L}{R_d} = \sqrt{1 + U^2}$$

Then the efficiency of the power transmission is maximized

$$\eta_{opt} = \frac{U^2}{\left(1+\sqrt{1+U^2}\right)^2}$$

Here one can see that highly efficient energy transfer is possible in systems with large values of. Note that the impedance matching described above is equivalent to the coupled mode theory treatment that shows that work extracted from a device can be modeled as a circuit resistance that has the effect of contributing an additional term w, to an unloaded device object's energy loss rate d, so that the overall energy loss rate is given by

$$\Gamma_d' = \Gamma_d + \Gamma_W$$

And that the efficiency of the power transmission is maximized when

$$\frac{\Gamma_W}{\Gamma_d} = \sqrt{\left[1+\left(\kappa^2 / \Gamma_s\Gamma_d\right)\right]} = \sqrt{1+k^2Q_sQ_d} = \sqrt{1+U^2}$$

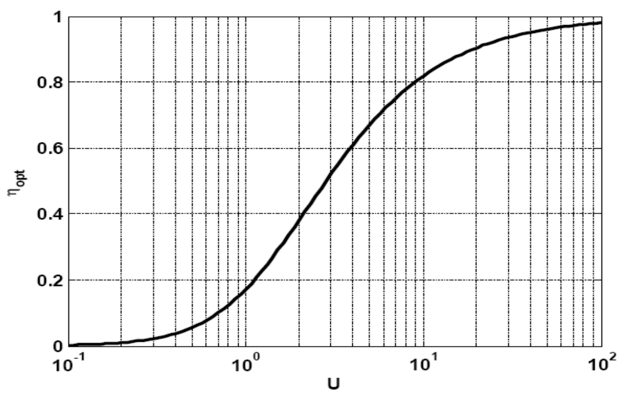

Fig 5: Optimum efficiency of energy transfer

Note that the best possible efficiency of a wireless power transmission system only depends on the system figure-of-merit, which can also be written in terms of the magnetic coupling coefficient between the resonators, , and the unloaded resonator quality factors, and

$$U = \frac{\omega M}{\sqrt{R_s R_d}} = k\sqrt{Q_s Q_d}$$

Knowing the resonator quality factors and the range of magnetic coupling between them for a specific application, one can use Equations to determine the best efficiency possible for the system.

WiTricity Technology: The Basics

WITRICITY is a term which describes wireless energy transfer, the ability to provide electrical energy to remote objects without wires. Wireless energy transfer also known as wireless energy transmission is the process that takes place in any system where electromagnetic energy is transmitted from a power source (such as a Tesla coil) to an electrical load, without interconnecting wires. Wireless transmission is employed in cases where interconnecting wires are inconvenient, hazardous, or impossible.

Though the physics can be similar (pending on the type of wave used), there is a distinction from electromagnetic transmission for the purpose of transferring information (radio), and where the amount of power transmitted is only important when it affects the integrity of the signal.

Electricity is today a necessity of modern life. It is difficult to imagine passing a day without electricity. The conventional use of electricity is made possible through the use of wires. The principle of wireless electricity works on the principle of using coupled resonant objects for the transfer of electricity to objects without the use of any wires. A witricity system consists of a witricity transmitter and another device called the receiver.

The receiver works on the same principle as radio receivers where the device has to be in the range of the transmitter. It is with the help of resonant magnetic fields that witricity produces electricity, while reducing the wastage of power. The present project on witricity aims at power transmissions in the range of 100 watts. May be the products using WiTricity in future might be called Witric or Witric's.

Results

Inverter voltage [V]	Input power [kW]	Output voltage [V]	Output current [A]	Output power [kW]	Efficiency [%]
230	55	620	69.1	42.84	77.89
280	68	620	89	55.18	81.15
332	82	620	108.9	67.52	82.34
388	97.2	620	128.8	79.86	82.16
450	113	620	148.8	92.26	81.64
482	121	620	158	97.96	80.96
500	125.6	620	163.7	101.49	80.81

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482	121	620	158	97.96	80.96
500	125.6	620	163.7	101.49	80.81

V. CONCLUSION

Wireless energy transmission holds great potential for the future. Magnetic induction, resonant induction, and electromagnetic wave power transmission all have applications that could revolutionize the way we live and use electricity. Keep your eyes open for wireless energy technology in new products, and look forward to when everything will truly be wireless. The resistance of the wire used in the electrical grid distribution system causes a loss of 26-30% of the energy generated. This loss implies that our present system of electrical distribution is only 70-74% efficient. We have to think of alternate technology to transmit and distribute the electricity. The transmission of power without wires may be one noble alternative for electricity transmission

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