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A Novel Witricity for Wireless Charging

Kannan S[1], N.Sasirekha.,M.E.,(Ph.D)[2]

[1]M.E Communication Systems,Sona College of Technology
Salem, India.

[2] Associate Professor, Department of ECE, Sona College of Technology
Salem, India.

[1] kannan248@gmail.com
[2] sasi_krishni@yahoo.com

***Abstract*— The main objective of this project is to develop a device for wireless power transfer. 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 connect electrically such as pace makers implanted in the body that runs on a battery. Moreover this technique can be used in number of applications, like charging a mobile phone, iPod, laptop battery, propeller clock wirelessly. This concept is an Emerging Technology, and in future the distance of power transfer can be enhanced as the research across the world.**

***Keywords*— Witricity, high frequency transformer, voltage regulator, transistor, coil.**

I. INTRODUCTION

WITRICITY is wireless electricity. It is based on the principle of the transmission of energy from one place to another without using wires. One of the best natural examples of wireless electricity is Lightning. Lightning is a massive electrostatic discharge caused by unbalanced electric charge in the atmosphere. A typical cloud to ground lightning strike can be over 5 km long. The terrestrial atmosphere is very good dielectric located between two conductors - a surface of the ground from below and the top layers of an atmosphere, including an ionosphere, from above. These layers are passive components of a global electric circuit. When the local electric field exceeds the dielectric strength of damp air, electrical discharge results, often followed by more discharges along the same path.

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 of 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 connect electrically such as pace makers which is an electronic device that works in place of a defective heart valve that is 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 designed to charge a rechargeable battery wirelessly for the purpose.

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 receiver that is separated with a considerable distance. Therefore the transfer could be seen as the primary transmits and the secondary receives the power to run load. This technique can also be used to charge a mobile phone, iPod, laptop battery, and 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.

II. THEORY AND DESIGN OF THE PROPOSED WITRICITY SYSTEM

Witricity is based on the concept of near-field and strongly coupled magnetic resonance. The fundamental principle is that resonant objects can exchange energy efficiently, while non-resonant objects only interact weakly. The Witricity system consists of source and device resonators, a driving loop, and an output loop. The source resonator is coupled to the driving loop which is linked to a convertor circuit which converts 230V AC into a 12V High Frequency signal that supplies energy to the system. The device resonator coil is coupled to the output loop to provide the power to an external load. Due to its large physical separation, wireless inductive coupling transformers have large leakage inductances and small mutual inductance. Thus the coupling rates are very small, quite often less than 0.1, while those for conventional transformers are between 0.95–0.98. For the Witricity system, the coupling rate can however be as high as 0.7–0.9 by virtue of the strong resonant frequency coupling between primary and secondary windings.

To achieve high coupling rate and transmission efficiency, sources with certain resonant frequency in the MHz range are fed to the primary windings. The coupling coefficient, k, between the transmitter and the receiver, represents the fraction of flux, created in the primary coil coupled into the secondary coil. It can be maximized by selecting the radius of the coils.

When the flux generated by the transmitter coil is only in itself and there is no common flux between the two coils, the coupling coefficient k is zero. k is equal to one when all of the fluxes created by the transmitter coil is in the receiver coil. Contrast to traditional wireless energy transmitting technology, the coupling coefficient of the proposed Witricity system is not only dependent on the geometry of the link; it also relies on the same intrinsic frequency of the transmitter and the receiver. Therefore, k is dependent on the design dimensions and the number of turns in either of the coils. An equation relating the inductances to the coupling coefficient is

$$k = \frac{M}{\sqrt{L1L2}} = \frac{Mon_1n_2}{\sqrt{n_1{}^2L_{10}n_2{}^2L_{20}}} = \frac{Mo}{\sqrt{L_{10}L_{20}}} \qquad (1)$$

where M is the mutual inductance between the coils; L_1 and L_2 are the self-inductances of the coils; n_1 and n_2 are the number of the transmitter and the receiver turns, respectively; Mo is the single turn mutual inductance; L_{10} and L_{20} are the single turn inductance of the transmitter and the receiver, respectively. The coupling rate has a relatively large value of about 0.81 when the distance is 5 cm for Witricity. It decreases gradually as the physical separation distance increases.

III. MAGNETIC RESONANT COUPLING

Wireless power transfer can be achieved using magnetic resonant coupling when the transmitting and receiving coils are in resonance and the resonance frequency of the receiving and transmitting coils is the same. This allows transfer of power across large air gaps with high efficiency. Wireless power transfer is achieved using magnetic field couplings that are nonradiative. As the characteristic impedance increases, the two resonance frequencies become equal and the efficiencies at resonance are improved to their maximum for a given air gap length. After that point, as the characteristic impedance becomes even larger, the efficiency at the equal resonance frequency worsens. The length of the air gap is varied between 20, 49,170, and 357 mm. When the air gap length is small; g = 49 mm, it can be shown that the process of two resonance frequencies merging into one resonant frequency is possible; therefore, the efficiencies increase as the characteristic impedance increases. On the other hand, when the air gap length is large at g = 357 mm, the two resonance frequencies have already become equal. After this point, the efficiency worsens as the characteristic impedance increases. The results of the experiment are almost the same as the theoretical results for the equivalent circuit. The losses at the impedance transformation section are 0.8% and 5.9% at 20 and 5 Ω, respectively. Therefore, when the characteristic impedance is 5 Ω, the error is larger than that at 20 Ω. The details of the relation of the efficiencies of the two resonance frequencies versus air gap lengths are shown in Fig. 1. The lines are the results of the equivalent circuit, and the dots are the results of the electromagnetic field analysis. These data show good agreement between the two analyses. The efficiency of the resonance frequencies is constant when the air gap length increases and when the resonance frequencies become equal.

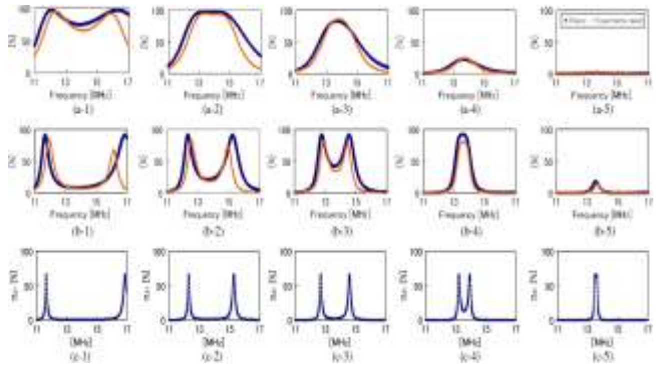

Fig.1 Peak efficiency for each gap length related to characteristic impedance.

A. Interaction in Lossless Physical System

Coupled mode theory based on a set of integrable coupled mode equations accounts well for the mechanisms of the wireless electric system, where power swapping follows a periodic manner and can be expressed analytically. Considering the modal signals or state variables in terms of linear dynamic systems $a_1(t)$ and $a_2(t)$ of two lossless objects with natural frequencies ω_1 and ω_2, we have

$$\frac{da_1(t)}{dt} = i\omega_1\, a_1(t) + k_{12}\, a_2(t) \qquad (2)$$

$$\frac{da_2(t)}{dt} = i\omega_2\, a_2(t) + k_{21}\, a_1(t) \qquad (3)$$

where k_{12} and k_{21} are the coupling coefficients between two modes. The roots of the equation can be obtained as

$$\omega = \frac{\omega_1 + \omega_2}{2} \pm \sqrt{\left(\frac{\omega_1 - \omega_2}{2}\right)^2 + |k_{12}|^2}$$

$$= \frac{\omega_1 + \omega_2}{2} \pm \Omega_0 \qquad (4)$$

it indicates that the two frequencies of the coupled system are separated by Ω_0. In particular, when $\omega_{1=}\ \omega_2$, the difference between the two natural frequencies of the coupled modes is $2\Omega_0$. Suppose, initially, that at t=0, $a_1(0)$ and $a_2(0)$, are specified, then the two solutions of (2) and (3) are expressed by

$$a_1(t) = a_1(0)\left[\left(cos\Omega_0 t - j\frac{\omega_2 - \omega_1}{2\Omega_0}\, sin\Omega_0 t\right) + \frac{k_{12}}{\Omega_0}\, a_1(0) sin\Omega_0 t\right].e^{j[(\frac{\omega 1 + \omega 2}{2})]t} \qquad (5)$$

$$a_2(t) = \left[\frac{k_{21}}{\Omega_0}\, a_1(0) sin\Omega_0 + a_2(0)\left(cos\Omega_0 t\, j\frac{\omega_1 - \omega_2}{2\Omega_0}\, sin\Omega_0 t\right)\right].e^{j[(\frac{\omega 1 + \omega 2}{2})]t} \qquad (6)$$

Let us consider the case where $a_1(0)$ =1and $a_2(0)$ =0 and $\omega_1 = \omega 2 = \omega$, we have $a_1(t) = cos\Omega_0 te^{j\omega t}$ and $a_2(t) = sin\Omega_0 te^{j\omega t}$. Mode 1 is fully excited at t=0, but at Ω_0 t= $\pi/2$, all the excitation appears in mode 2. At Ω_0 t= π, the excitation returns to mode 1 and mode 2 is unexcited. The process repeats periodically. Hence, the excitation is transferred back and forth with frequency $2\Omega_0$ or $2|k_{12}|$. Fig. 2 shows energy exchange between two modes. Here, Fig. 2 (a) indicates that resonant energy swapping with k= 500,000, $f_1 = f_2$ = 1MHz can be efficient and complete. If $f_1 \neq f_2$, the energy exchange is not complete, but partial and inefficient, this can be shown as in Fig. 2 (b).

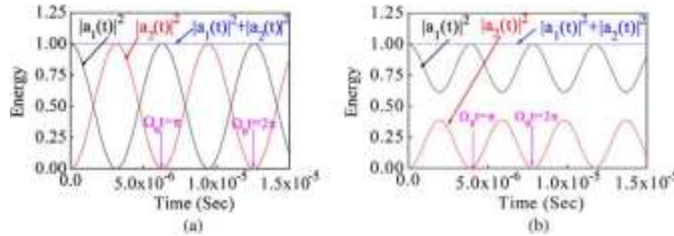

Fig. 2 Energy exchanges in two-object lossless system. (a) Symmetric resonant case. (b) Nonresonant case.

B. Interaction in Real Physical System

To easily link coupled mode theory to the present wireless electric system, we have the following coupled differential equations:

$$\frac{da_S(t)}{dt} = (i\omega_S - \Gamma_S)a_S(t) + ik_{SD}\, a_D(t) \qquad (7)$$

$$\frac{da_D(t)}{dt} = (i\omega_D - \Gamma_D)a_D(t) + ik_{DS}\, a_S(t) \qquad (8)$$

where $a_S(t)$ and $a_D(t)$ denote, respectively, the modal signals at the source and device objects, $\omega_{S,D} = 2\pi f_{S,D}$ are the individual angular frequencies, $|k_{SD}| = |k_{DS}|$ are the coupling coefficients, and $\Gamma_{S,D}$ are the individual intrinsic decay rates.

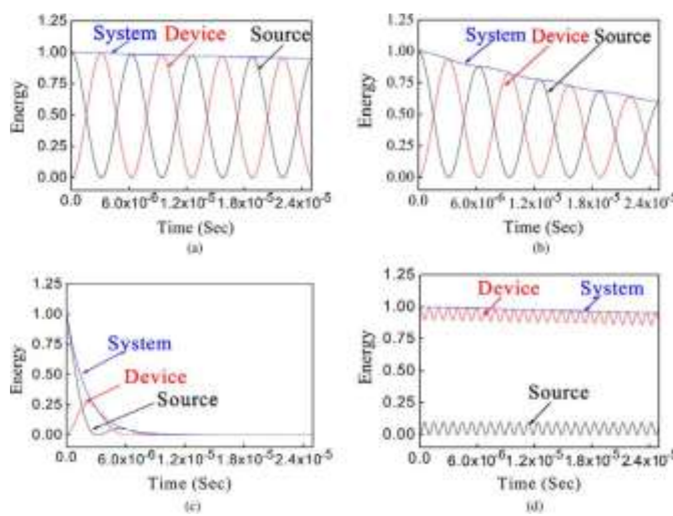

Fig. 3 Energy exchanges of a two-object lossy system. (a) Resonant strong coupling with identical resonators. (b) Resonant strong coupling for resonators with different decays. (c)Resonant weak coupling. (d)Nonresonant case.

a) Strong coupling $k/\sqrt{\Gamma_S \Gamma_D} >> 1$: As a key distance-dependent figure-of-merit, $k/\sqrt{\Gamma_S \Gamma_D}$ is known as the relative coupling parameter. It represents, intuitively, the ratio of "how fast energy is transferred between the source and device" to "how fast it is dissipated due to intrinsic losses in these resonators". Our desired strong coupling regime for wireless electricity is provided by $k/\sqrt{\Gamma_S \Gamma_D} >> 1$. When this inequality is satisfied, the coupling rate is much higher than the loss rate. However, to realize a wireless electric system, "strong coupling" and "resonance" must be guaranteed simultaneously. The fact that the coupling, in theory, is inversely proportional to the cube of the separation distance, and in practice, may decay even more steeply, leading to the 'mid-range' limitation of the present wireless electric systems. The energy exchange for $f_S = f_D = 1$ MHz, $k = 500{,}000$ and $\Gamma = 1{,}000$ is shown in Fig. 3(a). It can be seen that the source and device energies are continually and completely exchanged via a strong energy channel.

b) Weak coupling $k/\sqrt{\Gamma_S \Gamma_D} \approx 1$ *or* $k/\sqrt{\Gamma_S \Gamma_D} < 1$*:* If $k/\sqrt{\Gamma} >> 1$ is not satisfied, the system will not resonate since system energy will be lost before an avenue for wireless energy transfer is formed in space. This case is shown in Fig. 3(c) with k = 500,000 and Γ = 250,000.In order to transmit power at a high efficiency, the coupling rate should be much higher or faster than the decay rate.

c) Non resonant Case : The two non-resonant objects in Fig. 3(d) with f_S = 1MHz, f_D = 1MHz, k = 500,000 Γ = 1,000 interact weakly and exchange energy ineffectively. This is also true even under strong coupling, as is the case in Fig. 3 (d). It can be observed that the energy absorbed by the device is always very small and the total system energy is also decaying. Hence, no efficient energy exchange and transfer are achieved in this non-resonant case.

IV. WINDING ARRAY STRUCTURE OF COIL

The dimensional relationship of the transmitter coil and the receiver coil must be that the receiver coil must be able to fully enclose at least one primary coil regardless of where the receiver coil is placed. The three necessary conditions proposed for the winding areas are as follows: *1)* The receiver winding should be larger than the transmitter windings; *2)* the receiver winding must fully cover at least one transmitter winding wherever the electronic load is placed on the charging surface of the charging pad; and *3)* one transmitter winding is sufficient to provide enough power transfer for the electronic loads under consideration for the charging circuit. The receiver winding is embedded inside the electronic load for mutual coupling with the transmitter winding. In other words, the transmitter winding is equivalent to the primary winding of a transformer, and the receiver winding is equivalent to the secondary winding.

The inductance of single-layer air-cored cylindrical coils can be calculated to a reasonable degree of accuracy with the simplified formula

$$\mu H = \frac{R^2 N^2}{9R + 10L} \qquad (9)$$

where Henry [µH] , microhenries are units of inductance, *R* is the coil radius (measured in inches to the center of the conductor), *N* is the number of turns, and *L* is the length of the coil in inches.

V. BLOCK DIAGRAM AND OPERATION OF WIRELESS CHARGING SYSTEM

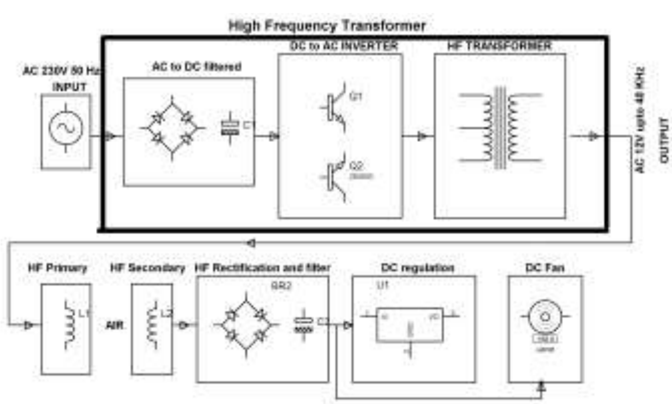

Fig. 4 Block diagram

Electronic transformer works on half bridge and double line frequency. The AC power is given as an input to the bridge rectifier where it is converted into DC using the bridge rectifier. through resistor capacitor gets charged .In one half cycle Q1 (collector to emitter) starts conducting, F1 provides biasing for this Q1 transistor. Current flows from D1 to D2 of primary coil. Then current passes through capacitor C4 and reaches ground. In another half cycle Q2 (collector to emitter) starts conducting and F2 provides bias for this transistor. Then current flows through C3 and then D2 to D1 reaches Q2 and then negative. So in one half cycle flow of current is from D1 to D2,in another half cycle flow of current is from D2 to D1. Biasing for F1, F2 is done automatically i.e. we can't say that when which coil gets bias. so current flowing in the primary coil in both half cycles generates A.C in secondary coil. As the transistors are fast switching devices frequency of A.C becomes 25KHz.This is fed copper windings L1 which are connected to secondary of transformer.L1 transfers the 25 KHz A.C. to L2 by means of EMF (Principle of transformer).

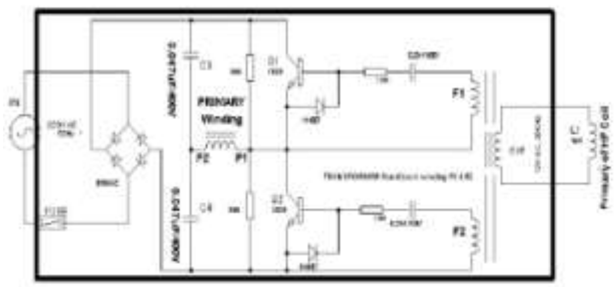

Fig. 5 Transmitter

Voltage induced L2 coil is fed to 4 diodes forming a Bridge Rectifier that delivers dc which is then filtered by an electrolytic capacitor of about 1000microf. The filtered dc being unregulated IC LM7805 is used to get 5v constant at its pin no 3 irrespective of input dc varying from 9v to 14v.

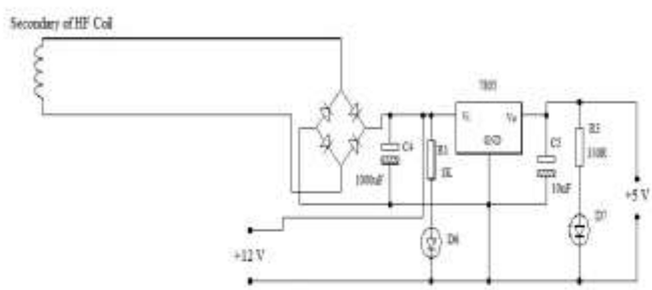

Fig. 6 Receiver

The regulated 5volts dc is further filtered by a small electrolytic capacitor of 10 micro F for any noise so generated by the circuit which can be used for battery charging. One LED is connected of this 5v point in series with a resistor of 330ohms to the ground i.e. negative voltage to indicate 5v power supply availability. The 5v dc is used for other applications as on when required. The output of bridge rectifier i.e., +12V is taken to charge the rechargeable devices.

Voltage rating

The required voltage rating of the devices is defined by the half-bridge topology. Supplying the circuit with 220V RMS A.C. mains, calculating peak value, and adding a safety margin, gives a maximum supply voltage VCC of:

$$
\begin{aligned}
VCC\ (max) &= 220V \times \sqrt{2} + 10\% \\
&= 310V + 10\% \\
&\approx 350\,V
\end{aligned}
$$

To this figure must also be added the overvoltage generated by the input filter at turn-off. In practice, devices are used with a rating of:

VCE (max) = 450V ~ 500V

Current rating

The nature of the half wave bridge topology is such that in normal operation, half the supply voltage is dropped across each device, so from the above figures VCE in steady state is 310V/2= 155V. Hence the collector current in the steady state
can be calculated as

$$POUT = IC\,(RMS) \times VCE\,(RMS)$$
$$VCE(RMS) = 1/2 \times Vmains$$
$$IC(RMS) = 2 \times POUT\,/\,Vmains$$
$$IC(RMS) = IC(peak)/\sqrt{2}$$
$$IC(peak) = 2 \times \sqrt{2} \times POUT\,/\,Vmains$$
$$= 2 \times \sqrt{2} \times 50W\,/\,220V$$
$$IC(peak) = 0.64A$$

VI. EXPERIMENTAL RESULT

If we are particularly organized and good with tie wrap then also a few dusty power cord tangles around our home. We have even had to follow one particular cord through the seemingly impossible snarl to the outlet hoping that the plug pull will be the right one. This is one of the downfalls of electricity. While it can make people's lives easier, it can add a lot of clutter in the process. For these reasons, scientists have tried to develop methods of wireless power transmission that could cut the clutter or lead to clean sources of electricity. Wireless power transmission is not a new idea. Many researchers developed several methods for wireless power transmission. But witricity is a new technology used for wireless power transmission. By the use of this technology transmission of electrical energy to remote objects without wires can be possible. The inventors of witricity are the researchers from Massachusetts Institute of Technology (MIT). They developed a new technology for wireless electricity transmission and this is based upon the coupled resonant objects. In this resonant magnetic fields are used. So the wastage of power is reduced. The system consists of witricity transmitters and receivers. The main areas of application of low power transmission include charging of portable electronic devices, in Medical field such as Implantable Cardiac Pacemakers and in electronic lab where bulky power sources are required in experiments**.**

The objective of this project was to design a novel witricity circuit for wireless charging. The witricity system which was developed in MIT campus was illuminated a 60 W light bulb wirelessly from a power source more than seven feet away. At this distance, the power transfer was achieved with an efficiency of approximately 40%. The existing system of low power transmission for wireless charging has an efficiency of 52% for a distance of 3.5cm. But in this project which uses magnetic coupling for wireless transmission the efficiency is improved at a distance of 5cm.

REFERENCES

[1] S. L. Ho, Junhua Wang,W.N. Fu, Mingui Sun "A Comparative Study Between Novel Witricity and Traditional Inductive Magnetic Coupling in Wireless Charging"

[2] Ning Yin , GuizhiXu , Qingxin Yang , Jun Zhao, XuewenYang , Jianqiang Jin , Weinong Fu ,Mingui Sun "Analysis of Wireless Energy Transmission for Implantable Device Based on Coupled Magnetic Resonance"

[3] Takehiro Imura, *Member, IEEE*, and Yoichi Hori, *Fellow, IEEE* " Maximizing Air Gap and Efficiency of Magnetic Resonant Coupling for Wireless Power Transfer Using Equivalent Circuit and Neumann Formula*"*