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Wireless Power Transmission through Air, Wood & Concrete Medium at Utility Frequency of 50 Hz

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Abstract**—** An attempt is made to perform wireless power transmission using circuits resonating at the utility frequency of 50 Hz. The purpose of this project is to develop a method for transmitting electrical power through air, wood and concrete walls. An equation for the theoretical transmission efficiency that considers the copper and core losses was derived through equivalent circuit analysis. The transmission efficiency was found to be strongly dependent on the shape of the magnet pole pieces.

The ultimate goal of this project is to do simulation using matlab and hardware design is done and obtained values are compared with theoretical and simulated values.

There are three possible methods of wireless power transmission (WPT) electromagnetic induction, magnetic resonance, and radio waves.In the present study, the efficiency of resonant power transmission through concrete was investigated at the utility frequency of 50 Hz, using magnet pole piece configurations

Keywords*- wood, concrete, frequency, magnetic resonance, wireless power transmission (WPT).*

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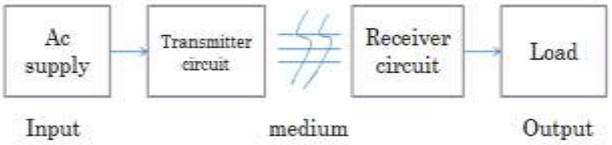
I. INTRODUCTION

The ultimate goal of the present project is to develop a method for transmitting a power operating instructures that humans cannot enter, such as areas contaminated by radioactivity, which is an issue that has become increasingly urgent in the wake of the Fukushima nuclear disaster. This would require energy being sent through thick concrete walls, possibly containing steel frames, so that workers could avoid contamination.

Thus there is a desire to use wireless power technology to eliminate the remaining wired power connection. Presently, several wireless power techniques are being pursued. The idea of wireless power transfer originates from the inconvenience of having too many wires sharing a limited Amount of power sockets. We believe that many people have the same experience of lacking enough sockets for their electronic devices Wireless Power Transfer via Strongly Coupled Magnetic Resonances by André Kurs, Aristeidis Karalis, Robert Moffatt, J. D. Joannopoulos, Peter Fisher, Marin Soljacˇic' Using self-resonant coils in a strongly coupled regime, we experimentally demonstrated efficient non-radioactive power transfer over distances up to 8 times the radius of the coils. We were able to transfer 60 watts with 40% efficiency over distances in excess of 2 meters. We present a quantitative model describing the power transfer, which matches the experimental results to within 5%. We discuss the practical applicability of this system and suggest directions for further study.Wireless Power Transmission through Concrete Using Circuits Resonating at Utility Frequency of 60Hz by Hiroki Ishida and Hiroto Furukawa IEEE the efficiency of resonant power transmission through concrete was investigated at the utility frequency of 60 Hz, using three different magnet pole piece configurations. The effect of a steel frame embedded in the concrete was also evaluated.

In the present research paper, the efficiency of resonant power transmission through air wood and concrete is calculated at the utility frequency of 50Hz using mat lab programming, for magnetic pole piece configurations. Matlab simulation is also done.

II. BLOCK DIAGRAM



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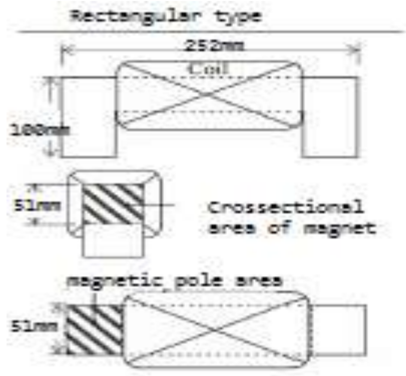
Source*:* AC supply given here is.

Transmitter coil: The transmitter coil is the one which transmits power wirelessly to the receiver coil.

Receiver coil: The receiver coil is the one which receives power from the transmitter coil.

Load 100watt incandescent bulb

Medium: air, wood and concrete



At a frequency of 60 Hz, no saturation of the pole pieces wasobserved up to a flux density of 0.7 T. The coils were wound from single-strand enamel covered copper wire with a diameter of 1.42 mm. These prototypes were designed based on an assumed operating voltage and current of 200 V 5A to 10 A, respectively. The same type of coil was used for the transmitter and receivercircuits We predicted the transmission power efficiency through analysisof the equivalent circuit of a 60-Hz WPT system. The parameters of the equivalent circuit used in the calculation (i.e.,the transformer constants) were determined experimentally using an actual WPT device.

III. CIRCUIT DIAGRAM

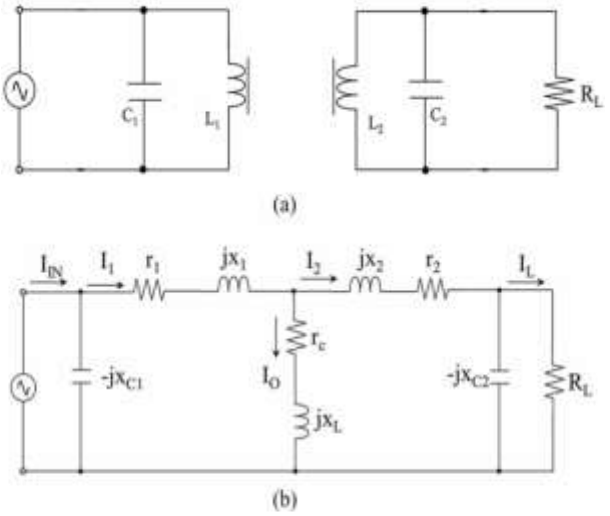


Fig.(2):- WPT system: (a) circuit diagram and (b) Equivalent circuit.

Fig. 2(a) shows a circuit diagram of the WPT system. The secondary condenserC_2 was connected in parallel with the load (PP mode). The configuration with C_2 connected in series (PS mode) can also be used. The equivalent circuit for that in Fig. 2(a) isalso simple, as shown in Fig. 2(b). Here r_1 is the primary winding resistance, jx_1 is the primary leakage inductance, $-jxC_1$ is the primary capacitance, r_2 is the secondary winding resistance,jx_2 is the secondary leakage inductance,$-jxC_2$ is the secondary capacitance, $r_c$is the core loss, $jx_L$is the mutual inductance, and $R_L$is the load resistance.When C2 is connected, the following equation holds for a resonance frequency ω_o

$$X_{c2} = \frac{1}{\omega_o c_2} = X_L + X_2 \qquad (1)$$

The overall impedance for the circuit in the absence of c_1

$$Z = \left(\frac{x_L}{x_L + x_2}\right)^2 R_L + j\left(\frac{x_L x_1 + x_1 x_2 + x_2 x_L}{x_L + x_2}\right) \qquad (2)$$

When c_1 is connected, the condition for which the imaginary part of Z becomes zero is given by

$$x_{c1} = \frac{1}{\omega_o c_2} \qquad (3)$$

For the equivalent circuit shown in fig(b), the transmission efficiency considering the copper and core losses is as follows

$$\eta = \frac{R_L I^2_L}{R_L I^2_L + r_c I^2_0 + r_1 I^2_1 + r_2 I^2_2} \quad (4)$$

When the turn’s ratio of the two coils is 1:1, the relationships between Currents can be expressed as

$$I_1 = \alpha I_L, \quad \alpha = \frac{x_L + x_2}{x_L} \qquad (5.1)$$

$$I_0 = I_1 + I_2 \qquad (5.2)$$

$$|I_2| = |I_L|\sqrt{1 + \left(\frac{R_L}{x_{c2}}\right)^2} \qquad (5.3)$$

$$|I_0|^2 = I^2_L\left[\alpha^2 + 1 + \left(\frac{R_L}{x_{c2}}\right)^2 \quad \cos\phi\right],$$

$$\cos\phi = \frac{x_{c2}}{\sqrt{R^2_L + x^2_{c2}}} \quad (5.4)$$

Substituting eqn (5) into eqn (4)

$$\eta = \frac{R_L}{R_L + r_1\alpha^2 + r_2\left\{1 + \left(\frac{R_L}{x_{c2}}\right)^2\right\} + r_c\left\{\alpha^2 + 1 + \left(\frac{R_L}{x_{c2}}\right)^2 - 2\alpha\sqrt{1 + \left(\frac{R_L}{x_{c2}}\right)^2} \cos\phi\right\}}$$

(6)

Where,

$$R_L = x_{c2}\sqrt{\alpha^2 \frac{r_1}{r_2} + 1} \qquad (7)$$

Thus, the maximum transmission efficiency considering the copper and core losses is [6]

$$\eta_{max} = \frac{1}{1 + \frac{2r2}{x_{c2}}\sqrt{\alpha^2 \frac{r1}{r2} + 1} + \frac{r_c\left\{\alpha^2\left(1 + \frac{r1}{r2}\right) - 2\alpha\sqrt{\alpha^2 \frac{r1}{r2} + 2\cos\phi + 2}\right\}}{x_{c2}\sqrt{\alpha^2 \frac{r1}{r2} + 1}}}$$

(8)

Here, k and the quality factors for the two coils $(Q_1 \& Q_2)$ Q_1

are defined as follows

$$Q_1 = \frac{\omega_0 L_1}{r_1},\ Q_2 = \frac{\omega_0 L_2}{r_2},\ k = \frac{M}{\sqrt{L_1 L_2}},\ M = \frac{x_1}{x_1 + x_2} L_2. \qquad (9)$$

Since eqn (10) is true under any conditions, the maximum efficiency can be approximated as shown by eqn(11)

$$\frac{1}{k^2}\frac{Q_2}{Q_1} > 1 \qquad (10)$$

$$\eta_{max} \approx \frac{1}{1 + \frac{2}{k\sqrt{Q_1 Q_2}} + \frac{2r_c(k + k^{-1} - 1)}{r_2 Q_2}} \qquad (11)$$

Three conclusions can be derived from (12): 1) a large valueof the product of *k* and *Q* yields high efficiency, 2) a large value of the product of *r*2 and *Q*2 (i.e., *ωL*2) is also required for high efficiency, and 3) both copper and core losses increase with decreasing *k* (i.e., increasing transmission distance).

IV. HARDWARE DESIGNE

Silicon steel plate:

Silicon steel is also called as electrical steel or lamination steels. The magnet pole pieces used in the present study were made from silicon steel platesIt has a thickness of 0.38 mm. They were cut using an electric discharge machine.

Copper wire:

The coils were wound from single-strand enamel covered copper wire with a diameter of 1.42mm.These prototypes were designed based on an assumed operating voltage and current of 200 V and 5A to 10A, respectively. The same type of coil was used for the transmitter and receiver circuits.

Insulation:

The purpose of insulating the winding is to keep the different phases / poles or coils insulated from each other and to keep the coils insulated from the iron core if there were insulation the windings would short out against each other or ground out against the core. Within the iron core electrons are manipulated around by Induction coming from the energized coils and this, in turn, builds a little extra heat which amounts a power loss. The phenomenon is known as Eddy currents. Laminating the segments of iron core reduces this power loss and insulating the iron segments from each other furthers the protection against this loss. The traditional process is varnish dip and bake. i.e. very economical and fast. It works pretty well for most small coils which can stand having some areas free to vibrate.

V. MATLAB SIMULATION

Simulation for the above circuit diagram is done by using the mat lab Simulink tools and input and output wave forms are shown below. The single phase Ac voltage of 100 to 200V is given to the transmitter, and voltmeter is used to measure the balanced input and output voltage through the scope1 and scope 2, Ammeter is used to measure the input current through scope and scope3. Load Resistance (R_L) of 530 is connected to receiver, simulation can be done for different values of Resistances

Mat Lab Simulation for Resistive load

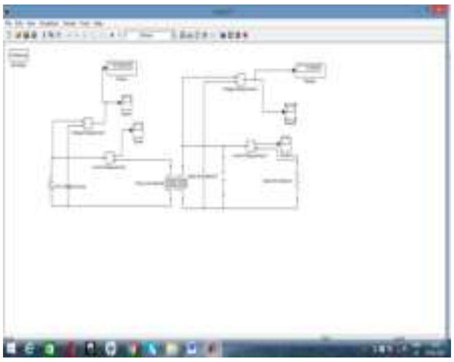


Fig (3):- Simulation circuit for resistive load

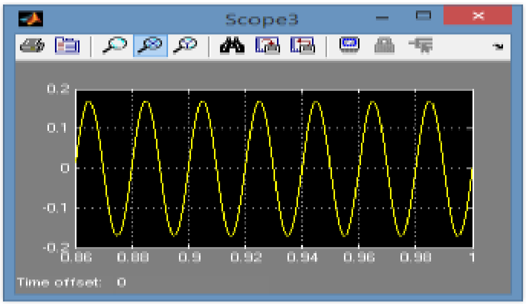


Fig (4):-Output current

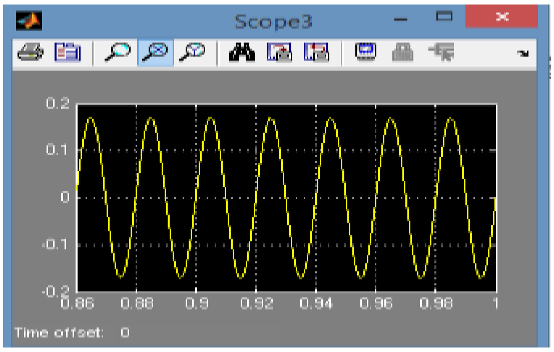


Fig (5):-Output Voltage

Mat Lab Simulation for Multi load

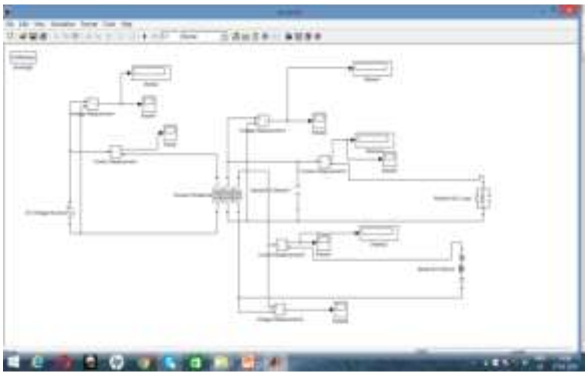


Fig (6):- Simulation circuit for Multi load

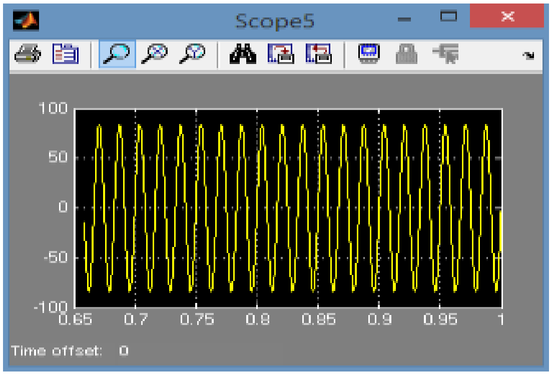


Fig (7):- Output Voltage for load 1

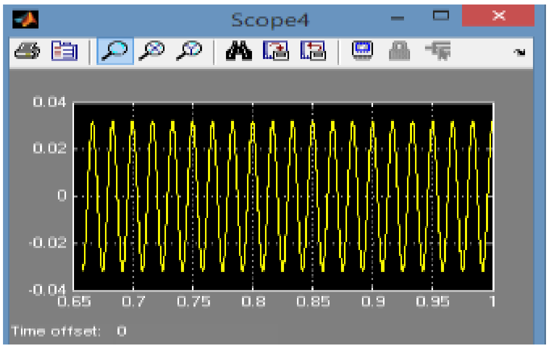


Fig (8):- Output current for load 1

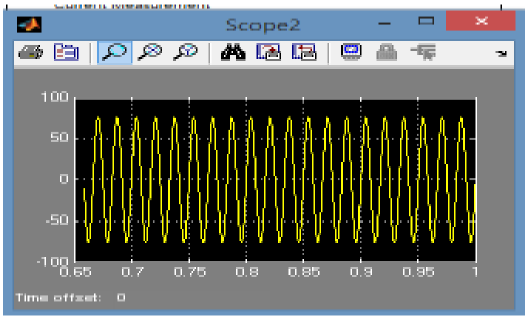


Fig (9):-Output voltage for load 2

VI. EXPERIMENTAL SETUP EXPERIMENTAL SET UP FOR AIR MEDIUM

Experimental set up for wireless powertransfer is as shown in figure. Here the transmitter and receiver are separated at respective distances and obtained values are tabulated as shown in the below table, as the distance increases the output voltage get decreases.

Distance in cm	I/p V_1 in Volts	I/p I_1 in Amps	O/p V_2 in volts	O/p I_2in Amps
4	180	7	110	3
6	180	7	80	3
10	180	7	70	3
12	180	7	40	3

EXPERIMENTAL SET UP FOR WTP IN WOOD MEDIUM

Experimental set up for wireless power transfer is as shown in figure. Here the transmitter and receiver are separated by a 2cm distance

Distance in cm	I/p V_1 in Volts	I/p I_1 in Amps	O/p V_2 in volts	O/p I_2in Amps
4	180	7	100	2
6	180	7	75	2
10	180	7	50	2
12	180	7	38	2

EXPERIMENTAL SETUP FOR WTP IN CONCRETE MEDIUM

The experimental setup of concrete medium is as shown in fig. Here a concrete of thickness 2cm is placed between Transmitter and Receiver. Obtained values are tabulated as shown in the below table

Distance in cm	I/p V_1 in Volts	I/p I_1 in Amps	O/p V_2 in volts	O/p I_2in Amps
4	180	7	100	1.5
6	180	7	70	1.5
10	180	7	50	1.5
12	180	7	32	1.5

VII. FFT ANALIYSIS

The total harmonic distortion obtained for one of the signal of wireless power transfer for resistive load is as shown in the fig (13)

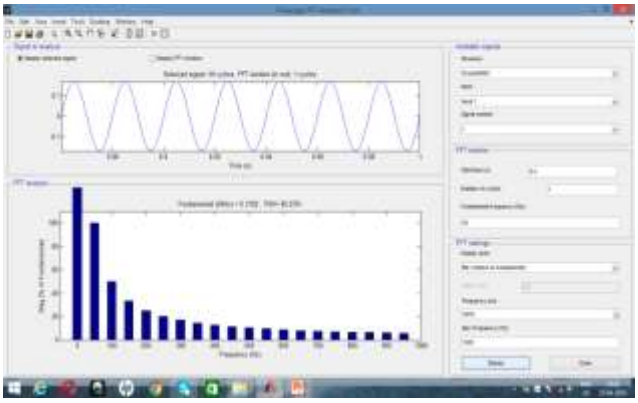


Fig (13):- FFT analysis of output voltage, THD of 80.23

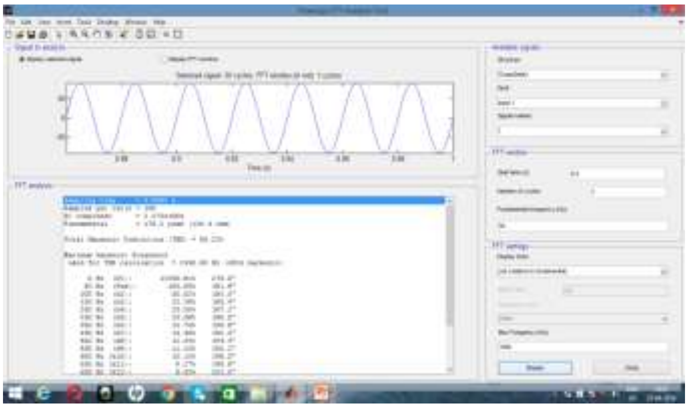


Fig (14):- FFT analysis of output current, THD of 80.23

VIII. CONCLUSION

Obtaining a large *Q* factor is difficult at low frequencies, which is the reason why low-frequency approaches have not been used until now. However, when silicon steel is used as the magnetic core. The efficiency depends upon the shape of magnetic pole pieces, here the rectangular shape pole piece are used.To achieve still more efficiency we can go for single and double flare shape of pole pieces.

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