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# Wireless Power Transmission Using Inductive Coupling

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**ABSTRACT:** Wireless power transfer (WPT) is a new technology by which we can transfer electrical power into devices without any physical connection between source and load. In this paper a simple circuit for wireless power transfer is being made. The different technologies that are developed and mathematical model is discussed. The technology used in this paper is resonance coupling. All the simulation is done on the software.

## I.INRODUCTION

In this modern world it is not possible to imagine a single day without electricity conventionally we are able to use electricity through the use of wires only. Transmission of electricity using wires is not efficient almost 20 to 30% energy got lost during distribution. With the increasing demand of mobile devices the need to charge batteries in these mobile devices is increasing although it is being full filled by the wired chargers but today's world need of the wireless power transmission is growing with the increase in the mobile devices like laptops and smart phones with the advantage of protection from any fault at the power source. The concept of wireless power transfer is not new it was first demonstrated by Nikola Tesla by using demonstration on resonant transformers called Tesla coils.

In 2007 a research done by group of researchers at MIT presented a method to transmit electric power wirelessly, they used an electromagnetically coupled resonance system, they were able to transmit power up to 2 meters[1]. The magnetic resonance coupling technology found to be useful for midrange energy transfer. It is used to charge electric vehicles and pacemakers also.

## II.TYPES OF WIRELESS POWER TRANSFER

Wireless power transfer is a general term for the number of technologies available so for these depend on the range between the transmitter and receiver, operating frequency and the amount of power transferred. [2-3]

Field wise it can be classified in to two categories, far field WPT and near field WPT far field WPT uses Microwave and light wave. The main deference between two of them is illustrated in table 1.

Table 1

| Technology | Range | Frequency |
|---|---|---|
| Microwaves | Long | GHz |
| Light waves | Long | >THz |

Near field WPT on the other hand can be categorized in magnetic induction WPT and electric induction WPT. In magnetic induction WPT (MIWPT) energy transfer is achieved by magnetically coupled coils whereas in the electric induction WPT (EIWPT) energy is transferred by electric field between the plates of the capacitor comparison between both of these technologies is shown in table 2

Table 2

| Technology | Range | Frequency |
|---|---|---|
| MIWPT | Short | 10-50kHz |
| EIWPT | Short | 100-500kHz |

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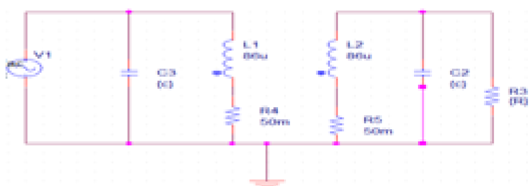
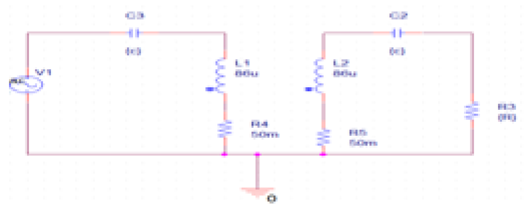
## III. SYSTEM DESCRIPTION

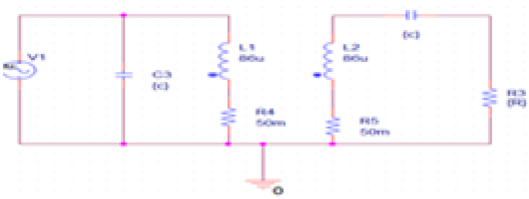
Wireless power transfer system at the transmitter side is composed of a power source which is a high speed switching circuit, a primary impedance compensating network and a coil. At the receiver side on the other hand it consists of a coil, impedance compensating network, a high frequent rectifier, a voltage regulator and DC load. High speed switching circuit is a single ended high frequency quasi resonant inverter it is made of power MOSFETs and triggering circuits MOSFETs can operate at high frequency up to hundreds of kHz. With the increasing development in the field of power electronics a new power MOSFET that is called SiC MOSFET is developed and can operate up to frequencies at MHz it can be used in devices for high switching frequency applications [4]. Impedance compensating network reduces the VA rating of the power source by minimizing the reactance of the input impedance and increasing the power transfer efficiency by using magnetic field resonance the simplest way to achieve this is to use a capacitor there, depending on how the capacitors are connected to the coils there are four basic compensation topologies possible these are series-series (SS), series-parallel (SP), parallel-series (PS) and parallel-parallel (PP). [5-6] as show in figure 1.



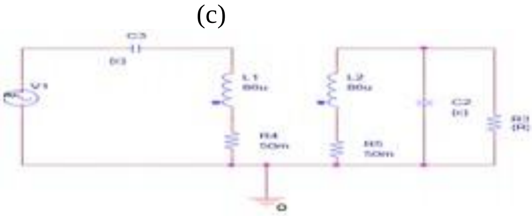

(a)




(b)




(c)




(d)

Fig.1 different compensation topologies (a) Series-Series (b) Series-Parallel(c) Parallel-Series (d) Parallel-Parallel

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The time varying field that is generated from primary coil is induce time varying field at secondary coil. Since received power is time varying so it needs to be converted into DC power so to convert it a high frequency rectifier is used, there are common losses are associated with diodes such as losses due to forward conduction and high frequency losses due to switching time of the diodes. To eliminate these losses schottky diodes or ultrafast diodes are used instead of normal didoes. [7] Then a voltage regulator is used to stabilize and control the DC voltage according to load voltage.The load is an electric load that consumes electrical power. Mobile battery and battery of vehicle are common load in the case of WPT.

## IV. MATHEMATICAL MODEL

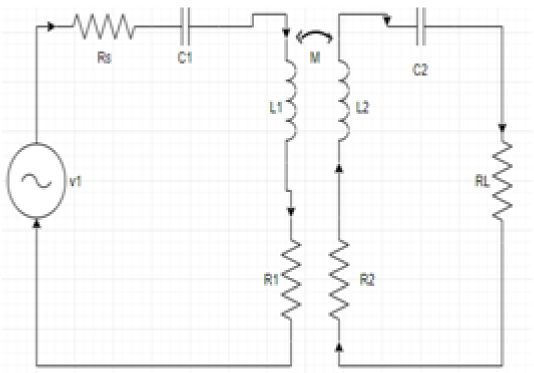


*Fig.2 mathematical model for WPT*

The mathematical model for WPT is shown above in figure 2
The loop equations of the equivalent circuit are given by:

$$V_1 = Z_1 I_1 - j\omega M I_2 \qquad (1)$$

$$|I_2| = \frac{\omega M I_1}{z_2} \qquad (2)$$

$V_1$ is supply voltage and $I_1$ and $I_2$ are currents in primary and secondary respectively. $Z_1$ and $Z_2$ are equivalent impedances of the transmitter and receiver coil respectively. $M$ is the mutual inductance between two coils, it depends on the coupling coefficient (**k**) between them and the self-inductances $L_1$ and $L_2$

$$\mathbf{M} = \mathbf{k}\sqrt{\mathbf{L_1 L_2}}. \qquad (3)$$

At resonance frequency impedances due to inductor and capacitor becomes equal and get canceled out and impedance due to resistor acts only in circuits thus $Z_1$ and $Z_2$ can be simplified as

$$Z_1 = R_s + R_2 \qquad (4)$$

$$Z_2 = R_L + R_1 \qquad (5)$$

Where $R_s$ and $R_L$ are the source and load resistances, respectively. $R_1$and $R_2$ are the series resistance of the primary and secondary coils, respectively.

Resonant frequency is defined as

$$\omega = \frac{1}{\sqrt{L_1 C_2}} = \frac{1}{\sqrt{L_2 C_2}} \qquad (6)$$

$_{Q\text{-}}$factor is defined as

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$$Q=\frac{\omega L}{R} \quad (7)$$

From equation (7) we can see that high Q factor can be achieved by increasing frequency or increasing inductance or decreasing overall resistance present in circuit. Wires used to make coil increases resistance present in circuit, so, to reduce resistance wires of large diameter are used.

Power at load resistor is defined as $\mathbf{P_L = I_2^2 R_L}$ (8)

Which can be simplified from equation (2) and (5) as

$$\mathbf{P_L = \frac{\omega^2 \cdot M^2}{R_L + R_2} I^2 R_L} \quad (9)$$

The efficiency is given by

$$\frac{\omega^2 M^2 R_L}{(\omega^2 M^2) R_L + (R_s + R_1)(R_L + R_2)^2} \quad (10)$$

From equation (10) it is seen that to achieve high efficiency we should decrease parasitic resistance and by increasing mutual induction. Losses due to parasitic resistance can be decreased by using Litz wires for designing coils. Litz wire also mitigate the skin and proximity effects. Coupling is interaction between two circuits, it describes how electrical energy is being transferred from one device to another. When interaction between circuits is due to magnetic field, coupling is known as magnetic coupling. In magnetic coupling magnetic field that is being produced by transmitter circuit induces current in the receiving coil, thus power can be transferred from one device to another. Coupling is expressed by the coupling factor k, from equation (3) it is clear that coupling coefficient k depends on the coil parameter such as number of turns, cross section for wire being used and coil length and on medium between two coils. As in the case of charging mobile and vehicles with WPT medium between coils is air so, relative permeability is 1. By increasing the coupling coefficient k power transfer efficiency will increase.

## V.SIMULATION WORK AND RESULT

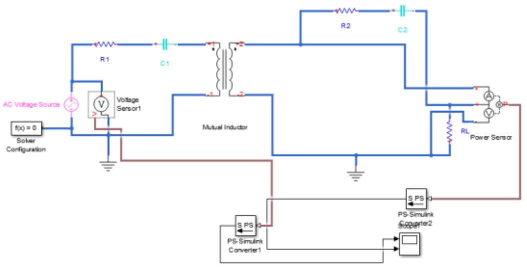


*Fig.3 circuit for WPT*

The circuit shown above is made on MATLAB Simulink software. Voltage source used here is high frequency AC source giving 12V ac a frequency of 100 kHz. Wireless power transfer is achieved by using mutual inductance block. Compensation topology used here is series- series topology because it gives large VA at input and suitable for the low output device such as mobile.

WPT by inductive coupling depends on the coupling coefficient as when coils are highly coupled transferred power is high and it decreases with the decreasing coupling coefficient as shown as figure 4 load voltage increases with the increase in coupling coefficient. It is clear from the graph in figure 4 that although coupling coefficient is at its maximum yet we only receive load voltage 11.8 in comparison to 12 volt at transmitter side.

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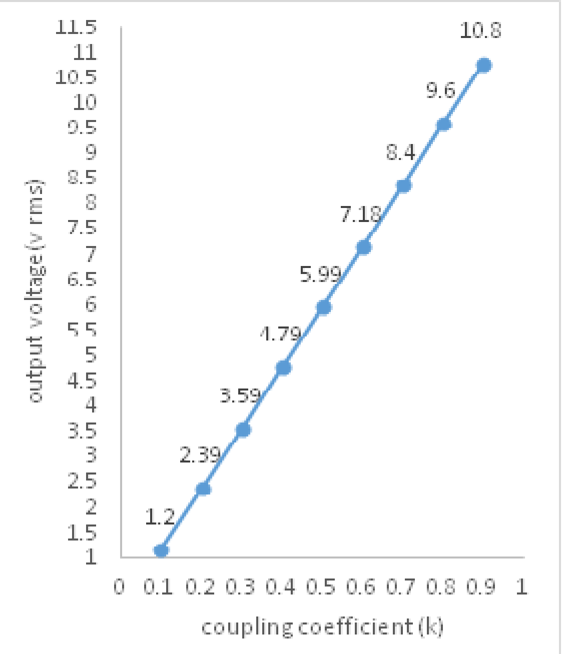


Fig.4 graph between load voltage and coupling coefficient

Also power received varies with the variation in coupling coefficient as shown in figure 5.

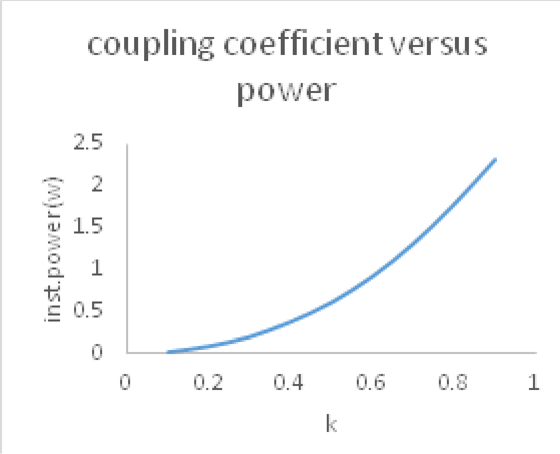


Fig.5 graph between instantaneous power at output and coupling coefficient

From this graph it is clear that maximum power is achieved with highly coupled coils as coupling coefficient depends on coil parameters as well as distance between coils so high power is received up to short distances. Input output waveforms for coupling coefficient 0.6 is shown in figure 6.

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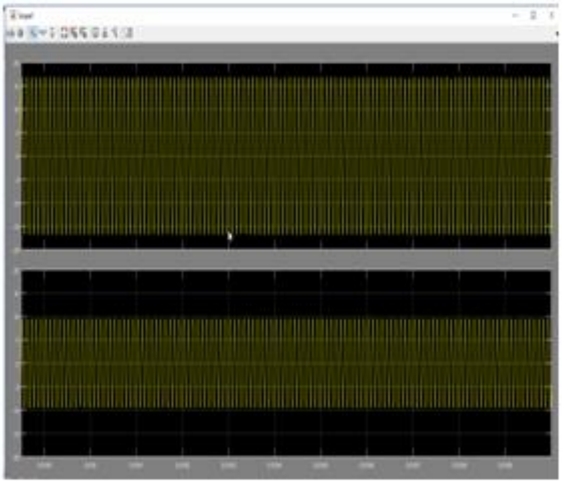

*Fig.6 input and output voltage waveforms*

## VI.APPLICATION OF WPT

There is numerous application of WPT as:

- Wireless charging of smart phones.
- Robots, packaging machine can take advantage of this technology
- It could be used to charge batteries of Electric vehicles in future.
- Direct wireless power for wireless sensor will eliminate the need for expansive power wring and battery replacement.
- It can be used to charge batteries in pacemaker.

## VII.CONCLUSION

Wireless power transfer is fastest growing and vast research field with this paper we presented a simplified circuit that is easy to implement. Future work will be more development of this circuit and to make model on the basis of this circuit and reducing cost and increasing efficiency and making compatible to charge any smart phone.

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