Wireless Power Transfer by Incorporation of Renewable Energy Sources

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ABSTRACT

This paper clarifies the transfer of electrical energy from one place to another, wirelessly avoiding traditional methods of power transfer. The phenomenon occurred here is to transfer power using a renewable source over a range, without the use of wired medium. Solar panels are added in this system as they play a key role in providing a renewable source of energy in the place of non-renewable or AC source supplies. The panels convert light into electrical energy and is stored in the batteries. This energy is then passed on to the transmitter, which basically transmits energy in the form of electromagnetic waves, through one inductor at the transmitting end and another at the receiver end. The receiver decodes the transmitted EM wave to its original form, producing the same voltage as applied at the transmitting end. This whole apparatus is confined into a panel where it could be placed on roofs or ceiling providing range over a wider area throughout the work space.

Keywords---- Electromagnetic, inductive coupling, renewable, resonance coupling, wireless charging

I. INTRODUCTION

Wireless Power Technology\cite{1-2} is emerging as a practical solution for providing energy for devices at remote distances. The current scenario revolves around the depletion of fossil fuels and other non-renewable sources of energy which is expensive and cannot reliable upon. So it is high time we shifted to renewable sources of energy. This paper will focus on the technology of inductively coupled\cite{3-4-5} wireless power transfer, incorporating a renewable source, i.e. solar panels. This provides a safe, efficient, convenient and eco-friendly method of transferring power to remote static devices, or recharging portable devices. This revolves around the principle of Resonant Magnetic Coupling (RMC),\cite{6-7} which can be applied to acquire maximum transfer of power\cite{8},contactless, thereby facilitating the individual to charge his electronic equipment efficiently. Nikola Tesla a Serbian American scientist, a futurist precisely of the year 1856, used high electric fields\cite{9-10} to transfer large quantities of energy by ionizing the air in the environment, which eventually is a bad conductor, to plasma. Similarity can be also be observed in lightning, where gigantic amount of energy is transmitted at higher frequencies is transmitted over a remote distance by ionization of the surrounding the medium. Such quantities of energy is of less use because they are non-renewable and are said produce hazardous electric fields. The pith of the phenomenon of Inductive coupling emphasizes that by varying the magnetic flux between two inductive coils to transfer energy from the source to load which is accordance to Faraday’s Law of electromagnetic induction\cite{11}. The system working is in similarity to the working of a resonant transformer\cite{12}. It comprises of a primary and secondary coil, which is tuned to a specific frequency by a LC tank circuit. The functioning of these circuits are ambiguous and may act as a resonator or an oscillator and multiply the applied frequency or simply escalate it to a large value. Being air core, these transformers possess low coupling coefficient. Most of the energy is transferred through magnetic field. The electric fields are confined within the capacitor. Even though the coupling coefficient being significantly low (i.e. k<0.1) much of the energy from the primary gets transferred to the secondary due to high frequencies\cite{13} (kHz to MHz).

II. LITERATURE REVIEW

For better comprehension theories related to Magnetic Resonant Coupling, quality factor and optimization techniques for wireless power transfer systems are presented here along with the working principles and constructions of various components. Magnetic coupling is an old and well understood method in the field of wireless power transfer. But as the magnetic field decay very quickly,
magnetic field is effective only at a very short distance. By applying resonance with in magnetic coupling, the power transfer at a greater distance can be obtained. For near field wireless power transfer, Magnetic resonant coupling can be the most effective method than any other method available. The block diagram for the whole experiment is shown below. It is consisting of an AC source, rectifier, oscillator, transmitter, secondary sources and load coil. It is observed that the voltage. The function of a solar cell in this system is to primarily provide a sustainable and renewable source of energy. This renewable source of energy is then is wirelessly transmitted to a remote load. Which is intern connected to the source of the wireless transmitter i.e. battery, keeping it fully charged at regular cycle.

![Fig-1:Block Diagram](image1.png)

A direct connection of the solar arrays to the storage battery should be avoided as it may be subjected to overcharging. Eventually resulting in efficiency loss of the battery. Also, the direct connection of the solar array to the battery will determine the voltage level at which the solar array will function. Hence, to avoid such losses and complications a charge controller is incorporated in the solar battery charging system. The Charge Controller is basically an electronic circuit which indicates and regulates the flow of charge from the solar panel to the battery, preventing the battery from the perils of overcharging. When the battery is fully charged the device detaches the battery from the charging process, protecting it from over charging.

**A. INDUCTIVE OR MAGNETIC COUPLING**

Inductive or Magnetic coupling works on the principle of electromagnetism. Transferring energy between wires through magnetic fields is inductive coupling. If a portion of the magnetic flux established by one circuit interlinks with the second circuit, then two circuits are coupled magnetically and the energy may be transferred from one circuit to the another circuit. This energy transfer is performed by the transfer of the magnetic field which is common to the both circuits.

![Fig-2: Magnetic coupling with four component fluxes.](image2.png)

**B. MAGNETIC RESONANT COUPLING**

Magnetic Resonant coupling uses the same principles as inductive coupling, but it uses resonance to increase the range at which the energy transfer can efficiently take place. Resonance can be two types: (a) series resonance & (b) parallel resonance. In these both types of resonance the principle which is to get maximum energy transfer is same but the methods are quite different.

![Fig-3: Equivalent Circuit of Magnetic Resonant Coupling](image3.png)

**C. RESONANT FREQUENCY**

Resonance is a phenomenon that causes an object to vibrate when energy of a certain frequency is applied. In physics, resonance is the tendency of a system (usually a linear system) to oscillate with larger amplitude at some frequencies than at others. These are known as the system’s resonant frequencies. In these particular frequencies, small periodic driving forces even can produce oscillations having large amplitude.

**D. QUALITY FACTOR**

In physics and engineering the Quality factor (Q-factor) is a dimensionless parameter that describes the characteristics of an oscillator or resonator, or equivalently, characterizes a resonator’s bandwidth relative to its central frequency. Higher Q indicates the stored energy of the oscillator is relative of a lower rate of energy loss and the oscillations die out more slowly. So it can be stated that, Oscillators with high quality factors have low damping so that they pendulum ring longer, in case of a pendulum example.
In an ideal series RLC circuit and in a tuned radio frequency receiver (TRF) the Q factor can be written as:
\[ Q = \frac{1}{R \sqrt{LC}} \]
Where, \( R \), \( L \) and \( C \) are respectively the resistance, inductance and capacitance of the tuned circuit.

**E. SOLAR CELLS (PHOTOVOLTAIC CELL)**

When the sunlight is incident upon the material surface, the electrons present in the valence band absorb the energy and, are then excited to higher energy levels, i.e. jump to the conduction band and become free. These highly excited, non-thermal electrons diffuse, and some reach a junction where they are accelerated onto a different material by a built-in potential. Generating an electromotive force, and thus a part of light energy is converted to electric energy. Photovoltaic cells are used as a photo-detector in this case of wireless power transfer system representing a renewable source of energy, charging the battery in the presence of an incident light.

**III. CIRCUIT DESIGN AND IMPLEMENTATION**

Our experimental realization of the project consists of three coils that are tuned at the same frequency. An oscillating circuit is connected with a source coil \( S \). Coil \( S \) is coupled resonant inductively to an intermediate coil \( Q \) which is coupled resonant inductively to a load carrying coil \( R \). The coils are made up of an electrically conducting copper wire of cross-sectional radius \( r \).

When a radio frequency oscillating signal is passed through the coil \( S \), it generates an oscillating magnetic field, perpendicular to the coil \( S \). The intermediate coil \( Q \) is placed near to the coil \( S \), which is tuned at the same frequency through the inductance of the coil and a resonating capacitor \( C_1 \). The coil \( Q \) being in the area of the magnetic field generated by coil \( S \), receives power. Not having any resistive load, the coil in turn generates its own oscillating magnetic field. The advantage of using this coil is that it is completely separated from the source internal resistance. This increases the Q-factor, allowing greater power to be radiated. In other words, the coil \( Q \) becomes the source of the system. The load coil \( R \), tuned at the same resonant frequency, receives the power through the magnetic field generated by the intermediate coil \( Q \). The equivalent circuit diagram of power transfer model is given in figure-5. The power transfer occurs from coil \( S \) to coil \( R \). The power loss in coil \( Q \) is neglected here, since the coil \( Q \) has a very small resistance.
WORKING PROCEDURE:
Step 1:- The solar panels convert sun light into electrical energy and are stored in batteries which is connected through the charge controller.
Step 2:- This energy stored is then passed on to the transmitter, which basically transmits energy in the form of electromagnetic waves, through one inductor at the transmitting end and another at the receiver end.
Step 3:- The receiver decodes the transmitted EM wave to its original form, producing the same voltage as applied at the transmitting end.

COMPONENTS DISCRIPTION:

<table>
<thead>
<tr>
<th>Name of Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOSFETS -</td>
<td>The IRFP250</td>
</tr>
<tr>
<td>Resistors</td>
<td>10k ohm (brown black orange), 1/4 watt</td>
</tr>
<tr>
<td>Ultrafast Diodes</td>
<td>Above 400 volts. UF4007</td>
</tr>
<tr>
<td>Schottky diodes</td>
<td>4007 family</td>
</tr>
<tr>
<td>Battery</td>
<td>12-24 Volt</td>
</tr>
<tr>
<td>LED</td>
<td>-</td>
</tr>
<tr>
<td>IC</td>
<td>7805 Family</td>
</tr>
<tr>
<td>Zener diodes</td>
<td>12 volt</td>
</tr>
<tr>
<td>Solar cells</td>
<td>Photovoltaic</td>
</tr>
<tr>
<td>Resistors</td>
<td>18k ohm 1/4 watt (brown - gray - orange)</td>
</tr>
<tr>
<td>Resistors</td>
<td>12k ohm 1/4 watt (brown - red – orange)</td>
</tr>
<tr>
<td>Ferrite toroid</td>
<td>It can be around 1/2 inch in diameter. Roughly 30 turns of enamelled wire is wound on it.</td>
</tr>
<tr>
<td>Tank capacitors</td>
<td>1uf</td>
</tr>
<tr>
<td>Gauge wire and tape</td>
<td>14</td>
</tr>
</tbody>
</table>

Table-1: Components table

IV. RESULT AND SIMULATION

Measurements are taken providing 12V battery along with the solar cell, with resonant frequency 1.5 MHz across the transmitter and without the intermediate coil:
- An LED bulb lit up at its full strength at a distance of 7 centimetre with voltage measured 12 volt.
- An LED bulb lit up to a maximum distance of 17centimetre with voltage measured 12 volts.

Voltage measured at a distance 1 meter was 3 millivolts.
Measurements taken with intermediate coil placed in between transmitter and receiver at a distance 12cm apart from the transmitter:

For this experimental setup, the voltage across the transmitter is 12V. The output rms voltage across a resistive load 17cm away from the transmitting coil is 10.6V. The coils were arranged in the configuration as shown below and voltage measurements were taken as a function of distance between the coils.

V. APPLICATIONS

1. Uses in stationary High Altitude Relay Platform (SHARP) [14]
2. Charging of electric vehicles [15]

VI. ADVANTAGE

1. Safe for human, simple implementation
2. Charging multiple devices simultaneously on different power, high charging efficiency
3. It improves user-friendliness as the hassle from connecting cables is removed. Different brands and different models of devices can also use the same charger.
4. It enhances flexibility, especially for the devices for which replacing their batteries or connecting cables for charging is costly, hazardous, or infeasible (e.g. body-implanted sensors).
5. It renders the design and fabrication of much smaller devices without the attachment of batteries.
6. It provides better product durability (e.g., waterproof and dustproof) for contact-free devices.

VII. CONCLUSION

The goal of this paper was to design and implement a wireless power transfer system via magnetic resonant coupling. After analysing the whole system step by step for optimization, a system was designed and implemented. Experimental results showed that significant improvements in terms of power-transfer efficiency have been achieved. Measured results are in good agreement with the theoretical models. It is described and demonstrated that magnetic resonant coupling can be used to deliver power wirelessly from a source coil to a load coil with an intermediate coil placed between the source and load coil and with capacitors at the coil terminals providing a simple means to match resonant frequencies for the coils. This mechanism is a potentially robust means for delivering wireless power to a receiver from a source coil.

VIII. FUTURE SCOPE

1. Wireless Charger Network: - Similar to wireless communication networks that provide data service, a wireless charger network can be built to deliver energy provisioning service to distributed users. The wireless charger network that connects a collection of distributed chargers through wired or wireless links allows to exchange information (e.g., include availability, location, charging status, and cost of different chargers) to schedule the chargers.
2. Green Wireless Energy Provisioning - Currently, how to perform green wireless energy provisioning remains an open issue and has been ignored by the majority of existing studies. One promising solution is to equip renewable energy sources, e.g., solar, for wireless chargers.

3. Open Issues in Wireless Charging - Inductive coupling- The increase of wireless charging power density gives rise to several technical issues, e.g., thermal, electromagnetic compatibility, and electromagnetic field problems [16]. This requires high-efficiency power conversion techniques to reduce the power loss at an energy receiver and battery modules with effective ventilation design.

REFERENCES