International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)) Volume 3, Issue 2, August 2014)

Wireless Power Transfer by Incorporation of Solar Energy

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***Abstract* — This paper elucidates the transfer of electrical energy from one place to another, wirelessly avoiding quotidian methods of power transfer. The phenomenon incorporated in here is to transfer power using a renewable source over a range, without the use of wired medium. Solar panels are incorporated in this system as they play a key factor in providing a renewable source of energy on contrary to non-renewable or AC source supplies. The panels convert light into electrical energy and is stored in 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*—–Quotidian, wireless, renewable, electromagnetic**

I. Introduction

Wired technology was initially a success, but transfer of power was achieved only by cables, which ended up as a costly affair. Lately, Wireless Power Technology 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 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 (RMS), which can be applied to acquire maximum transfer of power ,contactless, thereby facilitating the individual to charge his electronic equipment efficiently.

II. Concepts Involved

A. Wireless transmission

Wireless transmission, One of the greatest and extravagant achievement of mankind has always been wireless power transmission. Inchoate stages of this concept was widely considered as an impossibility and thus turned out to be a fiasco and never brought up to the knowledge of the society. Nikola Tesla a Serbian American scientist, a futurist precisely of the year 1856, used high electric fields to transfer large quantities of energy by ionizing the air in the environs, which eventually is a bad conductor, to plasma. Similarity can be also be observed in lightning, where mammoth 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.

B. Inductive coupling

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 which states " The varying magnetic flux produced by one coil will produce a varying magnetic flux in another induction coil when placed parallel"

The system working is in similarity to the working of a resonant transformer. It comprises of a 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 (khz to Mhz).

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Specified rate of voltage and frequency of a power supply or a battery at the primary coil is being transferred to the secondary coil by mutual induction. The frequency can be increased to a desired level in order to increase the efficiency as power transfers at an efficient rate.

Figure 1

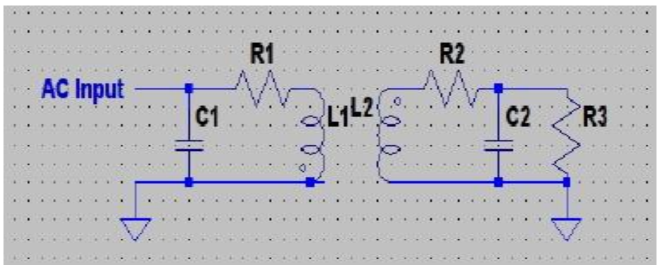

Fig1. A basic design for a Resonant transformer. In the figure above, the values of L1, C1 and L2,C2 should be such that they correspond to a common frequency for resonant energy transmission and reception.

C. Solar cells (Photovoltaic cell)

When the sunlight is incident upon the material surface, the electrons present in the valence band absorbs 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. Laws And Formulae

A. Lenz's Law

When an emf is generated by a change in magnetic flux according to Faraday's Law, the polarity of the induced emf is such that it produces a current whose magnetic field opposes the change which produces it. The induced magnetic field inside any loop of wire always acts to keep the magnetic flux in the loop constant. In the examples below, if the B field is increasing, the induced field acts in opposition to it. If it is decreasing, the induced field acts in the direction of the applied field to try to keep it constant.

Figure 2

$$\mathcal{E} = -\frac{\partial \Phi_B}{\partial t}$$

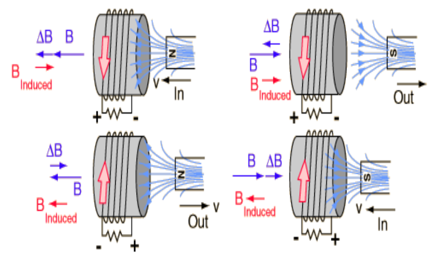

Fig.2. figure explaining the concept of lenz's laws

B. Faraday's Law

A voltage can be induced in a coil by changing the magnetic field strength around it. The change in magnetic field is irrespective and can be produced by any means, this induces a voltage to be generated. This change could be brought about by altering the magnetic field strength by moving a magnet toward or away from the coil, or on the contrary, moving the coil towards or away from the magnetic field, or even by rotating the coil in accordance to the magnet, etc.

Figure 3

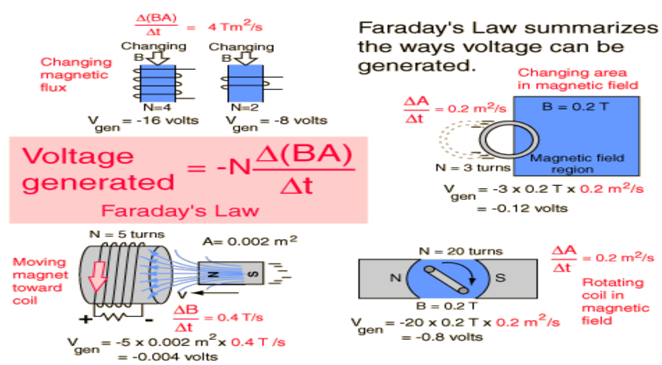

Fig.3. Faraday's laws summarizing the ways in which voltage is generated

Faraday's law is a fundamental relationship which is derived from Maxwell's equations. It serves as a succinct summary of the ways a voltage (or emf) may be generated by a changing magnetic environment. The induced emf in a coil is equal to the negative of the rate of change of magnetic flux times the number of turns in the coil. It involves the interaction of charge with magnetic field.

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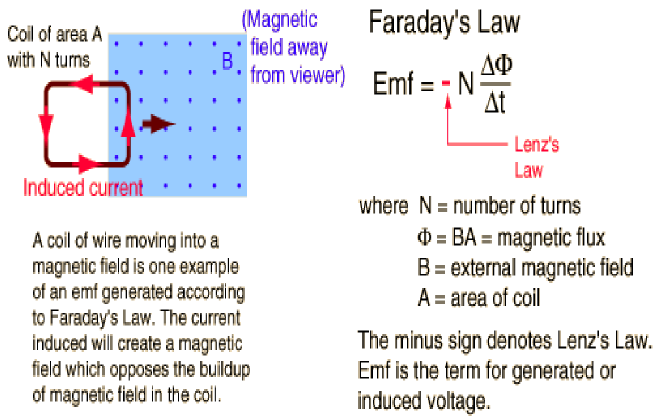
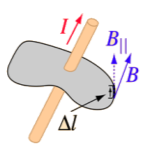


C. Ampere's Law

The magnetic field in space around an electric current is proportional to the electric current which serves as its source, just as the electric field in space is proportional to the charge which serves as its source. Ampere's Law states that for any closed loop path, the sum of the length elements times the magnetic field in the direction of the length element is equal to the permeability times the electric current enclosed in the loop.

Figure 4



$$\sum B_{||}\Delta l = \mu_0 I$$

Fig4. Ampere's laws

IV. THEORY OF SOLAR CELLS

The theory of solar cells explains the physical processes by which photons are converted into electrical current when striking a suitable semiconductor device. Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

The processes taking place are : Photogeneration of charge carriers, Charge carrier separation which involves the drift of carriers and their separation.

Figure 5

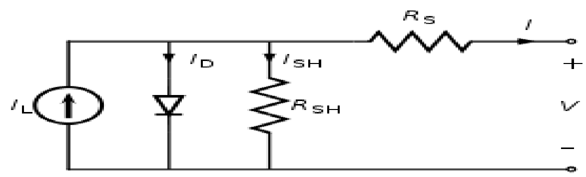


Fig5. Circuit connection for solar cell

D. Characteristic equation

From the equivalent circuit it is evident that the current produced by the solar cell is equal to that produced by the current source, minus that which flows through the diode, minus that which flows through the shunt resistor:

$$I = I_L - I_D - I_{SH}$$

Where

- I = output current (ampere)
- I_L = photogenerated current (ampere)
- I_D = diode current (ampere)
- I_{SH} = shunt current (ampere).

The current through these elements is governed by the voltage across them:

$$V_j = V + IR_S$$

Where

- V_j = voltage across both diode and resistor R_{SH} (volt)
- V = voltage across the output terminals (volt)
- I = output current (ampere)
- R_S = series resistance (Ω).

By the Shockley diode equation, the current diverted through the diode is:

$$I_D = I_0 \left\{ \exp\left[\frac{qV_j}{nkT}\right] - 1 \right\}$$ [6]

Where

- I_0 = reverse saturation current (ampere)
- n = diode ideality factor (1 for an ideal diode)
- q = elementary charge
- k = Boltzmann's constant
- T = absolute temperature
- At 25°C, $kT/q \approx 0.0259$ volt.

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By Ohm's law, the current diverted through the shunt resistor is:

$$I_{SH} = \frac{V_j}{R_{SH}}$$

Where

- R_{SH} = *shunt resistance (Ω).*

Substituting these into the first equation produces the characteristic equation of a solar cell, which relates solar cell parameters to the output current and voltage:

$$I = I_L - I_0 \left\{ \exp\left[\frac{q(V + IR_S)}{nkT}\right] - 1 \right\} - \frac{V + IR_S}{R_{SH}}.$$

An alternative derivation produces an equation similar in appearance, but with V on the left-hand side. The two alternatives are identities; that is, they yield precisely the same results.

In principle, given a particular operating voltage V the equation may be solved to determine the operating current I at that voltage. However, because the equation involves I on both sides in a transcendental function the equation has no general analytical solution. However, even without a solution it is physically instructive. Furthermore, it is easily solved using numerical methods. (A general analytical solution to the equation is possible using Lambert's W function, but since Lambert's W generally itself must be solved numerically this is a technicality.)

Since the parameters I_0, n, R_S, and R_{SH} cannot be measured directly, the most common application of the characteristic equation is nonlinear regression to extract the values of these parameters on the basis of their combined effect on solar cell behaviour.

Open-circuit voltage and short-circuit current

When the cell is operated at open circuit, $I = 0$ and the voltage across the output terminals is defined as the *open-circuit voltage*. Assuming the shunt resistance is high enough to neglect the final term of the characteristic equation, the open-circuit voltage V_{OC} is:

$$V_{OC} \approx \frac{nkT}{q} \ln\left(\frac{I_L}{I_0} + 1\right).$$

Figure 6

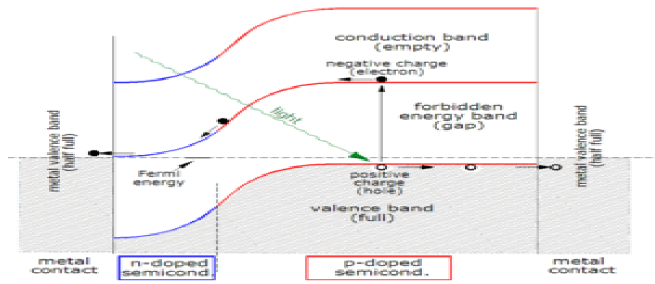


Fig6.Band diagram of a silicon solar cell, under short circuit conditions.

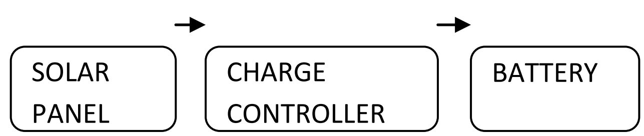
V. Components Required

2 * MOSFETS - The IRFP250.
2 * 10k ohm resistors - (brown black orange) 1/4 watt resistors
2 * Ultrafast Diodes - Above 400 volts. UF4007.
2* 12 volt zener diodes Solar cells (Photovoltaic) as required, Schottky diodes, battery to store charge, LED, IC 7805
2 18k ohm resistors - 1/4 watt (brown - gray - orange)
2 * 12k ohm resistors - 1/4 watt (brown - red - orange)
1* Ferrite toroid - It can be around 1/2 inch in diameter. Roughly 30 turns of enameled wire is wound on it.

2* sets of tank capacitors – 4* 1 uF capacitors can be used.

2* 2 uF capacitors can be used instead.
14 gauge wire and tape is also required.

VI. Schematic Solar Cell Section



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 wirelessely 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 cycles

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. The charge controller also comprises of a voltage regulator to regulate the input charging voltage given from the solar-panel to the battery in order to give a stable constant output voltage.

Battery Amperage-

Battery Voltage= 12V & Watt Hour=84Wh

Therefore I= Watt Hour/ Battery Voltage

I=84/12= 7Ah ~ 7.5

I= 7Ah

Solar panel-

Generally a battery charging current = 10% of its AH Charging current = 0.7A

Power (W) = Current (A) X Voltage (V)

Solar panel needed = 0.7 A 12 V = 8.4 W- 10W

Charge controller-12 Volt, .7 Amp Thus a solar system is calculated

(approximate 25% system loss should be added.)

Conclusion: So from calculation

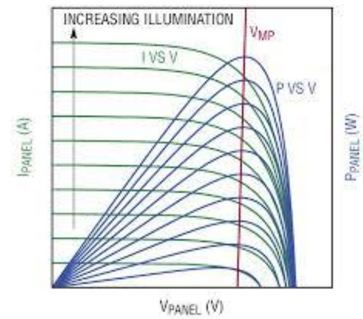
1. Solar panel =10W watt

2. Battery = 12volt, 7AH

3. Charge controller=12volt,1-2Amps

Efficiency of Solar panel: The output of the solar panel is directly propotional to the amout on light incident on the solar panel.

Figure 7



Transmitter Section

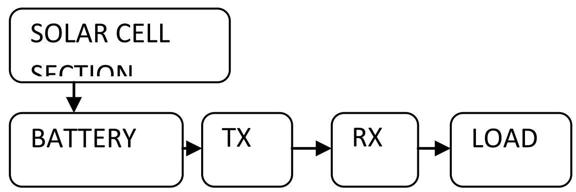
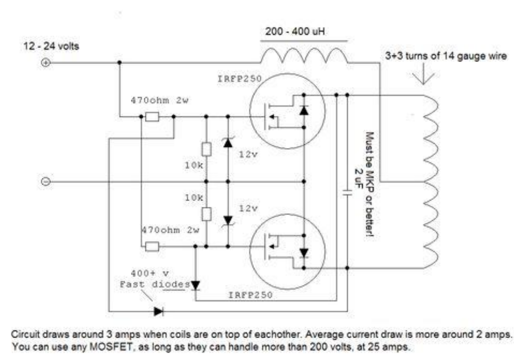


Figure 8



The IRFP250's pin out , from left to right; **Gate, Drain, and then Source.** The diodes should be placed correctly and exactly. A SMPS laptop cord can be used to power it, which puts out around 18 volts.

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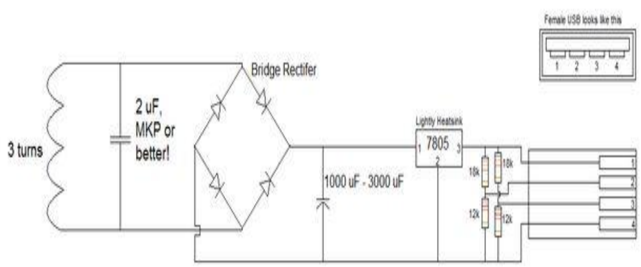
For the diodes, the black band on it, or the white band on the UF4007's indicates the cathode. The other end is the anode. Changing the inductor value will change the amount of current draw. A smaller value inductor will equal more current, a larger value one, less current.

Changing the coil turns will ALSO additionally change the current draw, as well as the frequency. More turns, lower frequency, lower current.

Receiver Section



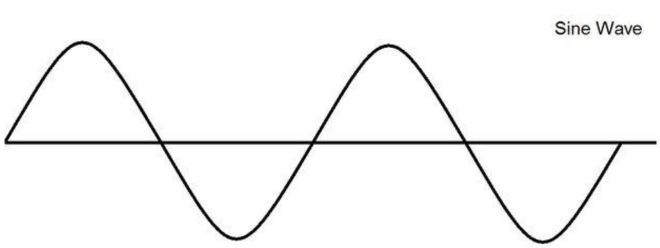
The receiving end is less complex. The same capacitor value, should be used as well as following the USB pinout

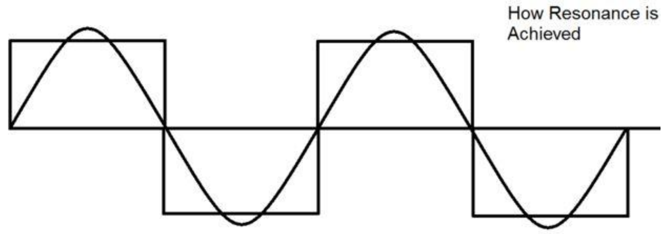
Different turn ratios can be used and the experiment can be performed. This has to do with resonance, and step-up / step-down ratios.

Add more voltage, and examine if more distance is obtained. Another way of possibly increasing distance is to increase the resonant frequency a bit. Increasing the frequency should give you more distance, with additional current draw.

To increase the frequency, the capacitor values are lowered. The lowest value is around 1 uF. This is done at both transmitting and receiving end.

VII. Waveforms And Explanations





The ZVS driver is used for a lot of things due to it's simplicity.

However, in this case, the reason it works is because the ZVS driver begins by oscillating at around 50 - 60 khz. It can't be heard since it's above our hearing range. Resonance can be thought of like a Pendulum. If a pendulum is hit, it will move forward, and then back. If the pendulum is hit again, right as it starts to swing downwards, the pendulum will travel faster and higher than before. It's very much the same in electronics, just instead of speed and height, it's voltage and current! It can observe it pretty easily with a cup of water. If it is shaken just the right way back and forth the water will spill right out of the cup, due to resonance.

Due to resonance, the voltage swings in the tank (between the 3 + 3 coil and the 2 uF capacitor) are much higher than what the input voltage is. Resonance helps with transmission distance, and also, as a result of how the MOSFETS turn on, hence called Zero Voltage Switching, where they turn on and off when the voltage across them is zero. (meaning, they generate little/no heat due to switching losses). However, due to on-state resistance, they still make a little bit of heat.

The reason it can transmit power is caused by magnetism. As the coil oscillates, it sends an alternating magnetic field through the air, which is picked up by the receiving coil (and again, due to resonance, the voltage rises upwards!) and thus, power is transmitted through air. The same basic concept is behind radio waves; though, amplifiers are needed to get the audio out of the air, and the frequency is much higher.

VIII. Results

Comprehensive experiments conducted by constructing the necessary circuit yielded successful results. It was proved that at close proximity the efficiency of power transfer was close to 100%. The main advantage of this technique is that renewable energy in the form of solar energy is used.

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The graph below denotes the simulation results of the conducted experiment. The experiment was successful and energy saving. Further research on improving the efficiency at greater distancesis being undertaken.

Output graph(distance vs output)

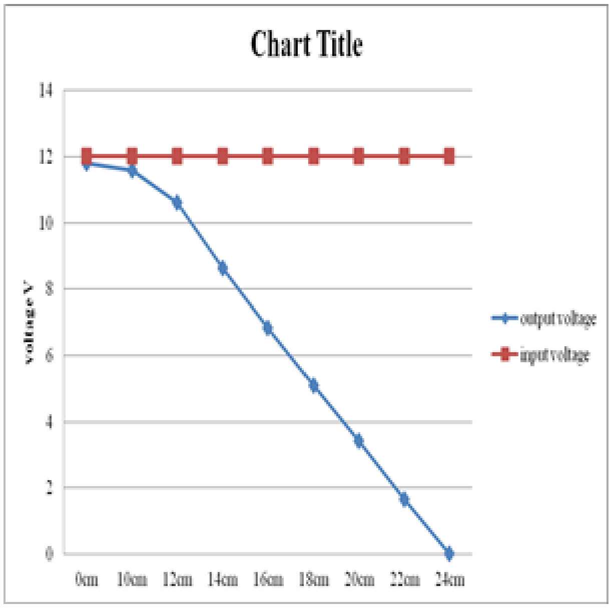

Fig9. Output graph

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