March - April 2020
ISSN: 0193-4120 Page No. 167 - 178

Solar Power based Wireless Power Transfer for Small Scale Applications

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Abstract

The main aim of this project is to design a solar power based Wireless Power Transfer (WPT) system for small scale applications. In this proposed system, resonance magnetic coupling technique is used where the phenomenon incorporated in here is to transfer power using solar power over a range, without the use of wired medium. The solar panel converts light into electrical energy and energy is then passed on to the transmitter, which basically transmits energy wirelessly through one inductor coil at the transmitting end to another coil at the receiver end. The performance of the developed proposed system is evaluated by testing the power transfer over distance variation in between TX-RX coil. It is observed that the integrated approach of transferred power over air medium performs better than the existing systems. The maximum power transfer distance between TX-RX coil achieved is 15 cm when the receiver is loaded with two 7.5 watts LED lamp, but without load the transfer distance between TX-RX is increased to 19 cm. Finally, the system proved to be very efficient with 82.44% with no loaded condition and 80.46% with loaded condition for a minimum air-gap, as compared to the various techniques employed in the literature.

Keywords: *Air-gap, Solar panel, TX-RX, Wireless power transfer.*

I. INTRODUCTION

Highlight Though electricity transmission through wire medim was initially an achievement, but later it was ended up as an expensive approach of transfering electrical energy. At present day, our daily life is mostly dependent on portable technology and batteries are using to power most of the portable electronic devices such as laptop, mobile phone, biomedical implants, smart card and so on. These appliances need to be recharged very frequently and wired charger are using to recharge those electrical appliances, and this is how from portability emerges another challenge, which is energy. Therefore, this fact makes people to think about the easy way of charging the battery, where this traditional hazardous charging method can be avoided, and this is how the Wireless Power Transfer (WPT) system is introduced. Here, WPT system has appeared as a feasible solution to charge electronic devices at a certain distance without the need of wired medium. Basically, WPT system is the concept of transmitting electricity from a source to a load through an air gap, without connecting current-carrying wired medium. (Anand & Yogesh, 2014) Sir Nikola Tesla was the first to introduce the transmission of electrical power without using wire medium in the year of 1891. Lately, in the year of 2005, the term WiTricity which is an abbreviation of wireless transfer of electricity was introduced by Dave Girding (Saurabh & Ameya, 2014). Currently, with the growing demand of electricity, it is necessary to come up with a considerable solution for electricity generation which is safe and sustainable and has no impact on environment. The current situation of electricity generation is revolved around the diffusion of fossil fuels and other non- renewable energy sources which is costly and at the same time not safe for the environment

March - April 2020
ISSN: 0193-4120 Page No. 167 - 178

and mankind. So this is the right time to move forward to the renewable sources of energy and the Solar Power can be considered one of the best options in terms of availability, among all renewable energy sources. The phenomenon is included here is to transfer electrical energy using Solar Power over a distance, without the need of connecting wire. Solar panels play as a key role to provide a renewable source in adverse of non-renewable or AC power supplies. Moreover, WPT system can be beneficial for providing electrical power to autonomous electrical and electronic appliances (Anand & Yogesh, 2014). However, the main objective here is to transfer electrical power without connecting wires. One kind of resonant transformer named Tesla coil which was introduced by Nikola Tesla and a huge progression was made to this WPT technology by transmitting 100 million volts of electricity wirelessly with a range of 26 miles to lighten 200 light bulbs with 95% efficiency, but the technology was kept on hold due to the drawback of transmitting this amount high voltages in electric arcs that could be dangerous for human body, electrical appliances and moreover for the environment (Rohan & Sahil, 2009).

Recently, Inductive coupling and resonant coupling are considered two main effective approach for WPT system. Though inductive coupling WPT system is very simpler to work on, but only can provide higher transfer efficiency at very short range in comparison to magnetic-coupled resonator WPT systems which comes with higher power transfer efficiency over a greater distance. Hence, this project is an attempt to overcome the specified obstacle through magnetic resonant coupling (Vijith & Jun, 2016).

The proposed project will focus on the magnetic resonant coupled WPT technology, incorporating of Solar Power to provide a secure, economical, appropriate and green method of transferring electrical power to distant static portable electrical appliences. The comprehensive aim of this project is to design, develop and implement a clean power generation and a wireless power transmission system, so that the system can achieve a moderate air-gap between TX-RX coil with optimum power transfer efficiency.

II. BACKGROUND

Medical devices such as heart-assist pumps are powered by a set of external power cable connected by a drive line routed into the body through the skin percutaneously or physical perforation. The wound where the drive line enters the body is prone to infection and can result in frequent hospitalization and medical complications for the patient. Moreover, using charging cables on the floor leads to the tripping hazards, leakage from damaged old power cable can make additional hazardous circumstances. Also, there is a risk of electric shock while plug-in electric cables (Siqi & Chunting, 2003). There are many situations present where the charge depletes in portable devices and further utilizing the device is prevented and if by any chance there is a port present to charge the device, movement will be banned firsthand due to the power cable attached to the power socket to the wall. Moving on, now-a-days, in terms of energy transfer, the electricity generation system is not very efficient and about 20% to 30% energy is lost during the generation and transmission of power. However, due to limited supply of resources, the pollution from present non-renewable resources, it is necessary to find alternative efficient renewable sources of energy. Therefore, in terms of efficiency solar power based WPT system can be an excellent pathway.

By targeting the research problem which is identified above, the main purpose of the proposed project is determined which makes everyday lives easier by minimizing the hazardous situation that comes with power cable and to ensure comfort and flexibility by eliminating the need of cables. Moreover, to make the system sustainable by introducing Solar Power.

The necessity of the system that can transmit power wirelessly is on great demand. Different researchers are working on this particular area to identify the most suitable approach of Wireless Power Transfer (WPT) system. The necessity of the system is discussed below:

Safety: There is always a risk of electrical shock while using electric cables or conductors because initially it is very difficult to identify if there is any leakage and very easy to get into physical contact

March - April 2020
ISSN: 0193-4120 Page No. 167 - 178

with conductors. Hence, severe life threating accident can happen very easily. This situation can be avoided by eliminating the need of wired medium and introducing WPT system.

Flexibility: The use of conductors and wires will be eliminated by using WPT system. Traditional hazardous way of charging and the mess causing by many wires running from a power source to charge the appliances, can be avoided by introducing WPT technology. Moreover, multiple appliances can be charged at a time without keeping close to power source.

Convenience: Convenient use of appliances can be ensured by using this WPT technology. For example, in remote area where there is no electricity, mobile or portable table lamps which use batteries can be recharged there very easily using this WPT system.

Reliability: People may fall into trouble while using appliances if it is run out of charge and no power source nearby or no cable to recharge. This risk of low battery can be eliminated by introducing WPT system. (Anand & Yogesh, 2014)

III. SOLAR BASED WIRELESS POWER TRANSFER DESIGN

Each section of the circuit design is involved with the functionality of each component which represent the specific design principle to determine the desired result. So, it is essential to choose the component wisely to function the design perfectly. As it is mentioned earlier, the system is consisted with the two main parts: transmitter and receiver respectively and the combination of these two parts deliver the complete function of the solar based WPT system. The construction details of transmitter and receiver circuit are shown in the Figure 1.1 and Figure 1.2 respectively and components are used to construct the circuit are explained further.

Solar panel

As the system is integrated with the solar power, so the input is given for the system with a solar PV module. Depending on the solar irradiance and temperature an unregulated DC voltage is generated by this solar panel. The specification for the module is shown below in Table 1.

Table 1: Solar panel specifications

Pmax (Maximum Power Point)	20 W
Tolerance	± 5%
Vmp (Maximum Power Point Voltage)	18 V
Imp (Maximum Power Point Current)	1.11 A
Voc (Open Circuit Voltage)	20.5 V
Isc (Short Circuit Current)	1.2 A
Size	440mmx340mm x18mm
Standard Test condition	1000 W/m^2 , AM 1.5, 25 Degree Celsius

Oscillator section

As mentioned earlier, energy produced by solar panel is DC. To make it AC, it must go through an oscillator. The most effective way of generating the switching frequency is to implement an astable multivibrator IC SG3524 in the design. It is a dedicated pulse width modulator and named as "free-running relaxation oscillator" and comes with two half-stable conditions where it continues oscillating without any peripheral excitation.

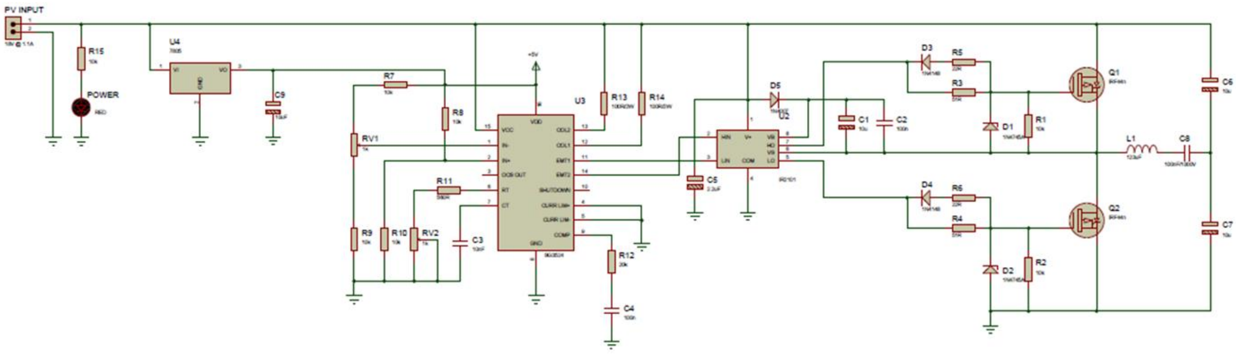

Figure 1: Transmitter circuit

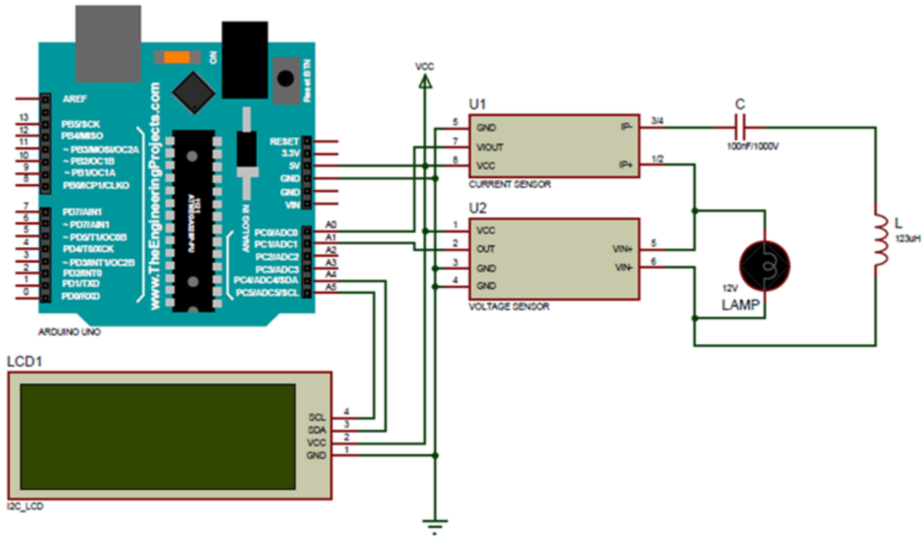

Figure 2: Recever circuit

To generate switching frequency, IC SG3524 is powered by supplying a constant 5 Volt DC through a voltage regulator LM7805. The LM7805 is used as a series of three terminal regulators. The input is given to this IC through the pin 1 which is an unregulated DC voltage generated by solar panel, pin 2 for this IC is ground and the output is a regulated 5V DC which is taken out with pin 3 to operate the IC SG3524.

The IC SG3524 is usually functioned at a fixed frequency and the oscillation frequency is obtained by one timing resistor RT and one timing capacitor CT. A constant charging current for capacitor resistance is set up by Timing resistor RT.

The frequency of the oscillating signals can be calculated using a variable resistor RV2, which is connected in series with a 560 Ω resistor and both connected in parallel with a capacitor 10nF to generate the RC time constant network. The variable resistor RV2 is varied until the optimum switching frequency is obtained.

$$Frequency, f = \frac{1.30}{RT \times CT} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Pin 1 and pin 2 are considered as inverting input and non-inverting input respectively. Both pins act as comparator and control the duty cycle for the feedback which is related with the PWM.

SG 3524 also has a current-limiting sense amplifier which shows a threshold of 200 mV ±25 mV and it must be grounded as the voltage range of the inputs is restricted in between 1 V to –1 V and it is necessary to take the caution to confirm the –1 V limit is not surpassed by any of the input, or else it will create damage the device.

March - April 2020
ISSN: 0193-4120 Page No. 167 - 178

Pin 14 and pin 11 are acting as the emitter terminals of the internal driver MOSFET.

A half bridge concept which comprising of two MOSFETs is included in the system. IRFZ44 module has been used here. Specification for this MOSFET is shown in Table 2.

Table 2: Specifications for MOSFET

Load Supply	12 to 60V DC
Load Current	30Amps (Peak 50Amps)
Logic Supply	12 To 15V DC
Input Signals	3V to 15V
Drain-to-Source Voltage	60V
On state resistance	0.024 Ω
Drain current	50A

A blanking pulse is generated at the output of oscillator circuit and then is fed to a high and low side of MOSFET driver IR2101. HIN and LIN pins in this driver are functioned as a logic input. A high signal is provided to HIN means it will drive the high-side of the MOSFET, and a high output will be generated on HO. A low signal is provided to HIN means it will turn off the high-side of MOSFET and ultimately a low output will be given on HO.

VB and VS is used to provide the floating voltage supply to drive the MOSFET. A bootstrap circuit is formed with the combination of D5, C1 and C2 with the IR2110. When LIN is high and Q2 is on that means C1 and C2 are charged up to the level of VB. When LIN is low and HIN is high, in this situation the charge at C1 and C2 is functioned to add the voltage to VB which must be more than the source level voltage of Q1 to run the Q1 for high-side arrangement. The capacitance of C1 must be chosen in a way so that it can provide the enough charge which is essential to retain the Q1 on. At the same time, it cannot be too large because it will take time to charge and the voltage level will not escalate adequately to keep the MOSFET turn on. A ceramic capacitor has been used in parallel with electrolytic capacitor.

D2 and D3 is included to discharge the gate capacitances of the MOSFET simultaneously. R3, R4, R5 and R6 are considered as gate current-limiting resistors. Following that, D1 and D2 is added in the design to prevent the voltage overshoot.

Resonant circuit design

The primary circuit of the system has a transmitter coil which is in series with a capacitor and similarly, the receiver circuit also has a receiver coil and it is in series with a capacitor. At the beginning the receiver's resonant frequency is predetermined and after that the resonant frequency of the transmitter circuit has been obtained by calculating the corresponding capacitors to match the resonant frequency with receiver. Hence, both transmitter and receiver has made the strongest coupling that can transfer the highest possible energy. Resonant frequency is varied with the variation of the inductance of the coil. In real time several resonant frequencies have been tuned and this is how the resulting selective resonant frequency has been selected which can be utilized greatly for some applications of the WPT system. The selected resonant frequency is required to feed the targeted receiver in order to transfer energy efficiently. Finally, the resonant frequency for this circuit has been selected 54 KHZ as the greatest transfer efficiency is shown at this frequency. The following Figure 4.3 is showing the resonant frequency developed by the resonant circuit.

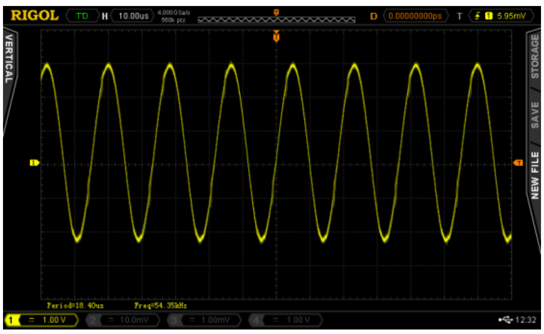

Figure 3: Resonant Frequency

In a series resonant circuit, the resonant frequency, can be calculated using following formula.

$$f = \frac{1}{2\Pi\sqrt{LC}} \quad (2)$$

For 54 KHZ resonant frequency and for a known capacitor of 100nF the inductance of the coil L can be calculated from the following:

$$L = \frac{1}{(2\Pi f)^2 C}$$

$$= \frac{1}{(2\Pi \times 54000hz)^2 \times 100nf}$$

$$= 86.86\ \mu H$$

Transmitter and Receiver antenna coil design

Coil design specifications are shown in Table 3.

Table 3: Coil design specifications

Material used	45 Gauge Litz wire
Thickness Of single strand	0.071 mm
Resistance At 20 degrees Celsius for 1-meter wire	4.29Ω
Cross sectional area Of single strand	0.00396 sq mm
Number Of turns	120 x 15
Inductance	86.66 µH
Diameter of the Coil	22 cm

For this system, several factors have been considered before designing the transmitter and receiver coils. Those are discussed as follows:

Thickness of material

Instead of using a thicker copper wire, 120 strands of very thin litz wire are arranged in parallel as conductance increases when more resistors are added in parallel, therefore resistance decreases. Mathematically it can be proved by following formula.

Conductance is defined as, $G = \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

The formula is defined that when some resistors are connected in parallel, the overall resistance is decreased. Each resistor can conduct a certain amount of current. Theoretically, when the resistors are added in parallel, an extra path is formed by which current can flow easily, and thus every resistor creates a certain amount of conductance. Having 120 strands in parallel means the conductance is 120 times higher than the single strand.

As mentioned above, transmitter and receiver coil are constructed using 45-gauge litz wire. There are several benefits of using litz wire specially when use in the magnetic component. For example, skin effect and proximity effect can be mitigated using this wire. Moreover, it allows to use for high frequency, reduce the weight and ultimately ensure the efficiency.

As conduction loss is mostly dependent on the skin effect and proximity effect, so smaller cross-sectional restrict these effects and thus increases the effective resistance.

Initially, 1 mm and 0.8 mm thicker copper wire used to construct the antenna coil, but the power transfer efficiency is not satisfactory.

Diameter of coil

After reviewing the several literatures, it is determined that, lareger the coil diameter larger the distance between transmitter and receiver coil.

March - April 2020
ISSN: 0193-4120 Page No. 167 - 178

Initially coil is designed for 10 cm and 15 cm diameter, which did not show the optimum transmission distance of power transfer in comparison to the 22 cm diameter of coil which is finally chosen for the system implementation.

Number of turns

Initially number of turns is calculated using wheeler's formula and implemented accordingly. Later, several number of turns is adjusted to get the maximum transfer efficiency.

Working principle

The following Figure 4 is showing the block diagram for the system.

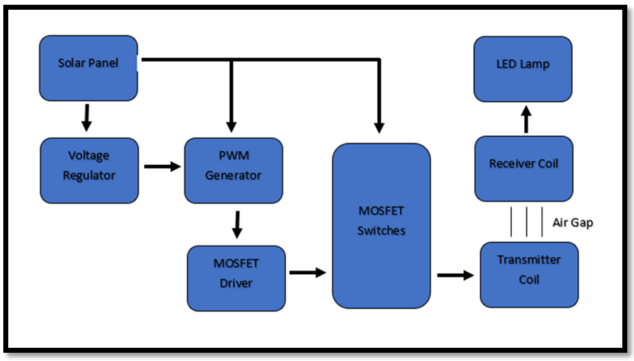

Figure 4: Block diagram

The experiment is developed to transfer the power wirelessly without any medium. As the system is integrated with solar power, the input is given to the system with a solar panel. Sunlight is absorbed by solar panel as a source of energy to produce electricity. This produced electricity is appeared as an unregulated form of DC voltage, which means depends on solar irradiance and temperature, the voltage level can be varied. This unregulated DC voltage is then fed to a voltage regulator IC 7805. The output of voltage regulator is given to a SG 3524 IC. SG 3524 has a built-in circuitry inside which is included with pulse width modulator, oscillator, voltage reference, error amplifier, overload protection circuit, output drivers etc. The output of PWM inverter is used to control the MOSFET driver IC. Thus, the MOSFET driver IC switches the MOSFETs. Thus, the generated AC signal passes through primary coil which further wirelessly transferred to the secondary coil. Resonant coupling is established between transmitter and receiver coils that are tuned at the same frequency. The maximum energy is transferred through the resonant path. Resonant occurs by designing a primary transmission coil which is capacitively loaded with an oscillating current and hence, magnetic field is generated because of its highly resonant capability. If a secondary receiver coil is placed near to it, the energy can transfer to it, even both coils are maintaining a certain distance. This is how, the effective energy transfer is performed wirelessly without any medium.

IV. DISCUSSION – PROJECT FINDINGS & TESTING

There are five testings which are conducted to evaluate the performance of the proposed WPT system. At the beginning, the experimental set-up has been established to determine the test result, consequently the data collection and analysis are done for each types of the testings. The type of testings are outlined as follows:

1. Distance variation test and efficiency test when loaded with two 7.5 watts LED lamps
2. Distance variation test without load

Test 1: Distance variation and efficiency test when loaded with two 7.5 watts LED lamps

This test is performed in order to identify the maximum transmission distance and efficiency achieved by the proposed solar based WPT system.

Experimental Set-up

For this experiment, the set up is established by placing the transmitter coil in a fixed position and the position of receiver coil is varied to establish the different test distance between TX-RX coil. Two 7.5 watt LED lamp is loaded at receiver side. For each 2 cm test distance, data is collected for input voltage, input current, output voltage and output current. Following that power consumption for both input and output is calculated using P=VI,

March - April 2020
ISSN: 0193-4120 Page No. 167 - 178

where where P is power in watt, V is voltage and I is current in amp. Later, efficiency is calculated using the ratio of output power to input power. The collected data are tabulated in Table 4 and Table

Data collection

Table 4: Collected data for Distance test

Input Voltage Vin	Input Current Iin	Output Voltage Vout	Output Current Iout	Distance
10.34 V	0.243 A	2 V	0.08 A	15 cm
11.49 V	0.236 A	4.90 V	0.10 A	13 cm
10.36V	0.224 A	4.53 V	0.12 A	11 cm
13.88 V	0.338 V	8.65 V	0.33 A	9 cm
10.59 V	0.395 A	6.66 V	0.35 A	7 cm
11.29 V	0.389 A	8.54 V	0.38 A	5 cm
13.75 V	0.357 A	9.30 V	0.35 A	3 cm
12.55 V	0.389 A	9.50 V	0.38 A	2 cm
13.80 V	0.378 A	11.50 V	0.36 A	1 cm

Table 5: Calculated data for Efficiency test

Input power	Output power	Efficiency
2.51W	0.16W	6.37%
2.71W	0.49W	18.08%
2.32W	0.54W	23.27%
4.63W	2.85W	61.55%
4.18W	2.85W	68.18%
4.18W	2.91W	69.18%
4.39W	3.24W	73.80%
4.90W	3.61W	73.94%
5.21W	4.14W	80.46%

Data analysis for distance variation

The collected data is plotted at the bar chart in Figure 5 which shows the graphical representation for distance vs input and output power.

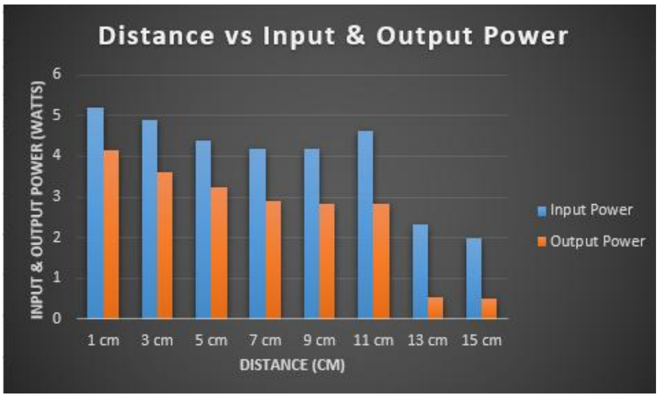

Figure 5: Graph for distance vs input and output power

This graph is given an information about input and output power variation with respect to distance. The x-axis is denoted the range of distance between 1 cm to 17 cm with an increment of 2 cm and the y-axis is denoted the power consumption for both input and output power. The main reason of conducting this test is to find the performance of WPT system for different test distance between TX-RX coil.

Overall, the system can transfer power for maximum 17 cm distance between TX-RX coil. At the minimum air-gap of 1 cm the system shows the maximum power transfer as the difference between the input and output power is very less and both LED lamps brightness is very high. With the increasing distance the difference between input and output power started increasing and at the same time the brightness of LED lamps are started becoming low and at maximum distance of 17 cm both lamps brightness become very low.

According to the chart, at smaller distance

March - April 2020
ISSN: 0193-4120 Page No. 167 - 178

between TX-RX coil, output power is maximum but with the increasing distance the power is reduced simultaneously.

Data analysis for efficiency

Figure 5.2 is shown the graphical representation of collected data for distance vs efficiency.

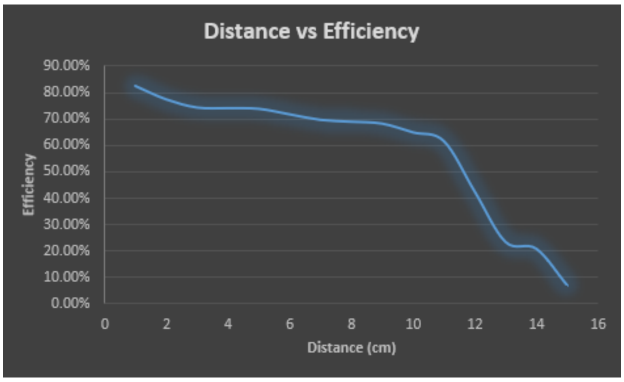

Figure 6: Graph for distance vs efficiency

This chart is providing a statistic of power transfer efficiency in concern with the distance variance. The main purpose of regulating this test is to identify the transfer efficiency of WPT system at different test distance. The x-axis of the is denoted with distance and the y-axis is efficiency.

Overall, it is found that, the maximum transfer efficiency is achieved with 80.48% when distance between TX-RX is 1 cm. But with the increasing distance the efficiency of the system is reduced simultaneously and at the maximum distance of 15 cm the system can only achieve an efficiency of 6.76%.

According to the chart, the efficiency of the system is reduced simultaneously with the increasing distance.

Test 2: Distance variation test without load

This experiment is performed in order to determine the maximum transmistsion distance achieved by the system without using any load at receiver side.

Experimental Set-up

For this experiment, the set up is made by keeping the transmitter coil in a static position and the receiver coil is addjusted to several position to generate the different test distance between TX-RX. For different test distance between TX-RX, data is collected for input voltage and output voltage. The collected data are tabulated in Table 6.

Data collection

Table 6: Collected data for distance variation

Input Voltage	Output Voltage	Distance
10.53V	1.89V	19 cm
10.36V	2.33V	17cm
11.14 V	3 V	15 cm
11.49 V	4.10 V	13 cm
10.26V	4.33 V	11 cm
13.98 V	8.45 V	9 cm
10.79 V	6.76 V	7 cm
11.49 V	8.64 V	5 cm
13.65 V	9.30 V	3 cm
12.45 V	9.60 V	2 cm
13.50 V	11.30 V	1 cm

Data analysis for distance variation

For this experiment the data is collected and then plotted in a bar chart. The following Figure 7 is showing the bar chart for distance vs input and output voltage.

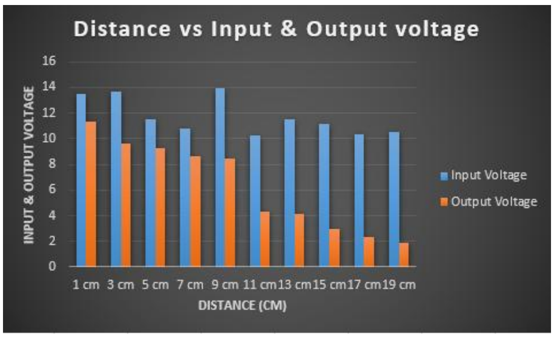

Figure 7: Graph for distance vs input and output power

TEST Engineering & Management

March - April 2020
ISSN: 0193-4120 Page No. 167 - 178

This graph is given a data about input and output power difference in concern to the different test distance The reason of conducting this test is to find the performance of WPT system without load for different test distance between TX-RX coil. Finally, the maximum 19 cm transfer distance achieved by the system without any load.

According to the chart, at smaller distance of 1 cm, the output voltage is maximum but with the increasing distance the power is reduced simultaneously.

Hardware results

The hardware results for proposed solar power based WPT system has been displayed in order to demostrate the overall functionality of the system. For the hardware experiment, the transmitter and receiver coil of the system is set up both for smaller and larger distances starting from 1 cm to 19 cm. Figure 4.5 and figure 4.6 are showing the set-up for long and short distances.

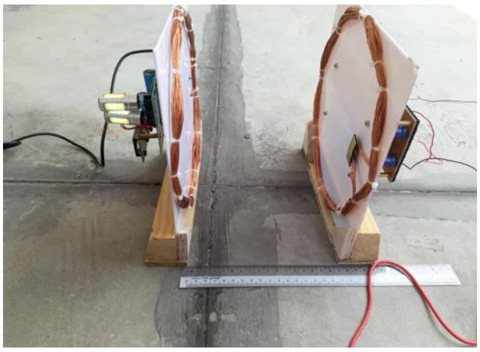

Figure 8: Experimental set-up for 15 cm between TX-RX

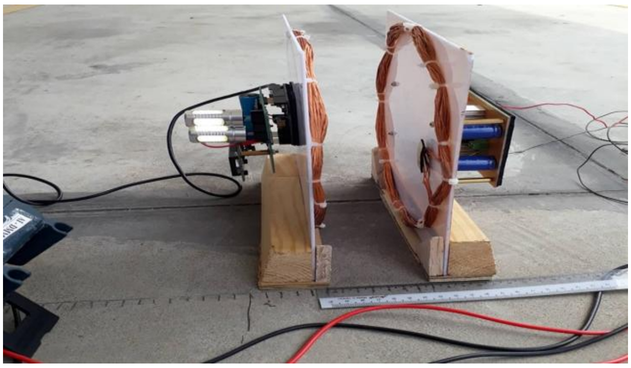

Figure 8: Experimental set-up for 7 cm between TX-RX

In order to perform the experiment, transmitter coil is placed to a fix position and the position of receiver coil is varied. Both short and long distances are able to transffer a sufficient amount of power which can light up two 7.5 LED blub. The maximum transfer efficiency has been achieved with shorter distance where both LED blubs are lit-up very brightly.

Later, several experiments is performed with different types of load and the system is worked perfectly. The following Figure 4.4 is showing the experiment set-up when it is loaded with a 7.5 watt LED bulb and a 3 watt fan.

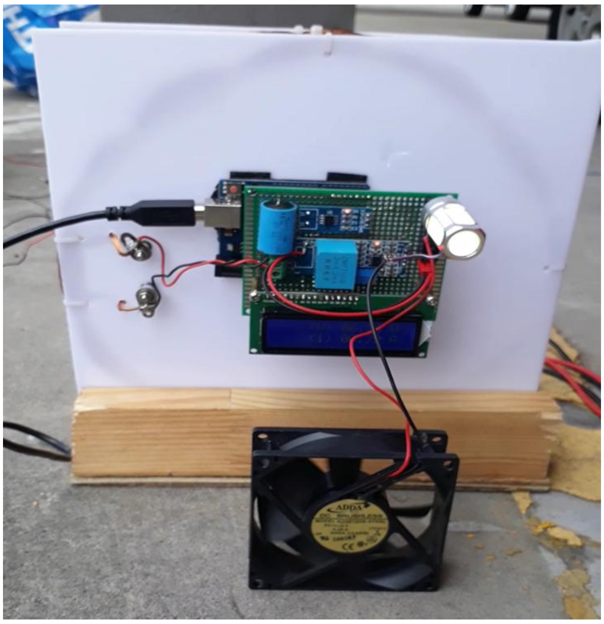

Figure 9: One 7.5 watts LED lamp and 3 watts fan is running with output power

To determine the efficiency of the system both input power and output power have been calculated for different distances between transmitter and receiver coil when the system is loaded with two LED blub. The following Figure 4.4 is showing the experiment set-up where two multi-meter have been used to measure the input current and voltage respectively. The output current and voltage are measured using AC current and voltage measurement sensor and result is displayed using LCD screen.

V. CONCLUSION

The aim of the proposed project is to design a solar power based Wireless Power Transfer (WPT) system for small scale applications. The following objectives are achieved successfully after implementation the project.

- To design the WPT system for small scale application.
- To integrate the solar power with WPT system.
- To evaluate the performance of the WPT system by conducting suitable tests and analyzing the test results.

WPT system is designed and explained the construction details and working principle of transmitter and receiver circuit in order to transfer energy wirelessly. Input power is given to the system and a certain air-gap is maintained in between TX-RX coil, the system managed to light-up maximum two 7.5 watts LED lamp wirelessly which indicates the successful accomplishment of the first objective for the proposed project. Furthermore, the second objective is achieved by integrating a solar panel to the system. Sunlight is absorbed by solar panel as a source of energy to produce electricity and generated electricity through the solar panel is given as an input to the system and consequently the given input power is transmitted through transmitter and received by receiver wirelessly in order to power up the load. This whole procedure is proved the proper execution of second objective of the project. The third objective of the project has been achieved by testing the system several times in order to ensure its efficiency and capability of transferring the enery wirelessly for different test distance between TX-RX coil. The maximum power transfer distance between TX-RX coil achieved is 15 cm when the receiver is loaded with two 7.5 watts LED lamp but without load the transfer distance between TX-RX is increased to 19 cm. Finally, the system proved to be very efficient with 82.44% with no loaded condition and 80.46% with loaded condition for a minimum air-gap, as compared to the various techniques employed in the literature. Additionally, the data has been collected and analyzed for the sake of validating the designed system.

In conclusion, the aim and objectives have been effortlessly achieved by designing the solar based WPT system prototype and validating the system in terms of data collection and investigation. The system mainly consists of transmitter and receiver circuit, along with solar panel. Additionally, four distinctive testing have been conducted in order to determine the system in terms of distance variation and efficiency.

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