iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VII **Month of publication:** July 2021

DOI: https://doi.org/10.22214/ijraset.2021.36937

Wireless Transmission of Solar Power

Ajay Bhardwaj[1], Anuj Nama[2], Atul Jain[3], Harshwardhan Singh Jadon[4], Lavesh Tiwari[5]
[1]*Assistant Professor, Dept. of Electrical Engineering, Swami Keshvanand Institute of Technology M&G, Jaipur*
[2, 3, 4, 5]*B.tech Scholar, Swami Keshvanand Institute of Technology M&G, Jaipur*

Abstract: The Solar Power Satellite (SPS) is an energy system that collects solar energy in the upper atmosphere and transfers it to the ground. It has been seen as one of the best ways to alleviate the problem of future electricity needs. In the times to come, wireless power transmission will be used as it requires less maintenance and numerous other benefits. Solar energy is used for wireless power transmission. The wireless transmission concept was first realized by Nikola Tesla. Wireless transmission can bring about a noticeable change in the field of electrical engineering, which can lead to the fact that traditional copper wire is no longer used. For this project we used renewable energy as a source for wireless energy transmission. The DC output voltage of the solar cell is increased with a step-up converter and converted into oscillating signals. These oscillating signals are amplified via an amplifier and then supplied to the transmitting coil. By operating at the resonant frequency and achieving good coupling between the transmitter and receiver coils, electrical energy is transmitted between the transmitter and receiver due to the Magnetic resonance.
Keywords: wireless, solar, power.

I. INTRODUCTION

The transmission of electricity from the generation/ source over a distance without conductive support such as wires or cables is called wireless energy transfer. Wireless power is required or necessary where no cable connection is possible, uncomfortable and dangerous. The concept of wireless power transmission was first visualized by Nikola Tesla in Early 1900s. Nikola Tesla invented a resonance transformer known as Tesla coil which uses the radiation method for transmission of Wireless power supply. However, Tesla coil produced dangerously high voltage electric arc which was a major concern in terms of safety. The wireless power technology has increased its popularity in recent years and also the interest towards magnetic power transmission has re-emerged. In the year 2007 MIT team was able to transfer watts wirelessly over a distance of 2 meters using a 60 cm diameter coil with an efficiency of < 40% [1]. There are three methods of wireless energy transfer: magnetic coupling mode, electric field coupling mode, and electromagnetic radiation mode. The magnetic coupling mode is classified into short range Electromagnetic induction and mid-range strongly coupled magnetic resonance. The power transferred and the transfer efficiency in the case of electromagnetic induction is high but the power transferred range is less. In the case of strongly coupled magnetic resonance method, the power can be transferred for a longer distance but with reduced efficiency when compared to short range electromagnetic induction type. The main principle in the case of electric field coupling mode is the redistribution of the surface charge on any object. The transmitter is excited with a high voltage and high frequency source to generate an alternating electric field which couples with the resonant receiver. The power transferred in this mode is less and the efficiency of the power transfer is largely affected by the surrounding medium. Lastly in the case of electromagnetic radiation, the electric energy is converted into electromagnetic energy such as laser beams or microwaves, which can be radiated over a longer distance. Then received electromagnetic energy is converted back into electric energy. With the increased distance of power transmission in electromagnetic radiation mode, the transfer efficiency is reduced.

DC transformers are used for the most part in switching mode regulated power supply and also in DC motor applications. These converters are many practical applications, such as solar cell power systems, and fuel cells Power transmission system, uninterruptible power supply System etc. The DC-DC converter requires large boost conversion from the panel’s low voltage to the voltage level of the appliance [3]. Some converters increase turns ratio of the coupled inductor obtain higher voltage than conventional boost converter. Some converters are effective combination fly back and boost converters. They are a range of converters combination developed to accomplish high voltage gain by using coupled inductor technique [2],[4]. Combinations of auxiliary resonant circuit, active snubber synchronous rectifiers, or switched capacitor based resonant circuits and so on, these circuits made active switch into zero voltage switching (ZVS) or zero current switching (ZCS) operation and improved converter efficiency. The main criterion for achieving wireless energy transmission is the generation of alternating signals in the transmitter. Power amplifiers are widely used to generate these AC signals, but there is a significant loss of power associated with the wireless power amplifier. Et al Sokal in [5] proposed a class E power amplifier which can achieve efficiency up to 100% with higher output power and reduced heat sink requirements.

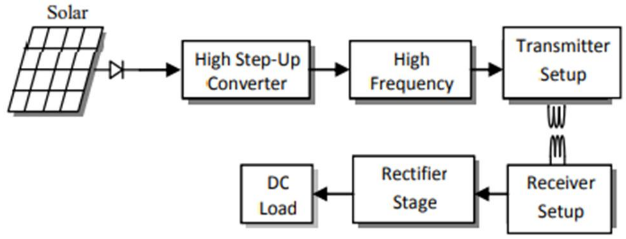

Fig. 1. Block diagram of the proposed wireless power transmission system

Fig. 1. shows the block diagram of the Wireless Power Transmission System model. It consists of a solar panel which will be used as an input source, whose input voltage will be boosted using a high step-up DC-DC converter [9]. This high voltage is then converted high frequency AC using class E power amplifiers. The oscillating signals are then fed into the transmitter setup. By achieving proper resonance coupling between the transmitter and the receiver setup power gets transferred wirelessly.

II. DESCRIPTION OF THE PROPOSED WIRELESS POWER TRANSMISSION SYSTEM

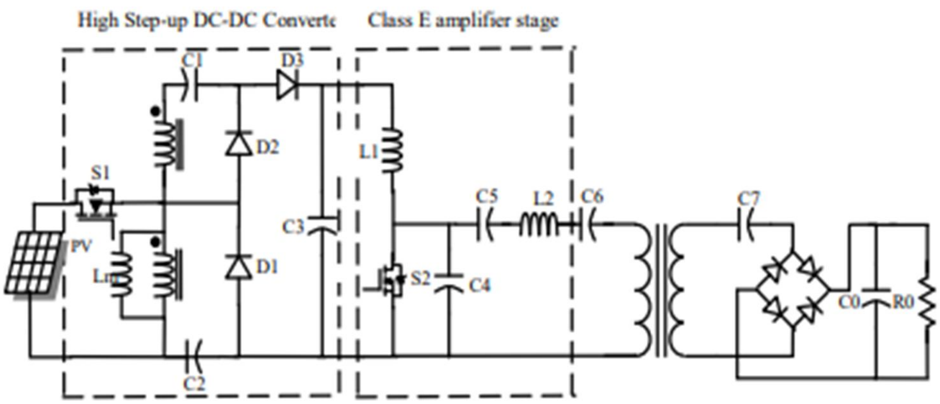

Fig. 2. Circuit configuration of the proposed wireless power transmission system.

The fig. 2 shows the two main stages of the proposed system. The first stage is the high step-up dc-dc converter which converts the low input voltage from the PV Cell to a higher value [11]. The step-up converter has following advantages:

1) The converter has a high step-up conversion ratio because of the connection of the coupled inductors, diodes and the capacitors.
2) It has very high efficiency and lower stress on the switches as the leakage inductor energy can be recycled. It consists of a coupled inductor T1 with the switch S1. The primary side winding N1 of a coupled inductor T1 is identical to the input inductor of the traditional boost converter, and diode D1, capacitor C1 receives leakage inductor energy from N1. The secondary side winding N2 of coupled inductor T1 is connected with another pair of diodes D2 and capacitors C2, which are in series with N1 in order to increase the boost voltage. The rectifier diode D3 is connected to output capacitor C3. The second stage is the class E amplifier which receives the dc input from the high step-up converter and converts to high frequency ac [10]. The class E amplifier is a highly efficient switch mode resonant converter. The high efficiency results from the reduced power losses in the transistor. The higher efficiency of the switch can be achieved by: I. Using the transistor as a switch to reduce the power II. Reducing the switching losses which result from finite transition time between ON and OFF states of the transistor. The Class E amplifier consists of a RF choke L1 and a parallel-series resonator circuit consisting of C4, C5 and L2.

The output of the class E power amplifier [7] is connected to the tank circuit formed by C6 and the transmitting coil as shown in the fig. 2. The receiver consists of a tank circuit formed by capacitor C7 and the receiving coil and a simple full bridge diode rectifier to convert the ac power transmitted from the transmitter coil to dc and a filter C0 is used to reduce the harmonics and then given to the load R0. The power gets transferred resonant frequency is achieved between transmitter and receiver pair.

III. OPERATING MODES OF THE PROPOSED WIRELESS TRANSMISSION SYSTEM

There are five modes of operation for high step-up dc-dc converter and class E amplifier has only two modes which will be discussed separately [6].

A. *Modes of Operation of High Step-Up DC-DC Converter:*

Mode I (t0 – t1): Fig 3 shows the mode I operation of the step-up converter. When the switch S1 is closed, the capacitor C2 gets completely charged by the magnetizing inductor Lm. The magnetizing inductor current IL_m decreases as the input voltage V_{in} crosses the magnetizing inductor Lm and the leakage inductor L_{k1}. L_m still continues to transfer energy to the capacitor C2 but this energy is decreasing. The current through the diode D2 and the capacitor C2 are also decreasing. The secondary leakage current iL_{k2} is also decreasing with a slope of $iL_{m/n}$. This mode ends when increasing iL_{k1} is equal to the decreasing iL_m at t=t1.

Mode II (t1 – t2): Fig 4 shows the mode II operation of the step-up converter. During this mode, the input source voltage Vin gets series connected with N2, C1 and C2 which charge the output capacitor C3. The currents iL_m, iL_{k1} and id3 increases as V_{in} crosses L_{k1}, Lm and N1. L_m and L_{k1} stores energy from V_{in} also C1 and C2 discharge their energy to C3. Hence id3 and the discharging currents ic1 and ic2 also increase. The switch is turned off at t=t2 and this mode ends.

Mode III (t2 – t3): Fig 5 shows the mode III operation of the step-up converter. During this mode the secondary leakage inductor L_{k2} keeps charging the output capacitor C3 when the switch is turned off at t=t2. Diodes D1 and D3 will be conducting. The stored energy in Lk_1 flows through D1 to charge the capacitor C1. Also, the stored energy in the leakage inductor L_{k2} is in series with C2 to charge the output capacitor C3. Since the inductances of L_{k1} and L_{k2} are very small compared to Lm, iL_{k2} decreases rapidly but iL_m increases as the magnetizing inductor Lm receives energy from L_{k1}. This mode ends when iL_{k2} decreases and reaches zero at t = t3. Mode IV (t3 – t4): Fig 6 shows the mode IV operation of the step-up converter. The magnetizing inductor Lm discharges its energy to C1 and C2. Diodes D1 and D2 are conducting in this mode. The currents i0 and iD1 are decreases continuously as the leakage energy charge the capacitor C1 through the diode D1. The magnetizing inductor Lm discharges its energy to charge the capacitor C2 through T1 and D2. The energy stored in C3 is continuously discharged to the load R. These energy transfers decrease the currents iL_{k1} and iL_m but increases the current iL_{k2}.This mode ends when iL_{k1} reaches zero at t=t4.

Mode V (t4 – t5): Fig 7 shows the mode V operation of the step-up converter. During this mode of operation, Lm continuously discharges its energy to C2 and diode D2 will be conducting. The current iL_m decreases as it charges the capacitor C2 through T1 and D2. This mode ends when the switch S1 is turned on at the beginning of the next switching period.

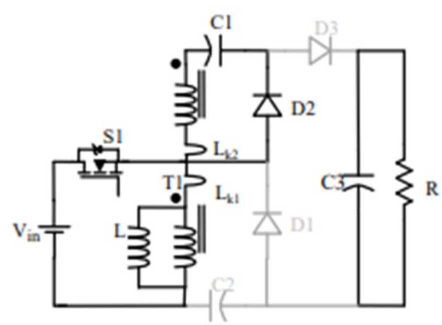

Fig. 3. Mode I operation of high step-up dc-dc converter

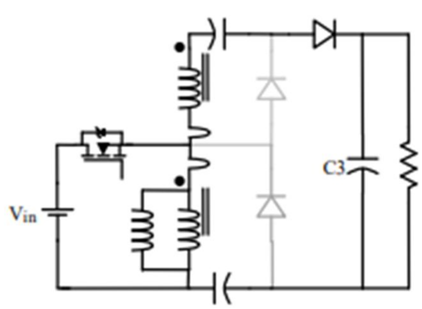

Fig. 4. Mode II operation of high step-up dc-dc converter

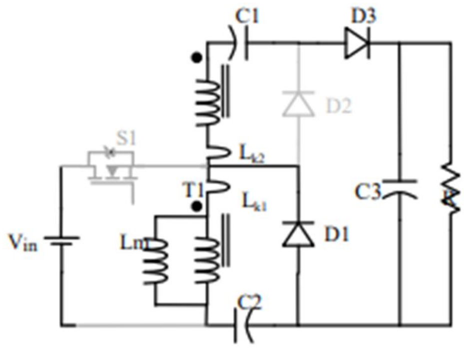

Fig. 5. Mode III operation of high step-up dc-dc converter

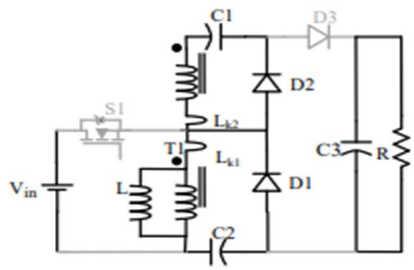

Fig. 6. mode IV operation of high step-up dc-dc converter

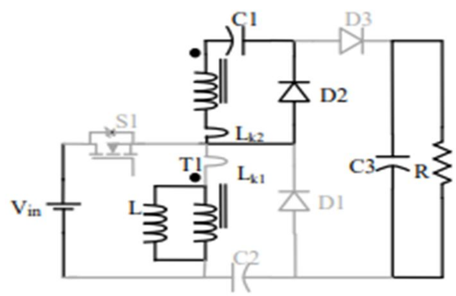

Fig. 7. Mode V operation of high step-up dc-dc converter

B. Modes of Operation of Class E Power Amplifier :

Fig. 8. shows the two switching stages of the switch S1 which is ON for a half cycle and off for another half cycle. The switch S1 is turned ON at zero drain voltage and zero drain current to reduce the switching losses when the transistor is turned ON.

1) *Optimum Operation Mode:* When the switch is turned OFF, there will be a jump change in the drain current but the drain voltage starts to increase slowly from zero thus reducing the switching losses. This will be the optimum mode of operation of class E amplifier as ZVS and ZCS has been achieved which provides the highest efficiency.
2) *Sub-Optimum Operation Mode:* Class E amplifier can be operated in a sub-optimum operation mode, where the capacitor C1connected across the switch S1 is discharged to zero before turning ON the switch S1 by proper gate signals. In this case the drain voltage becomes negative and the anti-parallel diode of the switch S1 conducts only the negative current and maintains the drain voltage close to zero before the switch S1 is turned ON, thus reducing the switching losses.

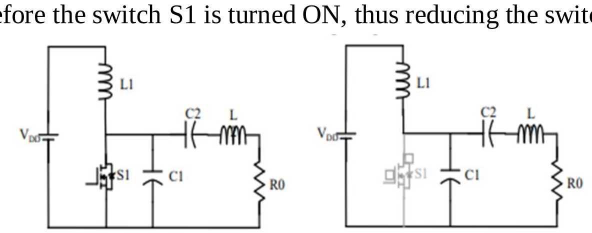

Fig. 8. Operation of class E power amplifier

IV. DESIGN OF THE PROPOSED WIRELESS ENERGY TRANSMISSION SYSTEM

Design of the proposed WPT system requires the design of the high step-up dc-dc converter and the design of the class E power amplifier. Hence, there are two design stages which will be discussed in this section. During the design procedure, following assumptions are made:

1) All the components are assumed to be ideal.
2) The ON state resistance and the parasitic capacitance of the switches are neglected.
3) The voltage drops across the diodes are neglected.
4) The capacitors are assumed to have a very large value.

A. High Step-Up DC-DC Converter Design:

Input Voltage, V_{in} = 12 V (1)

Output Voltage, V_0 = 70 V (2)

Switching frequency, f = 100 KHz (3)

Tranformer Turns Ratio, n = 2 (4)

Output R = 100 Ω (5)

Now the duty cycle D is calculated as

$$D = 1-\frac{\text{Vin }(1+n)}{\text{V0}} \tag{6}$$

$$D = 1-\frac{12(1+2)}{70}$$

$$D = 0.485 \text{ or } 48.5\% \tag{7}$$

The boundary normalized magnetizing time constant τLB is depicted as,

$$\tau\text{LB} = \frac{D(1-D)^2}{2(1+n)2} \tag{8}$$

At the boundary for converter's operation at 50% of the full load, the load resistance R=200Ω is selected. Substituting the value of D in the equation 4.8, we have

$$\tau_{LB} = \frac{0.485(1-0.485)2}{(1+2)^2}$$

$$\tau_{LB} = 7.1371 \times 10{-}3 \text{ s} \tag{9}$$

Now the boundary magnetizing inductance is found as,

$$L_{mB} = \frac{\tau_{LB}\,\text{R}}{\text{f}} = \frac{7.1371 \times 10^{-3} \times 100}{(50\times 103)}$$

$$L_{mB} = 14.275\ \mu\text{H} \tag{10}$$

Hence the magnetizing inductance Lm has to be greater than the boundary magnetizing inductance L_{mB}

i.e., L_m>14.275 μH (11)

B. Class E Transmitter Design:

To start with we have to first set the supply voltage of the class E power amplifier by using the equation

$$V_{CC} = \frac{BV_{CEV}}{3.56\ .SF} \tag{12}$$

Where BV_{CEV} is the breakdown voltage of the MOSFET which is to be used and SF is the safety factor whose value is not greater than

1) Assuming SF to be 0.8 and the supply voltage of 70 V, we have

$$BV_{CEV} = \frac{3.56\times \text{VCC}}{\text{SF}} \tag{13}$$

$$= \frac{3.56\times 70}{0.8} = 311.5$$

i.e. we have to choose a MOSFET whose breakdown voltage has to be greater than 311.5V.
Based on the power specification and QL, the load resistance can be calculated based on the following equation as shown in 14.

$$R_L = \frac{(V_{CC})^2}{P_{OUT}} 0.576801(1.001245 - \frac{0.451759}{Q_L} - \frac{0.402444}{Q_L^2}) \quad (14)$$

Where the value of Q_L is chosen by the designer, for a duty cycle of 50%, the minimum value of QL is 1.7879. In [8] the value of Q_L is chosen to be 2.134 and P_{Out} as 60 W, we have

$$R_L = \frac{(70)^2}{60} \times 0.576801\ (1.001245 - \frac{0.451759}{2.134} - \frac{0.402444}{2.134^2})$$

R_L = 32.98 Ω

Hence the value of R_L is chosen to be R_L = 50 Ω.
The next step is to calculate the value of the shunt capacitance C1 which is to be connected across the switch by the following equation.

$$C_1 = \frac{1}{(2\pi fo R_L (\frac{\pi^2}{4}+1)\frac{\pi}{2})} \times (0.99866 + \frac{0.91424}{Q_L} - \frac{1.03175}{Q_L^2}) + \frac{0.6}{(2\pi fo)2 L_1} \quad (15)$$

$$C_1 = (\frac{1}{34.2219\, fo R_L}) \times (0.99866 + \frac{0.91424}{Q_L} - \frac{1.03175}{Q_L^2}) + \frac{0.6}{(2\pi fo)2\, L_1} \quad (16)$$

We have chosen the operating frequency of 13.56 MHz, substituting the value of and R_L in the equation 16, we have the value of shunt capacitance C_1 as

$$C_1 = 51.74\text{pF} + \frac{0.6}{(2\pi fo)2\, L_1} \quad (17)$$

Usually, the value of XL_1 is chosen to be 30 or more than times the unadjusted value of XC1

i.e. $XL_1 > 30 \times XC_1$

$\omega L_1 > 30/\ \omega C1$

$L_1 > 30/\omega 2\ C1$ (18)

Substituting the value of C1 as 51.74pF and fo = 13.56MHz, we have
L_1>79.87µH

The value of L1 is chosen to be 80µH. Substituting this value of L1 in equation 17, the value of shunt capacitance C1 is found to be

C_1 = 79.4 pF

The value of C2 is calculated by using the equation below

$$C_2 = (\frac{1}{2\pi fo R_L}) \times (\frac{1}{Q_L - 0.104823}) (1.00121 + (\frac{1.01468}{Q_L - 1.7879} - \frac{0.2}{(2\pi fo)2\, L_1} L_1) \quad (19)$$

Substituting the value of fo, R_L and Q_L in the equation 19, we have C_2 = 689.9127Pf

The value of L2 is found from the equation below

$$L_2 = \frac{Q_L \times R_L}{2\pi fo} \quad (20)$$

Substituting the value of fo, RL and QL in the equation 20, we have
L_2 = 0.8µH

V. SIMULATION AND RESULT

The simulation of the proposed wireless power transmission model has been carried out using MATLAB/SIMULINK. The proposed model has been verified for an input voltage of 12V from the solar panel and the output is obtained to be 110V.

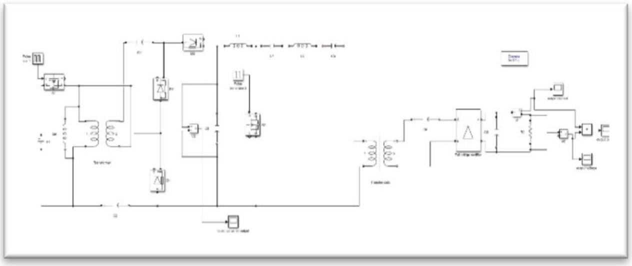

Fig. 9. Circuit arrangement of the proposed wireless power transmission system using MATLAB/SIMULINK package.

The specifications of various components used in the proposed model are tabulated below:

- *Results:* In this project we use 12 volts dc solar input and here we have assumed that the solar input is completely stable without any voltage regulations.

In this model first we step up the dc solar input with the help of dc-dc boost converter and then that boosted voltage is send to a class E amplifier to increase the frequency of the voltage waveform so that it can be transferred efficiently over the long distance. We use high frequency for the transmission of power i.e., 100Khz.

Table1. Component values of the proposed Wireless Power Transmission model.

S.no.	Parameter	Value
1.	Lm	15mH
2.	C1	47mF
3.	C2	47mF
4.	C3	47mF
5.	Duty Ratio of S1	48.5%
6.	Turns Ratio of T1	2
7.	L1	80mH
8.	L2	0.8mH
9.	C4	690pF
10.	C5	132pF
11.	C6	150pF
12.	C0	68mF
13.	R0	400
14.	Duty Ratio of S2	50%

After the transmission of the power with the help pf magnetically coupled coils the ac voltage is rectified with the help of full bridge rectifier and then capacitor is used as filter to rectify the output across the load that is purely resistive in this case.

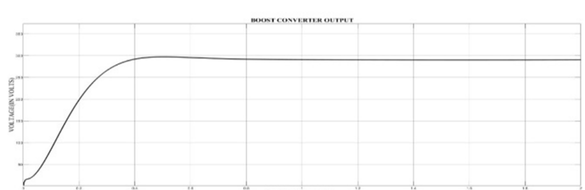

Fig. 10. Boost converter output

As we can clearly see in the above figure that the boost converter voltage stabilizes at 0.8 second which is acceptable in practical world and the boosted voltage is 290 volts.

In contrary with the boost converter output we have taken three other output across the load that is output voltage, output current and output power. The waveforms of all the three output are shown in below figures.

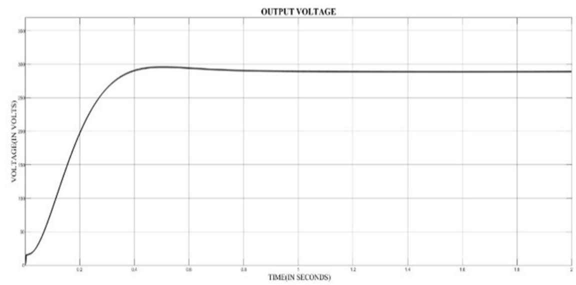

Fig. 11. Output Voltage

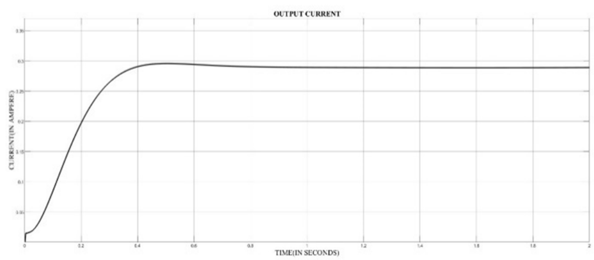

Fig. 12. Output Current

It is clearly seen in above waveforms that there is some time delay before the output gets stable and that delay is same for both (voltage and current) that is 0.8 seconds. After getting stabilize the output voltage attains the value of 290 volts which is same as the boost converter voltage which shows the efficient transfer of the power over the distance as there are no change in the stabilize value of transmitted voltage.

On the other hand, the output current steady state value is 0.29 ampere which is much better than our reference paper. In this some might worry about the low value of the output current but it is self-explanatory since we are increasing the value of the voltage the current is bound to decrease. The value of the current can be further increase by different kind of methods to our need.

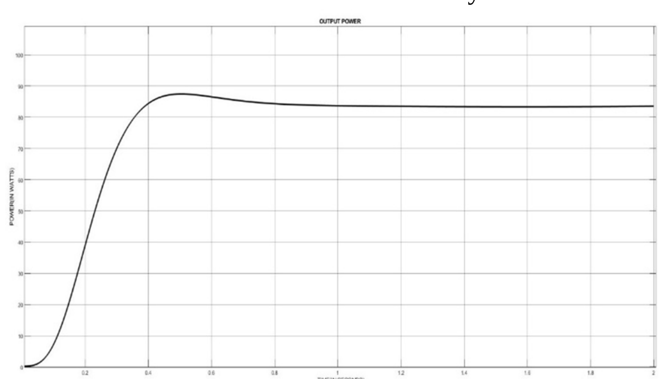

Fig. 13. Output Power

Output power follows the same waveform and output voltage and current since it comes with multiplication of both waveforms. The steady state value of transmitted output power is 84 watts which is good for basic practical purposes.

VI.CONCLUSION

This project has introduced the transmission of power wirelessly using the input from the solar panel. The proposed wireless power transmission using high step-up dc-dc converter for PV cells has been built based on the simulation performed on MATLAB/ SIMULINK. The model uses the input from the solar panel and by using a high step-up dc-dc converter, the input of 12V has been stepped up to 290V which is the given as the input to the class E transmitter. The secondary or the receiver of the proposed model receives a DC output of 290V and the power delivered to the load is nearly 84W.

REFERENCES

[1] Qiang wang and Hong Li, "Research on the wireless power transmission system based on coupled magnetic resonances", IEEE International Conference 2011.
[2] Q. Zhao and F. C. Lee, "High-efficiency, high step-up dc–dc converters," IEEE Trans. Power Electron, vol. 18, no. 1, pp. 65-73, Jan. 2003.
[3] R. J. Wai, C. Y. Lin, R. Y. Duan, and Y. R. Chang, "High-efficiency dc– dc converter with high voltage gain and reduced switch stress," IEEE Trans.Ind. Electron., vol. 54, no.1, pp. 354–364, Feb. 2007.
[4] S. M. Chen, T. J. Liang, L. S. Yang, and J. F. Chen, "A cascaded high step-up dc–dc converter with single switch for micro source applications," IEEE Trans. Power Electron., vol. 26, no. 4, pp. 1146– 1153, Apr. 2011.
[5] N. O. Sokal and A. D. Sokal, "Class E-A new class of high efficiency tuned single-ended switching power amplifiers," Solid-State Circuits, IEEE Journal of, vol. 10, pp. 168-176, 1975.
[6] Kuo-Ching Tseng, Chi-Chih Huang, and Wei-Yuan Shih, "A High StepUp converter with a Voltage Multiplier Module for a Photovoltaic System". IEEE transactions on Power Electronics, vol. 28, no. 6, June 2013
[7] Juliusz Modzelewski and Mirosław Mikołajewski," High-Frequency Power Amplitude Modulators with Class-E Tuned Amplifiers", Journal of Telecommunications and Information Technology April 2008.
[8] W. Chen, R. A. Chinga, S. Yoshida, J. Lin, C. Chen1 and W. Lo, "A 25.6 W 13.56 MHz Wireless Power Transfer System with a 94% Efficiency GaN Class-E Power Amplifier", Microwave Symposium Digest (MTT), IEEE MTT-S International, 2012.
[9] M.Karthika and Dr. C. Venkatesh," WiTricity: A Power Transmission Method for WSN", International Journal for Technological Research in Engineeing, Volume 1, issue 10, june-2014.
[10] T. Shimizu, K. Wada, and N. Nakamura, "Flyback-type single-phase utility interactive inverter with power pulsation decoupling on the dc input for an ac photovoltaic module system," IEEE Trans. Power Electron., vol. 21, no. 5, pp. 1264–1272, Jan. 2006.
[11] C. Rodriguez and G. A. J. Amaratunga, "Long-lifetime power inverter for photovoltaic ac modules," IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2593–2601, Jul.
[12] Saurabh, Dhruv Kapur, Raju J, "Wireless Power Transmission for Solar Input", International Conference on Computation of Power, Energy Information and Communication (ICCPEIC), 2016.