

Design of A Novel DC Multiplier for Solar PV Energy Applications



A.Jeyashree, P.Sathish Kumar, A.Imtiyas

Abstract: This paper concentrates on the design of DC multiplier for solar photovoltaic application. The main aim of this paper is to boost up the voltage from solar panel without using transformer and to track maximum power using maximum power point algorithm. The system design includes solar panel, snubber circuit, switching circuit, coupled inductor, opto isolator, voltage multiplier, microcontroller and load. Normally boost converter is used in conjunction with solar PV to boost the output voltage from panel. But the boost converter can be able to increase the input voltage to a limited value. In other, converter transformers are used. Hence core loss, magnetic loss and copper loss will occur. To overcome these losses and also to achieve isolation coupled inductor can be used. Thus proposed system overcomes the core loss, magnetic loss, copper loss and also helps to achieve the isolation between the circuits by using the coupled inductor. By using voltage multiplier, the boost converter can able to increase the input voltage beyond the rated value. Simulations are done in MATLAB/Simulink platform. It forms the voltage multiplier for renewable energy application to boost the DC voltage.

Index Terms: Photovoltaic system, Boost Converter, MPPT Algorithm, Snubber Circuit, Coupled inductor, Microcontroller and Voltage multiplier.

I. INTRODUCTION

The demand for electricity will keep on expanding as long as total population increases and people keep on requesting a higher standard of living. The challenge lies in giving this electricity from dependable and reasonable sources while keeping up regard for the surrounding. Thermal power and other fossil fuel based energy sources are currently available resource in production of electricity. But additionally it also causes some unfortunate consequences on the surrounding. While it is clear that renewable energy is an alternate energy source in production of electricity.

Renewable energy as of now faces a few disadvantages on its track to become the sole source to generate electric power. Solar energy is mainly depend on the geographic location and it is one of the major drawback of it. For instance, the best areas to reap solar energy lie in the desert locales of earth's surface. The photovoltaic solar energy is used to convert the irradiation into electrical energy and supplies all electrical loads. There are different topologies and design for embedding converters are introduced to improve the efficiency of the existing system[1-4].

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However, the majority of the energy consumers don't dwell in these parched locales. The alternate of solar energy is wind energy, but it's also depending on the geographic location. The voltage regulation is also vital parameter to transfer energy for wearable electronics application using inductor sizing [5-6]. The main objective of this paper is to boost up the voltage from solar panel without using transformer and to track maximum power using maximum power point algorithm. The exciting system consists of isolation transformer and voltage doubler. The efficiency of the conventional system is 94% only. But in proposed system the efficiency is 98% because of using voltage multiplier and coupled inductor. Here MPPT algorithm (P & O algorithm) is used to track maximum power from solar panel at different irradiation [7-8]. An isolated coupled inductor coordinated DC-DC converter with a snubber circuit to lessen the voltage spike on switches. The low turn's proportion is accomplished by diminishing the extent of the coupled inductor, accordingly improving effectiveness.

II. PROPOSED TOPOLOGY

Figure 1 represents the layout of the proposed topology. It comprises of a dc source, boost converter and load. Here the solar panel acts as an input DC supply. The output of the solar panel is fed to the boost converter. The boost converter consists of snubber circuit at primary side and voltage multiplier at secondary side. The dc-dc converter boosts up the voltage. The boosted dc voltage is given to the resistive load. The pulses are generated using microcontroller. The input of the microcontroller is 5V (2-5). Opto-isolator is to give detachment between low dimension gate circuit and the abnormal state power circuit.

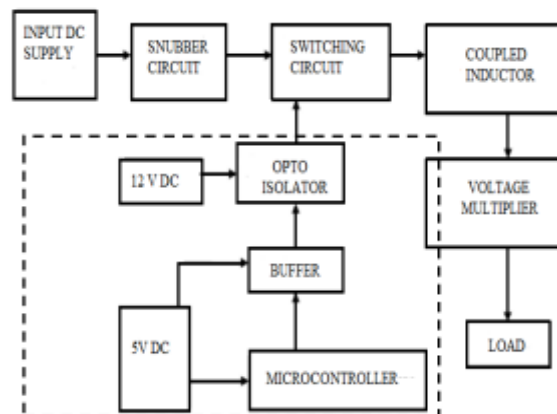


Fig.1. Block Diagram of Proposed System



III. DESIGN SPECIFICATION OF PROPOSED SYSTEM

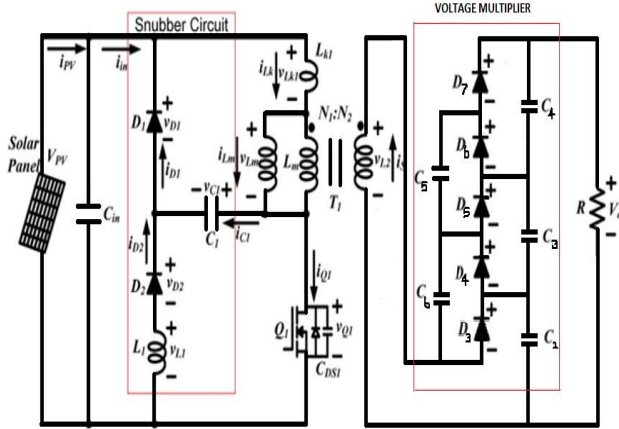


Fig.2. Schematic of the Proposed System

For the proposed system, the design procedure for voltage multiplier with respect to solar PV application is shown below

i).Solar Panel Specification:

Table No.1. Specification of Solar PV Panel

S.No	Parameter	Values
1.	Maximum Power	200 Watts
2.	Open Circuit Voltage, V_{oc}	34.1 Volts
3.	Short Circuit Current, I_{sc}	8.81 Amps
4.	Voltage at Maximum	30.2 Volts
5.	Current at Maximum Power	8.06 Amps
6.	No. of Parallel String	10
7.	Series Connected Module	1

The design procedure and the values are calculated using the operation of the proposed circuit for voltage multiplier circuits.

ii). Duty Cycle:

$$V_{Q1} = 45V \quad V_{PV} = 24V$$

$$V_{QV} = \frac{V_{PV}}{1-D}$$

$$1-D = \frac{V_{PV}}{V_{Q1}}$$

$$1-D = \frac{24}{45}$$

$$1-D = 0.533$$

$$D = 0.47$$

iii).Turns Ratio:

$$\frac{V_o}{V_{pv}} = n(1 + D)/1 - D$$

$$200/24 = n(1 + 0.47)/1 - 0.47$$

$$8.33 = n(2.7735)$$

$$n = 3$$

iv). Design of Coupled Inductor:

$$\tau LB = D(1 - D)^2/4n^2(1 + D)$$

$$\tau LB = 0.47(1 - 0.47)^2/4(3)^2(1 + 0.47)$$

$$\tau LB = 2.4947 * 10^{-3}S$$

$$\tau LB = L_m/RT_s \quad f_s = 50kHz \quad R = 500 \Omega$$

$$L_m = 2.49 * 10^{-3} * 5000 * (115000)$$

$$L_m = 4.29 * 10^{-5}$$

$$L_m \cong 25 \mu H$$

v).Snubber Capacitor:

$$C_1 = \frac{L_{k1}(i_{Lk-max}^2 - i_{Lk-min}^2)}{V^2_{C1-max} + V^2_{C1-min}}$$

$$Lk = 1\% \text{ of } L_m$$

$$Lk = (1/100) * 25 * 10^{-6}$$

$$Lk = 0.25 * 10^{-6}$$

$$Lk = 0.25 \mu H$$

$$iLk - max = 13A \quad iLk - min = 6.5A$$

$$Vc1 - max = 30V \quad Vc1 - min = -23V$$

$$C_1 = 0.25 * 10^{-6}(13^2 - 6.5^2)/(30^2 + 23^2)$$

$$C_1 = 2.2 * 10^{-9}F$$

$$C_1 = 22nF$$

vi). Snubber Inductor L1:

$$L_1 = D^2 min / C_1(\pi f)^2$$

$$D_{min} = 10\% \text{ of } D$$

$$D_{min} = (10/100) * 0.47$$

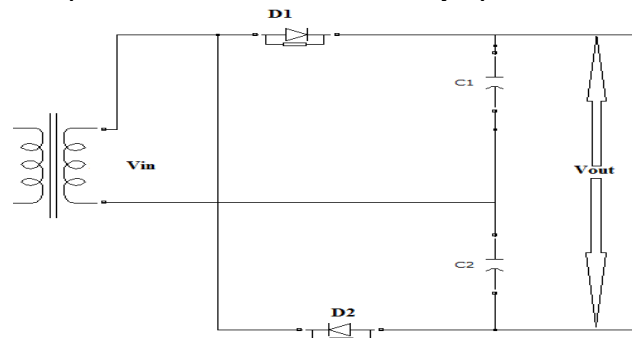
$$D_{min} = 0.47$$

$$L_1 = 0.5^2/22 * 10^{-9}(3.14 * 50000)^2$$

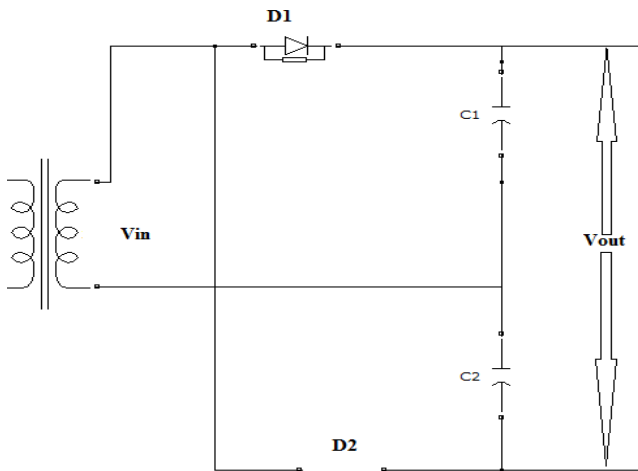
$$L_1 = 4.610 \mu H$$

Voltage Multiplier:

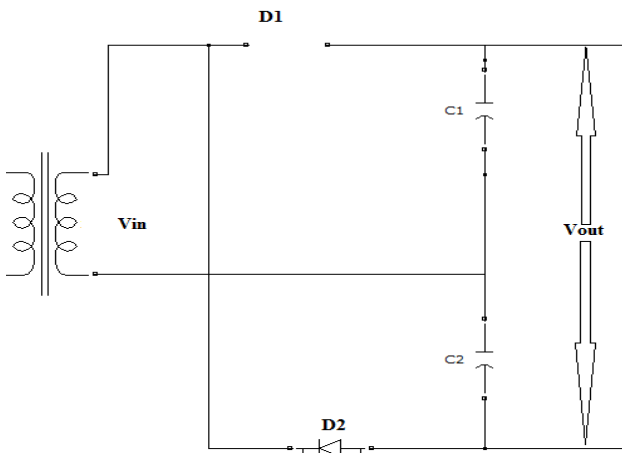
The input voltage from the transformer is boosted according our simulation requirement. The explanation for the voltage multiplier circuit is analyzed below. The basic voltage multiplier circuit is shown with necessary equations.



The output voltage across VC_1 and VC_2 . Assume, the capacitor C_1 and C_2 are discharged initially. For positive half cycle, the figure is shown below



Then the voltage across the capacitor is
By applying KVL, $VC_1 = +Vm$
For negative half cycle, the figure is shown below



Then the voltage across the capacitor is
By applying KVL, $VC_2 = +Vm$
BY applying KVL to entire loop shows,
 $V_{out} = VC_1 + VC_2 = 2Vm$

In this model, the voltage is doubled and thus the output voltage is boosted according to the capacitor location and the diode arrangement and act as a voltage multiplier. Thus, the coupled inductor and capacitor plays a vital role in boosting the voltage to the higher value for solar photovoltaic application [9]. This type of inductor sizing is also employed for AC applications [10].

IV. SIMULATION RESULTS

The voltage multiplier is simulated and connected to output of the panel is connected to the coupled inductor. The simulation results are obtained by using MATLAB/Simulink platform.

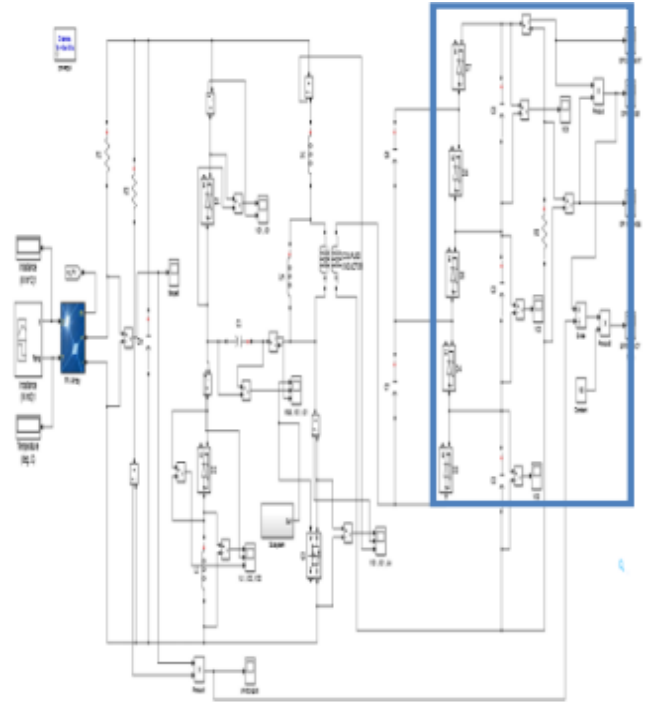


Fig.3. Simulation of Proposed System

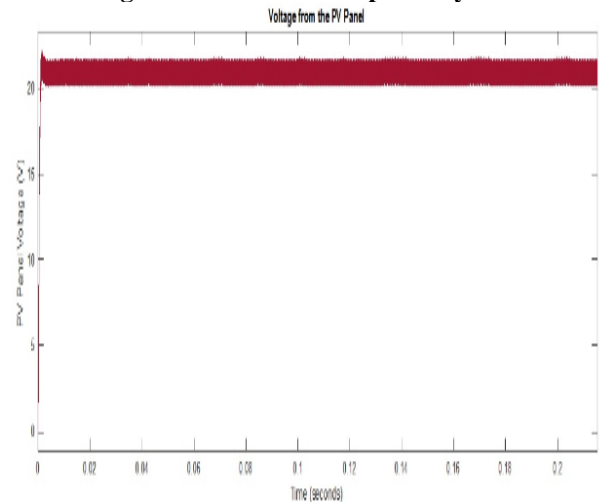


Fig.4. Input Voltage from the PV Panel

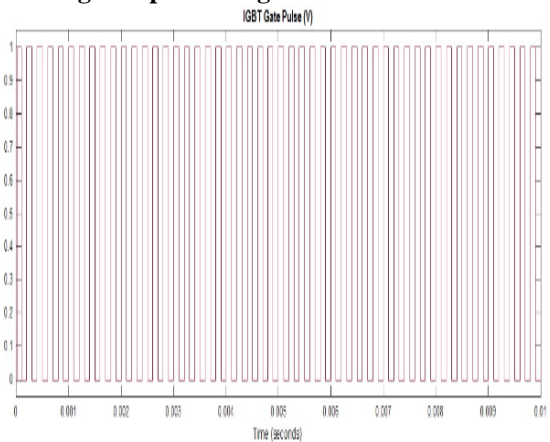


Fig.5. Gate Pulse from MPPT

V. CONCLUSION

Thus the photovoltaic system output is enhanced using the power conversion topologies. The voltage of the solar panel is boosted up without using the transformer and the maximum power point is tracked using the MPPT algorithm. The simulation results show that the usage of voltage multiplier with boost converter lead to boost up the input voltage beyond the rated value with increased efficiency. Due to the absence of transformer the losses are avoided and the isolation between the circuits is achieved by using the couple inductor. It has been demonstrated that the proposed control conspire perform sensibly well and the goal of voltage boosting is achieved.

REFERENCES

1. Christopher D. Lute. "An Improved Dc-Dc Converter for Photovoltaic Power System Applications" The Board of Trustees of the Colorado School of Mines.
2. P. Denholm, et al., "Bright future: solar power as a major contributor to the U.S. grid," IEEE Power & Energy Magazine, vol. 11, no. 2, pp. 23-32, Mar. /Apr. 2013.
3. M.G. Villalva, et al., "Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays," IEEE Trans. Power Electron., vol. 24, no. 5, pp. 1198-1208, May 2009.
4. A.Imtiyas, P.Sathish Kumar, U.Shyamala Devi. "Induction motor driven water pump fed by solar photovoltaic array using boost converter" International journal of mechanical engineering and technology (IJMET) 2018, pp: 336-347.
5. Mofan Tian, Xu Yang, Yang Chen, Laili Wang. "A Cable Type Packaging for Voltage Regulation and Energy Transport in Wearable Energy Harvesting Systems". IEEE Transaction on Power Electronics. Vol-34 Aug 2019, 7116-7120.
6. Shih-Kuen Changchien, J.F. Chen, Tsorng-Juu Liang, Lung-Sheng Yang. "Novel High Step-Up Dc-DC Converter for Fuel Energy Conversion System" IEEE Transactions on Industrial Electronics 57(6):2007 - 2017 · July 2010.
7. N. Mhiri, K. Ammous, A. Alahdal, H. Ghulman, and A. Ammous, "Design of a new analog circuit for Maximum Power Point tracking of photovoltaic panels," in Proceedings of the 7th International Renewable Energy Congress, IREC 2016, March 2016.
8. Nesrine Mhiri, Abdulrahman Alahdal, Hamza Ghulman, AnisAmmous "A Novel Analog Circuit Design for Maximum Power Point Tracking of Photovoltaic Panels" Advance in Power Electronics, Sep 2017.
9. Yong-Seng Wong 1,2, Jiann-Fuh Chen 1,*, Kuo-Bin Liu 2 and Yi-Ping Hsieh. "A Novel High Step-Up DC-DC Converter with Coupled Inductor and Switched Clamp Capacitor Techniques for Photovoltaic Systems". MDPI March 2017.
10. Shih-Ming Chen, Tsorng-Juu Liang, Lung-Sheng Yang, J.F. Chen. " A Boost Converter with Capacitor Multiplier and Coupled Inductor for AC Module Application" IEEE Transactions on Industrial Electronics 60(4):1503-1511 · April 2013.

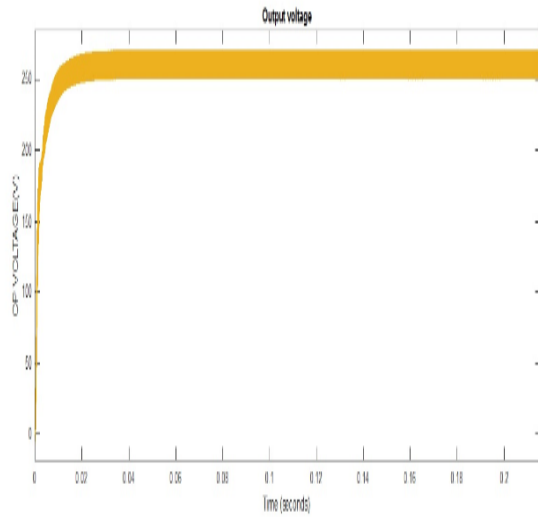


Fig.6. Output Voltage

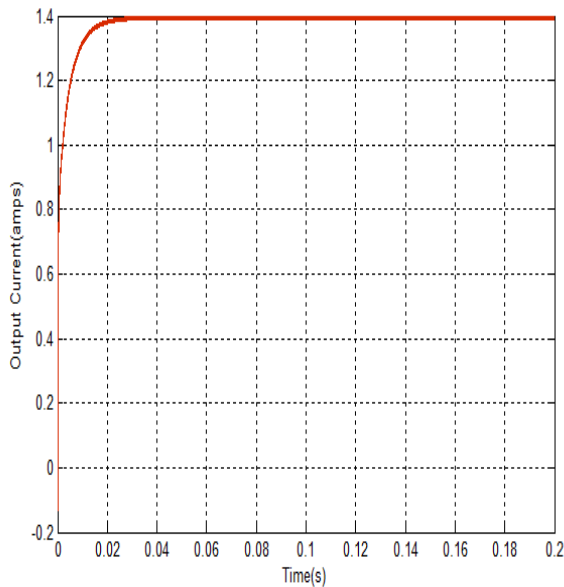


Fig.7. Load Current

Table No. 2. Simulation Results

Parameter	Values in Conventional Converter	Values in Proposed Converter
Solar Voltage V_{pv}	24 V	24 V
Operating Frequency	50 kHz	50kHz
Output Voltage V_o	200 V (Voltage Doubler is used)	260 V (Voltage Multiplier is used)
Maximum Input Power	200 W	200 W
Efficiency	96%	98%

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Jeyashree A currently working as a Assistant Professor in the Department of Electrical and Electronics Engineering at PSG Institute of Technology and Applied Research, Coimbatore. She completed BE (2011-2015) in the Department of Electrical and Electronics Engineering and ME (2015-2017) in the area of Power Electronics and Drives. She have supervised B.E (EEE) Projects for

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