www.ijaceeonline.com ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 2, Issue 9, September 2017, pp. 22–28

Design and Simulation of Superlift DC-DC Converter for Solar PV Applications

V.K.Vishwhak
PG Scholar, Department of EEE, SSN College of Engineering, Kalavakkam, India
Email: vkvishwhak@gmail.com

Dr. Seyezhai Ramalingam
Associate Professor, Department of EEE, REC Lab,
SSN College of Engineering, Kalavakkam, India
Email: seyezhair@ssn.edu.in

Abstract: *In this paper, a modified efficient step-up boost converter is proposed. The proposed structure employs coupled-inductor and super-lift technique to achieve high voltage gain. The super-lift stage clamps the off-state voltage of the main switch, and the coupled-inductor technique offers high voltage gain and alleviates the reverse-recovery problem of the output diode. Hence, using these two techniques, the proposed converter achieves high step-up voltage gain and eliminates the drawbacks of the conventional boost converter. The proposed converter is powered by photovoltaic (PV) source. The modeling of PV is carried out using PowerSIM (PSIM). To extract maximum power from PV, P&O MPPT algorithm is implemented. Simulation studies of the proposed converter are done with PSIM software. The voltage gain and ripple are calculated to show the importance of the proposed converter.*

Keyword: *PV, MPPT, Super lift, PSIM*

1. INTRODUCTION

Nowadays, photovoltaic solar system requires dc–dc converters with high voltage gain, high efficiency and low electromagnetic interference. Step-up converters are used in PV to boost the low input voltage. Several topologies of high step-up converters are reported in the literature [1-2] .These topologies achieve high voltage by voltage lift technique in which the output increases in arithmetic progression. Also, topologies such as switched-capacitor, switched inductor, voltage-lift and voltage-doubling have also been integrated to obtain a higher gain [3-5]. However, the main switch still suffers from high current stress leading to high conduction losses. Hence, this paper proposes a super lift DC-DC converter whose output progresses in geometric progression. The proposed topology combines the super-lift and coupled-inductor approach to achieve high gain and efficiency. The main highlight of this work is that PV is modeled using PSIM and the V-I and P-V characteristics for different irradiation and temperature is observed. Further, to get maximum power from PV, perturb and observe method is employed and the tracked power curve is shown. Then the proposed super lift converter is designed and interfaced with PV. The operational parameters of the converter are computed and the results are verified. The entire circuit along with PV is studied in PSIM. The paper is organized as follows: Section: II discusses about the PV modeling, Section: III deals with the operation and design of the proposed high gain DC-DC converter, Section: IV depicts the P & O algorithm, Section: V discusses the simulation results and finally the conclusion.

Cite this paper:
V.K.Vishwhak , Seyezhai Ramalingam, "Design and Simulation of Superlift DC-DC Converter for Solar PV Applications", International Journal of Advances in Computer and Electronics Engineering, Vol. 2, No. 9, pp. 22-28, September 2017.

2. PV MODELLING

Simulation of solar PV is shown in Figure 1. PV is made of cells connected in series and parallel combination. In order to model mathematically the equivalent circuit can be considered as current source followed by reverse biased diode in parallel [6]. From the equivalent circuit, the characteristics of PV can be simulated in PSIM and it is shown in Fig.1.

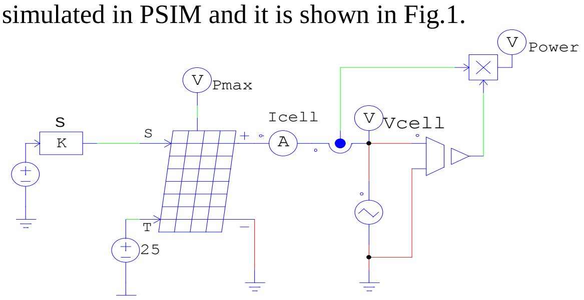

Figure 1 PV Model using PSIM

ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 2, Issue 9, September 2017, pp. 22–28

PV depends on input parameters like temperature and irradiance. If these parameters change, then output parameters also changes with respect to it. Characteristics curves of solar panel ie I_{cell} versus V_{cell} for different irradiation is shown in Fig.2. P-V characteristics is depicted in Fig.3.It is clear from the Fig.2.that the output power of the solar panel varies with the irradiance. Solar power is high at high value of solar irradiance and it starts decreasing as the irradiance decreases.

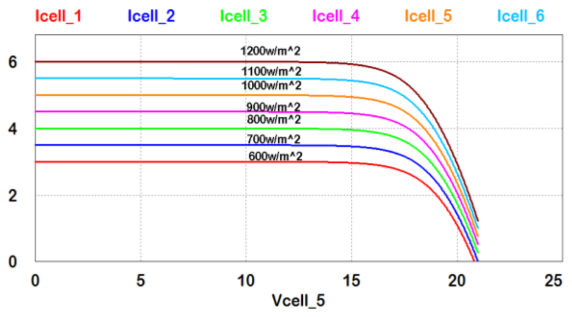

Figure 2 V-I Characteristics of PV

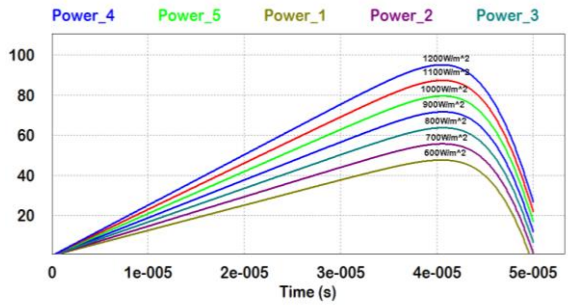

Figure 2- P-V Characteristics of PV

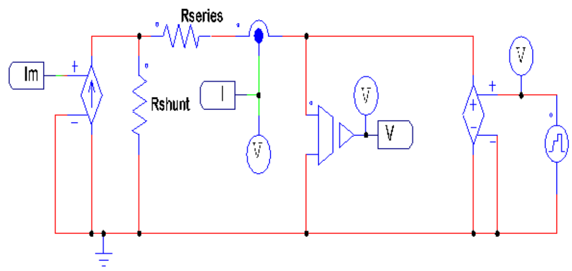

Figure 3 Equivalent circuit of PV

3. SUPERLIFT CONVERTER (DC-DC CONVERTER)

Fig.6. shows the circuit schematic of the proposed converter. It is a boost converter integrated with the coupled-inductor and super-lift stages [7-10]. This converter has one power switch, one coupled inductor, four diodes and four capacitors. The super-lift stage includes the capacitors C_1, C_2, C_3 and the diodes D_1, D_2, D_3. The coupled inductor is represented in terms of the leakage inductance L_k, the magnetizing inductance L_m and an ideal transformer. The presence of the super-lift stage mainly absorbs the energy of leakage inductance in the coupled inductor through D_2, C_1 and C_2. At this instant, the voltage across the main switch V_{ds} is equal to the sum of V_{C1} and V_{C2}. Since the capacitors C_1 and C_2 are connected in series and in reverse polarity, their voltages are subtracted from each other. For this reason, the voltage of the main switch S reduces the leakage energy absorbed by the capacitor C_2 and it is transferred to the capacitor C_3 when the main switch is turned on. Finally, the output voltage is equal to the sum of the dc input voltage, voltage across the coupled inductor and the voltage across the capacitor C_3.

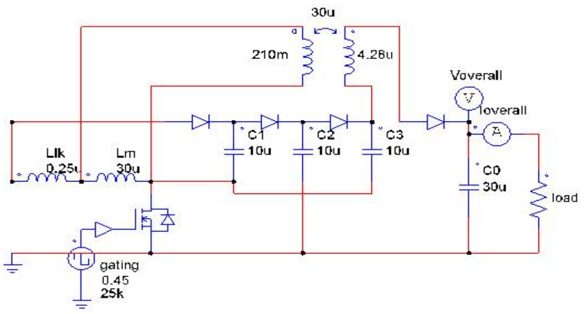

Figure 4- Circuit Diagram of super lift DC-DC converter

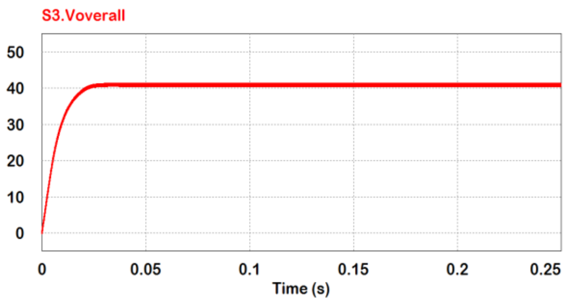

Figure 7- Output voltage of the converter

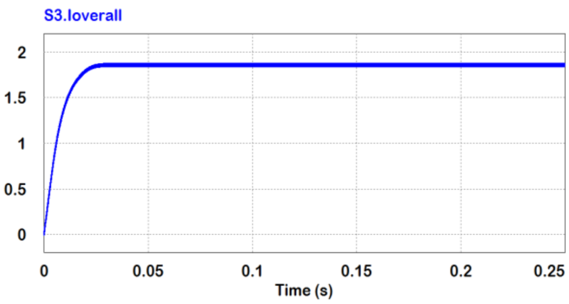

Figure 8 Output current of the converter

ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 2, Issue 9, September 2017, pp. 22–28

In order to perform the mathematical analysis of the proposed converter, the following assumptions are considered. First, the capacitors are assumed to be large enough, so the voltages V_{C1}, V_{C2}, V_{C3} and V_O remain constant during a switching period. Secondly, all diodes are ideal. Third, the parasitic capacitor of the main switch is assumed to be non-zero. Moreover, the coupling coefficient of the coupled inductor and the turns ratio of the coupled inductor are defined as $k = L_m/(L_m + L_k)$ and $n = N_s/N_p$, respectively. The ds

TABLE I PARAMETERS OF THE CONVERTER

PARAMETERS	***Cascaded boost converter***	***High gain boost converter***	***Super lift boost converter***
Voltage ripple	4V	20 V	3.8V
Current ripple	0.2A	0.4A	0.15A
No. of. switches used	2	2	1
No. of. diodes used	2	3	4
Gain	1.77	6.6	2.5

TABLE II COMPARISON OF THE PROPOSED CONVERTER WITH OTHER TWO DC-DC CONVERTERS

Parameters	**Values**
Input Voltage	12V
Expected Output	36V
Switching Frequency	25kHz
Duty cycle	10%
Turns ratio	1.25

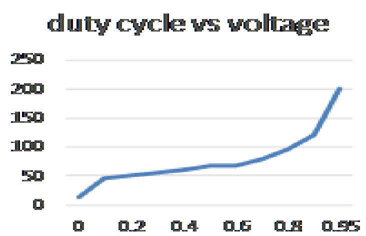

Figure 9 Duty cycle vs. voltage of the converter

From Fig.7, it is seen that the output voltage is boosted to 40V for an input of 12V and 1.8A output current is obtained for 10% duty cycle (Fig.8). Fig.9 shows the plot between duty cycle vs output voltage which depicts that increase in duty cycle increases voltage gain. Fig.10 shows the plot between duty cycle vs voltage ripple. This implies that the voltage ripple increases with increase in duty cycle. From Table: 2, it is seen that the superlift converter has low value of ripple content. Hence, the superlift converter is chosen for this work.

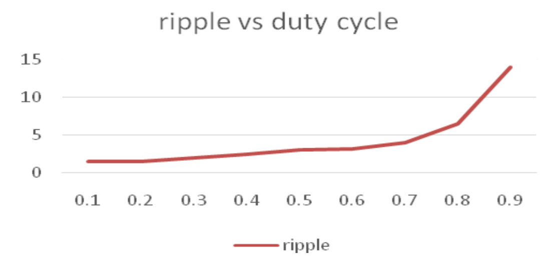

Figure 50 Duty cycle vs. voltage ripple

4. MPPT ALGORITHM

The efficiency of solar cell is very low. In order to increase the efficiency, methods should be adopted to match source and load properly. One such method is the Maximum Power Point Tracking (MPPT) [11-12]. In PV systems, V-I characteristics is nonlinear, thereby making it difficult to be used to power certain loads. This is executed by employing DC-DC boost converter whose duty cycle is changed with the help of MPPT algorithm.

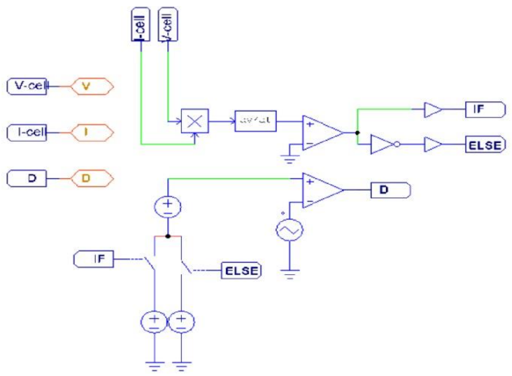

Figure 61Mathematic blocks of MPPT algorithm

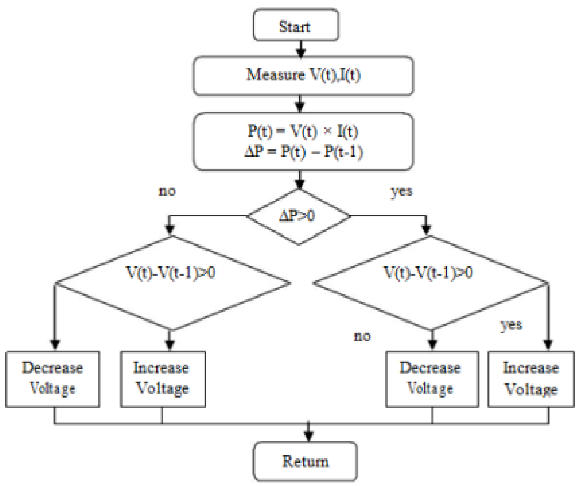

Figure 72 Flow chart of MPPT algorithm

ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 2, Issue 9, September 2017, pp. 22–28

A perturb and observation (P&O) method is the most popularly used algorithm to track the maximum power due to its simple structure and high reliability. This algorithm moves the operating point towards the maximum power point periodically for increasing or decreasing the PV array voltage by comparing power quantities between the present and past. When the PV power increases, perturbation is accomplished in the same direction in the succeeding perturbation cycle; otherwise its direction will be reversed. This way, the operating point of the system gradually moves towards the MPP and oscillates around it under steady-state conditions. This means the array terminal voltage is perturbed for every MPPT cycle. The logic of this algorithm and the flowchart are explained in Figs.11 & 13.

The operating voltage of the PV system is perturbed by a small increment of V, and these results in change of P. When PV power is positive, the perturbation of the operating voltage will be proceeded in the same direction of the increment. Otherwise, if PV power is negative, the operating point of the system diverts and it progresses away from the MPPT and hence the operating voltage should move in the opposite direction of the increment. The variations of the output voltage and power before and after changes are then observed and compared to the reference for increasing or decreasing the load in the next step. The advantage of the P & O is simple structure, easy implementation and less required parameter. This algorithm is not suitable when the variation in the solar irradiation is high. The voltage never actually reaches an exact value but perturbs around the maximum power at MPP.

5. SIMULATION RESULTS

Fig.13 shows the proposed converter interfaced with PV. It consists of PV array, Boost converter, MPPT block, and finally the load.

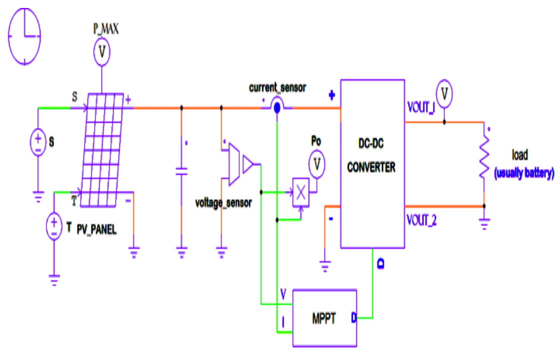

Figure 83 PSIM circuit of superlift converter with PV as source with MPPT

In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required. The heart of the model is MPPT block which helps in finding the maximum operating point of the solar panel. This can be carried out by using the MPPT algorithm which in turn gives the gating pulse to the buck converter. This maintains the operating voltage at the maximum point irrespective of the solar irradiance.

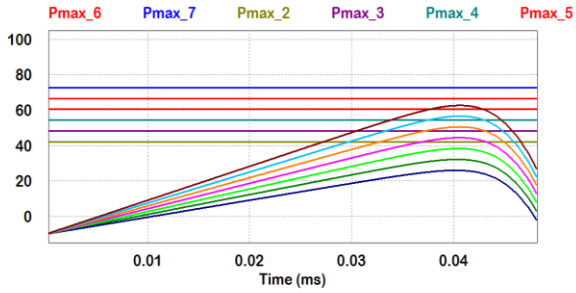

Figure 94 Characteristics of P Vs Vcell without MPPT with varying irradiance

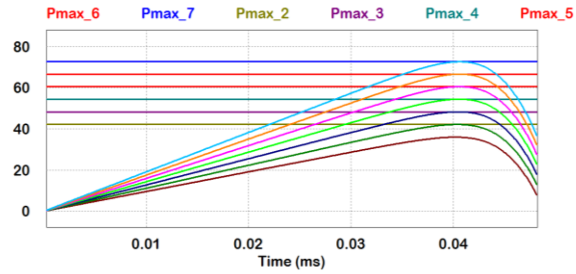

Figure 105- P Vs V with varying irradiance

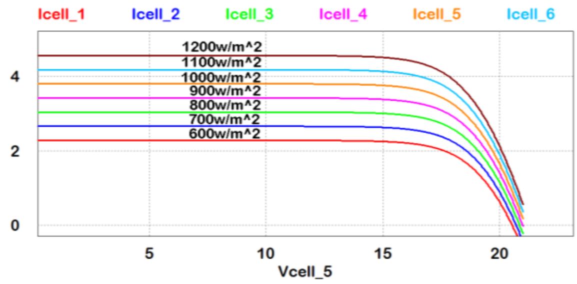

Figure 116 I Vs. V with varying irradiance

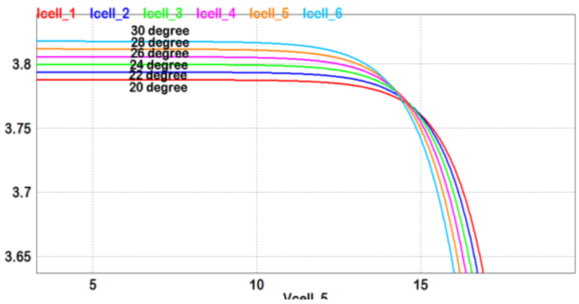

Figure 127 P vs. V with varying temperature

ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 2, Issue 9, September 2017, pp. 22–28

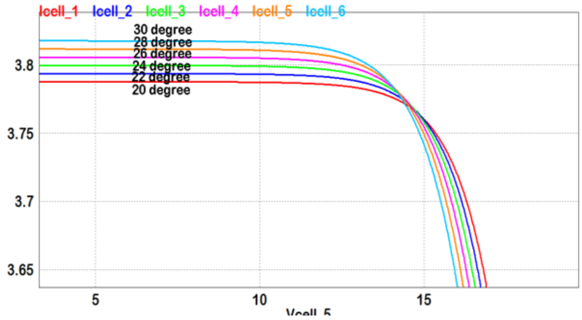

Figure 138 I vs. V with varying temperature

Fig.14 shows the characteristics of PV without MPPT where the power is equal to 60W.Figs.15-20 show the PV characteristics with MPPT and the power from PV is around 80W which is higher when compared to without MPPT. Also, the corresponding converter output voltage and current waveforms are shown.

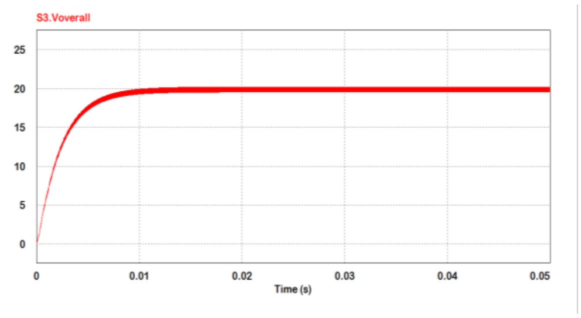

Figure 19 Output voltage of DC-DC converter with MPPT

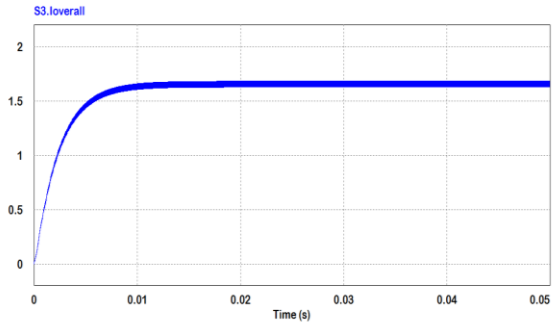

Figure 140 Output current of DC-DC Converter

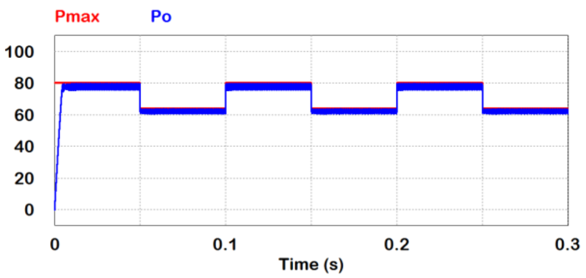

Figure 151 PV power without MPPT

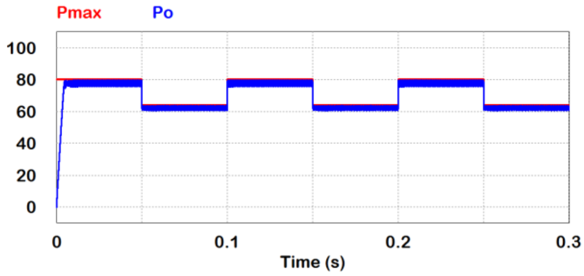

Figure 162 PV power with MPPT

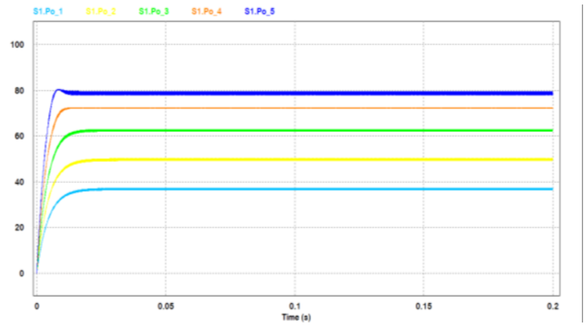

Figure 173 PV power with MPPT for varying irradiance

Fig.21 shows that the actual PV power without MPPT is around 60W and with the application of MPPT, the actual power and tracked power is almost the same (around 80W-Fig.22) . From Fig.23, the PV power for varying irradiance is shown and maximum power is obtained at the highest value of irradiation. Therefore, with proper tracking algorithm, maximum power can be extracted from PV.

6. HARDWARE IMPLEMENTATION OF DC-DC CONVERTER

Fig.24 shows the hardware implementation of the proposed dc-dc converter. The input of 20.8V is applied to DC-DC converter and the output obtained is about 40V with 10% duty cycle.

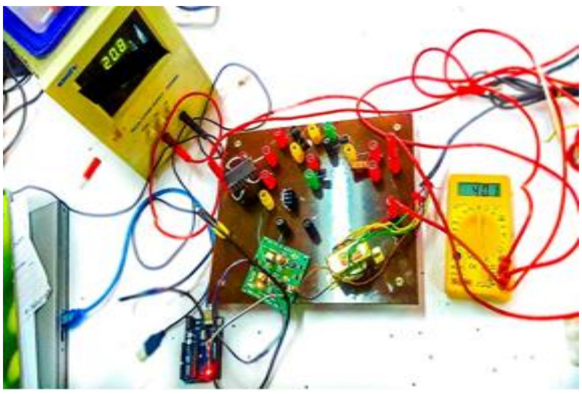

Figure 24 Prototype of the proposed DC-DC Converter

ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 2, Issue 9, September 2017, pp. 22–28

Figure 25 Gating pulse for the proposed DC-DC converter

Figure 26 Output voltage ripple of the DC-DC Converter

Fig. 25 shows the gating pulse generated using Arduino and Fig.26 shows that the output voltage ripple is around 2.83 % with peak to peak amplitude of 1.02V, thereby the simulation results are verified.

7. CONCLUSION

This paper has discussed a high gain DC-DC converter employing superlift technique. The proposed converter has been investigated for photovoltaic applications. From the results, it is observed that the converter results in high conversion gain and reduced output voltage ripple and reduced number of components compared to the classical topologies. Moreover, the performance of the converter is studied by interfacing with PV by employing a MPPT algorithm. With MPPT, maximum power is tracked from PV and the results are verified. Finally, a prototype has been built and the simulation results are validated. Hence, the proposed DC-DC converter is highly suitable for PV applications.

ACKNOWLEDGEMENT

The authors wish to thank the SSN Management for providing the financial support for carrying out this research work.

REFERENCES

[1] Wuhua Li and Xiangning He(2011), "Review of Non-isolated High-Step-Up DC/DC Converters in Photovoltaic Grid connected Applications", IEEE Transactions on Industrial Electronics, Vol. 58, No. 4, pp.1239-1250.

[2] Michael Douglas Seeman (2009), " A Design Methodology for Switched-Capacitor DC-DC Converters", Electrical Engineering and Computer Sciences, University of California at Berkeley, Technical Report No. UCB/EECS-2009-78.

[3] N. Vazquez, L. Estrada, C. Hernandez, and E. Rodriguez, "The tapped-inductor boost converter(2007)," in Proc. IEEE Int. Symp. on Ind. Electron. ISIE 2007, DOI: 10.1109/ISIE.2007.4374654.

[4] M.Nymand and M. A. E. Andersen(2010), "High-efficiency isolated boost DC-DC converter for high-power low-voltage fuel-cell applications,"IEEE Trans. Ind. Electron., vol. 57, no. 2, pp. 505514.

[5] Jailey Jose and B.Jayanand(2013), "Simulation and implementation of superlift Luo converter", International Conference on Renewable and Sustainable Energy, 2013, pp.128-132.

[6] Ahmed Bouraiou, Messaoud Hamoudaa ,Abdelkader Chakerb ,Mohammed Sadoka ,Mohammed Mostefaouia , Salah Lachta (2015), "Modeling and Simulation of Photovoltaic Module and Array based on One and Two Diode Model Using Matlab/Simulink", Energy Procedia 74, pp.864 – 877.

[7] Hamid bahrami , Hosseiniman-eini, Babakkazemi &Alirezatahri "Modified Step-up Converter With Coupled-inductor And Super-lift Techniques," IET Power Electronics, Vol.8, Issue.6 2015, pp.898-905.

[8] Freitas And Antunes(2013), "High Gain DC-DC Converter applied to Photovoltaic System with new proposed to MPPT Search ", IEEE, Eurocon 2013,pp.1081-1085.

[9] J.Ramprabhu and K.Deepa (2016), "Performance analysis of a seamless sliding mode control for a non-isolated multi input, multi output bidirectional DC-DC boost converter for EV applications", International Journal of Advances in Computer and Electronics Engineering, Vol.1, Issue 3, pp.1-9.

[10] C.Laksmanasamy and P.Rathinasamy(2017), "Design and Simulation of boost converter with MPPT techniques, International Journal of Advances in Computer and Electronics Engineering, Vol.2, Issue 5, pp.1-6.

[11] M. C. Cavalcanti, K. C. Oliveira, G. M. S. Azevedo, and F. A. S. Neves(2007). Comparative study of maximum power point tracking techniques for photovoltaic systems. Brazilian Journal of Power Electronics, SOBRAEP, 12(2):163–171.

ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 2, Issue 9, September 2017, pp. 22–28

[12] Miona Andrejević Stošović , Marko Dimitrijević , Vančo Litovski (2013),” MPPT Controller Design for a Standalone PV System”, 11th International Conference on Telecomminication, modern satellite, cable and broad casting services, TELSIKS, 2013, pp.501-504.

Author Biography

V. K. Vishwak completed his B.E. from Velammal Engineering college,Chennai. He did his post-graduation in M.E.(Power Electronics & Drives) in the year 2016 at SSN College of Engineering, Chennai.

Dr. R. Seyezhai, Associate Professor in the Department of Electrical and Electronics Engineering has 18 years of teaching and research experience including 10 years of research experience in Power Electronics and Renewable Energy Systems. She received her B.E. from Manonmaniam Sundaranar University in 1996 and M.E in Power Electronics & Drives from Bharathidasan University in 1998 and Ph.D from Anna University, Chennai. She has published over 150 research publications in referred International Journals and 130 in International and National Conferences. She received around 11 best paper awards in various international conferences.

Cite this paper:

V.K.Vishwhak, Seyezhai Ramalingam, "Design and Simulation of Superlift DC-DC Converter for Solar PV Applications", International Journal of Advances in Computer and Electronics Engineering, Vol. 2, No. 9, pp. 22-28, September 2017.