May – June 2020
ISSN: 0193-4120 Page No. 7889 - 7894

Design of Three Level DC – DC Boost Converter with High Voltage Gain

K Anusha, Anitha G S, Department of Electrical and Electronics, RV College of Engineering, Bangalore.

Article Info
Volume 83
Page Number:7889 - 7894
Publication Issue:
May-June 2020

Article History
Article Received: *19 November 2019*
Revised: *27 January 2020*
Accepted: *24 February 2020*
Publication: *18 May 2020*

Abstract**:**
The Boost converter is used for many applications, in hybrid electric vehicles, in medical equipment, as renewable energy sources, as Power Factor Correction [PFC] circuit, etc. This document proposes a new topology for the non-isolated threelevel dc-to-dc boost converter. This proposed system has a high voltage gain compared to the traditionalnon isolatedboost converter. The proposed dc-to-dcsystem is used in photovoltaic applications to extract the highest and constant output voltage from photovoltaics. The steadystate operation of the drive-in continuous conductionmode is analysed with a feedback circuit to extract the constant voltage with a high voltage gain for a resistive load. The performance of this proposed system is compared to the traditional non-isolatedboost converter. The proposed system is also simulated within the PSIM software to prove the calculations. The simulation results, show that the converter is one of the most suitable solutions for photovoltaic production systems**.**

Keywords- DC-to-DCConverter, BoostNon-Isolated Converter, three-level, Voltage Gain.

Introduction-Today, dc-to-dc converters are employed in several applications, like inHybrid Electric Vehicles [HEV], in sources of renewable energy technology, like wind power plants, Solar Battery and electrochemical cells, in medical instrumentation and in servomotors, in industrial circuits and as PFCcircuits, telecommunications. aeronautical and space systems, industry and in mobile electrical equipmentslike laptops andtelephones. The switching command of the converter is performed by modulating the width of pulses(PWM) or changing the switching frequency. The converters in which regulation is done by PWM are categorized asnon-isolateddc-to-dcconverters, likestepup (boost) converter, stepdown (buck) converter, stepup/down (buck-boost) converter, and isolated power converters as flyback converter, forward converter, halfbridge converter, fullbridge converter and pushpull converter[10]. Non-isolated converters are converters that does not have transformers in the topology. Therefore, they are smaller, cheaper andcontrol is simple. Among transformer less converters, converters that have a higher and constant output than the of the input voltage are widely used. Due to the through connection of the inductor to the supply and the smaller output capacitor and the smaller size of the output filter, the safety of the switch against Electro-Magnetic Interference (EMI) and overvoltage, a reduced amount of stress on the circuit elements, highereffectiveness, better transient response are the characteristics of non-isolated converters. Therefore, these converters find their use in severaldc-to-dc applications insources of renewableenergy and PFC and LED devices and are used to improve the quality of energy in industrial circuits.

The introduction of a new structure, performance analysis, stability analysis, modelling, and controller design for these converters are points of great attention to authors. In topology [1-2], converters based on stepup dc-to-dc (boost) has been presented to attain a maximum output voltage with a minimum number of switching elements. To improve thevoltage at the output of the traditional step-up converter, various new topologies and techniques are used, in particular the Capacitor Switching (SC) technique [4] and united with other dc-to-dc converter topologies [3] and Voltage Lift technique (VL) [5-6]. The SC technique integrates numerous switches and capacitors with a minimum number of inductors, making it possible to easily reach an increase in the output voltage. However, this technique increased complication due to the multiple switches and increased the current across the switches. To reduce the current, coupled inductors have been used, which in turn have increased the size, in turn the cost of the converter and is therefore not very widespread. In [3], several converters have been allied in series-parallel combinations to obtain higher performance than the input, used in particular for applications of sustainable sources of energy. But because of the increase in size, costs and complexity of control have increased. Finally, the VL technique based on the parameters of the inductance and capacitor circuits was introduced, with energy storage characteristics and a reduced voltage in the switches, and various new topologies were presented. A topology was proposed to increase the output using the least number of elements using the VL technique [7-9] and was compared with traditional topologies and other proposals. Meanwhile, the new topology with one power switch and two power switches has been proposed, respectively, in [10] and [11].

In this document, a new topology for the transformer-lessdc-to-dc converter has been proposed using the VL technique to achieve an voltage at the output higher than that of input. In this document, the performance of the novel transformer-less boost converter is analyzed, then the current and voltage gain of the converter are calculated and compared with the traditionaltransformer-lessdc-to-dc converter. This converter has the smallest input inductance value compared with the traditionalDC-to-DCboost converter. The proposed converter is analyzed with the feedback path to get a constant output voltage. Finally, this proposed converter is simulated within the PSIM software to confirm the calculations. The simulation outcomes show that the proposed converter is one of the most suitable solutions for photovoltaic production systems.

The Proposed Structure –The proposed topology of the three (*n*) level transformer-lesspulse converter is as shown in Fig.1. It includes 2 switches, four (*n+1*) inductive reactance, seven (*2n+1*) diodes and four (*n+1*) capacitors. In the presentedconverter, eachboost legcomprises of an inductor, a capacitor and two power diodes. The topology can be extended to "*n*" number of stages. The switch operation is done by the PWM method and works complementary to each other.

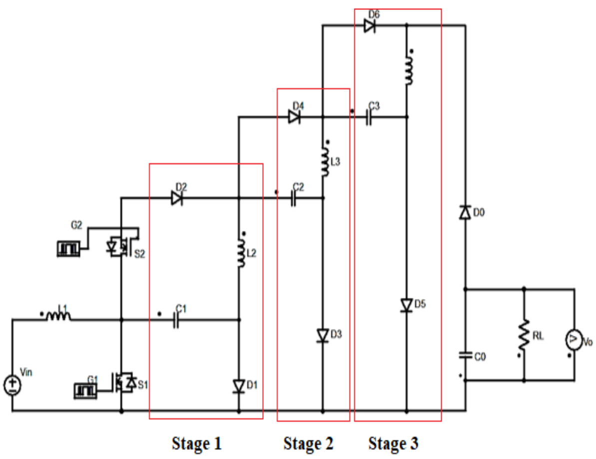


Fig.1: Proposed Boost Converter.

May – June 2020
ISSN: 0193-4120 Page No. 7889 - 7894

To make simpler the analysis of the converter,following conventions were considered:

- Converter operates in stable state, so output V_o is constant.
- The C_1 and C_o capacitances are huge enough that the voltage across them in each period isunaffected.
- All diodes, switches used are considered ideal.

The power switch,S_1 is ON and the power switch,S_2 is OFF. Then, power diode D_0 is forward biased and diodes D_1, D_2, D_3, D_4, D_5 and D_6 are reverse biased. The inductors L_1, L_2, L_3, L_4 and capacitors C_1, C_2, C_3 are linked in sequence, and hence their energy stored decreases. This stored energy is discharged into the output capacitor C_0. Therefore, the output voltage V_0 increases due to series connection of the capacitors.

The switch,S_2 is ON and the switch,S_1 is OFF. Then, diode D_0 is reverse biased and diodes D_1, D_2, D_3, D_4, D_5 and D_6 are forward biased. The inductors,L_1, L_2, L_3, L_4 and capacitors,C_1, C_2, C_3 are linked in series, and hence theirenergy gradually increases. The output capacitor C_0 discharges.

The voltage gain equation is gives as,

$$\frac{V_o}{V_i} = -\frac{3}{D(1-D)} \quad \ldots (1)$$

The critical inductance L_{C1} is given as,

$$L_{C1} = \frac{D^3(1-D)^2R}{18f} = \frac{{V_i}^2RD}{2{V_o}^2f} \quad \ldots (2)$$

The critical inductance values for other inductors are given as,

$$L_{Cn} = \frac{D^2(1-D)R}{2nf} = \frac{V_iRD}{2V_of} \quad \ldots (3)$$

Where n = 2, 3, 4.

The current gain equation is as follows,

$$\frac{I_i}{I_o} = -\frac{3}{D(1-D)} \quad \ldots (4)$$

Assuming the ripples in the inductor currents and the capacitor voltages are small, hence are neglected.

Inductor currents equals to,

$$I_{L_1} = I_i \quad \ldots (5)$$

$$I_{L_n} = 3I_o \quad \ldots (6)$$

Where n = 2, 3, 4.

Diode current,

$$I_{D_o} = 3I_o \quad \ldots (7)$$

Output capacitor voltage,

$$V_{c_o} = V_o \quad \ldots (8)$$

Current through switches,

$$I_{S_1} = I_{L_1} - I_{C_1} = I_{L_1} + I_{L_2} \quad \ldots (9)$$

$$I_{S_2} = I_{L_2} \quad \ldots (10)$$

Maximum Peak current of power switchS_1 is given as,

$$I_{SP_1} = \frac{6{V_o}^2}{RV_i} \quad \ldots (11)$$

Maximum Peak current of power switch S_1 is given as,

$$I_{SP_2} = \frac{6I_o}{D} \quad \ldots (12)$$

Evaluation of Proposed Converter with the Traditional Converter –

In this section, proposed transformer-less boost dc-to-dc converter is compared with other topologies presented previously and is represented in Table.1. This comparison is made by in view of same situationsof V_i, D and f (such as $V_i = 12V$, D =0.5, f = 10kHz).

May – June 2020
ISSN: 0193-4120 Page No. 7889 - 7894

Table.1: Comparison 0f Different Converters

Topology	No. of Switches	No. of Inductors	No. of Capacitors	No. of Diodes	Gain $\left(\frac{V_o}{V_i}\right)$
Traditional Boost Converter	1	1	1	1	$\frac{1}{(1-D)}$
Presented in [7]	1	2	3	3	$\frac{(1+D)}{(1-D)}$
Presented in [8]	2	3	3	4	$\frac{2}{D(1-D)}$
Presented in [9]	2	2	2	2	$\frac{1}{D(1-D)}$
Presented in [10]	2	1	3	2	$(1+D)$
Presented in [11]	1	2	5	6	$\frac{n(3D+2)+(2-D)}{2(1-D)^2}$
Proposed topology with 1st stage only	2	2	2	3	$\frac{1}{D(1-D)}$

From the table it can inferred that

- Though the quantity of elements in proposed converter and in the one presented in [7] are equal, the gain of presentedtopology is high.

- With the same number of switches as in converter presented in [10], the gain of presented topology is higher.

- The proposed topology requires one extra diode compared to the converter presented in [9] for same voltage gain. But the converter topology presented in [9] has limitations in D.

- Although the topology presented in [11] has high voltage gain compared to the converter topology presented in this paper, the number of elements used in the topology of [11] is more.

Closed Loop Analysis –

In this section, the threelevel non-isolateddc-to-dc converter is simulated with the feedback path as shown in Fig.2.

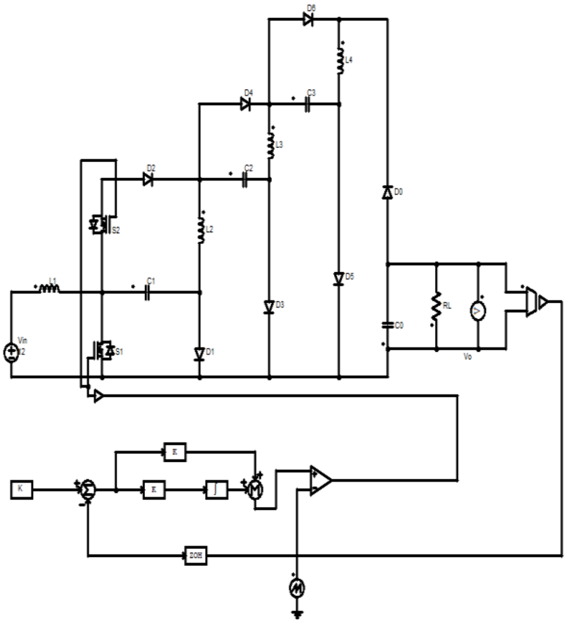


Fig.2: Closed loop Analysis of the Converter.

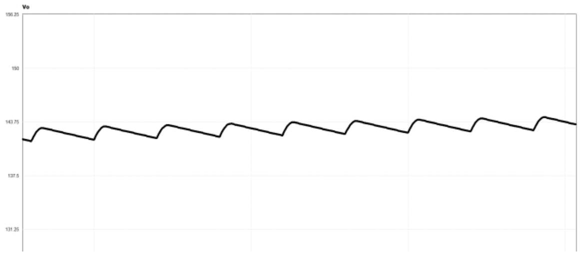
The closed analysis is done by the PI controller. The gain of the proportional and the integrator block is calculated using Ziegler-Nichols method.

Simulation Results –

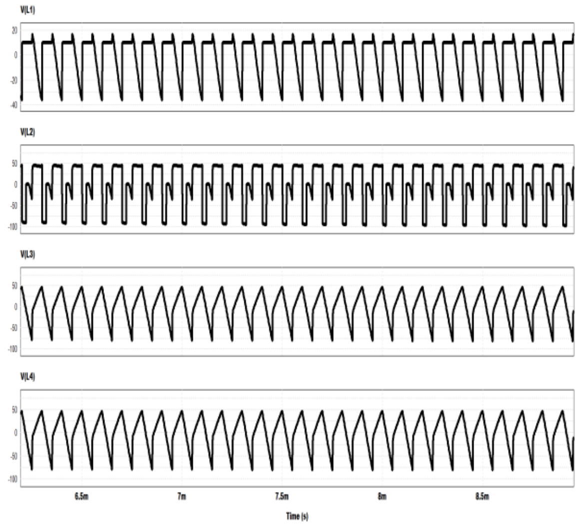
In the following section, simulation outcomesof the converter,in fig.1, are provided. Parameters for the simulation are given in the Table.2.

Table.2: ParametersConsidered for Simulation.

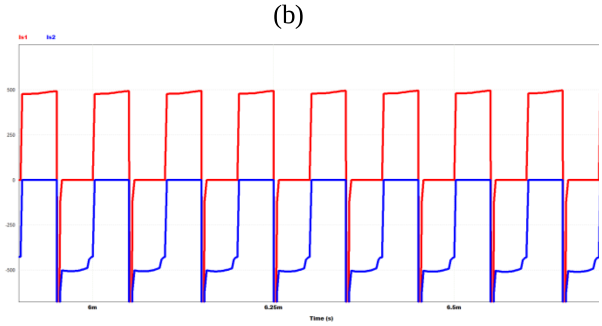
Parameters	Values	Unit
Duty Cycle	D = 50%	-
R	100	Ω
L_1	17.36	uH
L_2, L_3, L_4	208.33	uH
C_1, C_2, C_3	68	uF
C_o	47	uF
V_i	12	V
f	10	kHz



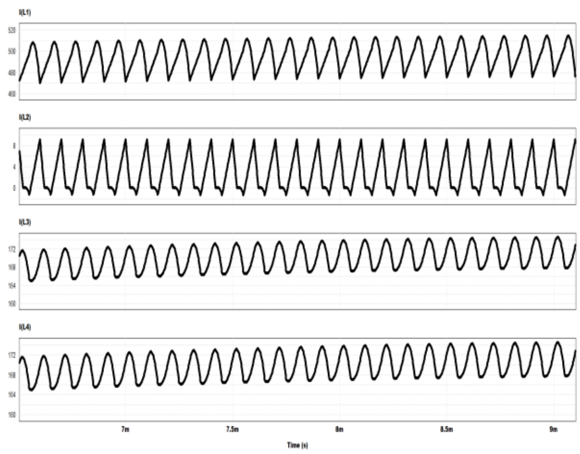
(a)



(b)



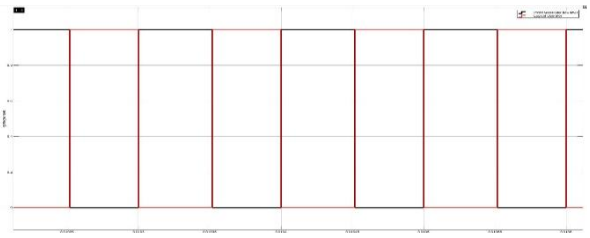
(c)



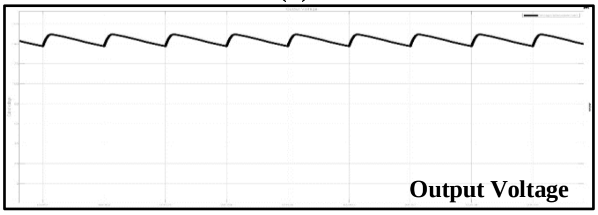
(d)

Fig.2: Simulation Results of Proposed Converter.

(a) Voltage across load,(b) Voltage across Inductors, (c) Current across Switches, (d) Current through the Inductors.



(a)



(b)

Fig.2: Simulation Outcomes of Proposed Converter with feedback path.
(a) Gate Pulses to the switches (b) Output Voltage

Conclusion-

In this document, a new topology of three level transformer-lessdc-to-dc converters is proposed. This converter has the characteristic of a high voltage gain. The theory presented was verified by the results of the converter simulation. Furthermore, the quantity of circuit elements and power switches of the proposed converter is compared with other pulse converter topologies presented on the basis of the VL technique and the voltage gain variations have been analyzed for the same voltage input and for various working values, duty cycle, D. Consequently, the converter produces a higher gain for the same input and duty cycle, D. As, V_i = 12 V, F = 10 kHz, D = 0.5, the theoretic concepts are confirmed with the results of simulations. As calculated, the average output voltage is 144 V in a steady state.

References-

1. M. R. Banaei, H. Ardi and A. Farakhor, "Analysis and implementation of a new single-switch buck-boost dc/dc converter," in *IET Power Electronics*, vol. 7, no. 7, pp. 1906-1914, July 2014.
2. doi: 10.1049/iet-pel.2013.0762
3. A. Ajami, H. Ardi and A. Farakhor, "Design, analysis and implementation of a

buck–boost DC/DC converter," in *IET Power Electronics*, vol. 7, no. 12, pp. 2902-2913, 12 2014.
doi: 10.1049/iet-pel.2013.0874

5. F. S. Garcia, J. A. Pomilio and G. Spiazzi, "Modeling and Control Design of the Interleaved Double Dual Boost Converter," in *IEEE Transactions on Industrial Electronics*, vol. 60, no. 8, pp. 3283-3290, Aug. 2013.
doi: 10.1109/TIE.2012.2203770
7. M. Forouzesh, Y. P. Siwakoti, S. A. Gorji, F. Blaabjerg and B. Lehman, "Step-Up DC–DC Converters: A Comprehensive Review of Voltage-Boosting Techniques, Topologies, and Applications," in *IEEE Transactions on Power Electronics*, vol. 32, no. 12, pp. 9143-9178, Dec. 2017.
doi: 10.1109/TPEL.2017.2652318
9. F. M. Shahir, E. Babaei and M. Farsadi, "Analysis and design of voltage-lift technique-based non-isolated boost dc–dc converter," in *IET Power Electronics*, vol. 11, no. 6, pp. 1083-1091, 29 5 2018.
doi: 10.1049/iet-pel.2017.0259
11. J. -. Lee and S. -. Hwang, "Non-isolated high-gain boost converter using voltage-stacking cell," in *Electronics Letters*, vol. 44, no. 10, pp. 644-645, 8 May 2008.
doi: 10.1049/el:20080371
13. F. M. Shahir, E. Babaei, M. Sabahi, and S. Laali, "A new DC-to-DC converter based on voltage lift technique," International Trans. Elect. Energy Syst., vol. 26, pp. 1260-1286, June 2016.
14. F. M. Shahir, E. Babaei and M. Farsadi, "Voltage-Lift Technique Based Non-isolated Boost DC–DC Converter: Analysis and Design," in *IEEE Transactions on Power Electronics*, vol. 33, no. 7, pp. 5917-5926, July 2018.
doi: 10.1109/TPEL.2017.2740843
16. F. M. Shahir and E. Babaei, "A new structure for non-isolated boost DC-to-DC converter based on voltage-lift technique," *2017 8th Power Electronics, Drive Systems & Technologies Conference (PEDSTC)*, Mashhad, 2017, pp. 25-30.
doi: 10.1109/PEDSTC.2017.7910373
18. F. M. Shahir, E. Babaei and M. Farsadi, "Extended Topology for a Boost DC–DC Converter," in *IEEE Transactions on Power Electronics*, vol. 34, no. 3, pp. 2375-2384, March 2019.
doi: 10.1109/TPEL.2018.2840683.
20. P. Saadat and K. Abbaszadeh, "A Single-Switch High Step-Up DC–DC Converter Based on Quadratic Boost," in *IEEE Transactions on Industrial Electronics*, vol. 63, no. 12, pp. 7733-7742, Dec. 2016.
doi: 10.1109/TIE.2016.2590991
22. M. Soltani, A. Mostaan, Y. P. Siwakoti, P. Davari, F. Blaabjerg, "Family of step-up DC/DC converters with fast dynamic response for low power applications IET Power Elect., vol. 9, no. 14, pp. 2665-2673, June 2016.