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Switched Inductor Based High Voltage Gain Sepic Converter

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ABSTRACT
The paper presents a new topology of SEPIC converter with high voltage gain and high efficiency for both renewable and photovoltaic boost applications. Here, a higher gain SEPIC converter is obtained from the conventional type SEPIC converter by placing switched Inductor and adding a boosting module. The structure formed with two inductors and three diode is termed as switched inductor. The newly introduced SEPIC converter provides a higher voltage gain compared to the conventional SEPIC and other converters with a single controlled active switch. The proposed converter is analysed in continuous conduction mode. Since the modified converter topologies avoids series connections and use of transformers, non complex and inexpensive structure is obtained for photo voltaic boost applications. The working of the converter is analysed in continuous current mode. Simulation of switched inductor based high voltage gain SEPIC converter is done in MATLAB/SIMULINK R2017a. From the simulation results and analysis it is observed that the converter has an efficiency of 95 % and voltage gain is about 11.08 .

Keywords – SEPIC converter , Continuous conduction mode, Photo voltaic

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I. INTRODUCTION

The usage of existed fossil fuels is tremendously

increased in the last decade, which leads to environmental contaminations and increases the cost of the system [1]. These problems leads us to work on Renewable Energy Resources[2] such as photovoltaic, wind turbine, fuel cells, etc. Among these renewable energy sources, photovoltaic is gaining more attraction and become noticeable as consequence of its various advantages such as eco-friendly, abundant in nature, freely available, etc. However, the voltage generated from the photovoltaic modules is comparatively low and depends on the environmental conditions [3].

To boost the photovoltaic voltage, series and parallel combinations of Photovoltaic panels can be a solution to achieve the load demand, which results in lower efficiency, high cost and large the size of the system. A high voltage gain DC-DC converter can be a practicable solution to boost the low voltage generated from photovoltaic. Among all the types of DC-DC converters SEPIC converters has large efficiency well as the voltage gain. Conventional boost converter is not proficient to produce high gain as it gets unstable when operated at high duty cycles. To make it high gain converter cascading of the converters can be done but again it not only increases complexity of the circuit but also increases losses and generate distinct voltage stresses across switches.Another popular way to increase gain of converter is use of transformers or coupled inductors which again decreases efficiency of the converter. Hence use of non-isolated converter is expedient solution for converters with high conversion ratio. Proposed converter masters the drawbacks of the isolated converters producing high gain. In this paper a switched Inductor based high voltage gain SEPIC converter is proposed. Switched Inductor based high gain SEPIC converter for photovoltaic and renewable energy applications has lower component count as compared to the normal high gain converters. The proposed converter topologies derived from conventional SEPIC converter by using switched inductors can produce high gain and which can extensively implemented for photovoltaic based applications without transformer or cascading. The converters are analyzed in continuous conduction mode. High efficiency and high voltage gain with continuous input current is the main advantage of the this modified switched Inductor based high voltage gain SEPIC converters. The working of the proposed

SEPIC converter is based on the operation of single active switch and with the comparison of other SEPIC converters modified switched Inductor based SEPIC converters having low components count, it reduces the size and complexity of the whole circuit.

II. OPERATING PRINCIPLES OF PROPOSED CONVERTER

2.1. Configuration of the Proposed Converter

The configuration of the proposed converter is shown in Figure 1. The converter configuration consist of 3 Inductors, 3 Capacitors, 6 Diodes and one switch along with load resistor R and input voltage V_{in} . This topology is obtained by applying the switched inductor technique along with voltage boosting method in a conventional SEPIC converter.

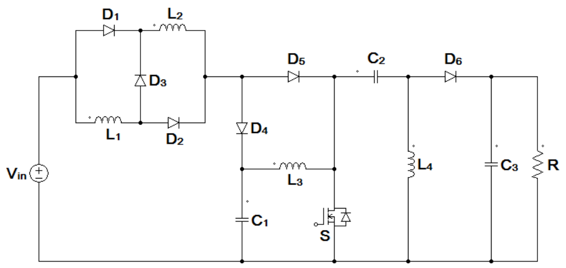

Fig.1. Configuration of Proposed Converter

The operating principles of the proposed converter are analyzed when the input current is continuous. The switch is operated with a duty cycle of 70% and the switching frequency is 50KHz. The switched inductor technique consist of L_1, L_2, D_1, D_2 and D_3. By using this topology we can achieve a high gain with high efficiency.

2.2 . Mode 1 [t_0-t_1]

During this mode the switch S is turned ON . Due to source voltage, diodes D_3 and D_5 are forward biased while the diodes D_1, D_2,D_4 and D_6 are reverse biased due to polarity of capacitors and inductors. During this mode of operation the circuit is working in continuous conduction mode. During this mode three inductors are charged with current path is as, inductor L_1 and L_2 from input supply V_{in} and inductor L_3 from capacitor C_1 and inductor L_4 from capacitor C_2. At the same instant, capacitor C_3 reverse bias the diode D_6 and transfer energy to the load.

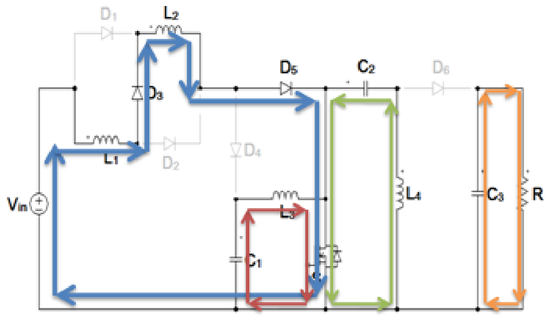

Fig. 2. Energy flow path in mode 1

2.3. Mode 2 [t_1-t_2]

During this period also the circuit is operated in continuous mode. The switch S is turned OFF. Due to polarity of the capacitors the diodeD_1, D_2, D_4 and D_6 are forward biased. Diode D_3 and D_5 are reverse biased. All three inductors are demagnetized as follow: inductor L_1 and L_2 along with input voltage V_{in} charges the capacitor C_1. The combination of inductor L_3 and capacitor C_1 charges to capacitor C_2. Also at the same time, inductor L_4 discharges through the load. Furthermore, the capacitor C_3 maintains the constant voltage across the load.

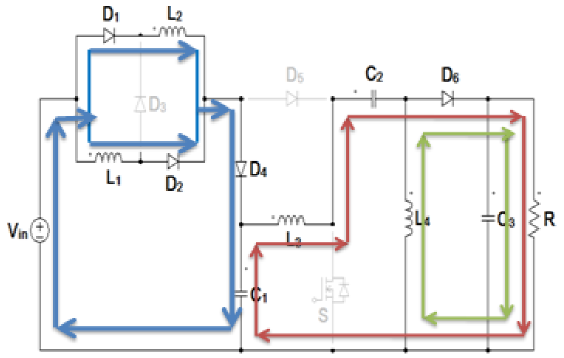

Fig. 3. Energy flow path in mode 2

The theoretical waveforms corresponding to two modes of operation of the converter is shown in figure 4. During mode 1, as all the inductor charges current through them increases, whereas voltage across all capacitors except C_3 decreases as they are discharging. The theoretical waveforms are comparable with the simulation results obtained. In mode 2 current through the inductors decreases as they are discharging and voltages across all capacitors except C_3 increases as they all are charging.

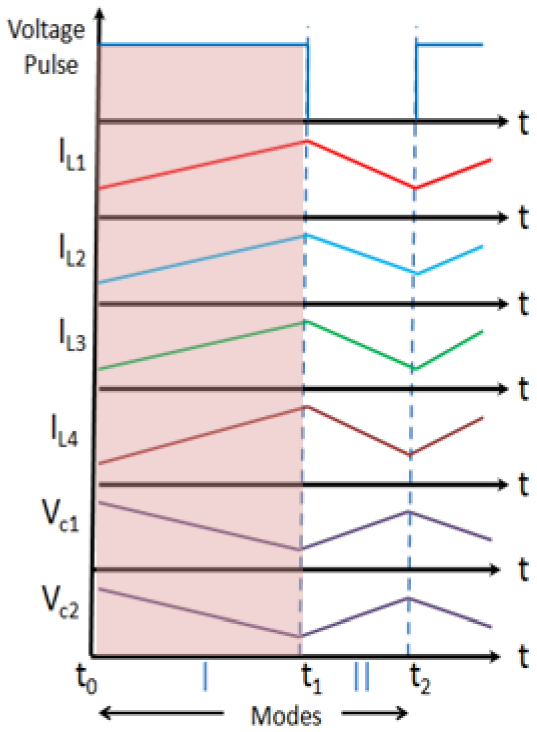

Fig.5. Theoretical Waveform

III. DESIGN CONSIDERATION OF MAIN COMPONENTS

The input voltage is taken as 24 V. The pulses are switched at the rate of 50 kHz with a duty ratio of 70% , Output Power, P_0=100 W. The output voltage is taken as V_0= 172 V. The voltage gain of the converter is given by,

$$\frac{V_O}{V_{in}} = \frac{D}{(1-D)^2} \quad (1)$$

3.1 Design of Inductors

For finding the values of inductors take the load resisitor R is 300ohm. Assume inductor current ripple rate as 10% of Inductor current I_{L1} and I_{L2}

$$L_1 = L_2 = \frac{\frac{V_{in} * D}{F_S * \Delta I_{L1}}}{2} \quad (2)$$

For calculating the value of L_3, assume inductor current ripple rate as 40% of Inductor current I_{L3}.

$$L_3 = \frac{V_{in} * D}{F_S(1-D) * \Delta I_{L3}} \quad (3)$$

For the value of L_4 ,assume the inductor current ripple rate as 40% of Inductor current I_{L4}.

$$L_4 = \frac{V_{in} * D}{F_S(1-D) * \Delta I_{L4}} \quad (4)$$

For continuos current the value of all the inductors are set as 1mH.

3.2. Design of Capacitors

The value of capacitor C_1 is calculated as,

$$C_1 = \frac{V_{C_1} * D}{F_S * R * \Delta V_{C1}} \quad (5)$$

assume the capacitor voltage ripple rate as 0.2% of capacitor voltage V_{C1}. Capacitor value C2 is calculated by considering the ripple content is 0.5% of the capacitor voltage V_{C2}

$$C_2 = \frac{V_O * D}{F_S * R * \Delta V_{C2}} \quad (6)$$

The value of capacitor C_3 is calculated as,

$$C_3 = \frac{V_O * D}{F_S * R * \Delta V_{C3}} \quad (7)$$

The values of capacitors C_1, C_2 and C_3 are selected as 220µF.

IV. SIMULATION RESULTS

The performance study of the converter is carried out with MATLAB/SIMULINK R2017a.The values of the parameters used for simulation is given in Table .1. below.

Table.1. Simulation Parameters

Parameters	Specification
Input Voltage (V_{in})	24V
Output Voltage(V_o)	172V
Switching Frequency(F_s)	50KHz
Duty Ratio(D)	70%
Output Power(P_o)	100W
Inductors L_x, L_y, L_z	1mH
Capacitors C_1, C_2, C_3	220µF
Load Resistance, R	300Ω

The switched inductor based high voltage gain SEPIC converter is simulated in MATLAB/SIMULINK by choosing the parameters listed in table. The simulation results of the converter are shown in the following figures.

It can be seen that the input voltage V_{in} is 24 V and the input current I_{in} is 9 A. The switching frequency is chosen to be 50 kHz and the duty ratios of S is equal to 70. From figure the ripple in input current is 0.5 A. The voltage stress and current through switch S is shown in figure7.

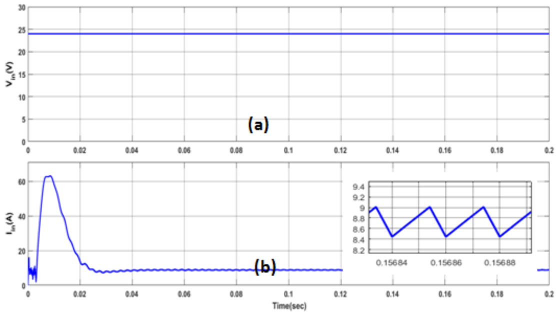

Fig. 6. (a) Input Voltage V_{in}, (b) Input current I_{in}.

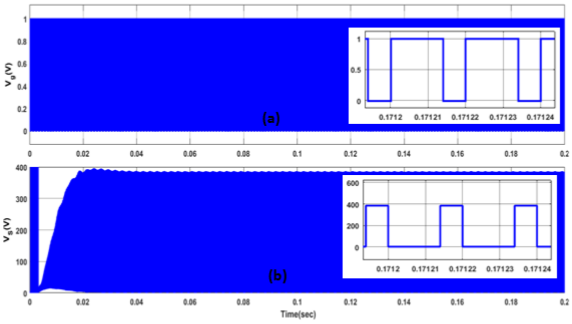

Fig. 7. (a)Gate pulse to S (b) Voltage stress across S

The capacitor voltage values are obtained as V_{C1}=117V, V_{C2}=116 V and V_{C3}=267 V and the respective ripple values in the capacitor voltage are 0.2 V, 0.5 V and 0.2 V as per simulation. Figure 8 shows the capacitor voltages of the converter. Figure 9 shows the inductor currents of the converter.

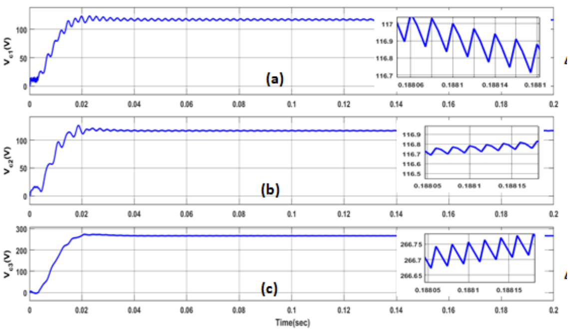

Fig. 8. (a) Voltage through C_1 (b) Voltage through C_2 (C) Voltage through C_3

The current flows through the inductor L_1 and L_2 are same and they are getting as 9A with ripple of 0.5A.The current through L3 and L4 are 3.2 and 1.48 respectivily with 1A ripple content.

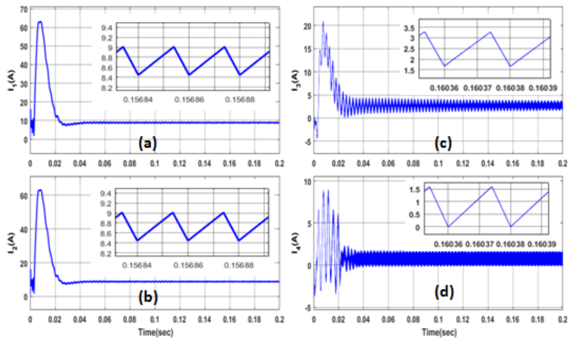

Fig. 9. (a) Current through L_1 (b) Current through L_2 (C) Current through L_3 (C) Current through L_4

For an input voltage of 24 V the converter has an output voltage of 267 V and an output current of 0.76 A.
Also the gain of the converter is 11.08 for 24 V input voltage. Figure.10. shows the output voltage and output current of the converter.

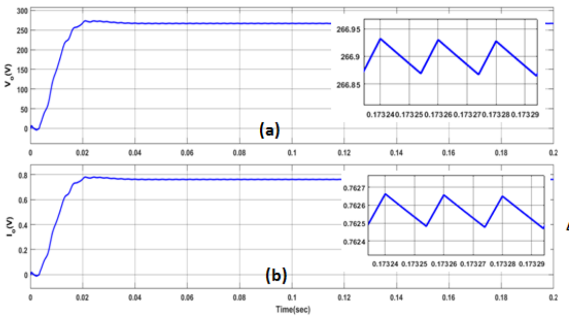

Fig. 9. (a) Output Voltage V_0, (b) Output current I_0

V. ANALYSIS FROM THE SIMULATION RESULTS

Based on the simulation results the analysis of the converter was performed to verify the operation of converter during different conditions.

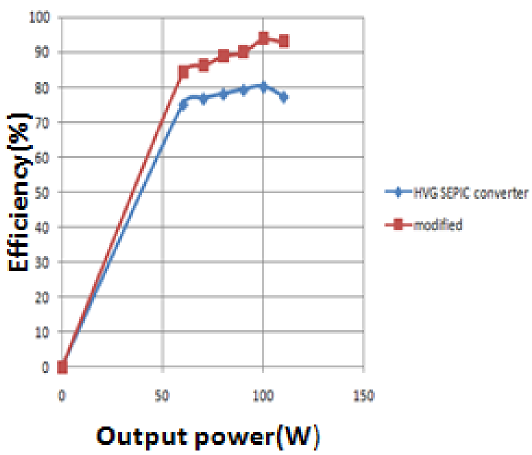

Fig. 11. P_0 Vs Efficiency

The analysis of this modified switched inductor based high voltage gain SEPIC converter is done by comparing with high voltage gain SEPIC converter. Figure.11. shows the power output Vs Efficiency curve of the converter for R load, for an input voltage of 24V. From the analysis it can be inferred that the converter has a maximum efficiency of 95% at an output power of 100 W.

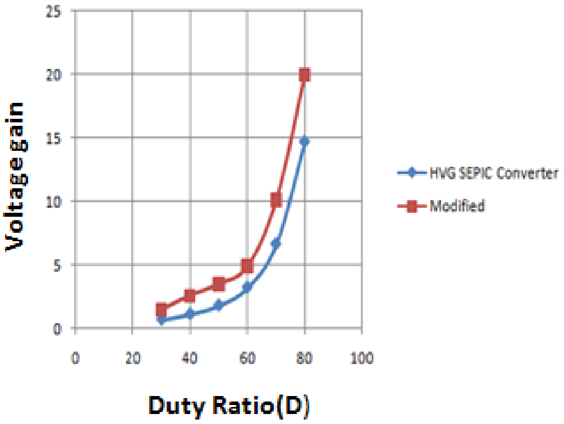

Fig. 12. Voltage gain Vs Duty ratio

The variation of voltage gain with duty ratio at a constant input voltage of 24 V is shown in Figure .12. As the duty ratio is varied from 30 to 80 % the voltage gain of the converter changes from 1.02 to 20 and it drops to 11.08 when the duty ratio is 70% . So by varying the control strategy the the gain of the converter has increased considerably. From the analysis of Output voltage ripple Vs switching frequency curve in Figure.13

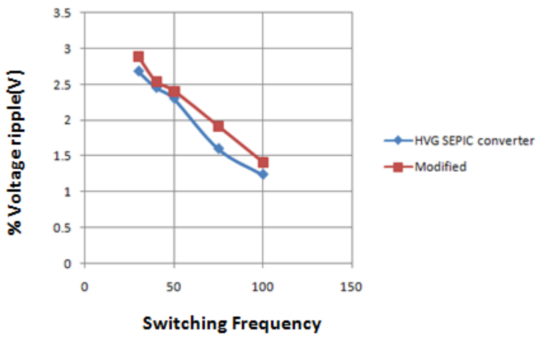

Fig. 12. Output voltage ripple Vs f_S

From the analysis of various performance characteristics drawn based on the simulation results it can thus be concluded that the desirable duty ratio of the converter is always 70% otherwise it will lead to very low voltage gain and also increased voltage ripple. Also it can is clear from the analysis the modified switched inductor based high voltage gain SEPIC converter performs well than other high gain SEPIC converters.

VI. CONCLUSION

The switched inductor based high voltage gain SEPIC converter has low number of components. This SEPIC converter approaches a new switched inductor technique to improve the efficiency and voltage gain of the converter. Also in this converter, the input voltage source is directly connected to the load through the output diode. From the simulation results it is observed that the voltage gain of the proposed converter is approximately equal to 11 which is high compared to the other high gain converters. The maximum efficiency is 95 % for an input voltage of 24 V. The output voltage ripple is 0.02 V and ripple in output current is 0.001 A. The converter also has low input current ripple as compared to normal high gain SEPIC converters . The converter can operate well, where a high voltage gain is needed and also suitable in high voltage applications.

REFERENCES

[1]. Pandav Kiran Maroti , Sanjeevikumar Padmanaban , Jens Bo Holm-Nielsen, Mahajan Sagar Bhaskar, Muhammad Miraj and Atif Iqbal,"A New Structure of High Voltage Gain SEPIC Converter for Renewable Energy Applications"*IEEE ACCESS, Vol.7,July.2019.*

[2]. L. S. Yang, T. J. Liang, H. C. Lee, and J. F. Chen, "Novel high stepup DCDC converter with coupled-inductor and voltage-doubler circuits," *IEEE Transactions on Power Electronics , vol. 58, no. 9, pp. 41964206,* Sep. 2011.

[3]. S. K. Changchien, T. J. Liang, J. F. Chen, and L. S. Yang, Novel high step-up DCDC converter for fuel cell energy conversion system," *IEEE Transactions on Power Electronics,vol. 57, no. 6, pp. 20072017,* Jun. 2010.

[4]. Y. P. Hsieh, J. F. Chen, T. J. Liang, and L. S. Yang, A novel high step up DCDC converter for a microgrid system*," IEEE Transactions on Industrial Electronics, vol. 26, no. 4, pp. 11271136,* Apr. 2011.

[5]. M. K. Nguyen, T. D. Duong and Y. C. Lim, "Switched-Capacitor-Based Dual-Switch High-Boost DCDC Converter*," IEEE Transactions on Power Electronics, vol. 33, no. 5, pp. 4181-4189,* May 2018.

[6]. Chung-Ming Young, Ming-Hui Chen, Cascade CockcroftWalton Voltage Multiplier Applied to Transformerless High Step-Up DCDC Converter,"*IEEE Transactions on*

Industrial Electronics, vol. 55, no. 1, pp. 240250, Jan. 2008.

[7]. M. M.Weiner, Analysis of CockcroftWalton voltage multipliers with an arbitrary number of stages," *IEEE Transactions on Power Electronics,vol. 40, no. 2, pp. 300333,*Feb. 1969.

[8]. C. M. Young and M. H. Chen, A novel single-phase ac to high voltage dc converter based on Cockcroft Walton cascade rectifier," *IEEE Transactions on Power Electronics,vol. 33, no. 5, pp. 4181-4189,* May 2018.

[9]. P. Wang, L. Zhou, Y. Zhang, J. Li, and M. Sumner, "Input-parallel output series DC-DC boost converter with a wide input voltage range, for fuel cell vehicles,," *IEEE Transactions on Vehicular Technology , vol. 66, no. 9, pp. 77717781,* Sep. 2017.

[10]. G. Lefevre and S. V. Mollov, "A Soft-Switched Asymmetric Flying- Capacitor Boost Converter With Synchronous Rectification," *IEEE Transactions on Power Electronics, vol. 31, no. 3, pp. 2200-2212,* March 2016.

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