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Switched Diode Inductor Current and Capacitor Voltage Accumulator Based Dual Input Boost Converter

[1,]Akhilesh A, [2,]Prof. Eldhose K A and [3,]Prof. Elizabeth Paul
[1,]PG Scholar, [2,3,]Professor *Department of Electrical and Electronics Engineering, Mar Athanasius College of Engineering, Kothamangalam, Kerala*

ABSTRACT
In the distributed generation systems, energy sources such as wind energy, fuel cells (FCs), photovoltaic cells (PVs), batteries, etc all, play a vital role to decrease the energy crises in this current scenario. By utilizing the principles of electronic interfaces, the alternative and renewable energy sources are interconnected. To achieve the aim of integration, a multi input converter (MIC) is a perfect choice. This paper introduces the application of a switched diode inductor current and capacitor voltage accumulator (SDICVA) on conventional boost converter. This paper aims to obtain two different kinds of dual input boost converters one is based on the serial SDICVA and the other based on the parallel SDICVA with low component stresses, high voltage gains, low ripples, high conversion efficiencies and simple PWM control. The simulations are done in MATLAB/SIMULINK

Keywords: *Boost Converter, Dual input, High Gain, MIC, SDICVA.*

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I. INTRODUCTION

In the renewable power generation system, MIC topologies are usually integrated with a DC link. However, most of these MICs do not take high voltage gain into consideration, since the output of PVs, FCs and batteries are typically unregulated low-level DC voltages that needs to be stepped up to regulated, high-level voltages for practical applications. To integrate different energy sources well and achieve high voltage gain, one possible solution to this problem is the application of the switched-capacitor and switched inductor technique on classical non-isolated dc-dc converters [1]. Based on it, a series switched-diode-inductor and parallel capacitor voltage accumulator (SDICVA) composed of a switched diode inductor in series and several switched-diode-capacitor cells in parallel and a serial SDICVA composed of a series switched-diode-inductor and several switched-diode-capacitor cells in series are introduced in this paper [2-4]. Then, a dual input step-up converter based on the parallel SDICVA and a dual input step-up converter based on the serial SDICVA is respectively presented. Both of them achieve a high voltage gain due to the accumulation of some or all capacitor voltages and inductor current of SDICVA. Other advantages are low voltage stress and current stress across components, low voltage ripple and current ripple, and a simple control circuit. Furthermore, these converters can be extended by simply increasing the number of switched diode capacitor inductor cells.

II. SDICVA CONVERTERS

2.1. Switched Diode Inductor Current Accumulator

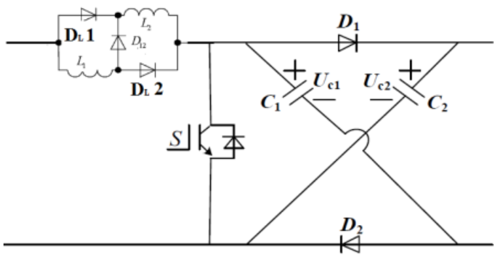


Fig. 1. Switched Diode Inductor Capacitor cell

The principle of the switched-diode-capacitor cell is that: when the main switch S is turned on, diodes D_1, D_2 are turned off with capacitors C_1, C_2 discharged in series and the inductor charged in parallel; when S is turned off, diodes D_1, D_2 are turned on with C_1, C_2 charged in parallel and the inductor discharge serially [4]. A high voltage gain can be attained since two capacitors are discharged in series and charged in parallel and inductor charged in parallel and discharged serially automatically by the on-off transition of the main switch [1].

2.2. Parallel SDICVA Converter

The parallel SDICVA shown in fig.2 with two input ports can be utilized to construct a double-input converter with a high voltage gain, which feeds power to the load individually. The two switches driven by a same switching signal provides a pathway for making two cells connected in parallel and a pathway for three capacitors of the parallel SDICVA connecting in series to feed the load power energy.

Topology and operation principle of the dual input step-up converter based on the parallel SDICVA at the mode of individual supplying power, are given in this Section.

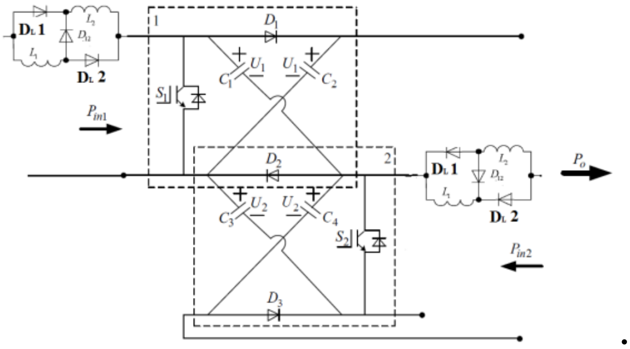
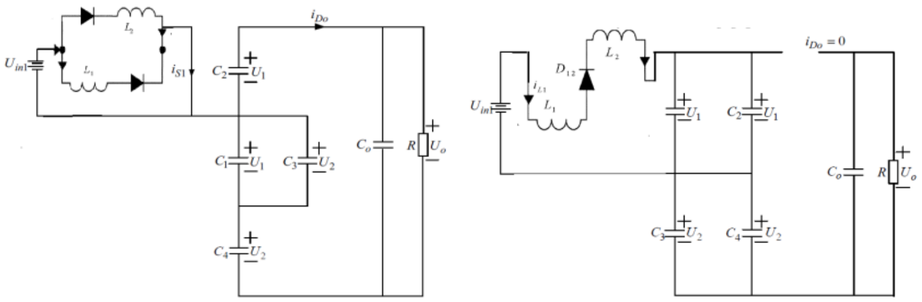


Fig. 2. Parallel SDICVA Structure

2.2.1. When Input Source 1 works independently



(a) (b)

Fig.3. Equivalent circuit of parallel SDICVA when one input source a) switch is ON b) switch is OFF

Equivalent circuits of the converter based on the parallel SDICVA when only input source 1 works independently are given in figure including two operating stages. When switches S_1 and S_2 are turned on which is shown in fig.3a, diodes D_1, D_2, $D_3$are reverse-biased while diode D_0 is forwarded. During the switch-on period, Inductor L1 and L2 are charged in parallel and the capacitors C_1, C_2, C_3 and C_4 are under serial-and-parallel connection, where C_1 and C_3 in parallel are connected with C_2 and C_4 in series. Thus, the capacitor voltage of cell1 equals to the capacitor voltage of cell2, i.e. U_1 equals to U_2. And it gives the reason why it is called the parallel SDICVA [4].

When switches S_1 and S_2 are turned off which is shown in fig.3b diodes D_1, D_2, D_3 are forwarded while diode D_o is reverse-biased. During the switch-off period, Inductors discharged in series and capacitors C_1, C_2 of cell 1 and capacitors C_3, C_4 of cell 2 are respectively connected in parallel, making each capacitor voltage of each cell equal.

Output voltage $U_0 = \frac{3(1+D)}{1-D} U_{in\ i} \quad i = 1\ or\ 2$ ……………………………..…… (1)

2.3. Serial SDICVA Converter

Another dual input step-up converter based on the serial SDICVA is proposed in this section. The converter can also feed load individually as well as simultaneously. Fig.4 shows the basic topology of the dual input step-up converter based on the serial SDICVA, which consists of two switched diode capacitor cells and switched diode inductor in series. In this converter, the operating mode of simultaneous supplying power and the operating mode of individual supplying power are respectively presented as below.

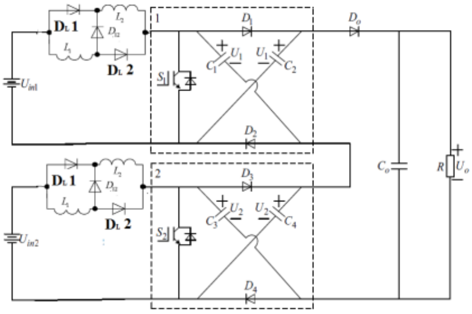
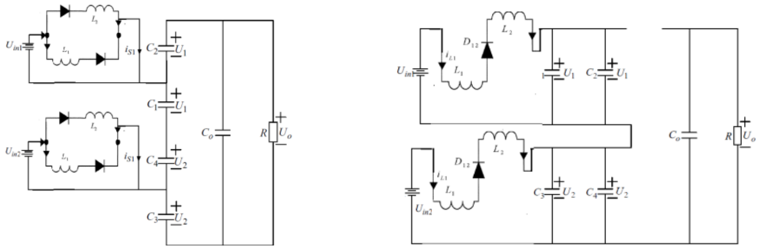


Fig. 4. Serial SDICVA Structure

2.3.1. Operating mode of Simultaneous Supplying Power

When switches S_1, S_2 are turned on which is shown in fig.5a, the voltage across inductor L_1. Since all capacitors of the SDICVA are connected in series to feed the load. When switches S_1, S_2 are turned off which is shown in fig.5b, inductors discharged in series. Capacitor C_1, C_2 of cell 1 and capacitor C_3, C_4 of cell 2 are respectively connected in parallel, making each capacitor voltage of each cell equal. The output voltage U_0 is given by,

$$U_0 = \frac{2(1+D)}{1-D}(U_{in1} + U_{in2}) \qquad (2)$$



(a) (b)

Fig.5. Equivalent circuit of serial SDICVA when one input source a) switch is ON b) switch is OFF

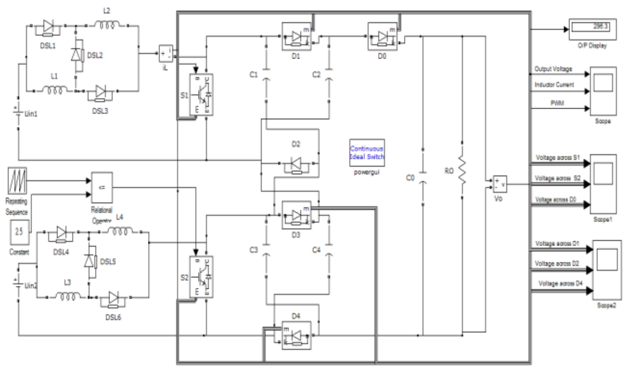
2.3.2. Operating Mode of individual supplying Power

In this operating mode of individual supplying power, the two input sources of the converter works alternately. When the input source 1 works, only cell 1 contribution to boost the low input voltage to the value 2(1+D)/(1-D)Uin$_1$ and cell 2 continues to work to provide a pathway for the boosting process. When the input source 2 works, only cell 2 contribution to boost the low input voltage to the value 2(1+D)/(1-D)Uin2 and cell 1 continues to work to provide a pathway for the boosting process. The voltage gain of the converter operating at the mode of individual supplying power is (1+D)/(1-D) smaller than that of the double-input converter based on the parallel SDICVA. The output voltage U_0 is given by,

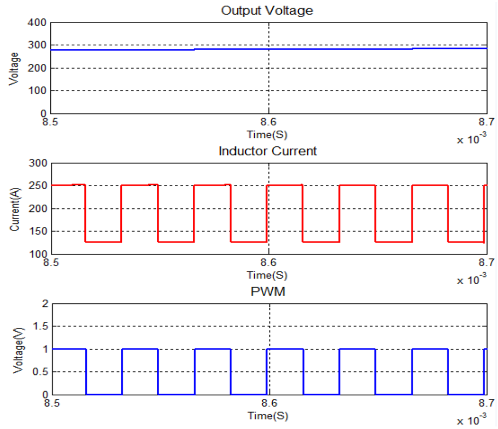
$$U_0 = \frac{2(1+D)}{1-D}\, U_{in\ i} \qquad i = 1\ or\ 2 \qquad (3)$$

III. SIMULATION MODELS AND RESULTS

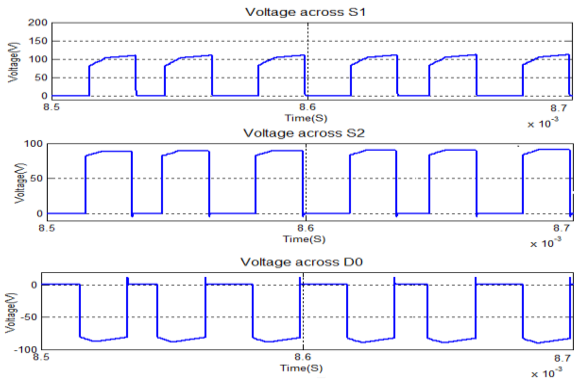
3.1. Parallel SDICVA Converter

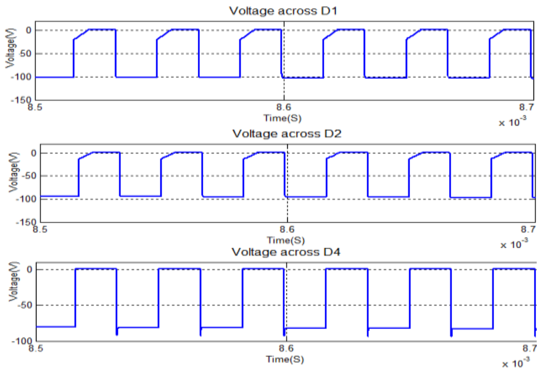


(a)



(b)





(c) **(d)**

Fig.6. a) Simulink model b) output Voltage c) Voltage across switches d) Voltage across diodes of parallel SDICVA Converter when one source acting only

Fig. 6a shows the Simulink model of the parallel SDICVA. The converter is developed to operate properly and produced output voltage when the input is 33V. The simulation results when the input source 1 acting alone is presented in fig. 6b, 6c and 6d. Fig. 6b shows the output voltage, inductor current and controlling signal applied to the switch. Here the inductor current or the source current is a perfect rectangular or square wave depending upon the duty cycle. When a 33V input is applied to the parallel converter, the output obtained is 293V, and their switching stress equations are shown in the table 1. Here the Control strategy adopted is simple PWM technique.

3.2. Serial SDICVA Converter

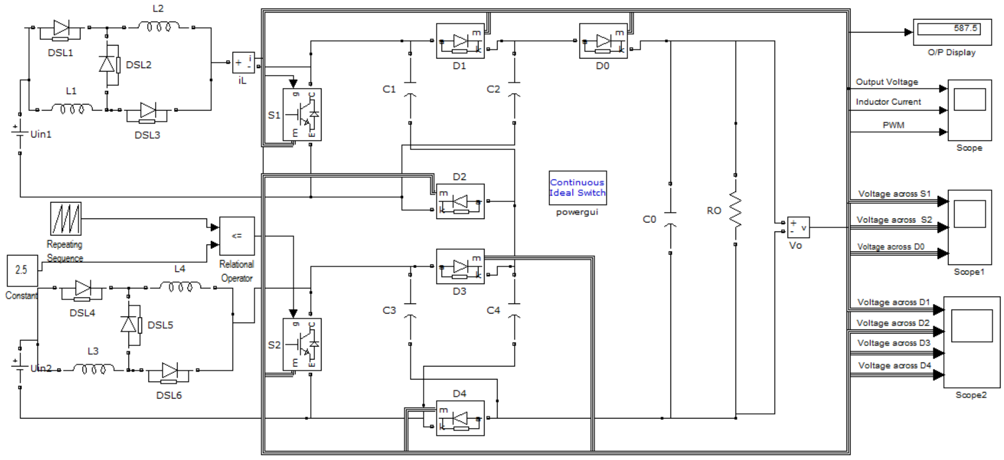
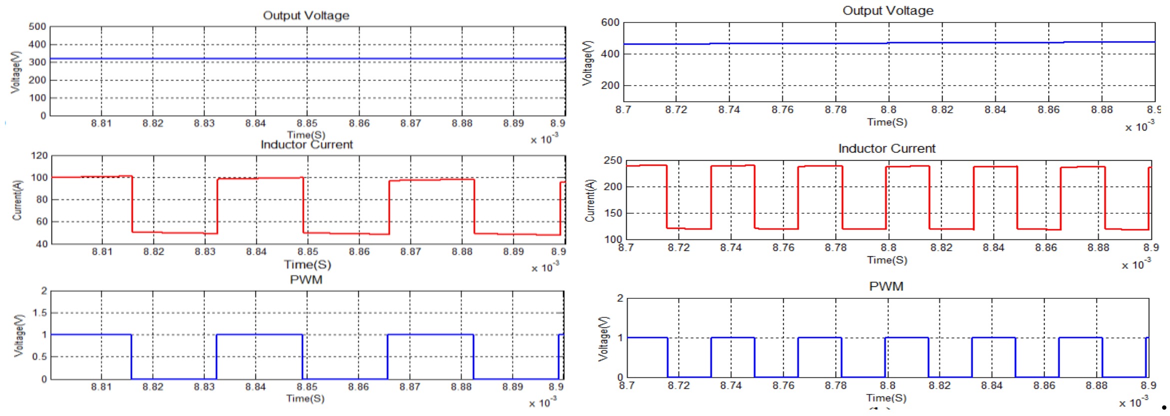
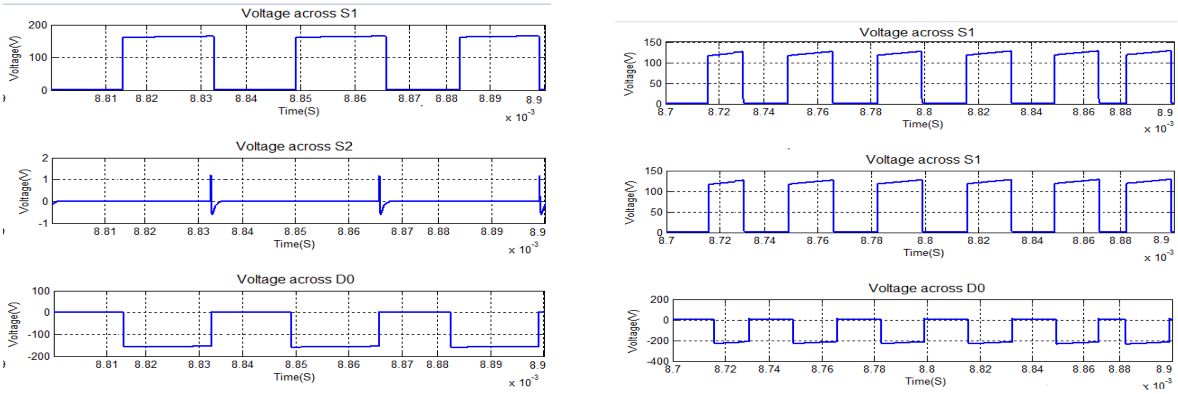


Fig.7. Simulink model of Serial SDICVA Converter



(a) (b)

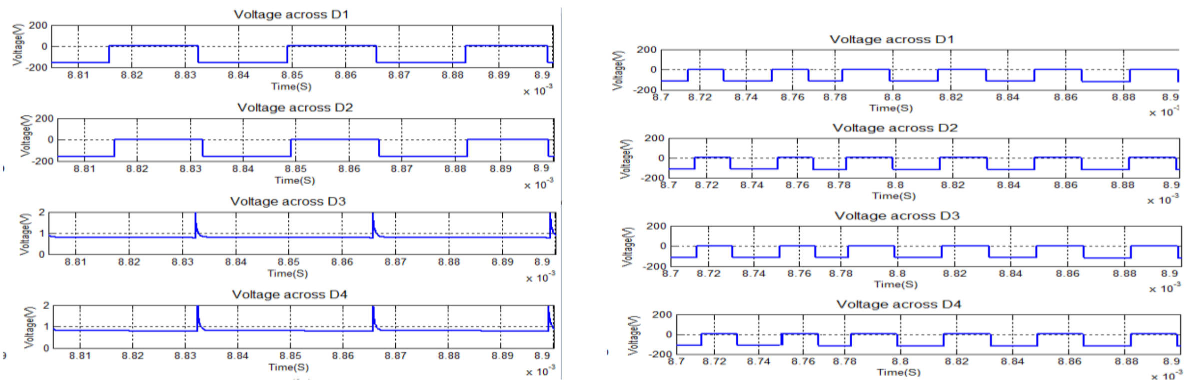
Fig.8. Output Waveforms of Serial SDICVA Converter when a) individually b) simultaneous supplying sources.



(a) (b)

Fig.9. Voltage across the switches S_1, S_2 and diode D_0 when a) individually b) simultaneous supplying sources.

Fig. 7 shows the Simulink model of the serial SDICVA. The converter is developed to operate properly in both independently and simultaneously and produced output voltage when the input is 33V. The simulation results when the input source 1 acting alone is presented in fig. 8, 9 and 10. Fig. 8 shows the output voltage, inductor current and controlling signal applied to the switch in both modes. Here the inductor current or the source current is a perfect rectangular or square wave depending upon the duty cycle. When a 33V input is applied to the serial converter, the output obtained is 310V and 450 in both independently and simultaneously respectively, and their switching stress equations are shown in the table 1. Here the Control strategy adopted is simple PWM technique. Fig.9 shows the voltage across the switches and fig.10 shows the voltage across the diodes, these simulation output waveforms satisfy the equation of the voltage across the switching devices which is shown in the table 1



(a) (b)

Fig.10. Voltage across the diodes D_1, D_2, D_3 and D_4 when a) individually b) simultaneous supplying sources.

3.3. Voltage Comparison

Table: 1 Voltage comparison between SDICVA Converter and Conventional Boost Converter

Dual input step-up converters			Output voltage Uo	Output voltage Uo after modification	Voltage stress of Diodes, Capacitors and Switches		
					Cell 1 & S_1	Cell 2 & S_2	Do
Converter based on the parallel SDICVA	Individual	Input source 1	$\frac{3\,Uin1}{(1-D)}$	$\frac{3(1+D)\,Uin1}{(1-D)}$	$\frac{1}{3}U_0$	$\frac{1}{3}U_0$	$\frac{1}{3}U_0$
		Input source 1	$\frac{3\,Uin2}{(1-D)}$	$\frac{3\,(1+D)Uin2}{(1-D)}$	$\frac{1}{3}U_0$	$\frac{1}{3}U_0$	$\frac{1}{3}U_0$
Converter based on the serial SDICVA	Individual	Input source 1	$\frac{2\,Uin1}{(1-D)}$	$\frac{2\,(1+D)Uin1}{(1-D)}$	$\frac{1}{2}U_0$	0	$\frac{1}{2}U_0$
		Input source 2	$\frac{2\,Uin2}{(1-D)}$	$\frac{2(1+D)\,Uin2}{(1-D)}$	0	$\frac{1}{2}U_0$	$\frac{1}{2}U_0$
	Simultaneo us	Input source 1,2	$\frac{2\,(Uin1+Uin2)}{(1-D)}$	$\frac{2\,(1+D)(Uin1+Uin2}{(1-D)}$	$\frac{Uin1}{(1-D)}$	$\frac{Uin2}{(1-D)}$	$\frac{1}{2}U_0$
Traditional boost converter			$\frac{Uin}{(1-D)}$	$\frac{(1+D)Uin}{(1-D)}$	Uo		Uo

IV. CONCLUSIONS

In this paper, a single SDICVA structure is introduced and two different double-input step up converters are explained based on the arrangement of these SDICVA structures. These converters can achieve high voltage gains with low component stresses, simple control, and high conversion efficiencies. By using the switched inductor circuit, the gain is increased by (1+D) times. Operating principle of the converter operating at this mode is that the input source delivers power to its corresponding switched diode capacitor cell and then the power stored in the cell is transmitted to its adjacent cell. In addition, for the dual input step-up converter based on the serial SDICVA, the high output voltage is attained by the accumulation of all capacitor voltages and inductor current of the serial SDICVA. Like the converter based on the parallel SDICVA, the converter based on the serial SDICVA can work at the modes of individual supplying power and simultaneous supplying power. When only one input source works independently, only the switched-diode-capacitor cell which is connected with the input source makes a contribution to the output voltage and the switched diode inductor make the input and the output current as square or rectangle depending upon the duty cycle. So the voltage gain of the converter operating at the mode of individual supplying power is less than that of the converter based on the parallel SDICVA. The input current from the source is square instead of triangular. High conversion efficiencies have been achieved in both the two converters.

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