

# ANALYSIS AND IMPLEMENTATION OF HIGH GAIN TWO INPUT BOOST CONVERTER FOR RENEWABLE ENERGY SYSTEM

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*Abstract: This paper proposes a voltage multiplier cell based two input Boost converter. By providing continuous input current with lower input current stress, high voltage gain and lower switching voltage stress ,the proposed converter is suitable to interface low voltage level sources like fuel cell, battery and solar cell The proposed converter can able to draw current from two input sources or a single source continuously. The operation principle, selection of components are provided. A 115 W prototype of the proposed converter with  $V_{in1}=12V$ ,  $V_{in2}=12V$  has been built to validate the analysis of the proposed converter.*

*Key words: Voltage multiplier Cell (VMC),Boost converter, Current stress, Voltage stress.*

## 1. Introduction.

Boost converter is the main component of fuel cell, battery & solar powered system. These converters are used to get the desired output voltage without increasing the size of the input sources and also the obtained voltage from these converters can be directly connected to a dc microgrid system. To obtain increase in output voltage boost and buck boost converter topologies are widely used and they need large duty cycle. This in turn increase the input current stress & increased switch voltage of the converter. Normally transformers or inductors are added in the converters to obtain increase in output voltage [1-4].But this in turn increase the design complexity of the circuit. In [5-12],it has been experimented that interleaving concept with some inductor and capacitor and voltage multiplier cell provide high voltage gain but the cost and complexity of the circuit has got increased. And also major drawback of these converters are high input current and high ripples in the circuit because of this size of the input inductor has got increased.

Converters with switched capacitors [13-14] can provide high voltage gain but the input current ripples of the converters are more and also it exhibits poor efficiency when compared to other type of converters.

Major solution for the above said problems are eliminated with the help of VMC based converters

and which will reduce the cost and size of the converter topology.

Many electrical systems in future will be supplied by two or more sources in order to increase the reliability, flexibility and more utilization of energy sources. Therefore two or more input sources must be combined to meet the future demands. Therefore many approaches [15-21] have been experimented .Transformers in different varieties are used in the approaches to meet the desired output voltage requirements. Conventional methods that are used to integrate the different input sources fall under two category and they are ac coupled systems and dc coupled systems. These converters attained importance in the literature because of higher efficiency but they have lack of bidirectional capability, highest part count and more complex circuitry. Many of the converters proposed has got advantages like high efficiency and higher output voltage but the voltage gain of the converters are limited by duty cycle and also if high duty cycle is used, then the current and voltage stress of the converter tend to increase. Many of the converters does not provide bidirectional capability and they are not able to boost the input voltage to a higher level.

To achieve high voltage gain, several converters has been designed. But the major drawback of all the converters are high input current, higher voltage stress across the switches and also converters are designed for single input sources. The proposed converter can achieve a gain of 9 and can draw current from single source or a two input source continuously. This converter can be linked to a dc microgrid also. The proposed converter has bidirectional capability and it has only two MOSFET switches. So, the control of switching is simple. In section II, the principle of operation of the proposed converter along with different modes of operation is explained. In Section III, the steady state analysis of the proposed converter is presented. In section IV, the experimental results of the proposed converter is presented and Section V concludes the paper.

## 2. Principle of Operation

The proposed converter is derived from the single phase voltage multiplier cell which is composed of diodes, capacitor and resonant inductor. This voltage multiplier cell is integrated to the normal boost converter consists of switch, inductor, and output diode and output capacitor. Fig.1 shows the proposed converter which consists of two VMC stages and can be extended to  $n$  stages to obtain increase in output voltage. The resonant inductor included in the structure is able to operate at zero current switching turn on. The gate signals of the proposed converter is shown in Fig.2.

In the normal operation of the converter, it has three modes of operation. The proposed converter can able to operate at small duty ratio.

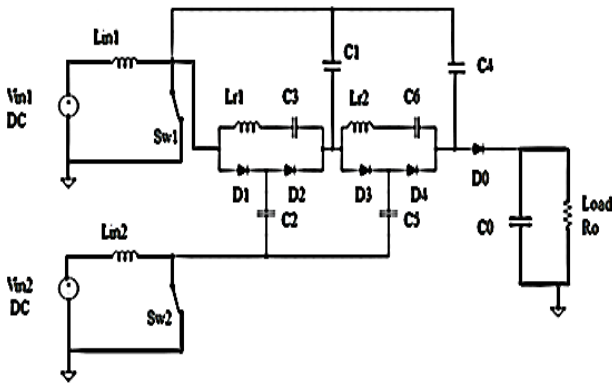


Fig.1. Proposed Converter

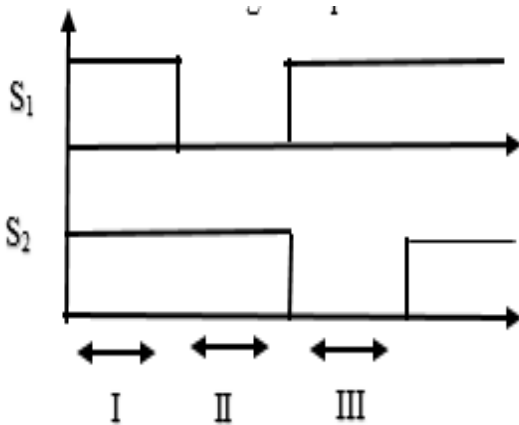


Fig.2. Gate Signals across Switches  $S_1$  and  $S_2$

### a. Mode I:

As Shown in Fig.3, switches  $S_1$  and  $S_2$  are on. The energy will be stored in the inductor  $L_{in1}$  and  $L_{in2}$  through the inputs  $V_{in1}$  &  $V_{in2}$ . the load is supplied by output capacitor  $C_0$ .

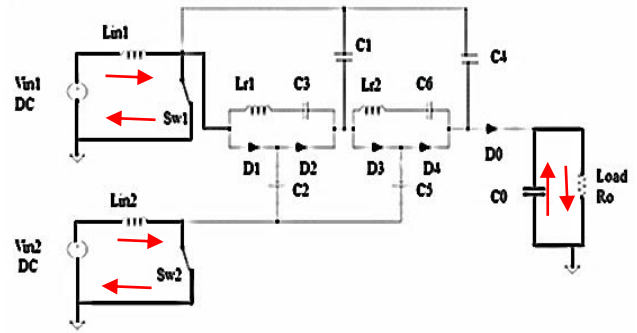


Fig.3. Mode I operation of the Proposed converter

### b. Mode II:

As Shown in Fig.4, the Switch  $S_1$  is OFF and  $S_2$  is ON. Input Inductor current flows through the diodes  $D_1$  &  $D_2$  and charging the capacitors  $C_2$  and  $C_5$  and discharging of  $C_1$  and  $C_4$  will takes place. And also the input inductor current charges  $L_{r1}$  and  $L_{r2}$ . Now  $D_0$  is forward biased which in turn charge the output capacitor and supplies to the load.

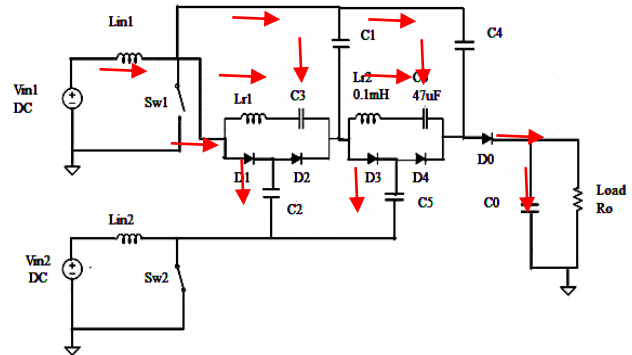


Fig.4. Mode II operation of the Proposed converter

### c. Mode III:

As Shown in Fig.5, the switch  $S_1$  is on and  $S_2$  is OFF. Now the capacitors  $C_2$  and  $C_5$  are discharging and capacitors  $C_1$  &  $C_4$  are charging. Because of this output diode  $D_0$  is blocked and load is supplied by the output capacitor  $C_0$ .

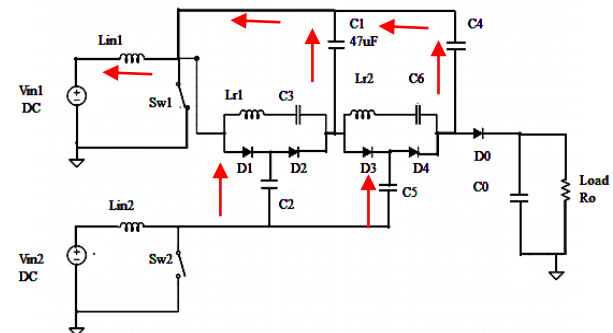


Fig.5. Mode III operation of the Proposed converter

**3. Analysis and design of the proposed converter:**  
The main equations that are used to design the two input converter is presented below.

**a. Voltage Gain**

The voltage gain of the proposed converter is derived from the volt-sec balance equation of the inductor.

The capacitor voltage

$$V_{c2} = V_{c5} - V_{c1} = V_{out} - V_{c4} = \frac{V_{in1}}{1-D_1} \text{-----(1)}$$

Where D<sub>1</sub> is the duty cycle of the switch S<sub>1</sub>.

Similarly we can write,

$$V_{c5} - V_{c2} = V_{c4} - V_{c1} = \frac{V_{in2}}{1-D_2} \text{-----(2)}$$

Where D<sub>2</sub> is the duty cycle of the switch S<sub>2</sub>.

From (1) and (2), the capacitor voltages can be written by,

$$V_{c2} = \frac{V_{in1}}{1-D_1} \text{-----(3)}$$

$$V_{c1} = \frac{V_{in1}}{1-D_1} + \frac{V_{in2}}{1-D_2} \text{-----(4)}$$

$$V_{c5} = \frac{2V_{in1}}{1-D_1} + \frac{V_{in2}}{1-D_2} \text{-----(5)}$$

$$V_{c4} = \frac{2V_{in1}}{1-D_1} + \frac{2V_{in2}}{1-D_2} \text{-----(6)}$$

$$V_{out} = V_{c2} + V_{c4} = \frac{3V_{in1}}{1-D_1} + \frac{2V_{in2}}{1-D_2} \text{-----(7)}$$

V<sub>c1</sub>, V<sub>c2</sub>, V<sub>c3</sub>, V<sub>c4</sub>, V<sub>c5</sub> are the voltage across the capacitors C<sub>1</sub>, C<sub>2</sub>, C<sub>3</sub>, C<sub>4</sub>, C<sub>5</sub>.

**b. MOSFET Selection:**

The MOSFETS are selected based on the maximum blocking voltage of the converter. The MOSFET selection of the proposed converter is same as that of the normal BOOST Converter and the maximum switch voltage across the switches are given by,

$$V_{s1} = \frac{V_{in1}}{1-D_1} \text{-----(8)}$$

$$V_{s2} = \frac{V_{in2}}{1-D_2} \text{-----(9)}$$

V<sub>s1</sub>, V<sub>s2</sub> are the voltage across the MOSFET Switches 1&2.

**c. Diode Selection:**

The diode voltage depends on the capacitor voltage of the converter. Since the diodes are active during

the Mode II & Mode 3, the diode maximum voltage (V<sub>DM</sub>) is given by,

$$V_{DM} = \frac{V_{in1}}{1-D_2} + \frac{V_{in2}}{1-D_2} \text{-----(10)}$$

**c. Inductor Selection:**

The design of input inductor is same as that of the normal boost converter and is given by

$$\Delta I_{Lin1} = \frac{P_o}{V_{in1}} * 0.45; \quad L_{in1} = \frac{V_{in1} D_1}{\Delta I_{Lin1} f} \text{-----(11)}$$

$$\Delta I_{Lin2} = \frac{P_o}{V_{in2}} * 0.45; \quad L_{in2} = \frac{V_{in2} D_2}{\Delta I_{Lin2} f} \text{-----(12)}$$

P<sub>o</sub>-Maximum output Power

f-Switching Frequency

Here 45% of the ripples are considered for calculation.

**e. Voltage Multiplier Cell Capacitor:**

The capacitance of the voltage multiplier cell depends on the maximum output power, capacitor voltage and frequency and is given by,

$$C_M = \frac{P_{omax}}{V_{c2}^2 f} \text{-----(13)}$$

**f. Resonant Inductor:**

The resonant inductor value depends on the rate of change of current and is given by,

$$L_r = \frac{V_{out} - V_{c2}}{di/dt} \text{-----(14)}$$

di/dt-maximum current variation at the input during turn on

**g. Output capacitor:**

The output capacitor value is given by

$$C_o = \frac{I_{out}(1-D)}{f \Delta V_C} \text{-----(15)}$$

D-either D<sub>1</sub> or D<sub>2</sub>

ΔV<sub>C</sub>-capacitor ripple voltage

**4. Experimental results**

An 115W prototype of proposed two input converter with voltage multiplier cell is tested. The electrical specifications are V<sub>in1</sub>=12V, V<sub>in2</sub>=12V, V<sub>o</sub>=104V, f<sub>s</sub>=2.5kHz and the corresponding rating and selection of the components are listed in Table I. The photograph of the proposed converter is shown in Fig 6. The input voltage, output voltage and current are shown in fig 7-8.

The design of proposed converter includes selection of components, input inductor design, selection of

MOSFET and output capacitor, resonant inductor and capacitor are based on the steady state analysis of previous section. In the proposed converter design, the input inductors are chosen as same for same current sharing at the two inputs. The experimental results of the switches S1 and S2 are shown in Fig 9-10 and it can be seen that the voltage stress of the two switches are 6V and 13V which is far lower than the 104V output voltage range. Hence, the low voltage rated MOSFETs are selected. The experimental results of the input inductors are shown in figure 5 and it is clear that each inductor takes only 5A and 4.6A input current. It can be seen that the input inductor current is far lower than the conventional boost converters. All experimental results matches with the steady state analysis of the proposed converter. The output voltage and output current of the proposed converter are shown in Fig.9 & Fig.10 and it can be seen that the output voltage is

104V and the output current is 1.1A. from these the proposed converter achieves a gain of 9 with the input voltage of 12V.

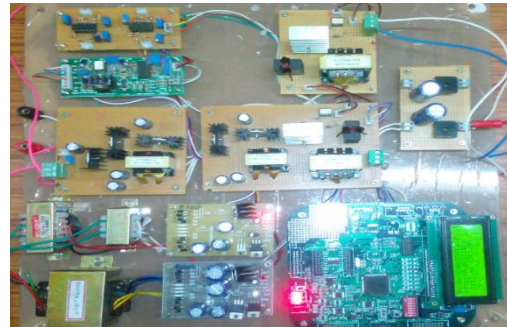


Fig.6. Photograph of hardware prototype

Table I Rating and Selection of components

Name of the Component		Rating of the component	Selected devices
Switches	$V_{peak}$	200V	IRF250 (200V,30A)
	$I_{rms}$	21A	
Diodes	$V_{peak}$	200V	BYQ28E-200 (200V,10A)
	$I_{av}$	7A	
Inductors Lin1 & Lin2	Inductance	0.57mH	Ferrite Material E Core
	$I_{rms}$	10A	
Inductors Lr1 & Lr2	Inductance	0.1mH	Ferrite Material E Core
	$V_{peak}$	10A	
Capacitors C1,C2,C3,C4,C5	Capacitance	47 $\mu$ F	Electrolytic capacitor
	$V_{peak}$	160V	
Output Capacitors Co	Capacitance	50 $\mu$ F	Electrolytic capacitor
	$V_{peak}$	160V	
FPGA Controller			Spartan 3E

Table II Comparison of the proposed converter with classical boost converter

Parameter	Proposed Converter	Classical Boost Converter	Extra High Gain Converter ToplogyI[22]
Output voltage	104V	37.43V	75V
Output current	$I_o=1.165A$	$I_o=1.5A$	$I_o=1.5A$
Voltage stress across the switches	$V_{sw1}=6V$ $V_{sw2}=13V$	$V_{sw}=35.4V$	$V_{sw}=56V$
Input inductor current	$I_{in1}=5A$ $I_{in2}=4.6A$	$I_{in}=11.5A$	$I_{in}=22.72A$
Duty cycle	0.6	0.6	0.6

The comparison of the proposed converter with classical boost converter and other topology is given in table 2. It is seen that the output voltage of the proposed converter is 104V whereas the classical boost converter output is 37.43 and other topology is 75V for 60% of duty cycle and also the voltage stress and input inductor current of the classical boost converter and extra high voltage converter is high whereas the proposed converter voltage stress is less.

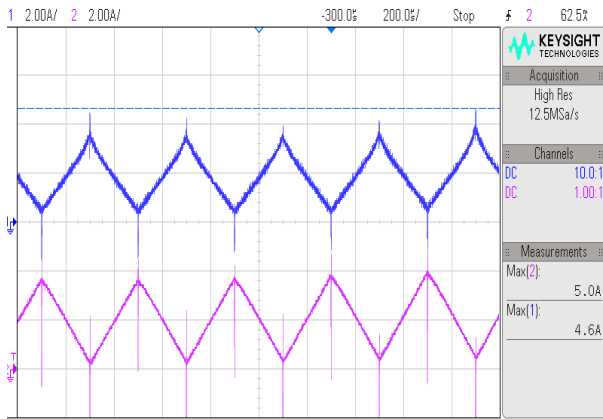


Fig.7.Input Inductor current waveforms



Fig.8.Input voltage wave forms

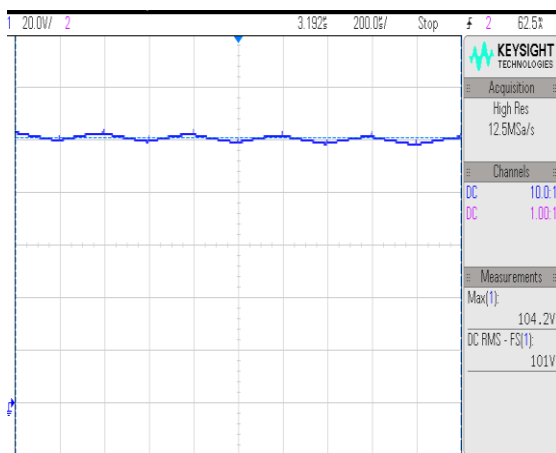


Fig.9.Output voltage waveform

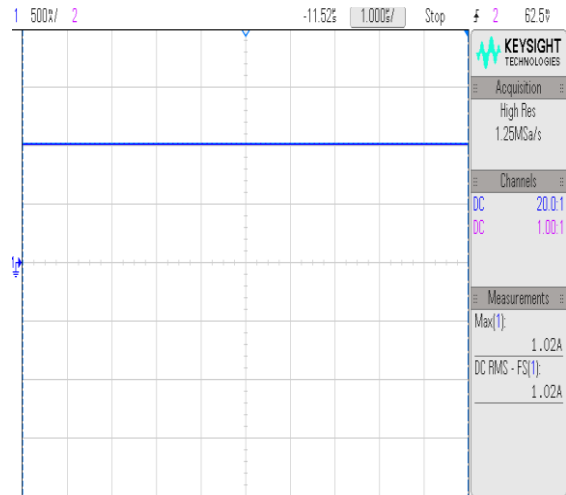


Fig.10.Output current waveform

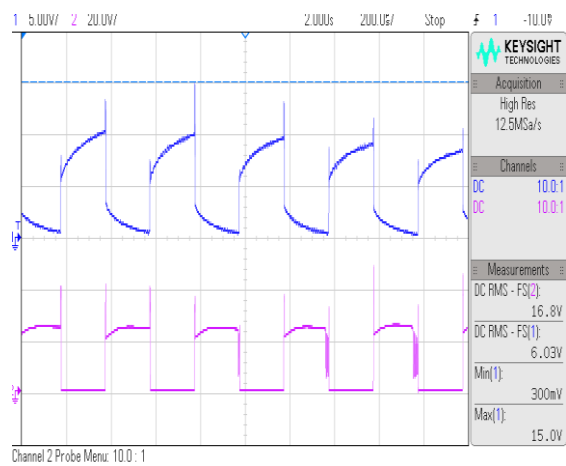


Fig.11.Voltage stress across Switch S1 & S2

### Conclusion

In this paper, a high voltage gain dc-dc converter with two input has been proposed. The proposed converter is based on voltage multiplier cell and the voltage gain is increased by voltage multiplier cell stages. This converter can draw power from two input sources or an independent source continuously. This converter has the flexibility of allowing control techniques for each input separately. Based on high voltage gain, small input current and small stress across the switches, the proposed converter is suitable for renewable energy systems that need higher step up ratio. Only one FPGA controller is used for generating pulses to the MOSFET.

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