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Dual Input DC-DC Converters with Input Boost Stages

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Abstract - *This paper proposes a high voltage gain dc–dc power electronic converter. This converter can draw continuous current from two input sources or a single source continuously which makes it suitable for the applications like solar panels. It can provide continuous input current with lower input current stress, high voltage gain and lower switching voltage stress. The charging and discharging of the voltage multiplier capacitors in the converter helps to achieve the high voltage gain. The proposed converter can be used to link individual solar panels onto the 400V distribution bus in DC micro grids. The design and component selection procedures are presented. The simulation of converter is done using MATLAB software.*

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

1. INTRODUCTION

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. A two input DC-DC converter is proposed for renewable energy applications where several renewable sources are employed. The versatile multiple input converters topologies give us the advantage of a large variety of connection. With the increased penetration of renewable energy sources and energy storage, high-voltage-gain dc–dc power electronic converters find increased applications in green energy systems. They can be used to interface low voltage sources like fuel cells, photovoltaic (PV) panels, batteries, etc., to the 400-V bus in a dc microgrid system.

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. But this in turn increase the design complexity of the circuit. It has been experimented that interleaving concept with some inductor, 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.

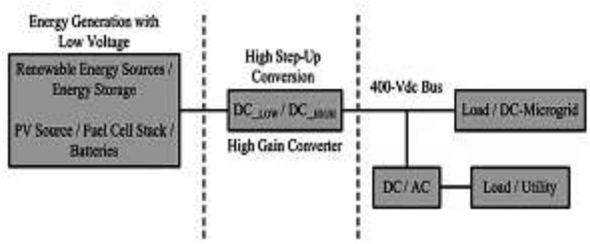

Fig -1: High-voltage-gain dc–dc converter in dc microgrid system

Non-isolated DC-DC converter topologies using capacitor-diode voltage multiplier cells can be used to, obtain high static gain, low voltage stress and low losses, improving the performance with relation the classical topologies. A high voltage gain dual input converter used voltage multiplier cells integrated with a classical boost converter is proposed was proposed. Several multiplier cells are connected together to boost up the output voltage without compromising the voltage stresses across the components. The main advantage is that voltage gain can be increased by adding of diode capacitor stages. The proposed converter can draw current from four independent sources. So in place of two different converters we can use a single converter. Thus, making the process of energy harvesting a very efficient process.

2. DUAL INPUT DC-DC CONVERTER WITH INPUT BOOST STAGES

The working of the proposed converter is inspired from the Dickson charge pump. Diode-capacitor voltage multiplier (VM) stages are integrated with boost stages at the input. The VM stages are used to help the boost stage achieve a higher overall voltage gain. The voltage conversion ratio depends on the number of VM stages and the switch duty ratios of the input boost stages. This converter is capable of stepping up voltages as low as 20V to 400V. The proposed converter offers continuous input current and low voltage stress (1/4th of its output voltage) on its switches. Thus, offering a gain of 20. 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.

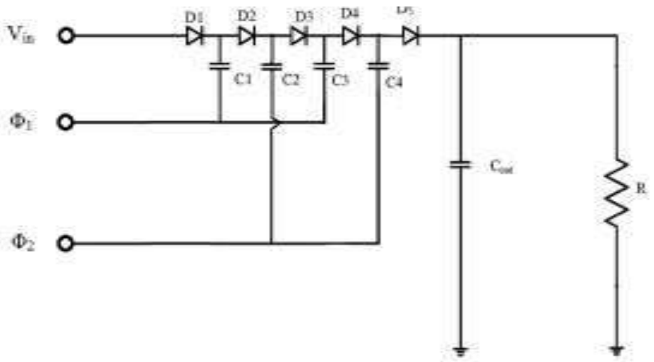

Fig -2: A Dickson Charge Pump

3. OPERATING PRINCIPLE

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. The proposed converter consists of two VMC stages and can be extended to n stages to obtain increase in output voltage. Theresonant 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.4. On a closer look, it can be seen that the converter is made up of two stages. The odd numbered upper stages, which have same mode of operation and the even numbered lower stages, which have same mode of operation

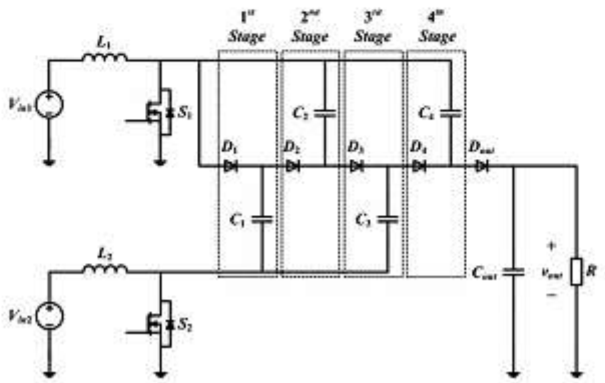

Fig -3: Proposed high-voltage-gain dc–dc converter with four VM stages

For normal operation of the proposed converter, there should be some overlapping time when both the switches are ON and also one of the switches should be ON at any given Therefore, the converter has three modes of operation. The proposed converter can operate when the switch duty ratios are small and there is no overlap time between the conduction of the switches. However, this mode of operation is not of interest as it leads to smaller voltage gains.

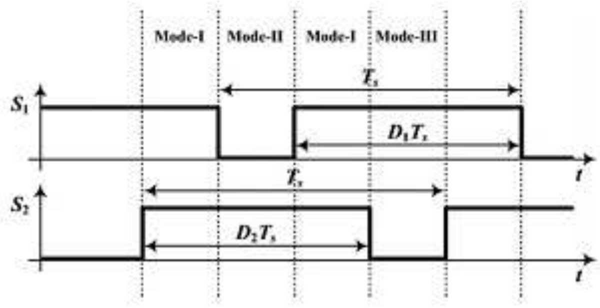

Fig -4: Switching signals for the input boost stage for the proposed converter

3.1. Mode I

In this mode all the switches are ON. All the inductors are charged from their input sources. The current in the inductors rise linearly. The diodes in different VM stages are reverse biased and do not conduct. The VM capacitor voltages remain unchanged and the output diode D-out is reverse biased Fig. V. Thus, the load is supplied by the output capacitor C-out.

3.2. Mode II

In this mode S1 is OFF and S2 ON. All the odd numbered diodes are forward biased and the inductor current IL1 flows through the VM capacitors charging the odd numbered capacitors and discharging the even numbered capacitors. If the number of VM stages is odd, then the output diode D-out is reverse biased and the load is supplied by the output capacitor. However, if the number of VM stages is even, then the output diode is forward biased charging the output capacitor and supplying the load.

3.3. Mode III

The switch S1 is ON and S2 is OFF. Now the capacitors C2 and C5 are discharging and capacitors C1& C4 are charging. Because of this output diode D0 is blocked and load is supplied by the output capacitor C0.

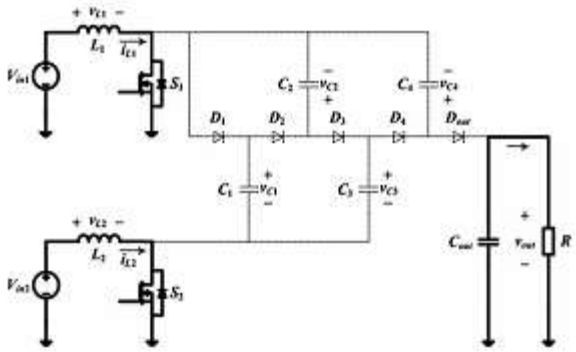

Fig -5: Mode I Operation

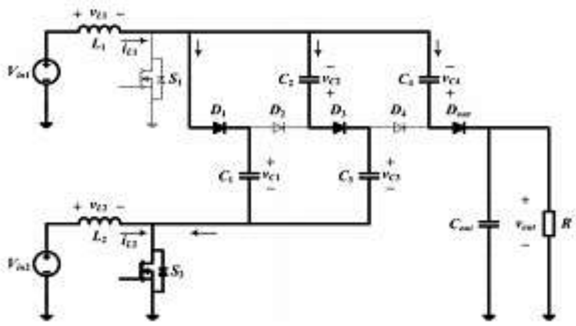

Fig -6: Mode II Operation

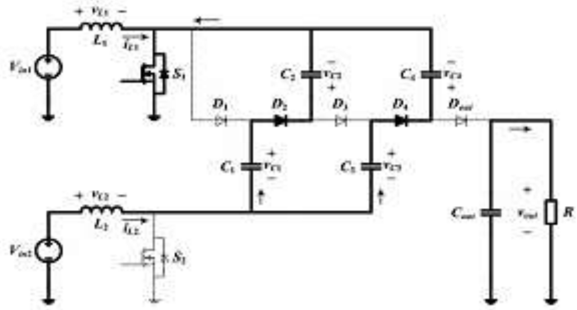

Fig -7: Mode III Operation

4. ANALYSIS AND DESIGN

The main equations that are used to design the two-input converter is presented below.

4.1. Voltage Gain

Voltage multiplier stage continuously transfers charge from input to output.

Node voltages of upper boost stage

VC1 = VC3 − VC2 = Vop − V4 = Vip 1/1−D1 ……….(1)

whereD1 is duty cycle of switch 1.

Node voltages of lower boost stage

VC2 − VC1 = VC4 − VC3 =Vip 2/1−D2 ………(2)

where D2 is duty cycle of switch 2.

From (1) and (2)

VC1 =Vip1/1 − D1

VC2 =Vip 1/1−D1 +Vip 2/1−D2

VC3 =2Vip1/1 − D1+Vip2/1 − D2

VC2 =2Vip1/1 − D1+2Vip2/1 − D2

Output voltage from equation (2)

Vop = VC4 +Vip1/1 − D1

Vop =3Vip1/1 − D1+2Vip2/1 − D2

Generalised equations for capacitor voltages of P number of voltage multiplier stages

$$V_{cq} = \left[\frac{q+1}{2}\right]\frac{V_{ip1}}{(1-D_1)} + \left[\frac{q-1}{2}\right]\frac{V_{ip2}}{(1-D_2)}$$

where q is odd and q<=P

$$V_{cq} = \left[\frac{q}{2}\right]\frac{V_{ip1}}{(1-D_1)} + \left[\frac{q}{2}\right]\frac{V_{ip2}}{(1-D_2)}$$

where q is even and q<=P

Output voltage equation depending on whether number of stages is even or odd

$$V_{op} = V_{cp} + \frac{V_{ip2}}{(1-D_2)}$$

$$V_{op} = \left[\frac{p+1}{2}\right]\frac{V_{ip1}}{(1-D_1)} + \left[\frac{p+1}{2}\right]\frac{V_{ip2}}{(1-D_2)}$$

when P is odd

$$V_{op} = V_{cp} + \frac{V_{ip1}}{(1-D_1)}$$

$$V_{op} = \left[\frac{p+2}{2}\right]\frac{V_{ip1}}{(1-D_1)} + \left[\frac{p}{2}\right]\frac{V_{ip2}}{(1-D_2)}$$

when P is even

4.2. 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,

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

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

V_{s1}, V_{s2} are the voltage across the MOSFET Switches 1&2.

4.3. 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(VDM) is given by,

$$V_{DM} = \frac{V_{in1}}{1-D_1} + \frac{V_{in2}}{1-D_2} \text{------------}(10)$$

4.4. Inductor Selection

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

$$\Delta I_{Lin1}=\frac{P_0}{V_{in1}}*0.45 \; ; \quad L_{in1}=\frac{V_{in1}D_1}{\Delta I_{Lin1}\,f} \quad \text{----------(11)}$$

$$\Delta I_{Lin2}=\frac{P_0}{V_{in2}}*0.45 \; ; \quad L_{in2}=\frac{V_{in2}D_2}{\Delta I_{Lin2}\,f} \quad \text{----------(12)}$$

Po -Maximum Output Power

f-Switching Frequency

Here 45% of the ripples are considered for calculation.

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

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

4.5. Resonant Inductor

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

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

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

4.6. Output capacitor

The output capacitor value is given by

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

D-either D1 or D2

ΔV_c-capacitor ripple voltage

5. SIMULATION RESULTS

The simulation parameters used for multiple input DC-DC converter are shown in Table I. The duty ratio and input voltage for all the branches are taken same. A 400W model of converter is simulated in MATLAB/ SIMULINK environment

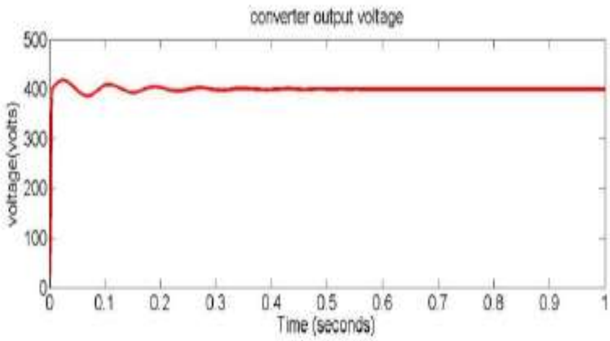

Fig -8: Converter output voltage

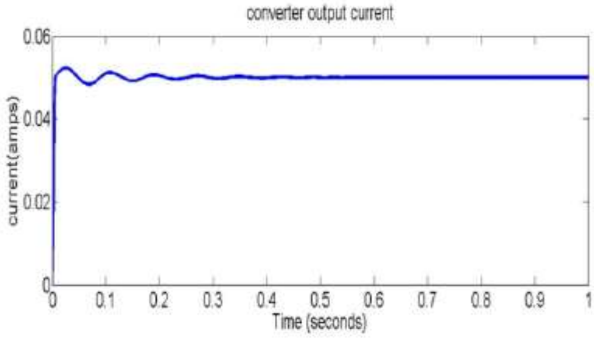

Fig -9: Converter output current

6. CONCLUSION

In this paper, a high-voltage-gain dc–dc converters with two input boost stages has been proposed. The proposed converter is based on diode–capacitor VM stages and the voltage gain is increased by increasing the number of VM stages. It can draw power from two input sources or can operate in an interleaved manner when connected to a single source. Since it is a multi-port converter with a high voltage gain, independent sources can be connected and power sharing, MPPT algorithms can be implemented independently at each input port. The proposed converter can be used for solar applications where each panel can be individually linked to the 400-V dc bus.

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