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ANALYSIS OF MULTILEVEL DC – DC BOOST CONVERTER WITH MULTIPLE DC SOURCES

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Abstract: The multilevel DC – DC boost converter with multiple DC sources is one of the most promising topology for photovoltaic system. In renewable energy sources like photovoltaic cells or array, the output voltage is of low level. In order to overcome this problem, the output voltage from the photovoltaic cell or array must be stepped up to a decent level and this can be done by using multilevel DC – DC boost converter with multiple DC sources which has been proposed in this paper. This DC – DC multilevel boost converter topology with multiple DC sources is a combination of simple boost converter and switched capacitor function to provide high voltage gain. The main advantage of this circuit is that it has multiple DC sources which means that different magnitudes of input voltages can be provided at individual sources. The proposed system is analyzed and simulated in MATLAB Simulink to validate the design.

Keywords: Boost converter; multilevel; photovoltaic; DC – DC conversion;

I. INTRODUCTION

Considering to the conventional coal based electrical energy generation, a very clean and alternative to it like Renewable energy sources consisting of solar and wind energy systems are being emerged. In this proposed paper we are considering multiple voltage sources which are connected to the converter thus it makes the system an attractive topology for renewable energy conversion. The output from the sources like PV /fuel cell are generally of low DC voltage therefore it needs to get boosted before being inverted and getting connected to the grid [2].This issue can be addressed with the help of multilevel DC – DC boost converter [3]. In order to get a high voltage gain , multilevel DC –DC boost converter with high voltage gain has been considered without using any transformer in the system[4]. In order to design a high efficiency multilevel DC – DC converter we should consider factors like stray inductances [6]. In this approach the output voltage is being controlled indirectly by defining a reference for the inductor current [1]. Different control techniques of controlling this device is being dealt in the literature[4]. As the system consists of less number of magnetic components on it, therefore the device can be used in higher temperature operation to a certain limit [3]. For PV application multilevel DC – DC converter with multiple DC sources becomes a good candidature because it has less amount of magnetic component on it and it is bidirectional in nature. The main advantage of this system is; - (i) High voltage gain can be obtained without the use of transformers or extreme duty cycles (ii) All the capacitors are self voltage balancing and the system consists of a simple single switch structure (iii) As there are multiple DC sources therefore individual voltage sources can be provided with different voltage inputs

II. CIRCUIT DESCRIPTION

A. Description of the system

The DC – DC conversion system which is proposed in this paper is shown in the figure 1.

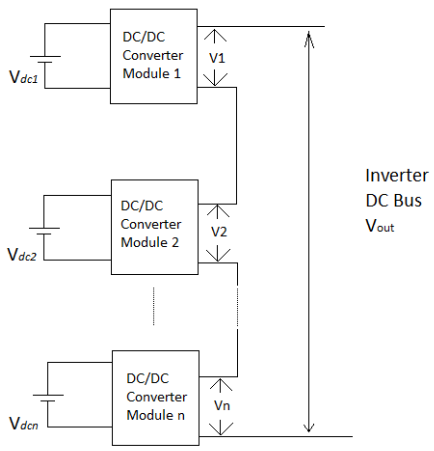

Figure 1: Block Diagram of a Multilevel DC – DC Boost converter with multiple DC sources

The system can be divided into N number of levels and in each level there are individual modules. Each modules consisting of high gain boost converters with individual sources in each modules. The number of level in the system can be fixed by the user depending upon the requirement. In this module the output is connected in series in order to get the integrated boosted output voltage from each module. Thus due to this the integrated high gain output voltage from each module can be obtained which is very useful for a PV system.

B. Analysis of Individual module.

Individual module of the system consists of a multilevel boost converter and a switched capacitor function to provide high voltage gain. This module includes voltage source and an inductor in series. In this system MOSFET is used as the switch. MOSFET / BJT / IGBT can be considered as a switch and here MOSFET is considered. An individual module from the Multilevel boost converter system is shown in the figure 2.

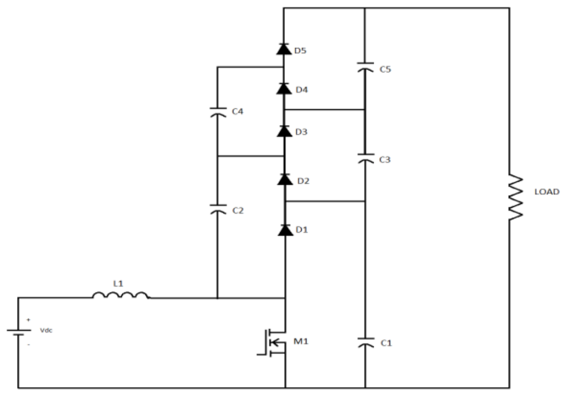

Figure 2: An individual module of a DC – DC Boost converter used in the system

Due to the presence of switch this circuit operates in two modes :-

- ON state
- OFF state

Mode 1: When the switch is turned ON

In this mode the switch present in the circuit is turned ON and the voltage source V1 charges the inductor L1. Now when the voltage across C1 is more than the voltage across C2 then clamping of the Voltage across C2 through the diode D2 is done by the capacitor C1. Similarly if the voltage across C1+C3 is more than that of C2 and C4 then clamping of the voltage across C2 and C4 through the diode D4 is done by the capacitor C1 and C3. The ON state of the circuit is shown in the figure 3.

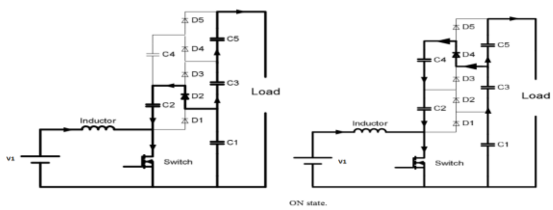

Figure 3: Operation of the converter when the switch is ON

Mode 2: When the switch is turned OFF

In this mode the switch present in the circuit is turned OFF and the voltage across the diode D1 gets forward biased due to the presence of the voltage across the inductor. Now in this state when the switch is turned off the capacitor C1 gets charged by the inductor current through the diode D1. Now when the diode D1 is forward biased the voltage across C1 and C3 through the diode D3 gets clamped by the voltage across the capacitor C2 and the source voltage. Similarly the voltage across C1 , C3 and C5 gets clamped through the diode D5 due to the presence of the voltage across the capacitor C2 and C4 and also due to the presence of the source voltage and the voltage across the inductor. The operation mode of the circuit when the switch is in OFF state is shown in the figure 4.

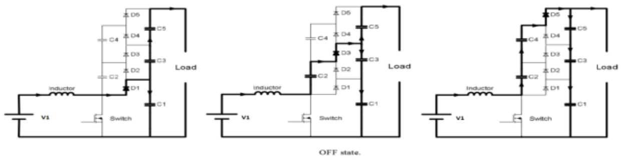

Figure 4: Operation of the converter when the switch is OFF

B. Modeling of the multilevel DC to DC converter with multiple DC sources.

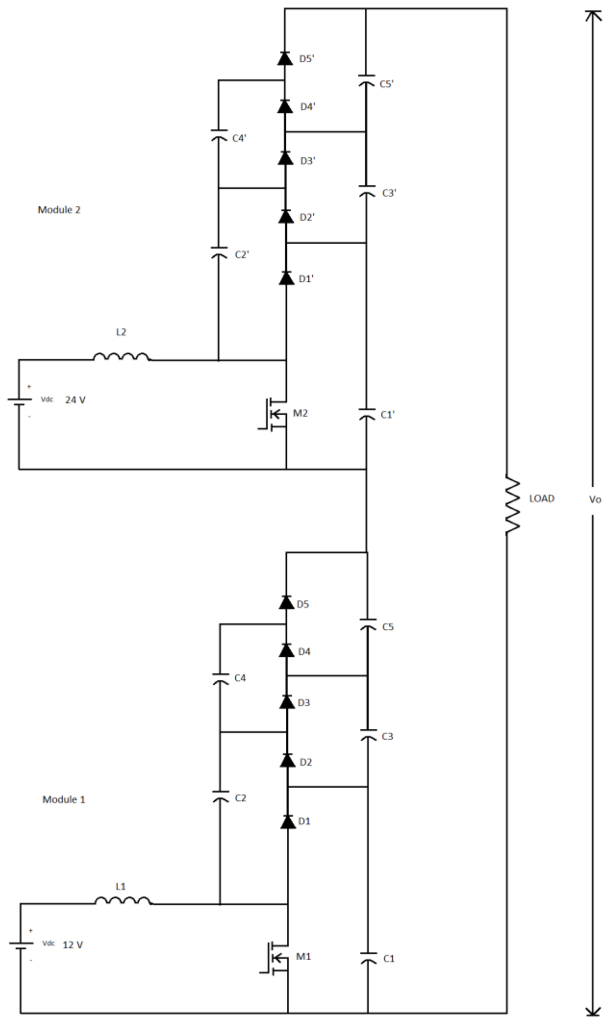

Figure 5: Multilevel DC – DC Boost converter with Multiple DC sources

The individual module which has been discussed earlier has high gain voltage outputs. The circuit diagram of Multilevel Boost converter with multiple DC sources is shown in figure 5. Now these module are just conventional boost converters

Module	Source Voltage	Inductor Value	Capacitor Value	Switching Frequency	Duty Cycle
1	12 V	300 µH	35 µF	20 kHz	0.65
2	24 V	300 µH	35 µF	20 kHz	0.65

with switched capacitor function which provides a high voltage gain which is very suitable for boosting the output voltage to a desired level. Now in order to design a multilevel boost converter with multiple DC sources different modules with individual voltage sources connected in series at the load side to get the integrated boosted output from different modules. This paper deals with a three level boost converter that is the multilevel boost converter consisting of two modules with different sources which are connected in series . The main advantage for which this system is used is that different input voltage can be applied in different modules which is very suitable application for a photovoltaic cell.

III. DETAILS OF THE DESIGN AND SIMULATION

This system consists of two modules with different voltage sources. The source voltage of module 1 is fixed as 12 V and the voltage of module 2 is fixed as 24 V. This system is designed to get an output voltage of 216 V from the input of 12 V and 24 V from the two modules at switching frequency of 20 kHz .In this proposed system we are considering the system with high voltage gain at low duty cycle.

A. Design of Capacitors and inductors

In a conventional boost converter the voltage gain of the system is defined by the following equation:-

$$Vg = \frac{1}{1-D} \dots\dots\dots\dots\dots\dots\dots (1)$$

Now for an N level multilevel boost converter the voltage gain is expressed as :-

$$Vg = \frac{N}{1-D} \dots\dots\dots\dots\dots\dots\dots (2)$$

Calculation of the values of the inductor is done by using this formula: -

$$L = \frac{k(1-k)}{2f} \dots\dots\dots\dots\dots\dots\dots (3)$$

For calculating the value of the capacitor the formula should be used is:-

$$C = \frac{k}{2fR} \dots\dots\dots\dots\dots\dots\dots (4)$$

In order to design the magnetic component calculation of the value of the inductor from equation (3) should be taken into consideration. As the switching frequency is taken as 20 kHz and the value of the load is taken as 50 Ω. As the duty cycle is taken as 0.65 therefore:-

L = 262.5 µH

The value of the capacitors of the system can be calculated by using equation (4) :-

C = 35 µF

where k = 0.65 , R= 50 Ω and f = 20 kHz

Now the output current from the system can be calculated by using the formula :-

$$Ia = \frac{2Vs}{(1-k)R}$$

Table 1: Output obtained from simulating the multilevel Boost converter with multiple DC sources

In this system of multilevel boost converter there are 2 levels.

Then the output voltage from the system is :

$$Vg = \frac{Vo}{Vs}$$

The power generated by the system can be represented as :-

$$P = Vo\ Io$$

IV. SIMULATION RESULTS

The proposed system has been simulated with the parameters Specified in MATLAB Simulink and results have been given in table 2. The simulation of various parameters is shown in Table 1.

Table 1: Simulation Parameters.

The table below shows the parameters considered for Simulation

Combined	12 + 24 V	300 µH	35 µF	20 kHz	0.65

Table 2: Output Results:

The table below shows the output results obtained from Simulation.

Modules	Output Voltage	Load Current	Voltage Gain	Power
1	78.11 V	1.562 A	6.5	122 W
2	162.8 V	3.257 A	6.78	530.23 W
Combined	211.3 V	4.236 A	5.896	895.06 W

The waveforms obtained from simulation is represented in the following figures:-

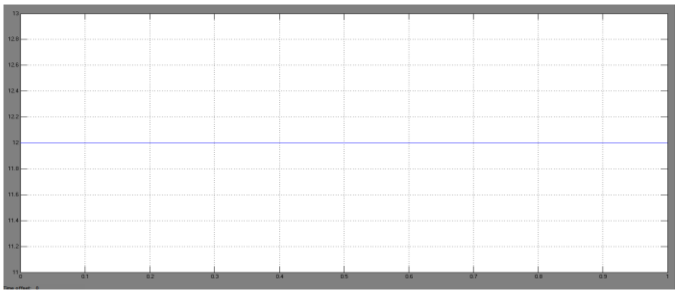

Figure 6: The input voltage across module 1

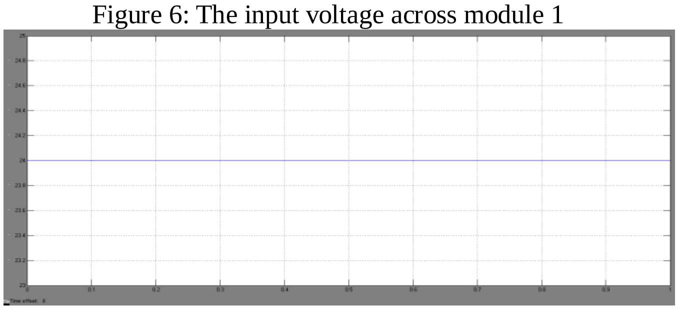

Figure 7: The input voltage across module 2

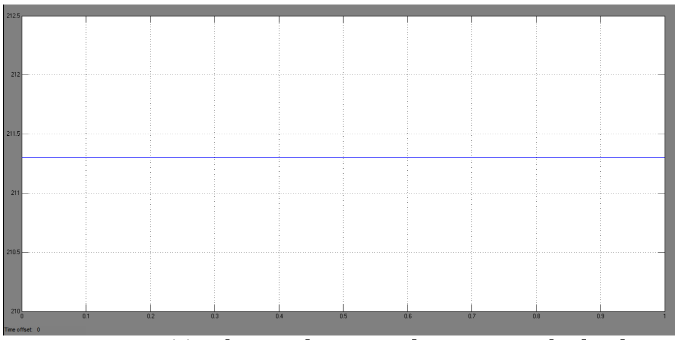

Figure 8(a): The steady state voltage across the load

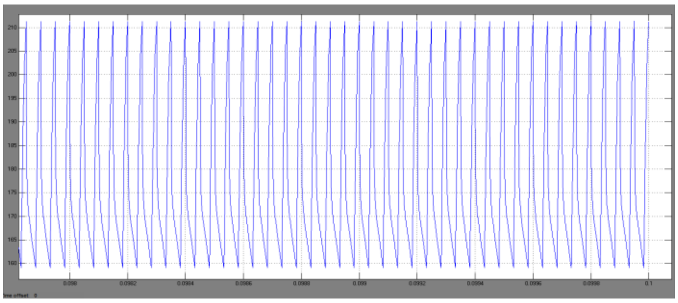

Figure 8(b): The voltage across the load

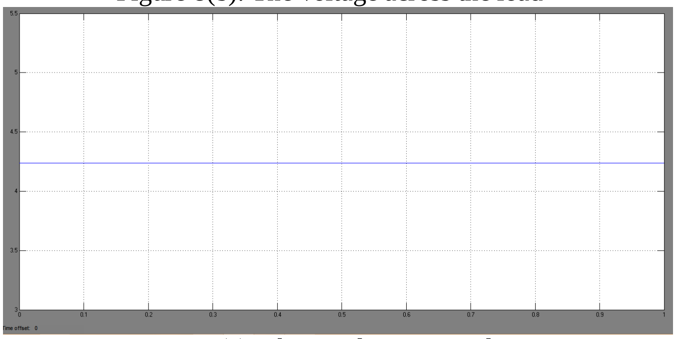

Figure 9(a): The steady state Load Current

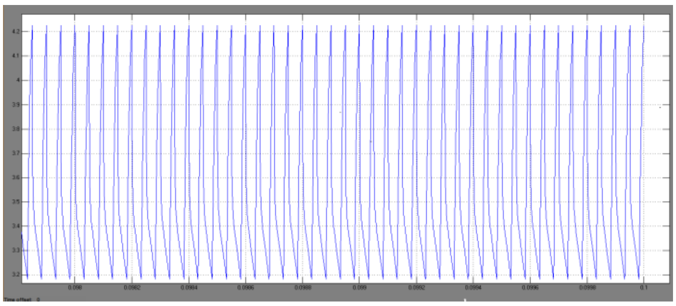

Figure 9(b): The Load Current

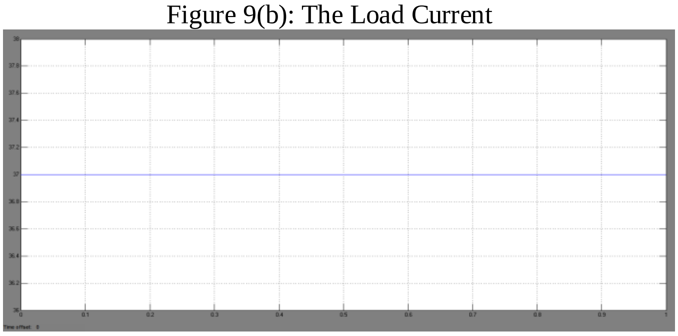

Figure 10(a): The steady state voltage across the top diode

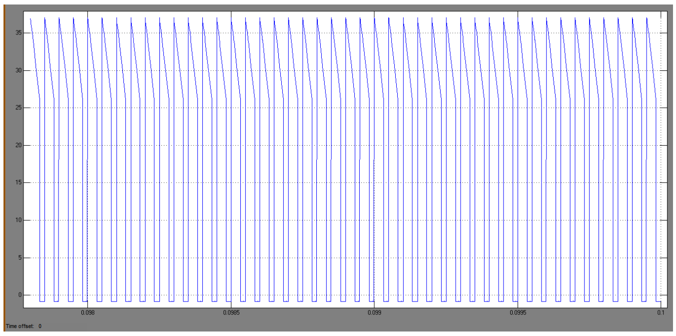

Figure 10(b): The voltage across the top diode

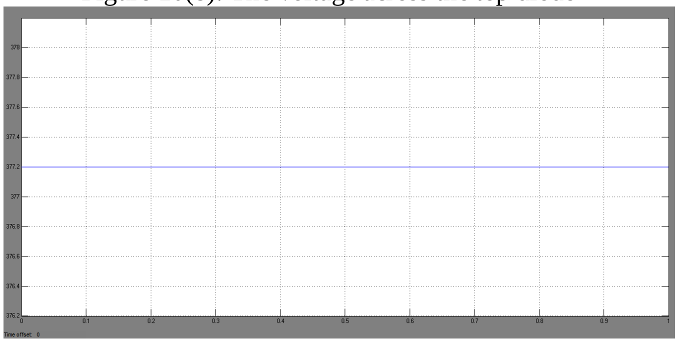

Figure 11(a): The current through the inductor L1

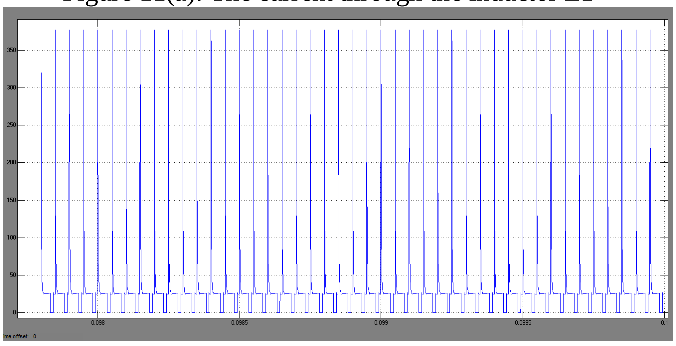

Figure 11(b): The current through the inductor L1

V. CONCLUSION

The system proposed in this paper consists of multilevel DC – DC converter with multiple DC sources. The performance of the system is obtained via simulations. It consists of a multilevel boost converter with two modules and two DC sources. This system is operated at a duty cycle of 0.65. A voltage gain of 6 is obtained from the system without using any transformer. The output voltage gets boosted to a higher level which makes this system very suitable for using it in photovoltaic application. The output waveforms obtained from the simulation confirms the performance of the proposed system.

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