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Modelling and Simulation of New Hybrid Boosting Converter for Photovoltaic System

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ABSTRACT: A hybrid boosting converter(HBC) having collective advantages of regulation competence from its boost structure and enhancement of the gain from its voltage multiplier structure is forthput in this paper. New converter incorporates a bipolar voltage multiplier, prominent symmetrical configuration, single inductor and single switch, high gain capability with wide regulation range, low component stress,small output ripple and obsequious extension, which make it suitable for front-end PV system and some other renewable energy applications. In the proposed work operation principle and voltage ripple are analysed. A 200-W 35V to 415V second order HBC prototype using open loop was designed. In proposed methodnew HBC with PI controller is designed.Thesimulation results assure the practicability of the converter.

KEYWORDS: Bipolar voltage Multiplier (BVM), Hybrid Boosting Converter(HBC),NatureInterleaving, Renewable Energy, Single Switch Single Inductor.

I.INTRODUCTION

There is a rapid development of renewable energy system calls for a new generation of high gain DC/DC converters with high efficiency and low cost.A MVDC converter is required which is able to boost the voltage from 1-6 to 15-60KV to link the output of generator to the MVDC line[1].Many high gain enhancement techniques were investigated in previous to achieve high voltage conversion ratio with high efficiency.Switched capacitor structure[2],tapped/coupled inductor based technique[3],[4],transformer based technique, voltage multiplier structure[5] or combinations of them[6] are thetechniques.But each technology has its unique advantages and limitations.In past many gain extension methods ofboost converter by adding only diodes and capacitors were investigated.The method of combing boost converter with traditional Dickson multiplier and Cockcroft-Walton multiplier to generate new topologies were proposed in[7].An elementary circuit employing the Super lift technique was proposed in[8].The concept of multilevel boost converters was investigated in [9].From the above topologies, a new boosting converter with a single switch and single inductor is proposed by employing bipolar voltage multiplier. The second order HBC is shown in Fig.2.which decreases the voltage rating of output filter capacity and exhibits the nature interleaving operation characteristics.A smaller ripple with single switch and single inductor has achieved in this topology on maintaining high voltage gain.Manymore structures are achieving high gain recently were also reported [10] but they adopted atleast two inductors or switches,or some are based on tapped inductor which may complicate the circuit design and increase cost.

II.OPERATION PRINCIPLE

A. *INDUCTIVE SWITCHING CORE*

Here the inductor, switch and input source serve as an inductive switching core as shown in Fig.1.This generates two complementary PMW voltage waveforms at port AO and port OB.Even if the two voltages waveforms have their individual high voltage level and low voltage level,the gap between the two levels is identical,which is an important feature for interleaving operation.

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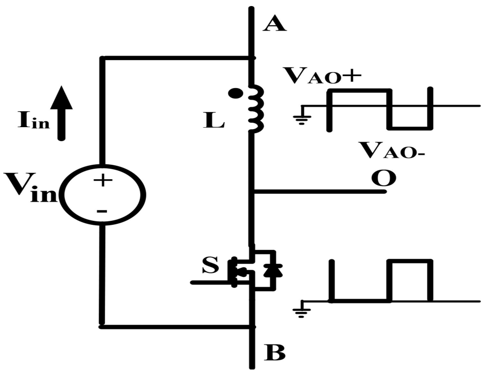

Fig.1.Inductive three-terminal switching core

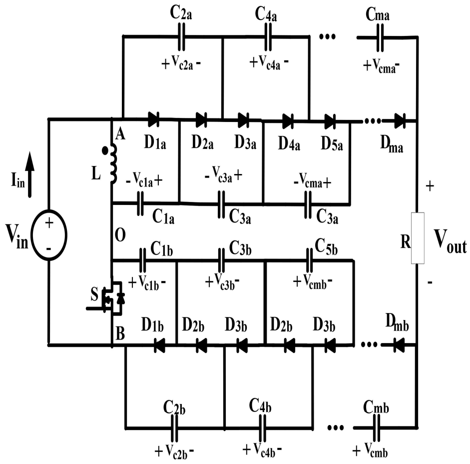

Fig.2. Even order HBC

B. *BIPOLAR VOLTAGE MULTIPLIER(BVM)*

A BVM comprises of a positive multiplier branch and a negative multiplier branch.Positive multiplier is the same as the traditional voltage multiplier while the negative multiplier has the input at the cathode terminal of cascaded diodes,which can generate negative voltage at anode terminal.

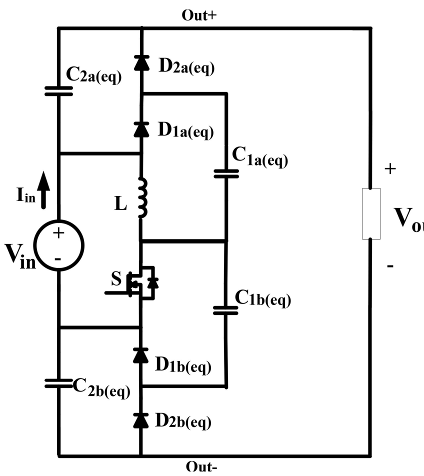

Fig.3.Equivalent even order HBC

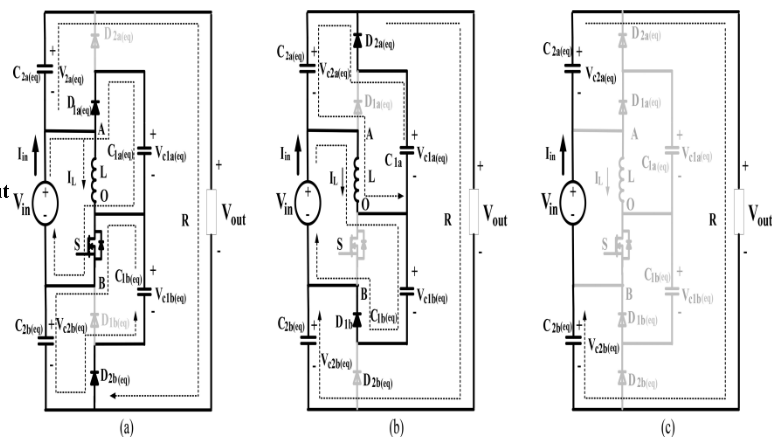

Fig.4.Three operation modes

C. *OPERATION PRINCIPLE OF HBC*

The general even-order HBC in Fig.2.simplied to an equivalent HBC circuit as shown in Fig.3. Careful examination indicates that two “boost” like sub circuits are intertwined through operating active switch S.The total output voltage of HBC is the sum of the output voltage of two boost sub circuits and the input voltage.Three operation modes are described as shown in Fig.4.

1) Mode 1[0,DTs]: InFig.4a, switch S is turned ON and diodes D1a(eq),D2b(eq) conduct while diodes D2a(eq) and D1b(eq) are reversely biased.The inductor L is charged by the input source. Meanwhile, capacitorC1a(eq).At this interval, following equations can be derived based on the inductive switching core analysis:

$$V_{AO+} = V_{in}V_{OB-} \quad (1)$$

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2)Mode 2[DTs,(D+D1)Ts]:As picturized in Fig.4b,when S is turned OFF,the inductor current will free wheel through diodesD2a(eq) and D1b(eq).The inductor is shared by two charging boost loops.In the top loop,capacitor C1a(eq) is releasing energy to capacitor C2a(eq) and load at the same time.In the bottom loop,input source charges capacitor C1b(eq) the inductor L. During this time interval voltage, generated at AO and OB is expressed as follows based on the inductor balance principle:

$$V_{AO+} = -V_{in}\frac{D}{D_1} \quad (2)$$

3)Mode 3[(D+D1)Ts,Ts]:At this condition, the circuit will work under DCM operationmode,thus the third state in Fig.4c.appear.At this state,the switch S is kept OFF.The inductor current has dropped to zero and all the diodes are blocked.TheC2a(eq) and C1a(eq) are in series with input source to power the load.During this time interval,voltage generated at port AO is zero while at OB is $V_{in.}$

TABLE 1: PARAMETERSELECTED FOR MODELING

Name	Denomination	Value
MOSEFT	S	250 V/40 A, 29 mΩ (IRFP4330)
Inductor	L	500 μH
Diode	$D1\ a$	200 V/20 A,VF = 0.78 V(STH2002C)
	$D2\ a$	
	$D1\ b$	
	$D2\ b$	
Capacitor	$C1\ a$	250 V/100 μF, electrolytic capacitor
	$C2\ a$	
	$C1\ b$	
	$C2\ b$	
Switching frequency	fs40 KHZ	
Load	R	722 Ω

TABLE 2: COMPARISION OF VOLTAGE GAIN

S.NO	Converters	Voltage gain	diodes	capacitors
1	Boost + Dickson multiplier [7]	1.98	5	5
2	Boost + Cockcroft Walton multiplier [7]	2	5	5
3	Multilevel Boost Converter [9]	2.1	5	5
4	Proposed New HBC	4	4	4

III.SIMULATION RESULTS

In order to verify the feasibility of proposing converter and its performance,simulationresults of a new HBC are provided. A 200W 35 to 415V second order HBC was designed and its specifications are listed in Table 1.
The input current is pulsating without terminating to zero and no rush current is observed due to the operation frequency is chosen properly.Theoutput voltage is boosted to 415V and kept stable without high voltage rating filter capacitor.
Fig.5. shows Simulink model of .Fig.3.where feedback method is used, output voltage is compared with that of reference voltage and sends to PI controller and tuned the error and produces pulses for switch, used in HBC.These pulses for switch used in the converter changes according to what amount of output voltage required.
Four diode voltage waveforms V_{d2a} ,$V_{d1a,}V_{d1b}$,$V_{d2b}$are shown in Fig.6. Moreover the voltage stress of four diodes is presented, which is relatively low and novoltage overshoot is observed. In Fig.7.drain source voltage and current are presented.
New HBC may enter DCM mode under light load conditions, unnoticeably overshoot at voltage $V_{ds}$is occurred due to the capacitors buffering function. Moreover PI controller provides zero steady state error and increase the output signal by the integral term. The output voltage is boosted to 415V,shown in Fig.10.,without any high voltage rating filter capacitor.Worthwhile, a comparison on voltage gain is carried out between proposed new HBC converter and other converters listed in Table 2.

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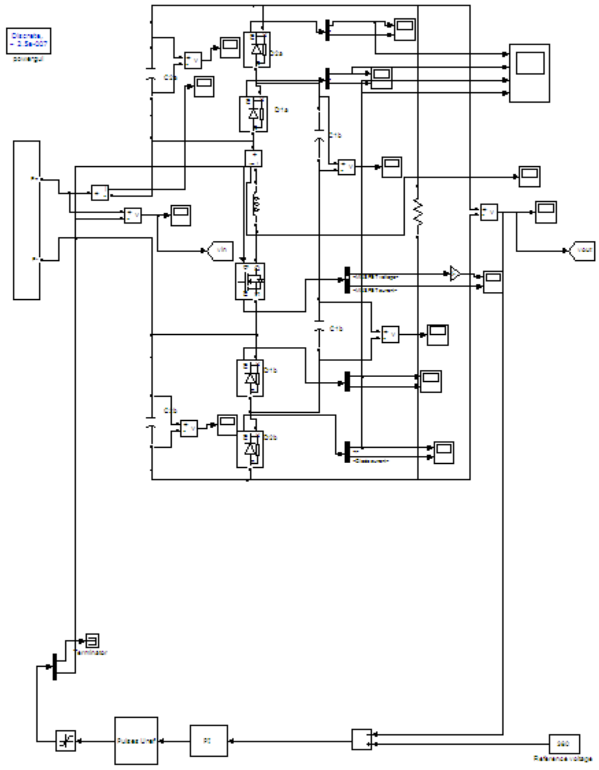

Fig.5. Simulink Model of Proposed Method

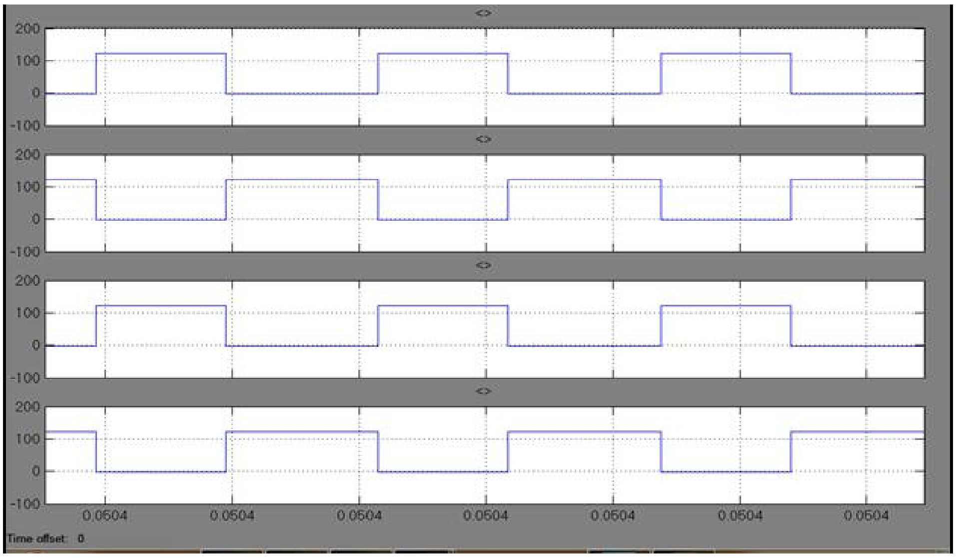

Fig.6. Simulink waveform of diode voltages in Proposed Method: V_{d2a}, V_{d1a} ,V_{d1b} ,V_{d2b}

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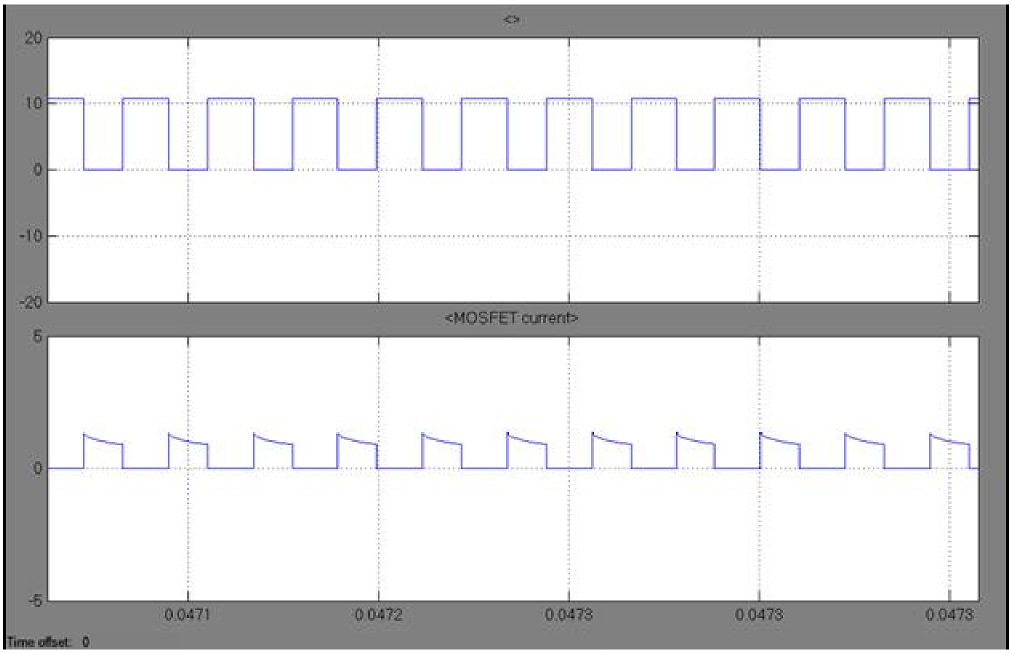

Fig.7. Simulink waveform of $V_{ds}$and I_{ds}

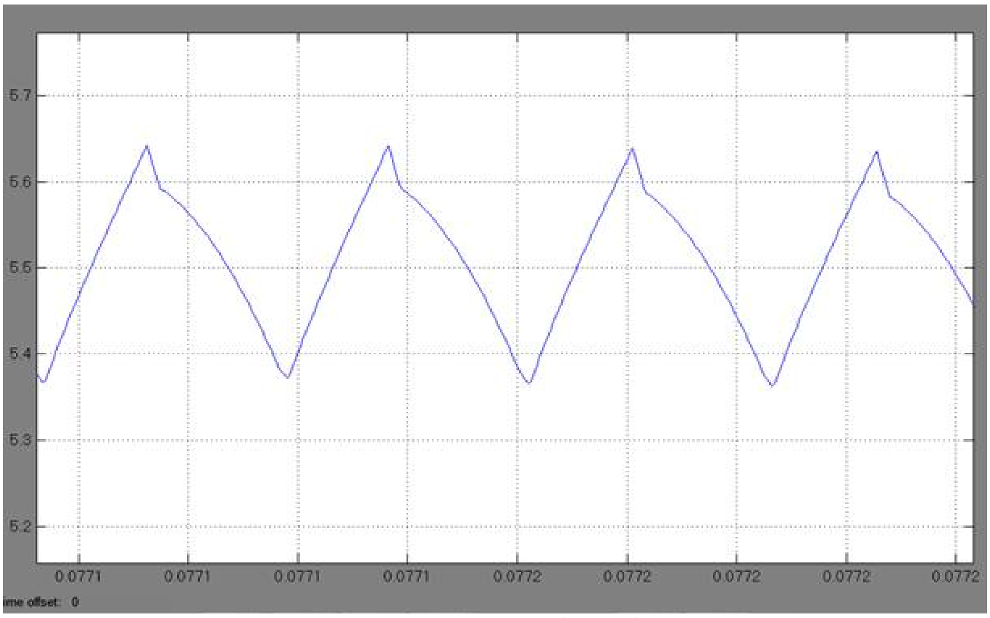

Fig.8. Simulink waveform ofI_L

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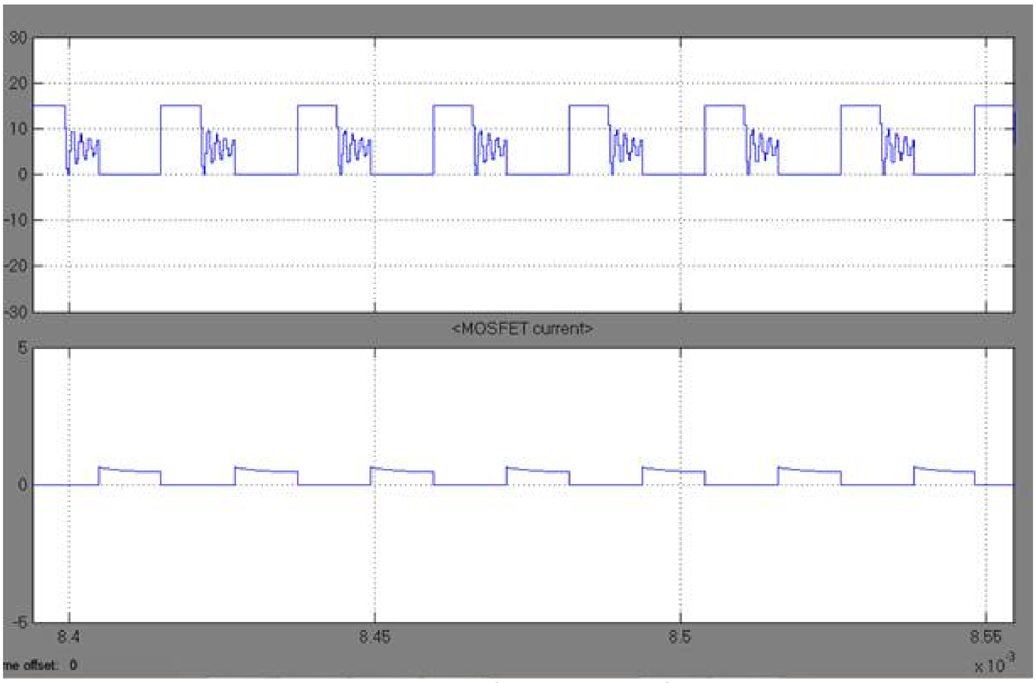

Fig.9. Simulink waveforms in DCMofV$_{ds}$and I$_{ds}$

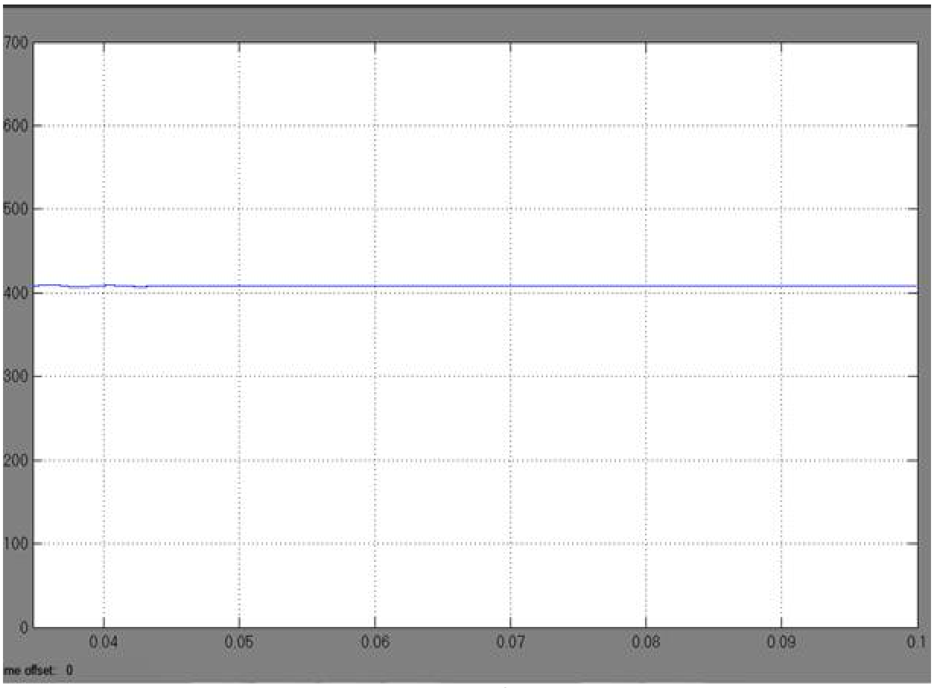

Fig.10.Simulation results of proposed method:Vout

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IV.CONCLUSION

Proposed new HBC composed of an inductive core and BVM having closed loop is useful for renewable energy applications.Collectiveadvantages of proposed method are gain boosting technique from the voltage multiplier and voltage regulation capability featuring in nature interleaved operation,wide regulation range,low component stresses,small output ripple,flexible gain extension and high efficiency.Compared with other gain boosting technologies like tapped inductor or transformer based method the proposed topology reduces the complexity which is applicable for mass production and it has a better component utilization factor compared with other single switch single inductor DC-DC converters.This work provides operation principle and design considerations.A 200-W35V to 415V second order HBC closed loop prototype was designed which achieved peak efficiency.This converter is suitable for many renewable energy applications. Moreover the PI controllers provide increase in speed of responses and provide applications in many processes. Furthermore the proposed method has lowest capacitor voltage stress which shows the superiority for high power density design and low cost design.

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