



# **A Non Isolated High Voltage Gain and Balanced Output Voltage DC-DC Boost Converter Based on SSC and VMC**

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**ABSTRACT:** In this paper a DC-DC boost converter with high voltage gain based on the three state switching cells and converter with three state switching cells(SSC) and voltage multiplier cell(VMC) together is compared. The DC-DC boost converter is analysed considering the operation in continuous conduction mode and duty cycle higher than 0.5, which corresponds to overlapping mode. The voltage stress across the switches is lower than half of the output voltage and naturally clamped by one output capacitor, allowing the use of MOSFET transistors with reduced intrinsic ON-resistance. To verify the operating principle BOOST converter is chosen. Experimental analysis is obtained from 1Kw prototype and the results are verified using MATLAB/SIMULINK.

**KEYWORDS:** Boost converter, State switching cell(SSC), Voltage multiplier cell(VMC), Continuous conduction mode, Voltage stress.

## **I. INTRODUCTION**

Depending on the appliance nature, many kinds of static power converters are necessary for the adequate conversion and acquisition of the energy provided by primary sources like electrical phenomenon arrays, wind turbines, and fuel cells. Besides, considering that the price of renewable energy systems is high, the utilization of high efficiency power electronic converters may be a necessary. A three-state switching cell (3 SSC) can be obtained by the association of two two-state switching cells (2 SSCs)interconnected to a centre -tapped autotransformer, from which a family of dc-dc converters can be derived. For good operation of the VMC ac input voltage is required, which is an important requirement of this cell. Due to this fact, the use of the 3SSC depicted is considered because it generates such ac voltage across the terminals of the autotransformer and therefore the drain terminals of the controlled switches. Within the ensuing cell, the controlled switches may be described by MOSFETs, junction field-effect transistors, insulated gate bipolar transistors, bipolar junction transistors, etc. Completely the generated topologies gift bifacial characteristics.

## **II. DC-DC CONVERTER BASED ON SSC**

The converter is composed of the following elements: input voltage  $V_{bat}$ ; inductor  $L_1$ ; transformer  $T_r$  connected to active switches  $S_1$  and  $S_2$ ; rectifier diodes  $D_1, D_2, D_3, D_4, D_5$ , and  $D_6$ ; auxiliary clamping polypropylene or polyester capacitors  $C_1, C_2, C_3, C_4$ , and  $C_5$ ; and output filter electrolytic capacitor  $C_{o2}$ . The figure is shown in the reference [9]. The operating stages for the boost converter are determined by the behaviour of the current flowing through  $L_1$ . Although the converter is able to operate in continuous conduction mode(CCM), discontinuous conduction mode (DCM), or critical conduction (CRM) with both conditions given by  $D > 0.5$  in overlapping mode (OM) or  $D < 0.5$  in non overlapping mode(NOM).Non isolated converters are preferred instead of isolated topologies in numerous applications. When VMCs are employed the voltage stress across the main switches can be reduced. The converter employing VMCs are introduced in the next section.

## **III. DC-DC CONVERTER BASED ON SSC AND VMC**

The converter proposed has high voltage gain, while the input current is continuous with reduced ripple. The input inductor is also designed for twice the switching frequency, implying reduction of weight and size. The voltage stress through the switches is less than half of the output voltage due to clamping performed by the output filter capacitor. It

is also important to mention that, for a given duty cycle, the output voltage can be increased by adjusting the transformer turns ratio without affecting the voltage stress across the main switches.

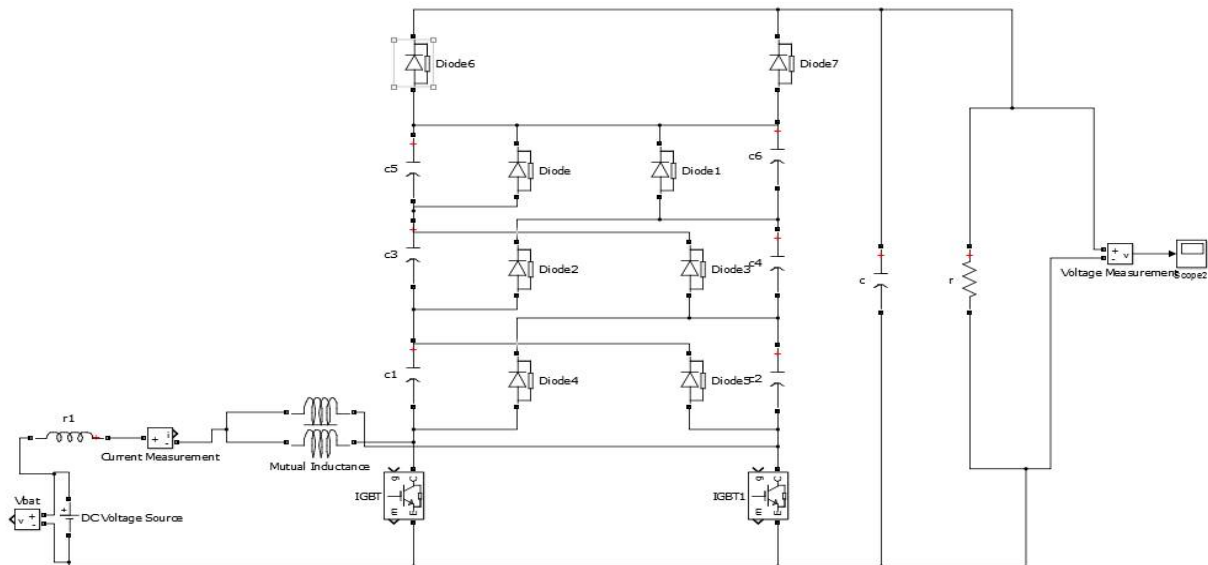


Fig. 1 DC-DC Converter Based on SSC and VMC

Three state switching cell and voltage multiplier cell is interleaved into the boost converter. Three state switching cell consist of two diodes, coupled inductor and two MOSFETs. Voltage multiplier cell consist of diodes and capacitors connected in parallel. The 3SSC and VMC can be interleaved into main circuit without disturbing the main circuit. A n number of voltage multiplier cell can be added to the circuit according to the requirement of voltage. Fig.1 shows the dc-dc converter based on ssc and vmc.

#### IV. MODES OF OPERATION

In order to better understand the operating principle of the structures, the following assumptions are made:

- The input voltage is lower than the output voltage
- Steady-state operation is considered
- Semiconductors and magnetics are ideals
- Switching frequency is constant
- The turns ratio of the autotransformer is unity
- The drive signals applied to the switches are 180

In mode 1 , switches  $S_1$  and  $S_2$  are turned ON, all diodes are reverse biased. Energy is stored in inductor L and there is no energy transfer to the load. The output capacitor provides energy to the load. This stage finishes

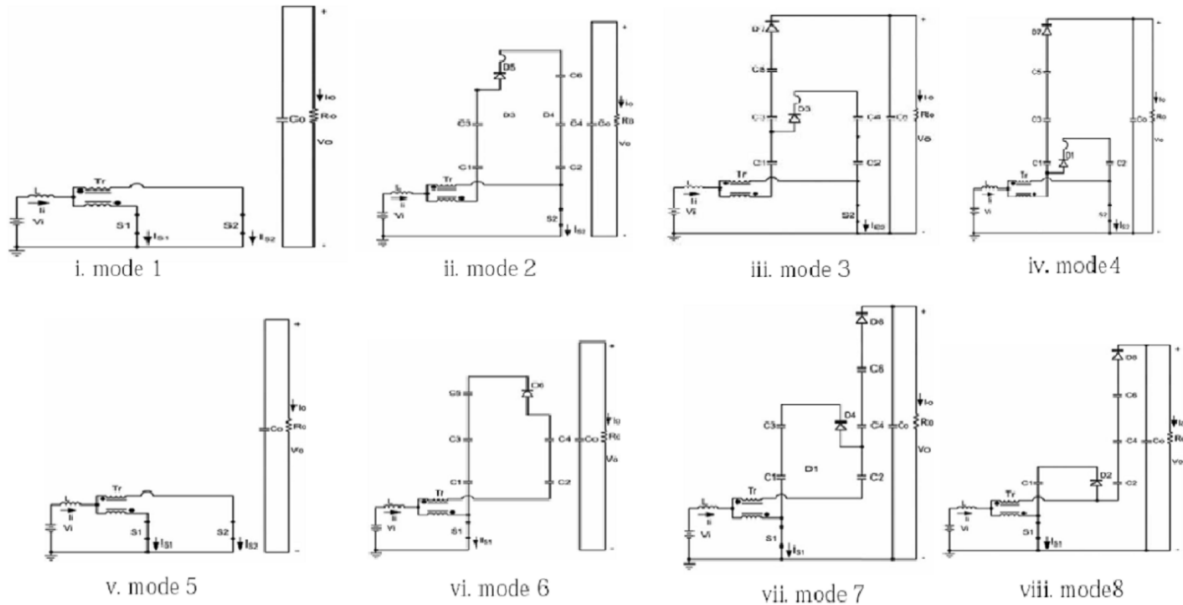


Fig. 2 Modes of Operation of DC-DC Converter Based on SSC and VMC

when switch  $S_1$  is turned OFF. In mode 2, switch  $S_1$  is turned OFF, while  $S_2$  is still turned ON and diode  $D_5$  is forward biased. There is no energy transfer to the load as well. Inductor  $L$  stores energy, capacitors  $C_1$  and  $C_3$  are discharged, and capacitors  $C_2$ ,  $C_4$ , and  $C_6$  are charged. In mode 3, switches  $S_1$  and  $S_2$  remain turned OFF and ON, respectively. Diodes  $D_3$  and  $D_7$  are forward biased, while all the remaining ones are reverse biased. Energy is transferred to the output stage through  $D_7$ . The inductor stores energy, and capacitors  $C_2$  and  $C_4$  are still charged. Capacitors  $C_1$  is discharged, and so are  $C_3$  and  $C_5$ . In mode 4, switch  $S_2$  remains turned ON, diode  $D_3$  is reverse biased, and diode  $D_1$  is forward biased. Energy is transferred to the load through  $D_7$ . The inductor is discharged, and so are capacitors  $C_1$ ,  $C_3$  and  $C_5$ , while  $C_2$  is charged. Mode 5, this stage is identical to the first one. Switch  $S_2$  is turned OFF and switch  $S_1$  is still turned ON. Diode  $D_6$  is forward biased. The inductor is charged by the input source, although capacitors  $C_2$  and  $C_4$  are discharged instead. In mode 6 switch  $S_2$  is turned OFF and switch  $S_1$  is still turned ON. Diode  $D_6$  is forward biased. The inductor is charged by the input source, although capacitors  $C_2$  and  $C_4$  are discharged instead. Mode 7 is similar to mode 3. In mode 8 switch  $S_1$  is turned ON, while  $S_2$  remains turned OFF. Diodes  $D_2$  and  $D_8$  are forward biased, while  $D_4$  is reverse biased as well as the remaining diodes. Energy transfer to the load occurs through  $D_8$ , and capacitor  $C_0$  is still charged. The inductor is discharged, while capacitor  $C_1$  is charged and capacitors  $C_2$ ,  $C_4$ , and  $C_6$  are discharged.

## V. SIMULATION MODEL AND RESULTS

DC-DC converter based on SSC and converter based on SSC and VMC cells are done by using MATLAB/SIMULINK R2010a. Simulation parameters of the converter are : The output power ( $P_o$ )=1000W, Min. input voltage( $V_{min}$ )=42V, Max. input voltage( $V_{max}$ )=54V, Rated input voltage( $V_i$ )=48V, Output voltage( $V_o$ )=400V, No. of multiplier cells( $mc$ )=3, Switching frequency( $f_s$ )=25kHz

In order to validate the converter based on ssc, an experimental prototype whose ratings are given above were implemented. Poor efficiency is expected in this case if the classical boost converter is employed. The non isolated topology is adequate for high voltage gain applications. The gain can be further increased as necessary. Some experimental waveforms are presented. The fig.3 shows the experimental waveforms of the boost converter based on ssc.

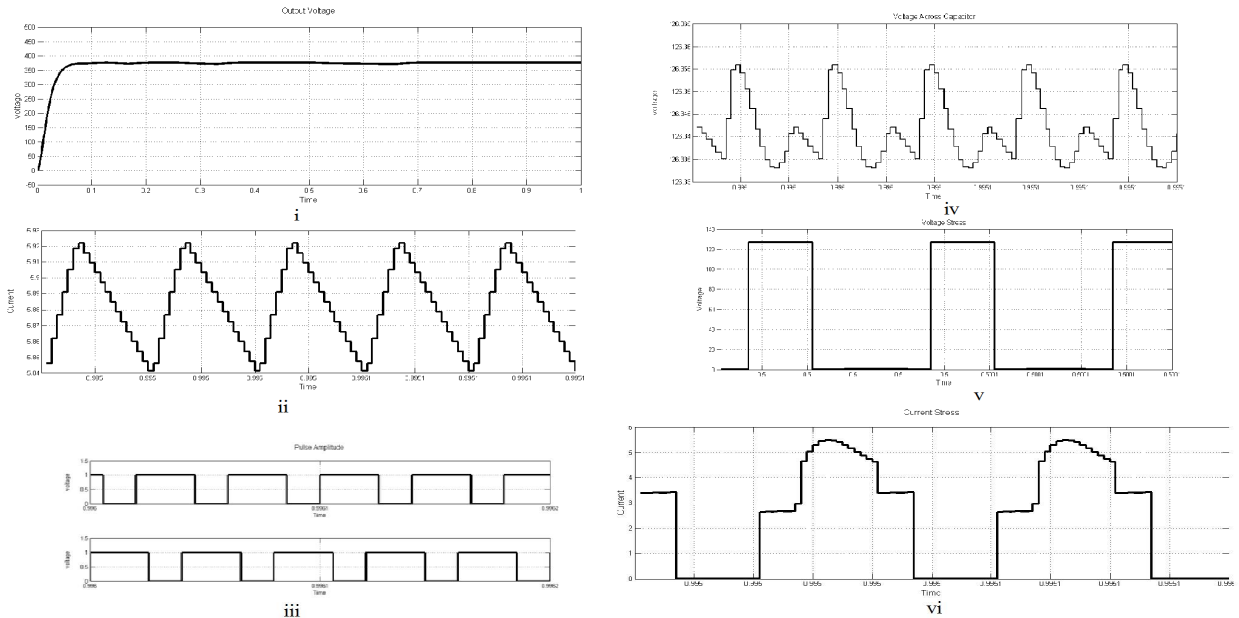


Fig. 3 i. Output Voltage of Converter based on SSC ii. Input Inductor Current iii. Gate pulses to switches iv. Voltage across capacitor v. Voltage stress across Switch 2 vi. Current stress of switch

The output of the converter based on ssc is shown in fig. 3.i. Gate pulses to the switches are shown in fig. 3.iii. Current waveform of input inductor is shown in fig. 3.ii. Voltage waveforms of capacitor and switch is shown in fig. 3.iv and fig. 3.v respectively. The voltage across switch is lower than half of the output voltage, allowing the use of MOSFETs with reduced ON-resistance. Fig. 3.vi shows the current waveform of switch. Good current sharing is seen.

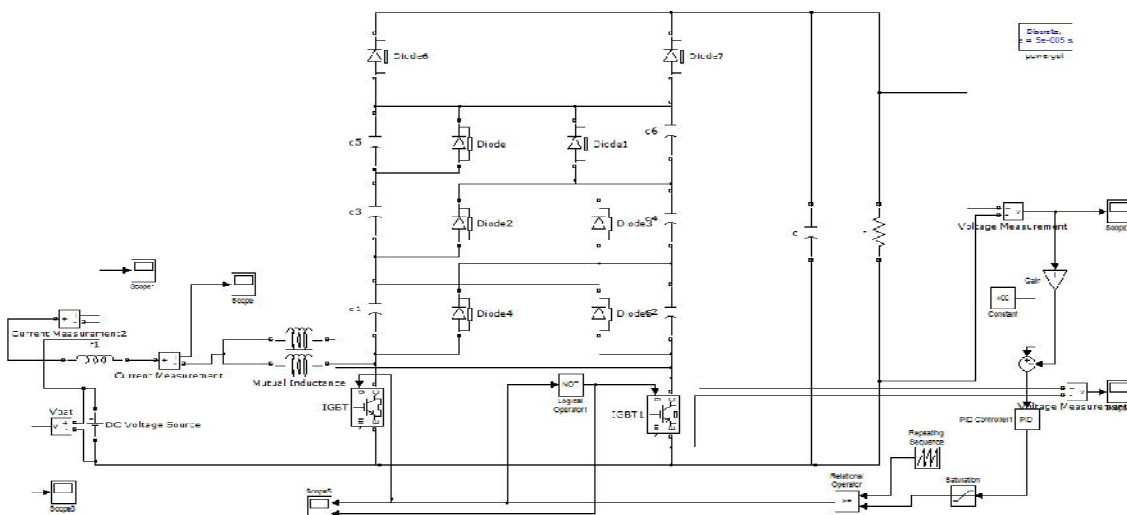


Fig.4 Simulation Diagram for Closed Loop

Figure 1 shows the simulation circuit of high voltage gain dc-dc converters based on 3 SSC and VMC. It can be done in open loop and closed loop.

**Open Loop :** SIMULINK model of the converter based on SSC and VMC is based on fig.1. Pulse generating circuit required is of less complexity as there is only 2 switches. PWM is shown as a subsystem in the SIMULINK MODEL. Output voltage values are verified from display icons and scope.

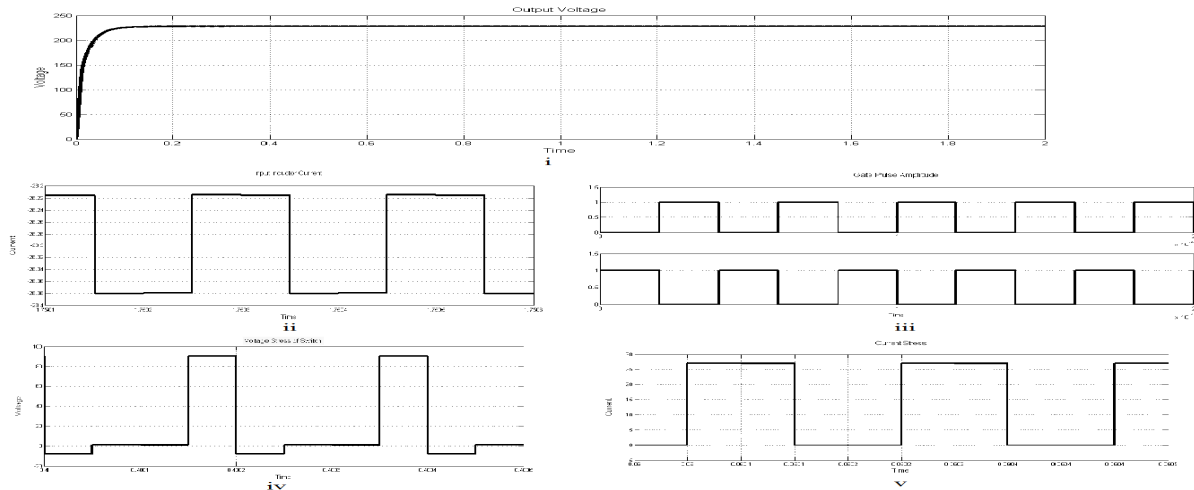


Fig. 5. i. Output Voltage for Open Loop ii. Input Inductor Current for Open Loop iii. Pulses for Switches - Open Loop iv. Voltage Stress across Switch 2 - Open Loop v. Current Stress across Switch 2 - Open Loop

The fig.1 shows the simulation diagram for the proposed boost converter based on 3 SSC and VMC. In this simulation switches  $S_1$  and  $S_2$  are taken as MOSFETs and then VMC can go to add the voltage levels at three stages and it produce the output voltage. We are giving the input voltage as 42V-54V based on the specifications. The fig.5.i shows the output DC voltage of the boost converter based on 3SSC and VMC in the open loop circuit. Other experimental waveforms are also presented in fig.5. The switching pulses for the switches is shown in fig.5.iii. The fig. 5.ii shows the input inductor current waveform. Fig. 5.iv and fig. 5.v shows the voltage and current waveforms for converter with ssc and vmc in open loop. The voltage stress is reduced.

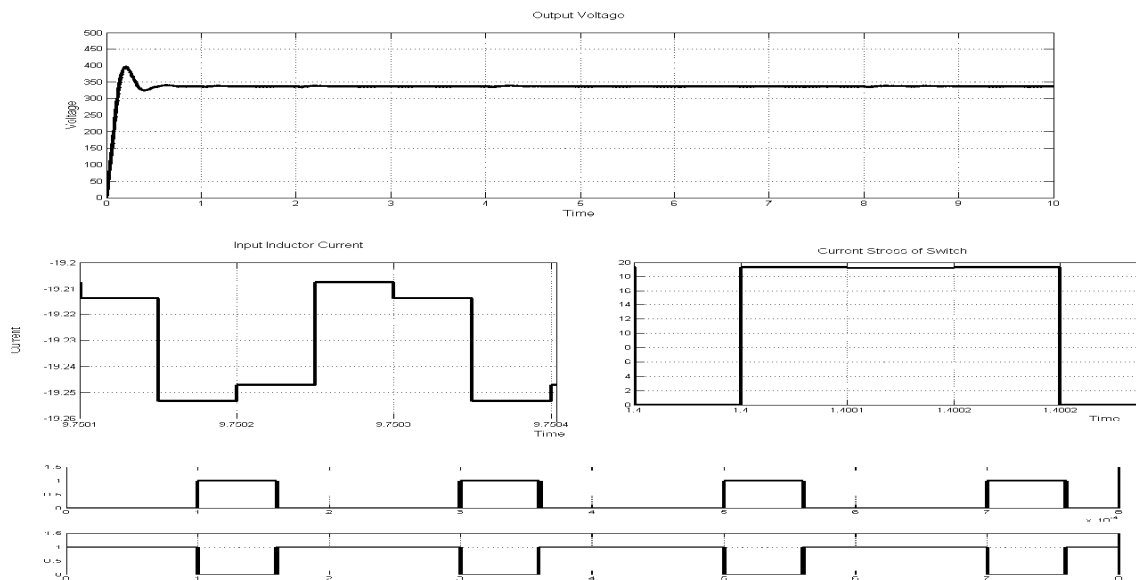


Fig. 6 i. Output Voltage for Closed Loop ii. Input Inductor Current for Closed Loop iii. Current Stress of Switch iv. Pulses for Switches - Closed Loop

**Closed Loop :** The fig.4 shows the closed loop circuit diagram of the proposed converter of the 3SSC and VMC by placing the PID controllers across the switches  $S_1$  and  $S_2$  of the boost converter and we are giving the source as 48V then we are getting the output. Output voltage waveform is presented in fig.6.i. Other experimental results are also



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shown. The current waveforms of the inductor and converter switches are shown in fig. 6.ii and fig.6.iii. respectively. The switching signals for switches S1 and S2 are shown in fig. 6.iv.

## VI. CONCLUSIONS

To verify the principle operation of the generated structures, the boost converter was chosen. The topology is adequate for several applications such as photovoltaic systems, fuel cell systems, and UPSs, where high voltage gain between the input and output voltages are demanded. An important characteristic that can be seen in the experimental results is the reduced blocking voltages across the controlled switches compared to similar circuits, allowing the utilization of MOSFETs with reduced on resistance. The voltage stress can further be reduced by using SSCs and VMCs together. And it has reduced ripple. A number of Voltage Multiplier Cells can be added to the circuit according to voltage requirement without disturbing the main circuit. Besides, the advantages of the 3SSC are also incorporated into the resulting topology. The current is distributed among the semiconductors. It is simple to conclude that this paper introduces a simple Soft-Switched technique circuit with the High Step-up DC-DC Converter. It is simulated with R-Load. The following are advantages: The turn-on and turn-off the components are reduced due to Soft Switching technique employed. Voltage Conversion Ratio is almost doubled compared to the conventional boost converter. The duty cycle loss is much reduced resulting in the increased step-up ratio. This method can be applied for all type of converters like BUK, BOOST, BUKBOOST, CUK, SEPIC ZETA. Moreover, the voltage stress regarding the active switches is low, it allows the use of lower cost switches and consequently high efficiency.

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