Advanced DC-DC Converter Topologies to Boost the Voltage Gain for High Voltage Applications

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Advanced DC-DC Converter Topologies to Boost the Voltage Gain for High Voltage Applications

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Abstract

High-gain dc-dc converter is used in renewable energy systems, electric vehicles, power supply applications, etc. Presently various types of dc to dc converters are invented which have several advantages and drawbacks. Two advanced topologies of high-voltage dc-dc converters are proposed in this paper. In both topologies, the high-voltage gain comes true by cascading voltage multiplier cells. Both proposed converters have only one switch and inductor, which reduces the design complexity and cost. Both converters have less voltage stress which increases their efficiency. The first proposed converter has more voltage gain than the second converter and the overall voltage gain of both converters is much higher than the conventional dc-dc step-up converters. By taking 10 voltage multiplier cells and 0.5 duty ratio, the output voltage of first converter is 960v for 12V input voltage, and for 0.25 duty ratio and the same number of voltage multiplier cells, the second converter output voltage is 480V for the same input voltage. To confirm and validate of the proposed converters, matlab simulation software is used. The operating principle and the design considerations under continuous conduction mode are described.

Keywords: High gain converters, DC-DC converter, Boost converter, Renewable energy applications, Voltage gain enhancement, Advanced control techniques

1 Introduction

In recent years, renewable energy systems, i.e., photovoltaic[1][2], fuel cell electric vehicle systems[3], super capacitor power conversion systems[4] are used widely instead of conventional energy and fuel to reduce pollution and fearing the depletion of fuel reserves. But the output voltage of a photovoltaic cell, fuel cell stacks, and supercapacitors are not high enough[5][6][7]. And power electronics play an important role in such low-voltage cases[8]. The converter is the main part of power electronics[9] which can step up or step down the voltage. The step-up converter is needed for high-voltage applications that can increase the voltage gain[10]. The conventional dc-dc converter is divided into two parts that are the isolated and non-isolated converter. The converter where input and output section are not separated is called non-isolated converter[11] such as buck converter, boost converter, sepic converter, etc[12][13]. For conventional boost converters like boost[14], buck-boost[15], cuk[16], zeta[17], sepic[16], etc can increase the voltage gain[18] but in the limited range which can not be usable for high voltage applications[19]. Therefore to overcome the limited voltage gain, different kinds of transformer-less high voltage gain (HVG) step-up converters have been proposed[20]. These converters are based on the traditional boost converters. These converters can be categorized as 3-state switching-based boost converters, active network-based boost converters, 3-level-based boost converters, switched capacitor-based boost converters, coupled inductor-based boost converters, cascaded-based boost converters, switched inductor-based boost converters, multiport-based boost converters, and interleaved-based boost converters[21]. Transformer-less converters have high voltage gain and can be used in microgrid and high voltage applications[22]. But the transformer-less converters have voltage regulation and fluctuation problems as more passive elements and switches are used[23]. To surmount this issue non-isolated step-up with an extendable voltage gain converter is introduced[24][25]. By modifying this converter, the cascaded boost converter is introduced[26][27][28]. Cascading is nothing but the repetition of the same circuit to meet up the desired output voltage gain. Cascading the boost converter makes the circuit bulky and a huge number of switches and passive elements are needed that can increase the voltage stress[29]. To outsmart this difficulty multiport based boost converter has come[30][31][32]. Multiport converters have multiple input and output ports that can interface multiple energy sources and load simultaneously. But it has low efficiency and control challenges[33]. Hence super lift voltage converter and modified voltage lift converter are introduced in recent studies [34][35][36]. In super lift voltage converter and modified voltage lift converter, voltage increase step by step along the geometric progression[37]. In fact, based on these topologies, boost derived MIESC SC-cell converter and buck-boost derived MIESC SC-cell converter are introduced as the very high-gain converter[38]. This converter has a high voltage gain rather than other dc-dc converters. But they faces efficiency challenges due to its design intricacies and increased system complexity. Then switched capacitor-based boost converters with n times voltage gain ushered in the era of cascading[39][40]. This creates an evaluation in dc-dc converter. However, switched capacitor-based converters introduce design complexity with an increased number of passive elements. Interleaved boost converters have also higher voltage gain that is introduced in[41][42]. Conventional interleaved boost converter[43], interleaved boost converter with voltage multiplier[44][45][46], and zero voltage switching (ZVS) interleaved boost converters[47][48] are some interleaved converters that are introduced in[49][50][51]. So the major problem of each topology is the limited voltage gain and additional switches are used to improve the voltage gain that increases the switching loss and cost. The high-voltage gain converter topologies that are proposed have been made up of a combined conventional doubler and boost circuit by cascading voltage multiplier cell (VMC) and a conventional switch boost converter by cascading VMC. These two topologies voltage gain is much higher than the conventional converter. The attractive features of the proposed topologies are:

1. Voltage gain can be varied by changing the number of VMC.

2. By using the same parameters and 10 cascading cells, the voltage gain of the DB_VMC is 20 times higher and the SB_VMC is 10 times greater than the conventional boost converter and double than the cascaded converter.

3. In most of the high-voltage gain converters, more inductor cores are used which can increase the ripple and cost but the proposed topologies need only 1 inductor and switch that is cost-effective.

4. The proposed converter has high voltage gain that can easily be used in the micro-grid, renewable energy applications, electric vehicles applications, and supercapacitor power conversion systems.

The proposed dc-dc topologies have been tested in matlab simulation software.

2 Proposed Topologies

We propose two different topologies. The first one is doubler boost converter with cascading voltage multiplier cell (DB_VMC) and the second one is switch boost converter with cascading voltage multiplier cell (SB_VMC). The basic structures of the proposed topologies are described in the following sections.

2.1 Proposed DB_VMC Topology

The DB_VMC of the proposed converter is shown in figure 4. Here doubler boost converter is used as the root converter that is shown in figure 1. The voltage multiplier cells are cascaded upon it to gain high voltage output and this flowchart is shown in figure 3. A doubler boost (DB) converter is a dc-dc converter where the boost converter and voltage doubler circuit form a new converter. In the DB converter, two capacitors, one bidirectional power switch, and one inductor are used. A VMC is a network of capacitors and diodes that can make the input voltage twice in output. The schematic diagram of doubler boost converter with cascading VMC is given in figure 3. The input voltage will boost the DB converter and this boosted voltage will make twice in every section of VMC. So the total output voltage will depend on the number of VMC is used.

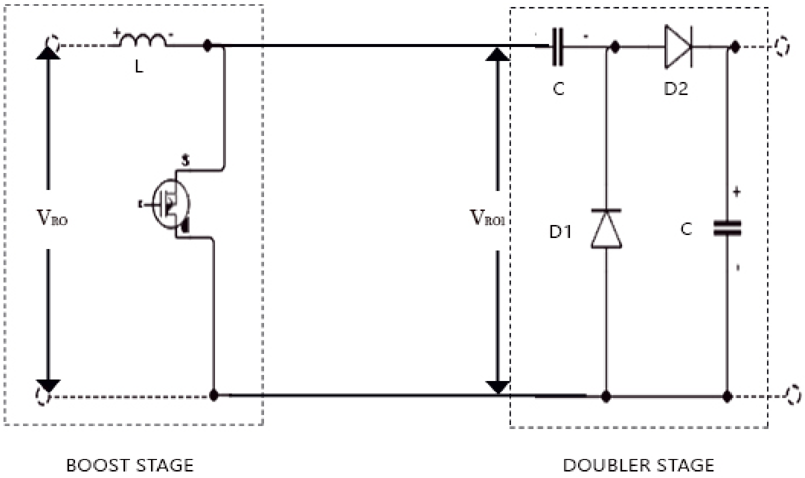

Fig. 1 Doubler boost converter.

2.2 Proposed SB_VMC Topology

The proposed SB_VMC is shown in figure 6. This topology is based on switch boost (SB) converter[52] thai is shown in figure 2. The SB converter is a step up dc-dc converter where 1 bidirectional power switch, 2 capacitors, 1 inductor and 2 diodes are used. Here, two passive elements are used, and the VMC is cascaded upon it, as described above. In an SB converter with cascading VMC, C_f capacitor is used as a filter that can reduce the voltage ripple. The SB converter boost the input voltage and the output voltage of SB converter will act as the input of first VMC and it makes the voltage twice and it will continue till the last VMC. The schematic diagram of SB converter with cascading VMC is given in figure 5.

3 Principle of Operation

The operation principle refers to the opertion of input stage, shoot through stage, non shoot through stage, and the output stage of the converter. Each and every sections of the proposed two topologies are elaborated upon below.

3.1 Operation Principle of DB_VMC Topology

The base converter of DB_VMC is the DB converter which is shown in figure 1. The total operation of the DB converter is divided into two parts. This is shoot-through state and non-shoot-through state. In shoot through state, the switch will be on and all diodes will act as open. Switch and diodes are mutually excluded. In non-shoot-through state, the switch will be off and all diodes will on. At 0 - T_{on}, the converter will run on the shoot-through state, and at T_{on} - T, the converter will run on the

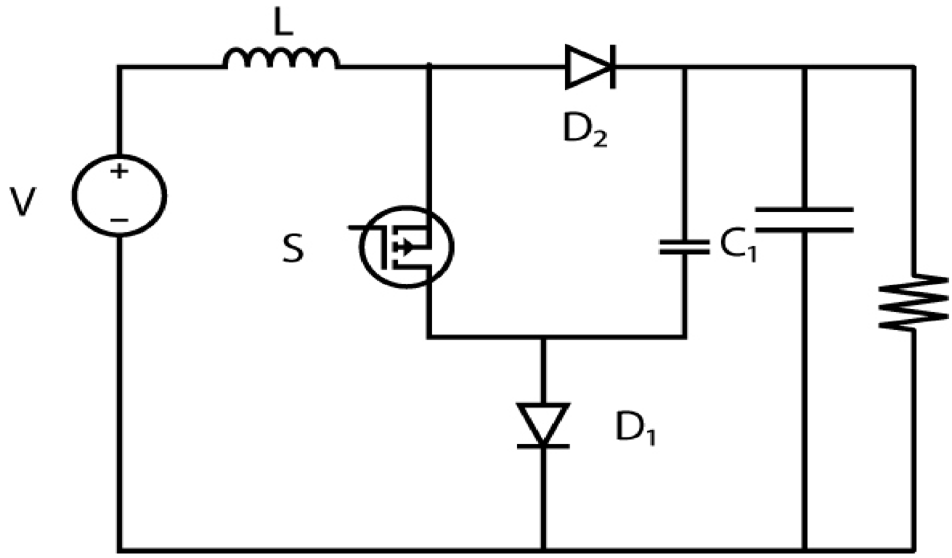

Fig. 2 Switch boost converter.[52]

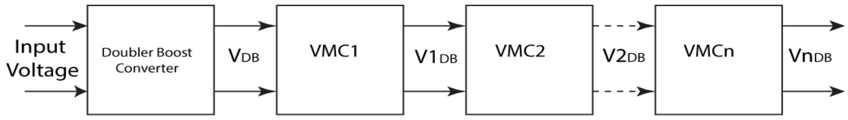

Fig. 3 Schematic diagram of doubler boost converter with cascading VMC.

non-shoot-through state. At 0 - T_{on}, applying KVL in figure 1,

$$V_{ro} - V_L = 0 \tag{1}$$

$$V_{ro} = V_L \tag{2}$$

At T_{on} - T,

$$V_{ro} - V_L - V_{ro1} = 0 \tag{3}$$

$$V_L = V_{ro} - V_{ro1} \tag{4}$$

Where V_{ro} is the input voltage and V_{ro1} is the output voltage of boost stage that acts as the input voltage of doubler circuit. The doubler circuit makes the input voltage twice in output.

$$V_{out} = 2V_{ro1} \tag{5}$$

$$V_{ro1} = \frac{V_{out}}{2} \tag{6}$$

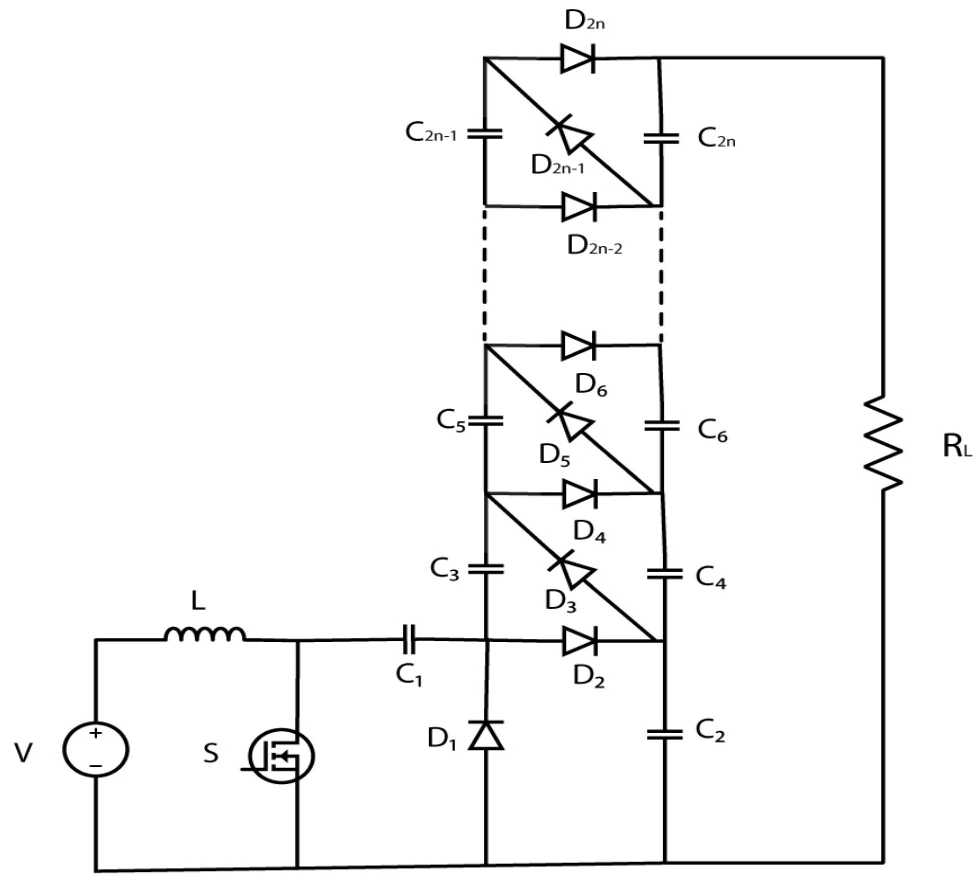

Fig. 4 Doubler boost converter with cascading VMC.

Substituting the value of V_{ro1} in equation 4.

$$V_L = V_{ro} - \frac{V_{out}}{2} \tag{7}$$

As $\int_0^T V_L = 0$.

$$\int_0^{T_{on}} V_L dt + \int_{T_{on}}^{T} V_L dt = 0 \tag{8}$$

$$\int_0^{T_{on}} V_{ro} dt + \int_{T_{on}}^{T} (V_{ro} - \frac{V_{out}}{2}) dt = 0 \tag{9}$$

$$V_{in}T_{on} + (V_{in} - \frac{V_{out}}{2})(T - T_{on}) = 0 \tag{10}$$

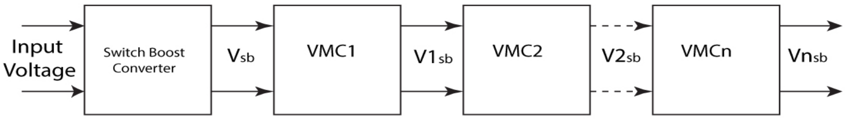

Fig. 5 Schematic diagram of switch boost converter with cascading VMC.

We define, D=T_{on}/T, where, D is the duty ratio. The duty ratio is expressed as the percentage of ON time.

$$V_{ro}DT + (V_{ro} - \frac{V_{out}}{2})(1-D) = 0 \tag{11}$$

$$V_{out} = \frac{2V_{ro}}{1-D} \tag{12}$$

$$V_L = L\frac{di}{dt} \tag{13}$$

$$I_L = \frac{1}{L}\int V_L dt \tag{14}$$

At shoot-through state

$$I_L = \frac{1}{L}\int_0^{T_{on}} V_{ro}dt \tag{15}$$

$$I_L = \frac{V_{ro}}{L}T_{on} + C \tag{16}$$

At non-shoot-through state

$$I_L = \frac{1}{L}\int_T^{T_{on}} (V_{ro} - \frac{V_{out}}{2})dt \tag{17}$$

$$I_L = \frac{1}{L}(V_{ro} - \frac{V_{out}}{2})(T - T_{on}) + C \tag{18}$$

From figure 7, at 0-T_{on}, as the switch is on, no current flows through the output portion. At T_{on}-T, the switch is off, and current flows through the output.

$$I_{out} = \frac{(1-D)I_{in}}{2} \tag{19}$$

Now by cascading VMC, If single VMC is cascading them total V_{out} is

$$V_{out1} = 2 * \frac{2V_{ro}}{1-D} \tag{20}$$

$$V_{out1} = 2V_{out} \tag{21}$$

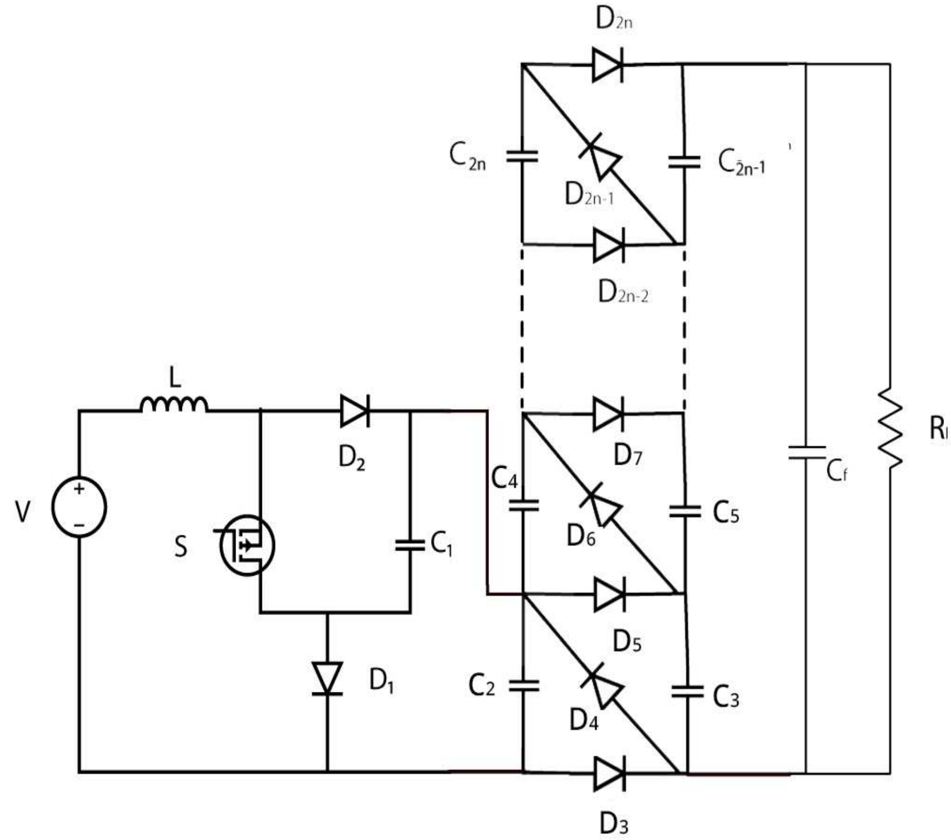

Fig. 6 Switch boost converter with cascading VMC.

If 2-stage VMC are cascading then

$$V_{out2} = 4 * \frac{2V_{ro}}{1-D} \tag{22}$$

$$V_{out2} = 4V_{out} \tag{23}$$

Similarly, if n- stage VMC are cascading then the total output voltage will

$$V_{outn} = 2n * \frac{2V_{ro}}{1-D} \tag{24}$$

$$V_{outn} = 2n * V_{out} \tag{25}$$

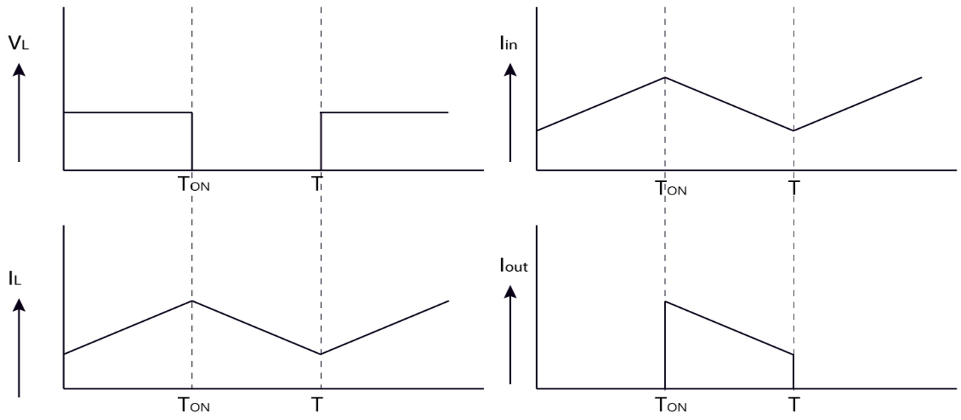

Fig. 7 Inductor voltage V_L, inductor current I_L, input current I_{in} and output current I_{out} of DB converter.

3.2 Operation Principle of SB_VMC Topology

The SB_VMC is SB converter-based. The total operation of the SB converter is divided into shoot-through and non-shoot-through state that is already described above. At 0-T_{on}, applying KVL in figure 2,

$$V_{in} - V_L - V_C - V_{out} = 0 \tag{26}$$

$$V_L = V_{in} - V_C - V_{out} \tag{27}$$

At T_{on} - T,

$$V_{in} - V_L - V_{out} = 0 \tag{28}$$

$$V_L = V_{in} - V_{out} \tag{29}$$

Now,

$$\int V_L = 0 \tag{30}$$

$$\int_{T_{on}}^{0} (V_{in} - V_c - V_{out})dt + \int_{T}^{T_{on}} (V_{in} - V_{out})dt = 0 \tag{31}$$

By solving equation 31,

$$V_{out} = \frac{V_{in}}{1 - 2D} \tag{32}$$

Now

$$I_L = \frac{1}{L} \int V_L dt \tag{33}$$

$$I_L = \frac{1}{L}(V_{in} - V_c - V_{out})T_{on} \tag{34}$$

At T_{on} - T,

$$I_L = \frac{1}{L}\int_{T}^{T_{on}} (V_{in} - V_{out})dt \tag{35}$$

$$I_L = \frac{1}{L}(V_{in} - V_{out})(T - T_{on}) \tag{36}$$

When the input and output power are the same then we get

$$P_{in} = P_{out} \tag{37}$$

$$V_{in}I_{in} = V_{out}I_{out} \tag{38}$$

$$I_{out} = \frac{V_{in}}{V_{out}}I_{in} \tag{39}$$

$$I_{out} = V_{in}\frac{1-2D}{V_{in}}I_{in} \tag{40}$$

$$I_{out} = (1-2D)I_{in} \tag{41}$$

Now by cascading the VMC, If 1 VMC is cascading then total V_{out} is

$$V_{out1} = 2 * \frac{V_{in}}{1-2D} \tag{42}$$

$$V_{out1} = 2V_{out} \tag{43}$$

If 2 VMC is cascading then

$$V_{out2} = 4 * \frac{V_{in}}{1-2D} \tag{44}$$

$$V_{out2} = 4V_{out} \tag{45}$$

Similarly, if n VMC is cascading then the total output voltage will

$$V_{outn} = 2n * \frac{V_{in}}{1-2D} \tag{46}$$

$$V_{outn} = 2n * V_{out} \tag{47}$$

4 Design Considerations

The design should be considered according to the continuous conduction mode (CCM). The CCM is a mode where the inductor will not discharge completely before the switch is changed state from T_{OFF} to T_{ON}. So inductor value should be determined by considering CCM to make the inductor current continuous. Otherwise, the discontinuous inductor current can increase the ripple and noise at output. From figure 8,

$$I_{Lmax} = I_L + \frac{1}{2}\Delta I_L \tag{48}$$

$$I_{Lmin} = I_L - \frac{1}{2}\Delta I_L \tag{49}$$

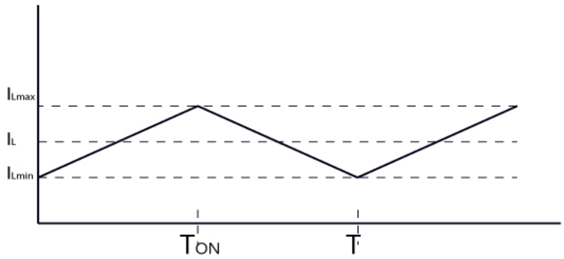

Fig. 8 Inductor current at CCM.

where $\Delta I_L = I_{Lmax} - I_{Lmin}$ at the boundary condition of CCM,

$$I_{Lmin} = 0 \tag{50}$$

$$I_L - \frac{1}{2}\Delta I_L = 0 \tag{51}$$

$$I_L = \frac{1}{2}\Delta I_L \tag{52}$$

4.1 Design consideration for DB_VMC Topology

The general equation of the straight line is y=mx+c where m is the slope. From equation 16, at 0 - T_{on}, m= $\frac{V_{ro}}{L}$ The formula of m is

$$m = \frac{y2 - y1}{x2 - x1} \tag{53}$$

Substituting the value of m, y2-y1, and x2-x1,

$$\frac{V_{in}}{L} = \frac{\Delta I_L}{T_{on}} \tag{54}$$

$$\Delta I_L = \frac{V_{in}}{L} T_{on} \tag{55}$$

Substituting the value of ΔI_L in equation 52

$$I_L = \frac{1}{2}\frac{T_{on}}{L} \tag{56}$$

$$I_L = I_{in} \tag{57}$$

$$I_{in} = \frac{1}{2}\frac{T_{on}}{L} \tag{58}$$

$$\frac{2}{1-D} I_{out} = \frac{TD}{2L} * \frac{1-D}{2} V_{out} \tag{59}$$

$$\frac{2}{1-D}\frac{V_{out}}{R} = \frac{TD}{2L} * \frac{1-D}{2} V_{out} \tag{60}$$

$$L = \frac{TD(1-D)^2R}{8} \tag{61}$$

$$L = \frac{D(1-D)^2R}{8f} \tag{62}$$

This L is the minimum value of the inductor to satisfy the condition of CCM. Now the equation of the capacitor current is

$$C\frac{\mathrm{d}V_c}{\mathrm{d}t} = I_C \tag{63}$$

$$I_C = I_0 \tag{64}$$

$$\frac{V_0}{R} = C\frac{\mathrm{d}V_c}{\mathrm{d}t} \tag{65}$$

$$C = \frac{V_0DT}{R\Delta V_C} \tag{66}$$

$$C = \frac{DT}{R\frac{\Delta V_C}{V_0}} \tag{67}$$

$$C = \frac{D}{RfZ} \tag{68}$$

where, Z= $\frac{\Delta V_C}{V_0}$ = ripple factor

4.2 Design consideration for SB_VMC Topology

From equation 52, we can write,

$$I_L = \frac{1}{2\Delta}I_L \tag{69}$$

$$\Delta I_L = \frac{V_{in}T * 2D(1-D)}{L(1-2D)} \tag{70}$$

$$I_L = \frac{1}{2}\frac{V_{in}T * 2D(1-D)}{L(1-2D)} \tag{71}$$

$$I_L = I_0 \tag{72}$$

$$I_0 = \frac{(1-2D)V_{out}T * 2D(1-D)}{L(1-2D} \tag{73}$$

$$\frac{V_0}{R} = \frac{(1-2D)V_{out}T * 2D(1-D)}{L(1-2D)} \tag{74}$$

$$L = \frac{D(1-D)R}{f} \tag{75}$$

Here L is the minimum value of the inductor to stay the inductor current at CCM. Now capacitor current is

$$I_C = C\frac{\mathrm{d}V_c}{\mathrm{d}t} \tag{76}$$

$$\Delta V_C = \frac{I_CDT}{C} \tag{77}$$

$$C = \frac{I_C DT}{\Delta V_C} \tag{78}$$

$$I_C = I_{in} = \frac{V_{in}}{R} = \frac{(1-2D)V_{out}}{R} \tag{79}$$

$$C = \frac{(1-2D)V_{out}DT}{R\Delta V_C} \tag{80}$$

$$C = \frac{(1-2D)D}{Rf\frac{\Delta V_C}{V_{out}}} \tag{81}$$

$$C = \frac{(1-2D)D}{RfK} \tag{82}$$

where k= $\frac{\Delta V_C}{V_{out}}$ is the ripple factor

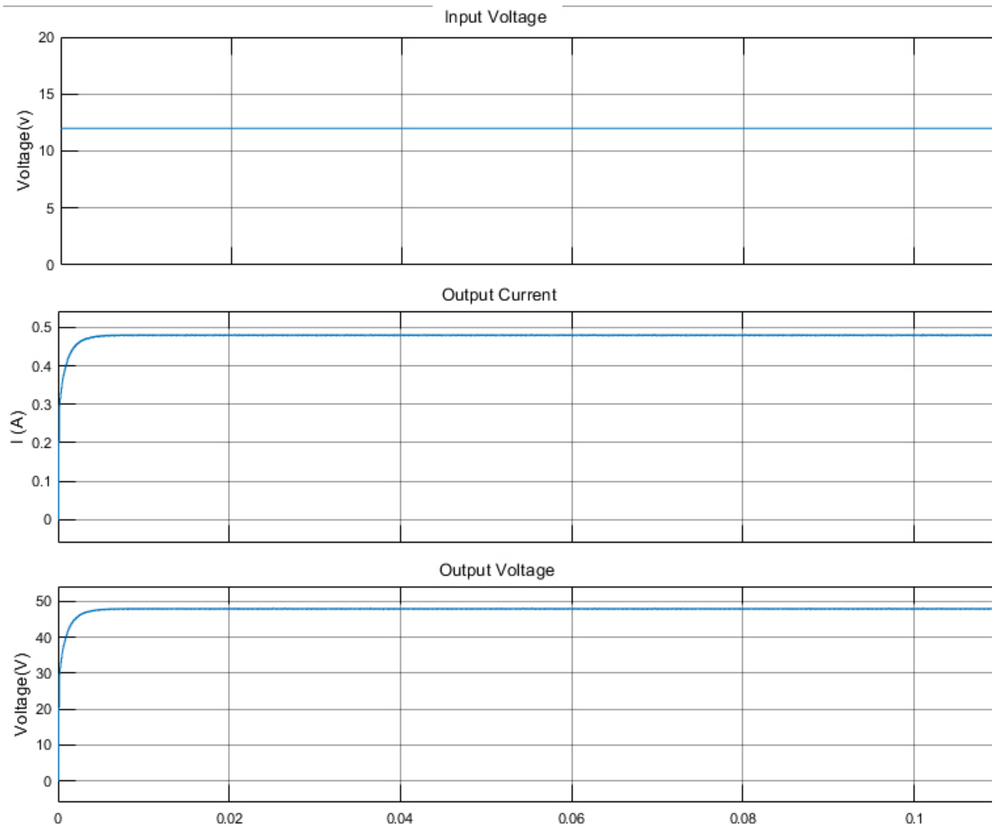

Fig. 9 Input, output voltage and current of DB converter.

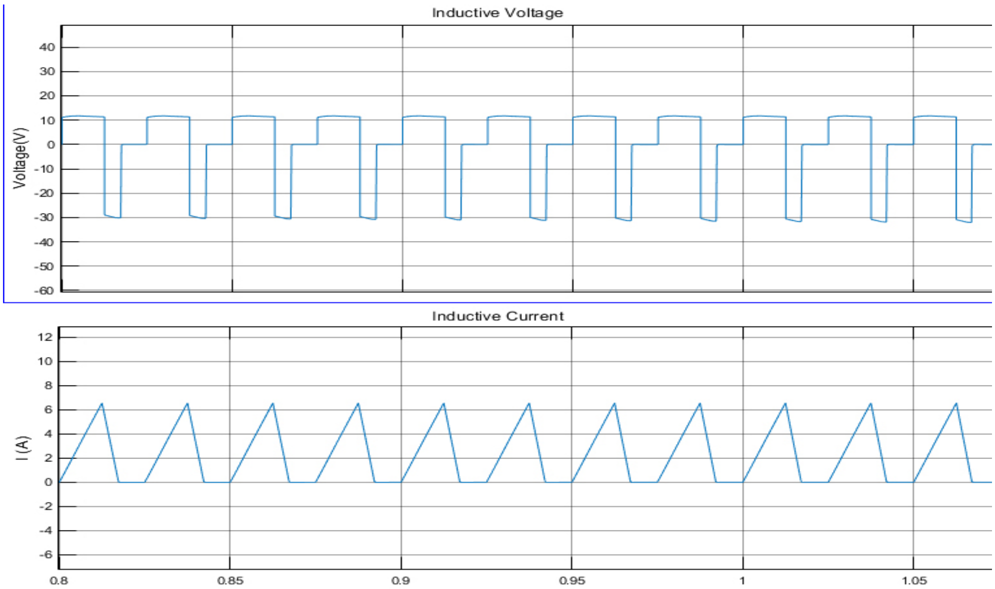

Fig. 10 Inductive voltage and current of DB converter.

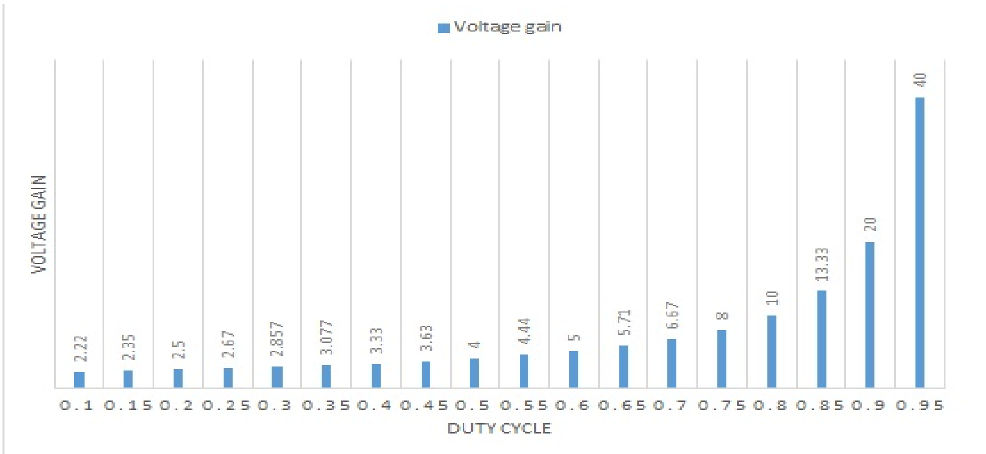

Fig. 11 Duty ratio vs voltage gain for DB converter.

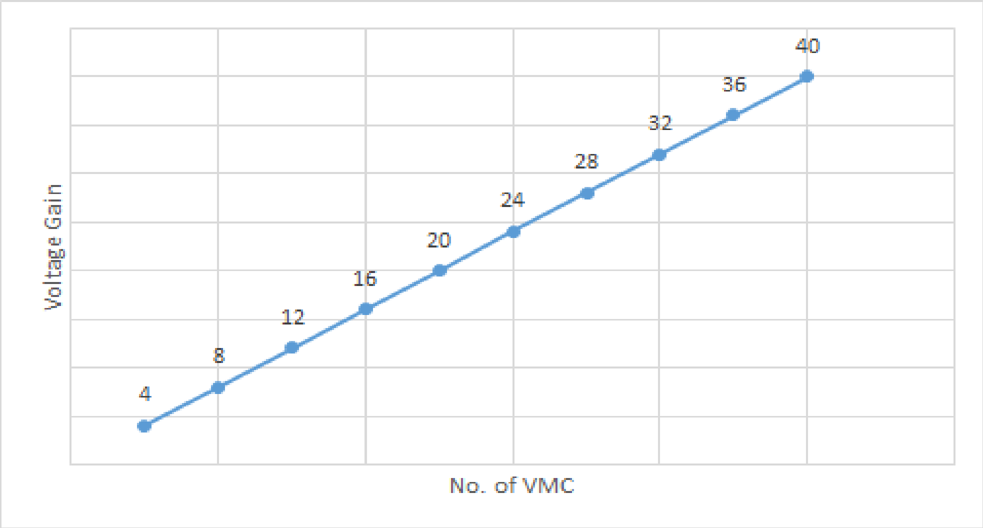

Fig. 12 No. of VMC vs voltage gain of DB converter by cascading VMC.

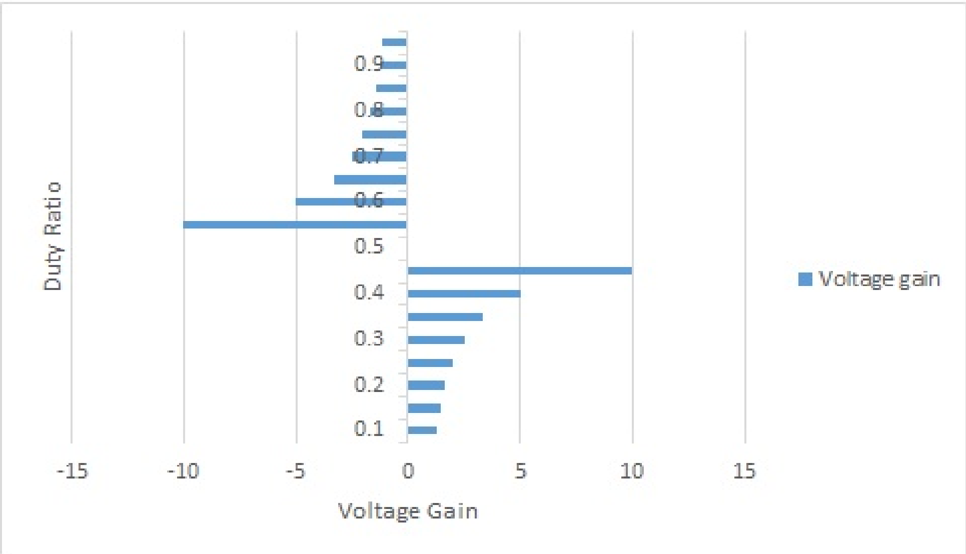

Fig. 13 Duty raio vs voltage gain for SB converter.

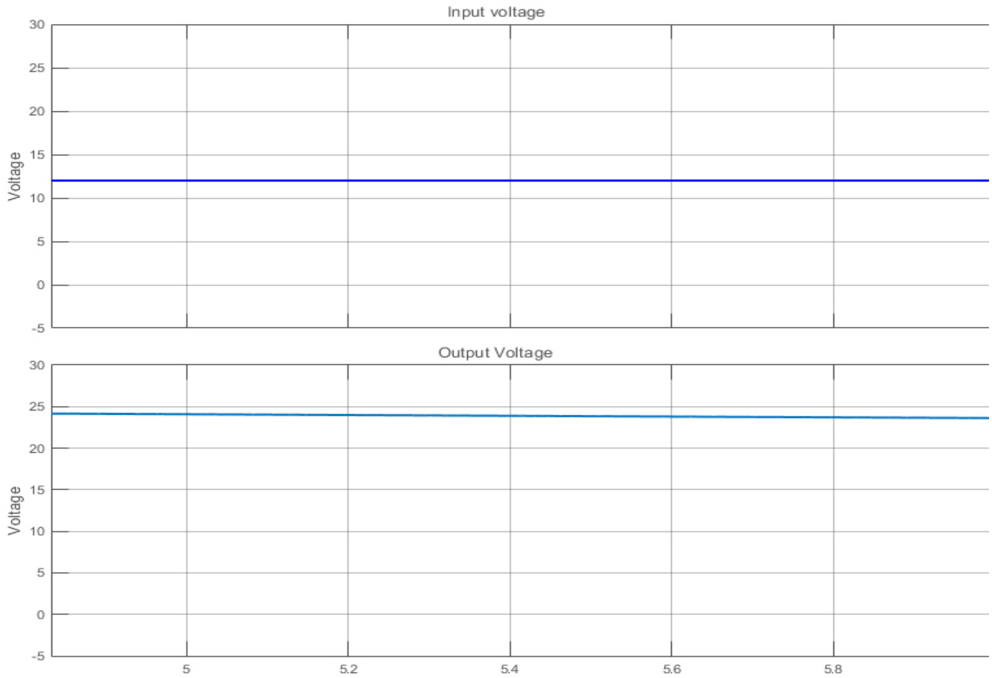

Fig. 14 Input and output voltage of SB converter.

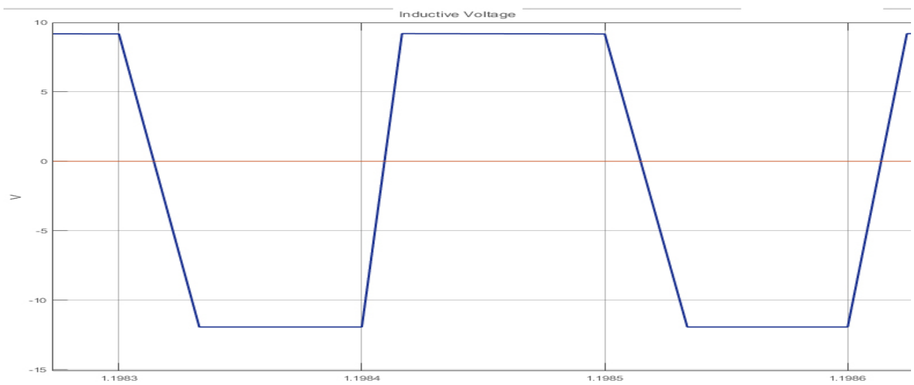

Fig. 15 Inductive voltage of SB converter.

5 Results and Discussion

We evaluated the performance of the proposed DB_VMC and SB_VMC topology in terms of voltage gain. By simulating the MATLAB simulation software we get the desirable data that are described in section 5.1 and 5.2.

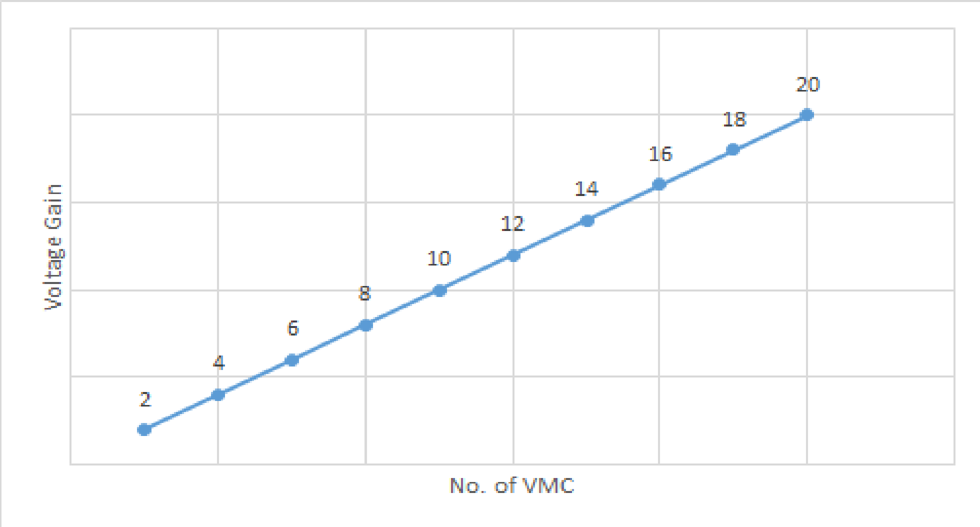

Fig. 16 No. of VMC vs voltage gain of SB converter by cascading VMC.

5.1 Result for DB_VMC Topology

DB_VMC is DB converter with cascading VMC. For the simulation setup, the input voltage is taken at 12V dc and switching frequency is 40KHz. From the equations 62 and 68, substituting the vaule of ripple factor of capacitance 1.56%, the value of l and c get 0.2198μH and 25μF. All the value of the parameters are listed in table 1. According the equation 12, taking the duty cycle 0.5, the theoretical value of output voltage without cascading VMC is 24V that is approximately same as the simulated value. Simulated value of input and output voltage is shown in figure 9. The inductor current get continuous is shown in figure 10. Now if duty ratio is varied the the output voltage also varied and this is shown in figure 11. From this figure, it is clear that increasing the value of D causes an increase in the magnitude of output voltage exponentially. Now if VMC is cascaded upon the DB converter then the theoretical calculation is given in equation 24. From the figure 12, an increase the number of VMC causes an increase in the output voltage linearly that fit with equation 24. Let the number of VMC is 10 then the output voltage will 80 times higher than the conventional DB converter. If 12v is taken as input then 960V is produced in the output section. So it is possible to get high voltage by cascading the required number of VMC.

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5.2 Result for SB_VMC Topology

SB_VMC is based on SB converter. Input voltage is taken at 12V dc. Duty ratio is captured at 0.25. The switching frequency is 5KHZ. Substituting the value of ripple factor, and frequency on equations 75 and 82, the value of L and C get 290μH and 3mF. The parameter value for the simulation setup is given table 1. The simulated output voltage of the SB converter without cascading is 24.4V shown in figure 14

Table 1 The parameter values for simulating DB_VMC and SB_VMC

Parameters Name	Value for DB_VMC	Value for SB_VMC
Input Supply Voltage	12V	12V
Duty ratio	0.5	0.25
Value of L	0.2198µH	290µH
Value of C	25F	3mF
Switching frequency	40KHZ	5KHZ
Ripple factor	0.32%	0.53%

Table 2 Duty ratio vs voltage gain of SB_VMC and DB_VMC

Duty ratio	Voltage gain for SB_VMC	Voltage gain for DB_VMC
0.1	1.25	2.22
0.15	1.42	2.35
0.2	1.67	2.5
0.25	2	2.67
0.3	2.5	2.857
0.35	3.33	3.077
0.4	5	3.33
0.45	10	3.63
0.5	∞	4
0.55	-10	4.44
0.6	-5	5
0.65	-3.33	5.71
0.7	-2.5	6.67
0.75	-2	8
0.8	-1.67	10
0.85	-1.42	13.33
0.9	-1.25	20
0.95	-1.11	40

which is similar to the theoretical value. Changing the duty ratio causes the change the output voltage. From figure 13, increasing the value of D causes increasing the magnitude of output voltage in range D<0.5. At D=0.5, the output voltage is infinite which is the major drawback of this converter. In the range of D>0.5 SB converter act as step down converter. So SB converter can be used as a step-up and step-down converter.The inductor voltage is also shown in figure 15 By cascading the VMC, the output voltage of SB converter can be increased that is shown in figure 16. Increasing the number of VMC triggers the increase of output voltage linearly. If number of VMC is taken 10 then the output voltage will increase 40 times greater than the conventional SB converter.If input is taken 12V then the output voltage will 480V for n=10.

5.3 Comparative analysis

The comparative analysis of the different types of dc-dc converters is given in table 3. The conventional boost converter voltage gain is 2 if 50% duty cycle is considered. That is not enough for high-voltage applications. Conventional three-level boost converter and single switch quadratic boost converter voltage gain is 4 which is better than conventional boost converter. Without cascading, the maximum voltage gain produce active-network-based dc-dc converter and hybrid boosting converter. But for

Table 3 Comparative analysis of different types of DC-DC converters. Here VG, D_r, #S, #D, #L, #C, #I/p,# O/P represent the number of Voltage Gain, Duty Ratio, number of switches, number of diodes, number of inductors, number of capacitors, Input tested voltage, output tested voltage, and N is considered 10, respectively.

Converters	VG	D_r	#S	#D	#L	#C	#I/P	#O/P
Conventional boost converter	$\frac{1}{1-D}$	0.5	1	1	1	1	12V	24V
Conventional three-level boost converter	$\frac{2}{1-D}$	0.5	2	2	1	2	12V	48V
Single switch quadratic boost converter	$(\frac{1}{1-D})^2$	0.5	1	3	2	2	12V	48V
Quadratic three-level boost converter	$\frac{1}{2(1-D)^2}$	0.5	2	4	2	3	12V	24V
SL boost converter	$\frac{1+D}{1-D}$	0.5	1	4	2	1	12V	36V
High step-up SL boost converter	$\frac{1+D}{1-D}$	0.5	2	1	2	1	12V	36V
Cuk derived converter	$\frac{2}{1-D}$	0.5	1	3	1	3	12V	48V
Active-network-based DC-DC converter	$\frac{1+3D}{1-D}$	0.5	2	7	4	1	12V	60V
Super-lift with Elementary Circuit	$\frac{2}{1-D}$	0.5	1	3	1	3	12V	48V
Modified voltage lifter	$\frac{3}{1-D}$	0.25	1	5	1	5	12V	48V
Dickson multiplier-based boost converter	$\frac{3}{1-D}$	0.25	1	5	1	5	12V	48V
Cockcroft Walton multiplier-based boost converter	$\frac{1+D}{1-D}$	0.25	2	1	2	1	12V	20V
Boost derived MIESC SC-cell converter	$\frac{2+(N-1)D}{1-D}$	0.5	1	4	2	5	12V	156V
Buck-boost derived MIESC SC-cell converter	$\frac{1+ND}{1-D}$	0.5	1	4	2	5	12V	144V
Hybrid boosting converter	$\frac{3-D}{1-D}$	0.5	1	4	1	4	12V	60V
Single-phase high step-up converter with coupled inductor multiplier	$\frac{2(1+N)}{1-D}$	0.5	2	4	2	4	12V	528V
State Switching Boost Converter Mixed With Magnetic Coupling and Voltage Multiplier	$\frac{2N+3}{1-D}$	0.5	2	4	2	4	12V	552V
Conventional interleaved boost converter	$\frac{1}{1-D}$	0.5	2	2	2	1	12V	24V
Interleaved boost converter with voltage multiplier	$\frac{2(N+1)}{1-D}$	0.5	2	6	2	5	12V	960V
Doubler Boost converter with cascading VMC	$\frac{4N}{1-D}$	0.5	1	2	1	2	12V	960V
Switch Boost converter with cascading VMC	$\frac{2N}{1-2D}$	0.25	1	2	1	2	12V	480V

renewable energy and high voltage applications, this voltage gain is not sufficient. For this cascading must be needed. In boost-derived miesc sc-cell converter, for n=10 and

D=0.5 the voltage gain is 13 which is far better than a conventional single step-up converter. Single-phase high step-up converter with coupled inductor multiplier voltage gain is 44 that is outstanding. State switching boost converter mixed with magnetic coupling and voltage multiplier voltage gain is 46 that is also excellent. This voltage gain can be increased more and more by increasing the number of cell. Two proposed advanced converter doubler boost converter with cascading VMC And switch boost converter with cascading VMC is more better and has exceptional voltage gain. By taking 10 VMC and 0.5 duty ratio, the voltage gain of doubler boost converter with cascading VMC is 80 that means for every step of cascading it increases the voltage gain 4 times. This voltage gain is maximum compared the other converters considering the same num of multiplier cells and duty ratio. Switch boost converter with cascading VMC voltage gain is less than oubler boost converter with cascading VMC but still higher than the others converter. But the main problem is cascaded converter required more diodes, capacitors and inductors that make the converter bulky and costlier.

6 Conclusion

In this article, two step-up dc-dc converter topology named doubler boost converter and switch boost converter with cascading VMC was proposed. The conventional step up dc-dc converter has limited voltage gain. For using high voltage and renewable energy application, this limited voltage gain is not sufficient. This limitation can be overcome by using the proposed DB and SB converter with cascading VMC. Voltage gain will increase twice by adding every VMC and the number of VMC can be scaled up as per the output voltage requirement. By changing the duty ratio, the output voltage can also be varied and the overall voltage gain and duty ratio is shown in table 2. The experimental validity of these two converters is tested by matlab simulation software. By taking 12 v dc input and 10 VMC, the output voltage attains 960v for DB_VMC and 480v for SB_VMC. So DB_VMC is far better than SB_VMC. Thus, with mentioned features, the proposed two topology are suitable for high-voltage and renewable energy applications

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