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# Analysis of Single Switch Step Up Dc-Dc Converter for Alternative Energy Systems

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**Abstract:- This work proposes high step-up DC-DC converter to acquire power from low voltage ambient sources like TEG, solar PV panels etc... The proposed converter provides high DC voltage gain, with reduced component count with high efficiency. Additionally, this topology significantly improves the voltage conversion ratio in comparison with other similar DC-DC converters presented recently. Besides, the design part includes less number of passive components to ensure compactness and low cost. The validation of the converter in continuous conduction mode (CCM) is carried out with detailed design method and performance of the same is verified using simulated using the MATLAB/Simulink.**

***Keywords:-*** *DC-DC Converters; Voltage Boosting Techniques; DC Transmission; PV Systems; Switch Mode.*

## I. INTRODUCTION

DC-DC conversion technology has been developing very rapidly, and these converters have been widely used in industrial application such as dc motor drives, computer system and communication equipment. DC-DC converter that convert unregulated DC input voltage into regulated DC output voltage. Nowadays, all the modem power electronics system need high quality, simple, lightweight, cheap, highly reliable and efficient power supplies. In order to regulate the output voltage of DC-DC converters irrespective of load variation and line disturbances, it is necessary to operate the converters in closed loop mode. Conventionally, classical proportional-integral-derivative (PID) and proportional-integral (PI) controllers are used for the control of various type of DC-DC power converters has been well reported in past [1], [25] and [30]. The proposed topology is a suitable structure for low voltage applications. The operation principles, the steady-state relations, and different switching strategies to further improve the voltage gain performance of the proposed converter are described. [2]. The dc-dc converters with high step-up DC-voltage gain play a vital role in integrating low voltage DC sources. Though several converter topologies are reported in the recent past, attempts have been made to reduce the components, especially the switching devices, passive elements, converter losses, etc., of the converter. The conception of a family of dc-dc converters with wide conversion range (WCR) based on the multistate switching cell (MSSC) for high-power, high current applications. The resulting topologies allow achieving high-voltage step-up/step-down in a modular approach, as the WCR-MSSC cell is obtained by using isolated secondary windings coupled to the autotransformer of the MSSC with series connected controlled rectifiers [3]. Hybrid non-isolated active quasi-switched dc-dc converter with a high-boost voltage gain, which can reduce the voltage stress and conduction loss on power switches [4].The generated voltage needs to be step-up with high conversion ratio by using the DC-DC converter as per the requirement of the load. The drawbacks of traditional boost converter are it required high rating semiconductor devices and have high input current ripple, low efficiency, and reverse recovery voltage of the diodes [5]. The SCLN converter can achieve ultra dc voltage gain with minimum number of devices when compared with other existing converters. The parasitic elements are considered to estimate the dc voltage gain and the efficiency of the converter more precisely [6] and [22]. The modified SEPIC proposed topology is analysis in [17]-[18] and [20]. The APN configuration is proposed in [14]-[15]. High voltage gain DC-DC converter is a prime requirement for renewable applications, in particular for PV. For increasing the voltage gain, the passive elements requirement is higher It’s reduces the compactness, consequently, increases the cost of the system [7]. The major drawback of high gain inverters is that they draw very high input current. Thus, the switching and conduction losses increase in the front stage converter, resulting in reduced efficiency [8]. A non-isolated bidirectional dc–dc converter is proposed for energy storage systems in this article. The converter is composed of three active switches, two synchronous rectifiers, two clamping capacitors, and two inductors [9]. The super lift converter topology is analysed [21] and [27]-[28]. The DC-DC converters are the essential modules in electric vehicles, grid interface of renewable energy sources and DC power supplies. The proposed bidirectional converter utilizes a switched-capacitor concept with inductors for high voltage gain. It has common ground between input and output, and uses only 5 active switches and 4 passive elements with reduced switch voltage stress [10], [26] and [29]. The high gain DC-DC converter is topology is mention in the paper [11]-[12]. The active SL network is proposed and the quadratic boost converter topology is presented [13], [16] and [23].

### ➢ *Operation and the Switching Modes*

The DC-DC boost converter proposed in this paper has one power switch, which is a power MOSFET, three diodes, two inductors, and two capacitors. The topology of this converter is presented in Figure 2.1. Due to the existence of only one switch, the converter operates in two switching modes: Mode 0 (M0) and Mode 1 (M1). Proposed converter operates in a continuous conduction mode (CCM) and is capable of driving a wide range of resistive loads.

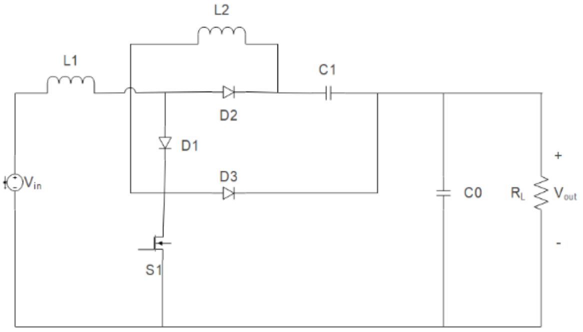

**Fig 1. Topology of the DC-DC boost converter.**
**Mode 1 operation**

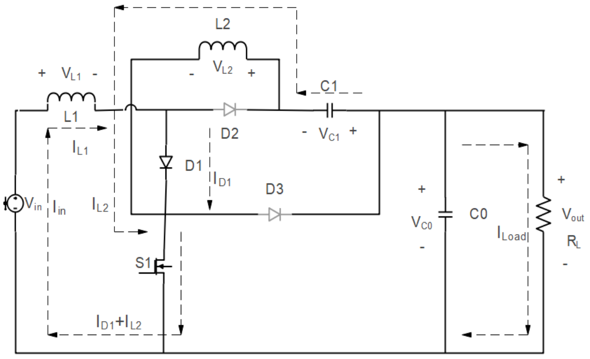

**Fig 2 Mode 2 S₁ operation**

The MOSFET $S_1$ is turned on, and diode D1 is forward biased and hence starts conducting. This causes the linear flow of current $I_{L1}$ through the inductor $L_1$, and hence the energy is stored in it. After passing the short lived transient phase, inductor $L_2$ is also magnetized by the current $I_{L2}$. The directions of $I_{L1}$ and $I_{L2}$. Power diodes $D_2$ and $D_3$ are off, due to the reverse voltage polarity across them and hence do not conduct. The reason that capacitor $C_1$ is in series with the inductor $L_2$, is that the current $I_{L2}$ also charges $C_1$ with the voltage polarity, The current that flows through $S_1$ is the algebraic sum of $I_{L1}$ and $I_{L2}$

The voltage across the inductor $L_1$, $V_{L1}$, ON, is only equal to the input DC voltage Vin,

$V_{L1,ON}= V_{in}$

The voltage across $L_2$, $V_{L2}$,ON, is the same as the voltage across $C_1$, $V_{C1}$.

$V_{L2,ON}= V_{C1}$

- *Mode 2 operation*

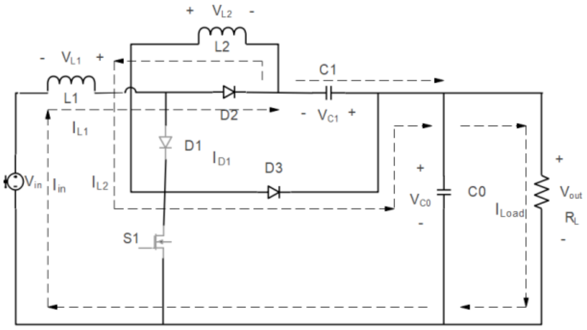

**Fig 3 Mode 2 S₁ OFF**

Figure 2.3 shows the mode 2 operation .The switch $S_1$ is turned off and the polarity across both $L_1$ and $L_2$ is reversed to maintain the current flow in the same direction as in Mode 0. In this mode, diode $D_1$ is off, due to the reverse bias polarity across it, and diodes $D_2$ and $D_3$ are on energy that was stored in L1 and $L_2$ is now released and transferred to the capacitors $C_1$ and $C_o$. Capacitor $C_o$ starts charging by developing the voltage $V_{Co}$ across it according to the polarity. During Mode1, the voltage $V_{L1}$, OFF across $L_1$ is the difference of the input DC voltage $V_{in}$and the voltage $V_{C1}$ across $C_1$.

$V_{L1,\,OFF} \;=\; V_{in}\text{-}\, V_{C1}$

$V_{L2,\,OFF} \;=\; V_{C1}\text{-}V_{OUT}$

$$V_{in} = L_1\left(\frac{di_{L1}}{dt}\right)$$

where D is the duty-cycle and T is the switching period of the $S_1$.

$$V_{in} = L_1\left(\frac{di_{L1}}{D.T}\right)$$

$$V_{in} - V_{C1} = -L_1.\left(\frac{di_{L1}}{(1-D).T}\right)$$

- *WAVEFORMS*

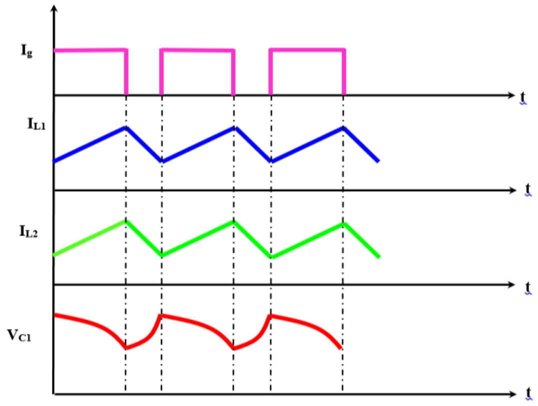

**Fig 4waveform**

Figure 4 shows the switching waveform of the converter. A prototype of the proposed boost converter with a 50 kHz switching frequency was configured for the most practical parasitic values of the components used in the modeling. These values are given as: ON of the MOSFET was set to 0.02 Ω, the forward voltage drop for each diode was set to 0.6 V, ESR for each capacitor was set to 0.001Ω, nd the series resistance for each inductor coil was set to 0.1 Ω

## II. DESIGN AND SIMULATION

### ➢ *DESIGN EQUATION*

**The voltage transfer gain is**

$$G = \left(\frac{V_{out}}{V_{in}}\right) = \frac{1}{(1-D)^2}$$

**Design of inductor L1**

$$L_1 = \frac{V_{in} \cdot D \cdot T}{\Delta I_{L1}}$$

$$L_1 = \frac{V_{out}(1-D)^2 \cdot D}{\Delta I_{L1} f_s}$$

**Design of inductor L2**

$$L_2 = \frac{V_{in} \cdot D}{\Delta I_{L2} \cdot (1-D) \cdot f_s}$$

$$L_2 = \frac{V_{out}(1-D)^2 \cdot D}{\Delta I_{L2} \cdot (1-D) \cdot f_s}$$

**Design of capacitor C1**

$$C_1 = \frac{I_0 \cdot D \cdot T}{\Delta V_{C1} \cdot (1-D)}$$

$$C_1 = \frac{I_0 \cdot D \cdot T}{\Delta V_{C1} \cdot (1-D) \cdot f_s}$$

**Design of capacitor C0**

$$I_{C_0} = C_0 \cdot \frac{dV_{out}}{dt}$$

$$C_0 = I_{C_0} \cdot \frac{D}{\Delta V_{out} \cdot f_s}$$

### ➢ *DESIGN OF PARAMETERS*

Where,
$V_{in}$ = Input voltage
$V_{out}$ = Output DC voltage
D = Duty ratio
$L_1$&$L_2$ = Inductor
$\Delta I_{L1}$& $\Delta I_{L2}$ = Rippled inductor current
$f_S$ = Switching frequency
$I_0$ = Output current
$C_1$& $C_2$ = Capacitor
$\Delta V_{C1}$ & $\Delta V_{C2}$ = Permitted voltage ripple
$C_0$ = Output capacitor

**Table 1 Design parameter**

| Parameters | Values |
|---|---|
| INPUT VOLTAGE | 25 V |
| OUTPUT VOLTAGE | 655 V |
| INDUCTANCE | 400 µH |
| CAPACITOR | 100 µF |
| OUTPUT CAPACITOR | 1000 µF |
| LOAD RESISTANCE | 150 Ω |
| DUTY CYCLE | 0.80 |
| FREQUENCY | 20 kHz |

### ➢ *SIMULATION DIAGRAM*

Figure 5 shows the simulation circuit diagram of single switch step up DC-DC converter with an open loop control. The values of the energy storage elements were set as: $L_1$ = 400 µH, $L_2$ = 100 µH, C1 = 100 µF, and $C_o$ = 1000 µF. The switching frequency of the power switch was set at 50 KHz. Simulation results were obtained with different input DC voltages, ranging from 5 V to 25 V and with different values of load resistance, ranging from 0.1 Ω to 150 Ω .

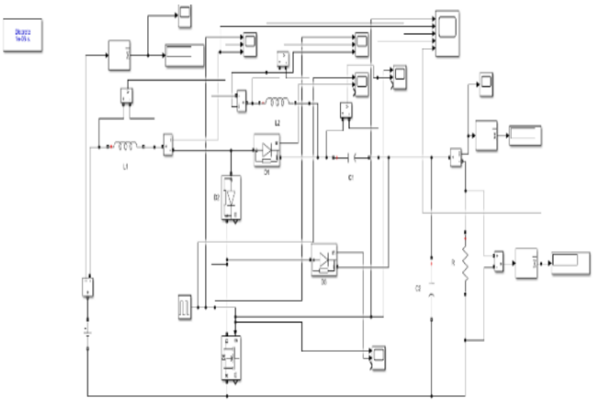

**Fig 5 Simulation diagram of open loop**

## III. ANALYSIS

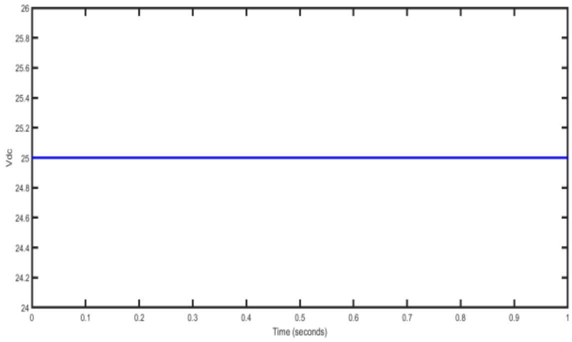

**Fig 6 Input voltage**

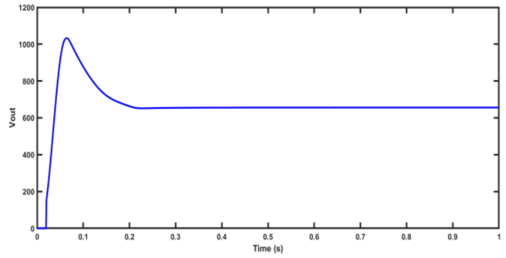

**Fig 7 output voltage**

Figure 6 shows the input voltage of the dc supply 25V. The dc output voltage waveform. The output voltage rise from 0V and attains constant value 665V. Simulation response of the voltage gain, shown in Figure 7, demonstrates that the converter remained in the transient state for less than 0.2 s and enters quickly into the steady-state phase.

During ON period of switches $S_1$ and $S_2$ the output current rises to a value of 4.37. During OFF period the current decreases

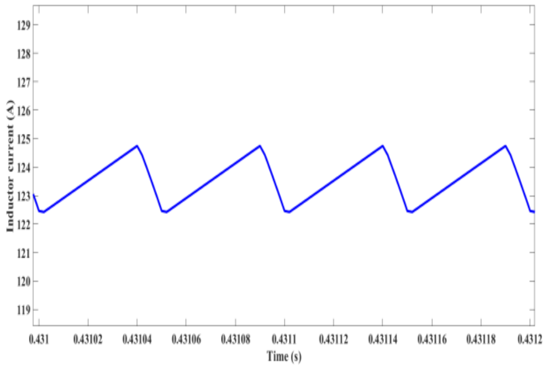

**Fig 8 Inductor L1 and L2 current**

Figure 8 show the proposed converter is intended to be used in a wide array of applications that range from PV grids to hybrid vehicles. Such applications demand that the converter operates in a continuous-conduction mode (CCM). The proposed boost converter operates promisingly in CCM, even when it is loaded heavily (R Load = 150 Ω) to maintain the smooth flow of power to the load. Therefore, all the relationships derived in Section 3 are validated. The current waveforms through the inductors L1 and L2 are shown in Figure 8. The inductor current waveform. During ON period, the inductor stores the energy and hence the current through the inductor rises to 124.86A.

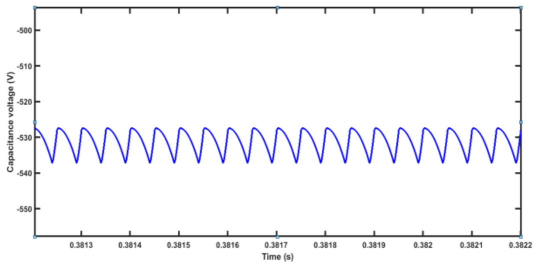

**Fig 9 Capacitor Voltage**

Figure 9 shows the intermediate capacitor voltage waveform. During ON period the capacitor charges and hence the voltage rises. During OFF period the capacitor discharges so the voltage decreases. The minimum output capacitor value with $\Delta V_{out}$ ripples in the output voltage. If switching frequency, the output voltage ripple and output capacitor current are kept constant, then the upper limit of the output capacitor is set by the duty-cycle of the converter. This leads to designing the output capacitor by operating the converter at the maximum permissible duty-cycle.

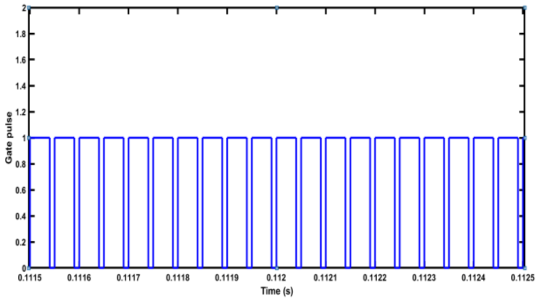

**Fig 10 Gate pulse**

**Table 2 Open loop performance analysis of converter with duty cycle variation**

| Duty cycle | Simulink Output voltage (V) | Theoretical Output voltage (V) |
|---|---|---|
| 0.1 | 35.67 | 30.86 |
| 0.2 | 56.21 | 39.06 |
| 0.3 | 84.28 | 51.02 |
| 0.4 | 122.3 | 69.44 |
| 0.5 | 174.9 | 100 |
| 0.6 | 249.5 | 156.25 |
| 0.7 | 341.7 | 277.77 |
| 0.8 | 655.9 | 625 |

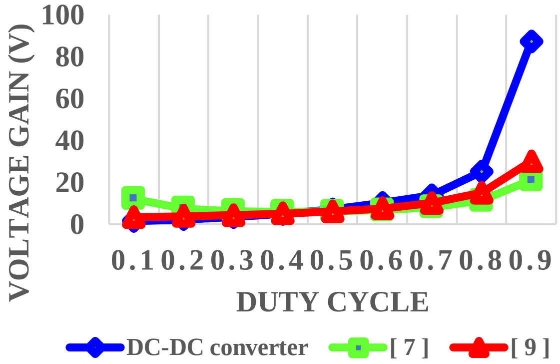

**Fig 11 Comparison of DC-DC converter and [7] and [9]**

The use of a single power switch makes the converter more efficient while operated at a lower duty-cycle. Operating the converter at a lower duty-cycle allows the switch to remain off for most of the time during its switching period, and hence the average on-state voltage drop across the switch is reduced. Moreover, diodes that do not conduct during the ON state of the power switch do not dissipate any notice able power. Therefore, power dissipation in the form of heat is reduced considerably, and, ultimately, the efficiency of the converter increases. In this present DC-DC converter, the efficiency is higher than the [7], [9] converter for lower duty-cycles, without compromising the DC voltage gain, as evident from Figure 11. The efficiency curve of the converter also implies that this design can be integrated with its replica to achieve even higher DC voltage gain. This approach will be helpful when both the [7], [9] converters are operated at a relatively low duty-cycle

**Table 3 0Performance analysis of converter with duty cycle variation**

| Duty cycle | Input voltage (V) | Input current (A) | Output current (A) | Efficiency (%) |
|---|---|---|---|---|
| 0.1 | 25 | 0.345 | 0.2378 | 98.25% |
| 0.2 | 25 | 0.866 | 0.3748 | 97.21% |
| 0.3 | 25 | 1.966 | 0.5619 | 96.33% |
| 0.4 | 25 | 4.173 | 0.8153 | 95.59% |
| 0.5 | 25 | 8.583 | 1.166 | 95.03% |
| 0.6 | 25 | 18.28 | 1.663 | 90.78% |
| 0.7 | 25 | 33.54 | 2.278 | 92.83% |
| 0.8 | 25 | 123.5 | 4.373 | 92.86% |

## IV. CONCLUSION

The DC-DC converter is presented that utilizes a low component count in comparison to some recently proposed high DC voltage gain DC-DC converters. The proposed converter was simulated for the DC voltage gain, voltage stresses, and efficiency. The comparison clearly revealed that the proposed design promisingly met the objective of achieving high-voltage gain, while keeping the component count low.

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