

# High Gain Step up DC-DC Converter with Different Output Voltage Level

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**ABSTRACT:** In conventional boost converter like switched capacitor converter, switched inductor converter, cascaded boost converter maximum voltage gain is limited due to extreme duty cycle. This results in reverse recovery problem at the switches, high conduction losses, high electromagnetic interference. These problems can be overcome by isolated converter such as fly back converter, push –pull converter, forward converter, bridge converter etc., however inclusion of transformer or coupled inductor introduces voltage spike and power loss. This project aims at providing different voltage levels required by the D.C load depending upon the power rating. The primary source of energy for DC micro grid is photovoltaic source. Therefore a very high voltage gain converter is designed which is realized by step up DC-DC converter. Steady state analysis and PWM control strategy is proposed in this paper. The proposed converter is simulated in Matlab.

**KEYWORDS:** Step up DC- DC Converter, PV cell, Duty cycle, DC micro-grid,

## I. INTRODUCTION

In present years energy demand as well as concern towards the green energy is increasing quite significantly. This basically motivates towards distributed generation system(DG) which uses renewable energy source for power generation. Renewable energy sources like photovoltaic source, fuel cells generate DC power. So these days DC microgrid are used in the DG system for optimal control of power flow from the source to load side as well as supplying a high quality power to consumers. Now a days most of the consumer loads are either DC based or adaptable to DC which requires different DC voltage levels[1].

Photovoltaic generation is one of the major source of energy in DG system. Photovoltaic panel has the drawback of low single cell voltage, reliability issues. To overcome these problem a step up converter is used in between PV source and DC bus[2]-[3]. When the conventional boost converter, cascaded boost converter etc operated at extreme duty cycle to get higher voltage gain experience issues like reverse recovery problem and electromagnetic interference. High voltage gain can be achieved by isolated converters by varying the transformer turns ratio. But the controlled switch of these converters suffer from high voltage spike and power loss due to leakage inductance of the transformers. All these problem can be overcome by using dual output DC-DC boost converter[4]-[5]. Different DC output voltage can be obtained by the proposed converter. In this paper a high voltage gain step up DC-DC converter is proposed. It is capable to maintain two DC voltage level( one of very high voltage level for high power DC bus and another of less high voltage level for low power DC bus).

The proposed converter has lower number of high voltage capacitors in comparison to the transformer less self-lift boost converter for the same voltage gain, which in turn reduces the system size. Because of the higher voltage gain the relatively lower duty ratio is utilized to maintain the high voltage level. The control complexity of the converter is reduced as the proposed converter is controlled by a single control switch. The voltage gain at two buses depends on single duty cycle as a result the voltage can be maintained within a range at one bus and as desired at another bus.

The paper includes operation of proposed converter with different operating modes, the mathematical expression and the simulation results.

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## II. PROPOSED STEP UP DC-DC CONVERTER

The proposed converter is capable of maintaining two different level voltages at low and high power DC buses. The high power loads are connected to high power DC bus, whereas low power loads are connected to low power DC bus.

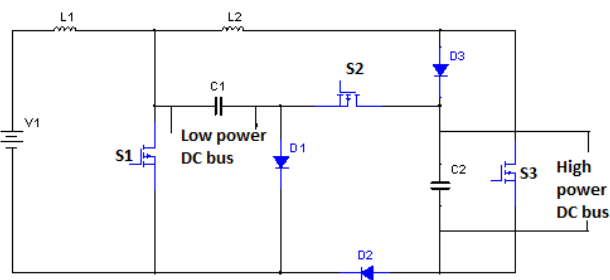


Figure 1 : Proposed Step up DC - Dc Converter

The proposed converter has two inductors ( $L_1$ ,  $L_2$ ), two capacitors ( $C_1$ ,  $C_2$ ), three diodes ( $D_1$ ,  $D_2$ ,  $D_3$ ) and three controlled switches ( $S_1$ ,  $S_2$ ,  $S_3$ ) to maintain two DC voltage levels as shown in figure 1. The high frequency switches ( $S_1$ ,  $S_2$ ,  $S_3$ ) can be taken as IGBT or MOSFET. Input represents the low voltage PV source. The controlled switches are operated based on the duty cycle to control the voltages at two DC buses. Only one control signal is required to operate all the controlled switches, as a result control complexity and sensor requirement are reduced. Voltage gain at two buses are dependent on single duty cycle, so voltage at one bus can be maintained within a range, keeping other bus voltage as desired.

The operation and steady state analysis of the proposed converter are discussed as follows. For easy understanding the DC buses are replaced by loads. From the equivalent circuit, it is realized that the voltage at low power DC bus is same as the voltage across capacitor  $C_1$ . Similarly the voltage at high power DC bus is same as the voltage across capacitor  $C_2$ .

Let,

$V_i$  = Low voltage source

$V_{L1}$  = Voltage across inductor  $L_1$

$V_{L2}$  = Voltage across inductor  $L_2$

$V_{C1}$  = Voltage across capacitor  $C_1$

$V_{C2}$  = Voltage across capacitor  $C_2$

$T_s$  = Switching time period of controlled switches

$T_{on}$  = Switch ON time period of controlled switches

$D$  = duty cycle of controlled switches (ratio of  $T_{on}$  to  $T_s$ )

1) Operation of the converter:

There are two stages of operation

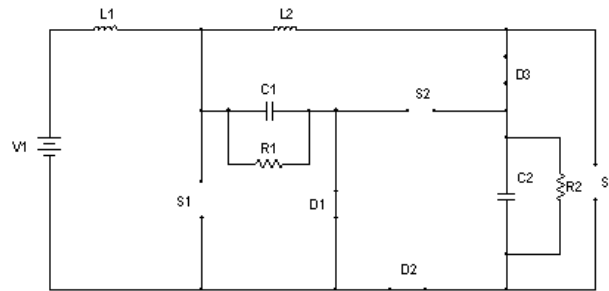
A. Stage 1 - When switches  $S_1$ ,  $S_2$ ,  $S_3$  are Turned OFF

During the interval when the switches are off, the diodes  $D_1$ ,  $D_2$ ,  $D_3$  in fig becomes forward biased. Thus input  $V_i$  and inductors  $L_1$  and  $L_2$  energize the capacitors  $C_1$  and  $C_2$  as well as supply power to the load.

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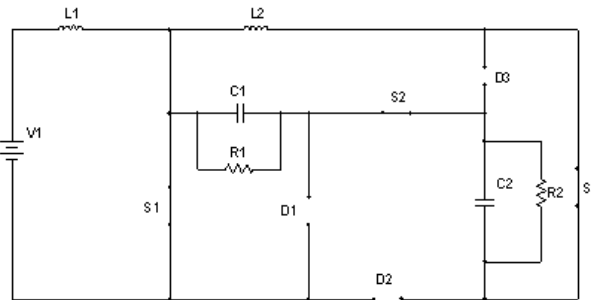


**Figure 2: Equivalent Circuit when the switches are turned OFF**

By applying kirchhoff's voltage law to the figure : 2 , voltage across inductors  $L_1$  and  $L_2$  are found to be as:

$$V_{L2} = V_{C1} - V_{C2} \tag{1}$$

$$V_{L1} = V_i - V_{C1} \tag{2}$$



**Figure 3: Equivalent Circuit when the switches are turned ON**

*Stage 2 -* When switches  $S_1, S_2, S_3$  are Turned ON:

During the interval when the switch is turned ON, the diodes( $D_1, D_2, D_3$ ) becomes reverse biased. The capacitors along with input  $V_i$  energize the inductors and supply power to loads.

By applying Kirchoff's voltage law, voltage across inductor are

$$V_{L1} = V_i \tag{3}$$

$$V_{L1} = V_{C1} + V_{C2} \tag{4}$$

Since in steady state the time integral of the inductor voltage over one time period must be zero, using equation (1) and equation (3),

$$(V_i - V_{C1})(1 - D)T_S + V_i D T_S = 0 \tag{5}$$

or

$$V_{C1} = \frac{V_i}{(1-D)} \tag{6}$$

Similarly, Applying Volt-second balance across inductor  $L_2$ , using equation (2) and equation (4),

$$(V_{C1} - V_{C2})(1 - D)T_S + (V_{C1} + V_{C2})D T_S = 0 \tag{7}$$

or

$$V_{C2} = \frac{V_{C1}}{(1-2D)} \tag{8}$$

Substituting  $V_{C1}$  from equation (6) in equation (8),

$$V_{C2} = \frac{V_i}{(1-D)(1-2D)} \tag{9}$$

From equation (9), it is found that voltage gain at capacitor  $C_2$  is significantly higher compared to capacitor  $C_1$ .

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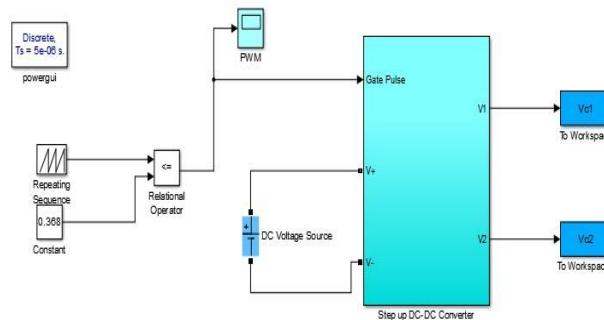
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### III. SIMULATION RESULTS

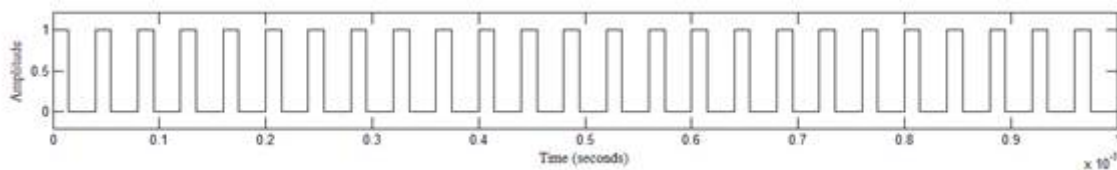
The circuit has been designed and implemented in MATLAB/Simulink environment. The circuit parameter is shown in table 1. From equation (6) and (9), mathematically the high and low power DC bus voltage for the given source voltage is found to be 20V and 72V respectively., The simulink model of closed loop is shown in Figure 10.

**Table 1 : Simulink model parameters**

Sl.No	Parameters	Value
1	Switching Frequency	25kHz
2	Duty ratio	0.368
3	Inductor $L_1, L_2$	350 $\mu$ H, 600 $\mu$ H
4	Capacitors $C_1, C_2$	470e-6 F
5	Resistors $R_1, R_2$	180 $\Omega$ , 170 $\Omega$
6	Supply voltage	12V

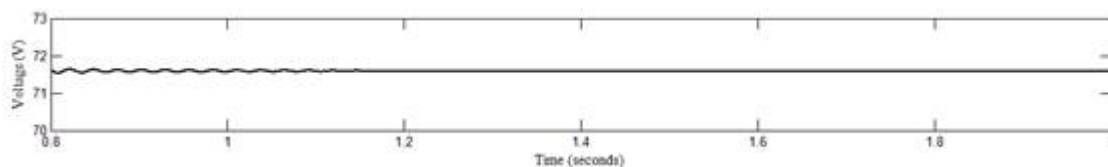


**Figure 4 : Simulink Model of the Proposed Converter**



**Figure 5: Gate pulses at duty ratio 0.369**

Gate pulses to the switches are obtained by comparing a repeating signal with a reference. Here the repeating sequence is the ramp waveform of frequency 25kHz. The gate pulses generated at a duty ratio of 0.368 are given to the switches  $S_1, S_2, S_3$



**Figure 6: Voltage at high power DC bus**

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From the simulation result obtained, it can be observed that the voltage at high power DC bus is found to be 72V.

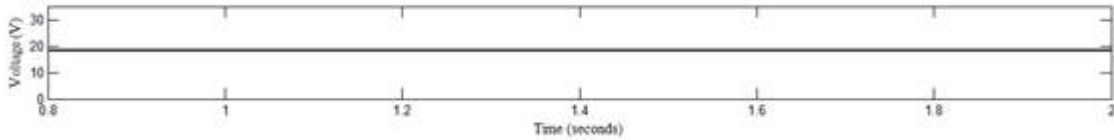


Figure 7: Voltage at low power DC bus

It can be seen that from the simulation result (figure 7) the voltage at low power DC bus is nearly 20V with negligible ripple content.

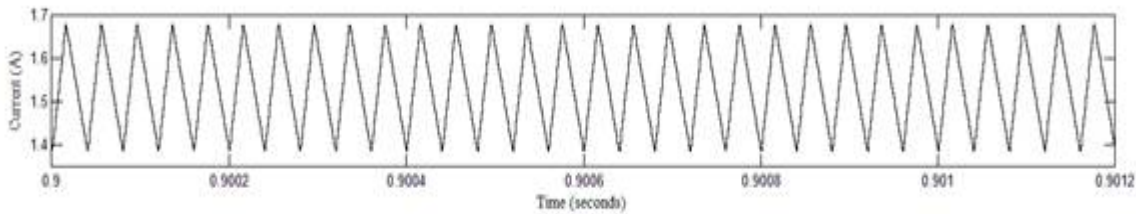


Figure 8: Inductor Current  $I_{L1}$

The inductor current  $I_{L1}$  is equal to the source current when the switches are closed. From the simulation result (figure 8) the inductor current  $I_{L1}$  is found to be 1.65A and inductor current  $I_{L2}$  is found to be 1.6A (figure 9).

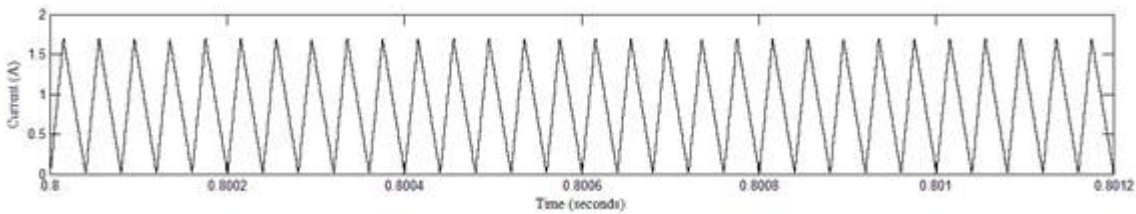


Figure 9: Current across inductor  $L_2$

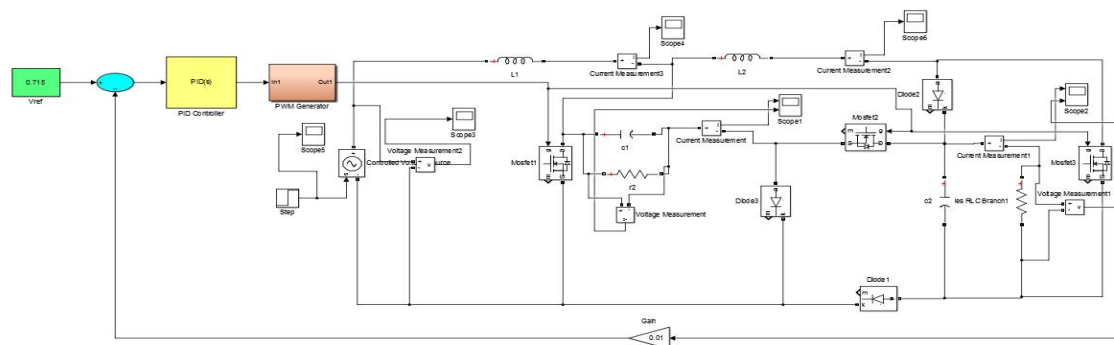


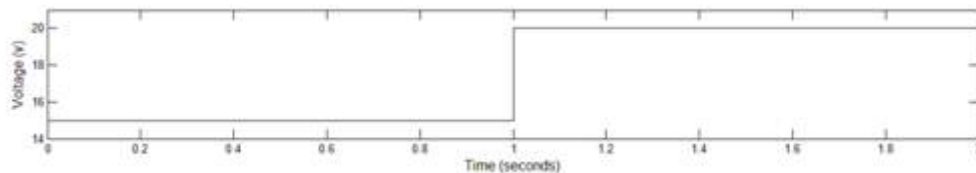
Figure 10 :Closed loop simulink model of Converter

In order to overcome the voltage drift problem of the power source under the load variations the closed loop control methodology has been utilized. The closed loop simulink model is shown in figure 10

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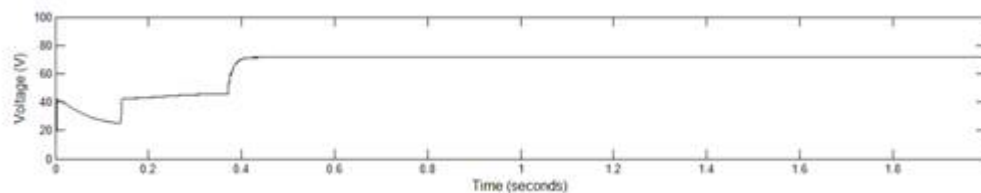
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**Figure 11: Step Input Voltage**

A step input voltage of 15 is given for 1s and 20V is given for other 1s (figure11). When this step input voltage is applied it can be seen that from figure 12 the output voltage remains same even though when there is variation in the input voltage. Therefore problem of voltage drift can be overcome by closed loop method.



**Figure 12: Output voltage**

## IV. CONCLUSION

A high gain step up DC – DC converter with smaller duty cycle is presented in this paper. It overcomes the limitation of conventional boost converter due to extreme duty cycle for getting higher voltage. The proposed converter as the advantage of lower number of passive components. The converter operation is analysed and verified by simulation using MATLAB/Simulink.

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