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Research Article

Solar Energy Based Transformer Less DC-DC Converter with Multiple Output Voltages

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Abstract

The conventional converters like Cuk, Sepic and Buck-boost Converters offer limited voltage gain due to internal duty cycle constraints. The operation of these converters at extremely high duty cycles to deliver high output voltages will lead to severe issues. The voltage spikes and electromagnetic interference problems are most commonlywitnessed in isolated Converters like Forward, Full Bridge, Resonant and Bidirectional Converters due to the use of transformer which has finite leakage inductance. In this paper, a new topology of a transformer less DC-DC boost converter with multiple output voltages has been proposed to surpass the above specified drawbacks. The proposed converter is operated in a minimum duty cycle range and simultaneously supplies multiple output voltages of different magnitudes. These converters are fed with solar energy and find the major applications in Micro grid applications.

Keywords: DC-DC boost converter, duty ratio, multiple output voltages.

In Distributed generation system (DG) the primary source for energy is photovoltaic source (PV). The photovoltaic source from the single cell is very low[7]. In order to boost the voltage a boost converter is introduced between PV source and load. The concept of DG system is shown in the figure 1. A dc-dc step-up converter is introduced in between PV source and the load to boost the voltage[8]. By this system higher voltage gaincan

INTRODUCTION

Tomeet the energy needs distributed generation (DG) plays a vital role[1]. Non-conventional sources such as solar energy, wind energy ocean energy, tidal energy, bio gas energy to generate the DC power[2]. Energy storing devices such as batteries, ultra capacitor.
primary and secondary battery also supply dc power to load[3]. Now a day's DC micro grid is used for DG system application for reliable power supply from source to load as well as to increase power supply quality [4]. Another major aspect of dc system is mostly electronic gadgets' work by dc source such as mobile phones, laptops, charging devices, back up supplyetc[5].

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Another important aspect is lightening, it is considered as 35% of global energy consumption, and electronic gadgets consumes 20% of global energy. LEDs are emerginging trend now a days which is used as efficient lightining system works on dc energy. for all above applications DC micro grid ispreferred[6].

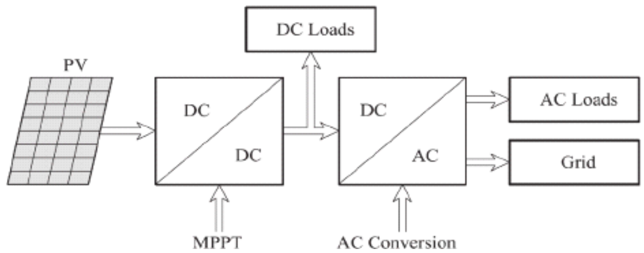


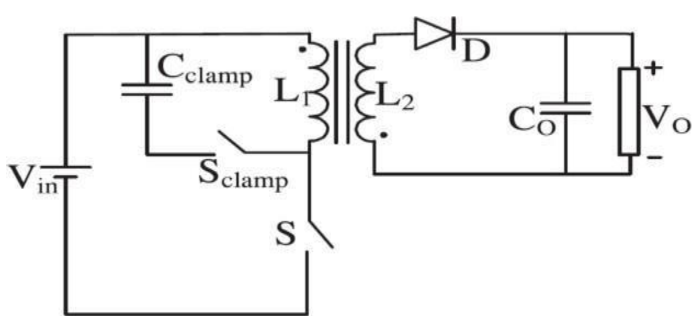
Fig. 1 Block diagram of DC micro-grid

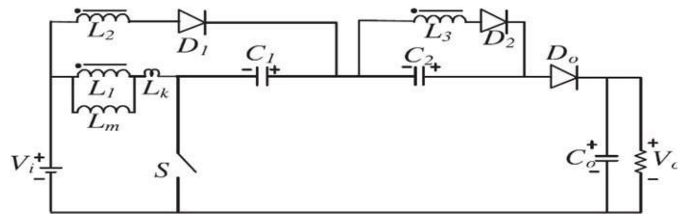
In traditional converters like boost converter, buck-boost converter and cuk converteretc[9], it experiences a problem of reverse recovery and EMI problem, when a converter is operated in a extreme duty cycle i.e.(more than one) to achieve a higher voltage gain in the converter output. Isolated converter such as forward converter, full bridge converter, resonant converter, bidirectional converter[10], etc overcome the above issue by changing the transformer turns ratio. Isolated converter suffers from voltage spikes and leakage reactance in a transformer. Self lift converter may overcome the problems by usages of additional inductors and capacitors in the boost converter circuit to step up voltage. In a proposed converter in this paper all the above problems can be overcome by obtaining multiple voltages in across thecapacitors[11].

(a) NEW TOPOLOGIE OF DC-DC STEP-UP CONVERTER In dc-dc boost converter, the boostedvoltage depends

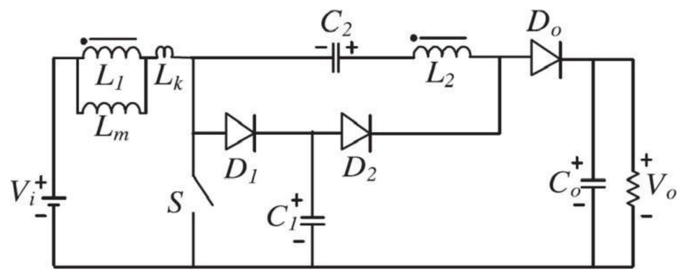
upon the duty cycle of the circuit at which the voltage is boosted. In this paper, a new model of dc-dc converter is proposed to boost the input voltage to two different voltages one is of high voltage range and another is of low voltage range. This two different step-up voltages is used for two differentapplications.

(a)




L2
D1
L3
D2
C1
C2
Do
L1
Lk
Lm
Vi
S
Co

(b)


C2
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Co
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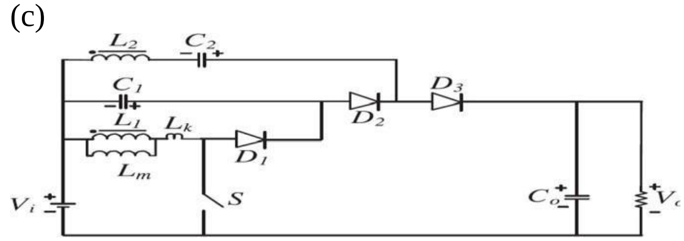
(c)


L2
C2
C1
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D2
L1
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D1
Lm
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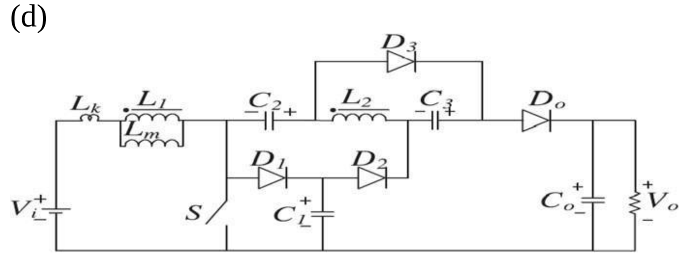
S
Co

(d)


D3
Lk
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C3
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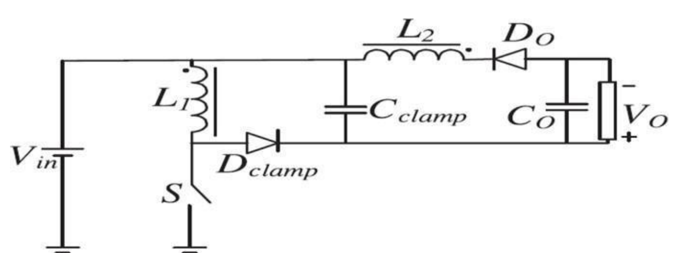
(e)


L2
DO
L1
Cclamp
CO
VO
Vin
Dclamp
S

(f)

(b) Fly back converter, (b) reduced switching stress and high voltage gain converter,(c)coupledinductorconverter,(d)softswitchedconverter
(e) super high voltage gain converter, (f) step-up converter.

A. Proposed topology

In this paper a DC-DC boost converter is proposed. It is used to get two output voltages at a different levels one voltage level is at across output capacitor and another voltage level across input capacitor. The voltage across output capacitor is called as high power output bus. The voltage at input capacitor is called low power input bus. The two different output voltages at the two buses of different magnitude depends upon the duty cycle of the control switches. In this topology by use of low duty cycle the size of the converter is small compare to conventional boost converter. The operation of the boost converter is divided into various sections as discussed in detailed in the paper. In section1 when the the switches are opened and in the section 2 when the switches are closed .The detail description of the two sections is discussed below. The outputs of the proposed topology is traced in matlab such as the ouput voltages versus time curves, The voltage gain curve versus duty cycle, voltage curve versus frequency, voltage curve versus amplitude, The inductor voltages, Inductor currents, voltages across the switches and diodes all the curves are discussed in thepaper.

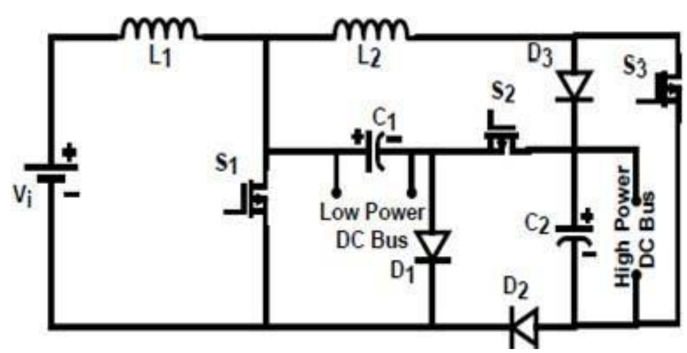


Fig. 3 Circuit of DC-DC converter with multiple buses

2. PROPOSED DC-DC STEP-UPCONVERTER

The dc-dc converter uses a inductor of notations (L1,L2) and capacitor (C1,C2) and diodes (D1,D2,D3) and the switches of (S1,S2,S3).To maintain a output dc voltages of boosted value use the switches of high frequency that is S1,S2,S3 can taken as IGBT or MOSFET. The input voltage is represented as Vi equivalent to PV source.The above switches is operated by varying duty ratio to control a output voltages at the two output buses. The uncontrolled switches (*D*1, *D*2 and *D*3) and three semiconductor switches (*S*1, *S*2 and *S*3) to maintain two higher DC voltage levels as shown in Fig.2*Vi*represents the low voltage PV source. The switch is operated by varying duty ratio to control a output voltage at the two output buses. The two output voltages of the converter is controlled by a single duty ratio i,e.(α) . The output voltages are obtained in two different states, one is when switches are closed and feedback diodes are opened and in other case when switches are opened and the feedback diodes are closed.

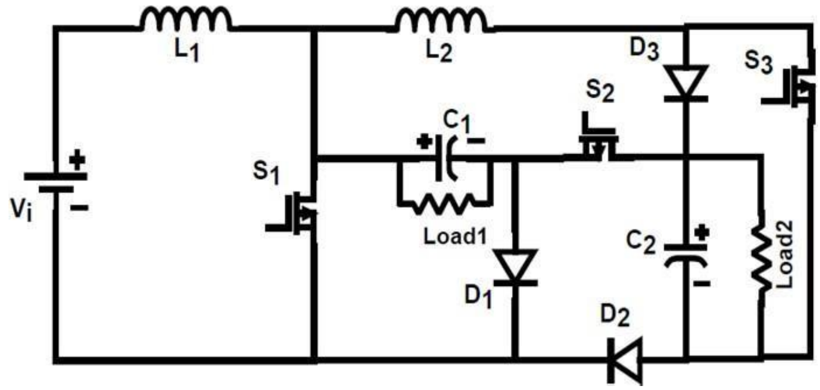


Fig. 5. Now by the figure 5 applying KVL to the loop then Then the voltage equations will be shown below.

VL1 □*VS* *VL2*□*VC1* □*VC2*

(3)

(4)

By applying average voltage across inductor is zero for inductor L1, from the equations (1) and (3) we get.

□*VS*□*VC*1 □□1□*α*□*T* □*VS* *αT* □ 0

or,VC1 □*VS*□1□*α*□

(5)

(6)

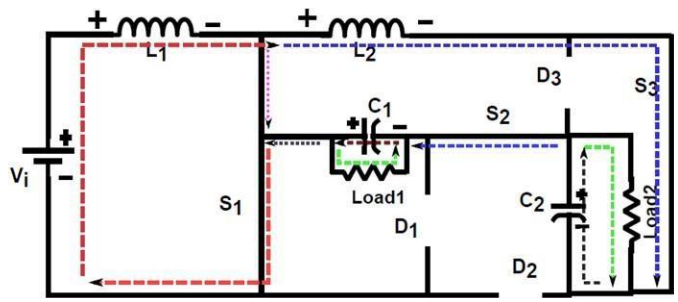
Fig. 4. Equivalent circuit of a DC-DC converter when multiple buses can replaced by equivalent loads.

By applying average voltage across inductor is zero for inductor L2, from the equation (2) and (4) we get.

The operation of dc-dc boost converter is explained from the figure 3 and by figure 4. In the figure 4 the dc buses are replaced by loads, load1 is connected across capacitor C1 and the load 2 is connected across capacitor C2.and the operation can be explained by considering two modes as below.

Consider,

Vs = Input supply
VL1 = Potential drop across inductor L1
VL2 = Potential drop across inductor L2
VC1 = Potential drop across the capacitor C1
VC2 = Potential drop across the capacitor C2
T = Switching duration of a of controlled switches
Ton = Turn on period of semi-conductor switches



α = duty cycle

A. *Consider a switches* **S1, S2, S3***areopened*

3. □*VC1*□*VC2*□□1□*α*□*T* □□*VC1*□*VC2*□*αT* □ 0

4. *or,VC2* □*VC1* □1□ 2*α*□

5. Now, using the value of *VC*1 from equation(6),

6. *VC2* □*VS* □1□*α*□□1□ 2*α*□

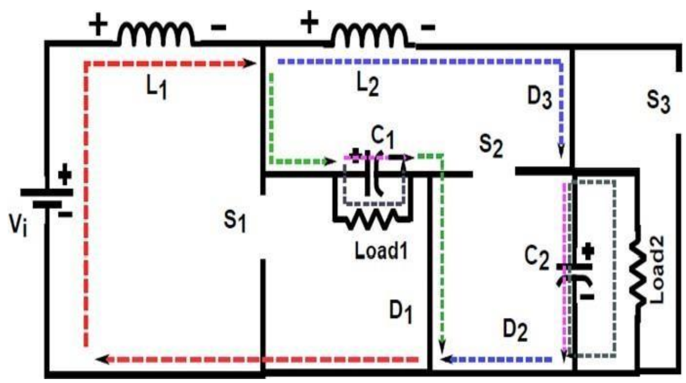


Fig. 5. The equivalent circuit of a converter when all the controlled switches are opened

When all the switches are opened, the forward bias diodes D1,D2,D3 will conduct the input voltage Vi is applied across inductors, the inductors energize the capacitors C1 and C2 now by applying KVL to the inductors L1 and L2 we get the following equations.Now from the Fig. 4, voltage across inductors *L*1 and *L*2 are asfollows.

VL1 □*VS*□*VC1 (1) VL2*
□*VC1*□*VC2 (2)*

A. *Consider a S1, S2, S3 areclosed*

In this period, all semi-conductor switches are turned ON, then diodes in the circuit will be reverse bias D1,D2,D3 as shown in figure below in this condition the capacitors in the circuit will energize the inductors (L1,L2) by applying KVL to theinductorsL1andL2theequationwillbeasfollow

Fig. 6. The equivalent circuit of high gain step up DC-DC converter when all the controlled switches are turned ON

When the switches are closed and the diodes are opened the voltage equation is obtained i.e. the voltage across the capacitor C2 and the voltage across capacitor C1 is derived above from that the voltage across C2(9)capacitor is much greater than the voltage across capacitor C1(6).The voltage across capacitor C2 is considered as high voltage bus and the voltage across capacitor C1 is consider as low voltage bus similarly from the figure 7 the voltage gain across the C2 is much higher than the voltage gain across C1.The voltage gain at the C1 can be improved by varying duty ratio of the switch ,so by selecting the suitable value of duty cycle (α) the output voltages can maintained at a certain voltage ranges. By varying the input voltage and by keeping the duty cycle of the switches constant we can vary the output boosted voltages without varying the duty cycle of the switches. From the figure 6 the load is connected across the two capacitors of C1 and C2.The load which is connected across the capacitor C2 is called load2 and the load which is connected across the capacitor C1 is called load1.The current directions when the switches are closed is represented in the figure 6 as well as load current directions is represented in the figure. Voltage versus frequency curve at low voltage bus is shown in figure 13,and the voltage versus frequency curve at high voltage dc bus is represented in figure 14,similary the

voltage versus amplitude curves at both the buses is represented at figure 15 and figure.

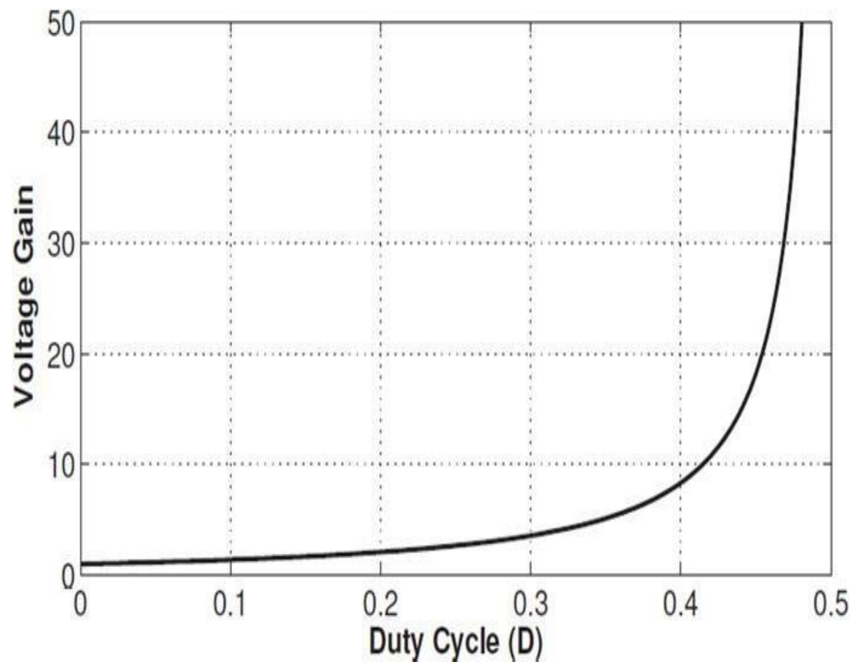


Fig. 7.High voltage DC Bus gain

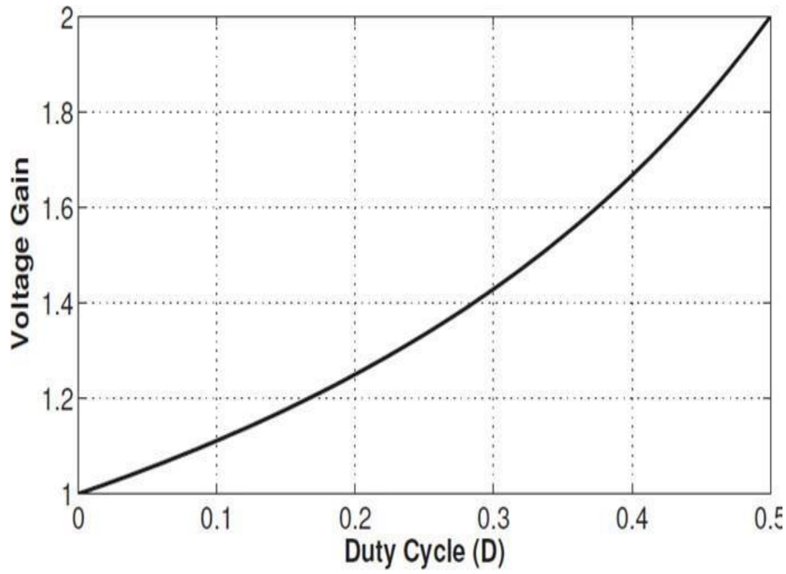


Fig. 8. . Low voltage DC Bus gain

TABLE I

S. No	*Symbols*	*Operating range*
1.	f switching	15KHz
2.	Duty Ratio	0.386
3.	L_1,&L_2	450µH, 700µH
4.	C_1& C_2	570 µF
5.	R1 &R2	190 Ω, 150 Ω
6.	Vs	18V

I. SIMULATIONRESULTS

The proposed topology is implemented using MATLAB.The various outputs are plotted such as voltage versus time, voltage gain versus duty cycle, voltage versus frequency, voltage versus amplitude, inductor currents, inductor voltages, switching voltages at different switches. From the output curves i.e., fig.10, fig.11, the output voltage at low voltage bus VC1=80,and the output voltage at the high voltage bus VC2=300,the two voltages appears across the two buses simultaneously, by this multiple voltages can be obtained by using a dc-dc boost converter. The two voltages at the two buses are plotted with respective to time (secs).similarly from figure 7 and figure 8 the voltage gain curve are plotted between voltage gain versus duty cycle similarly the remaining curves are shown below.

The voltage gain curve shows when the duty cycle is zero then the corresponding voltage gain will be zero, subsequently by increasing the duty ratio from 0 to 0.5 the voltage gain varies corresponding to duty ratio (α).at a certain duty ratio (α) the voltage gain will be maximum at that certain point dc- dc boost converter is efficient to operate. The voltage gain at high voltage bus is much higher than the low voltage bus. The voltage gain at high voltage bus is 50 at 0.5 duty ratio, where as low voltage bus the voltage gain in 2 at 0.5 duty ratio from figure 8.

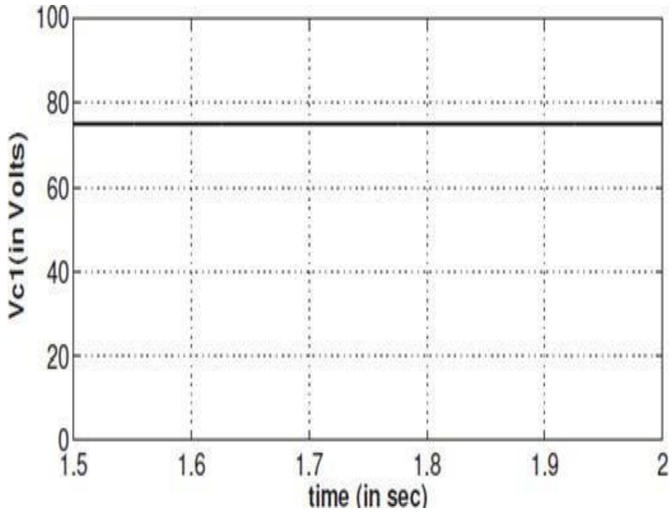


Fig.10. Voltage versus time (secs) at low voltage dc bus of the convert

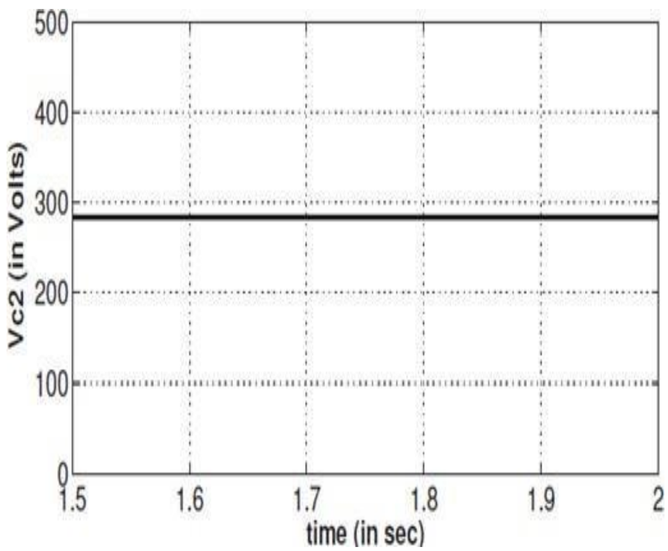
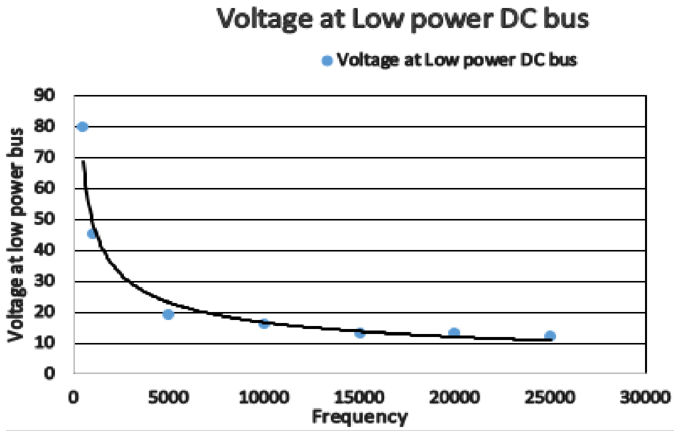


Fig.11.Voltage versus time (secs) at high voltage dc bus of the converter


Voltage at Low power DC bus
Voltage at Low power DC bus
Voltage at low power bus
90
80
70
60
50
40
30
20
10
0
0
5000
10000
15000
20000
25000
30000
Frequency

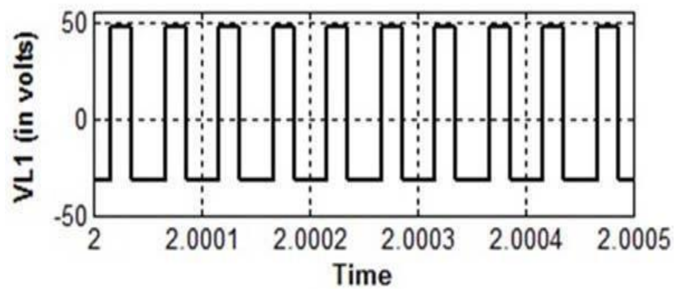


Fig.12. Voltages vs. Frequency at low voltage Bus

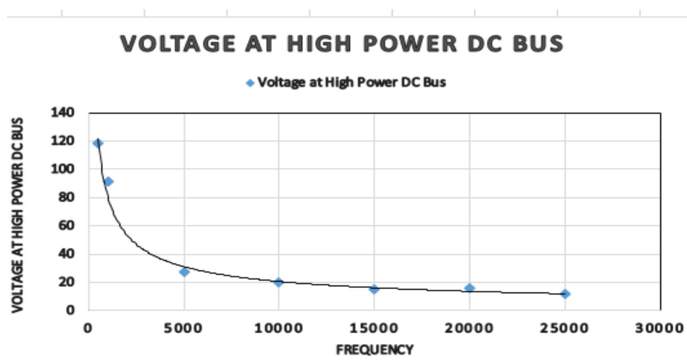


Fig.13. Voltage vs. Frequency at high voltage Bus

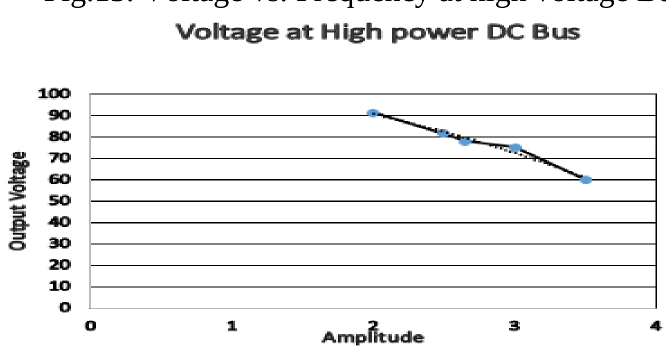


Fig.14. Voltage vs. Amplitude at high voltageBus

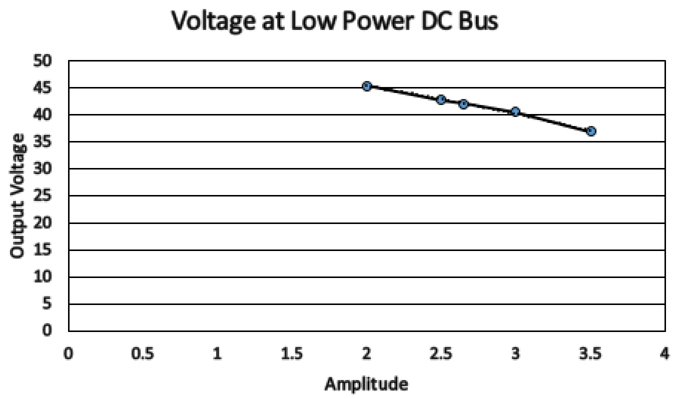


Fig.15. Voltage vs. Amplitude at lowvoltage Bus

Fig. 16. Voltage at the inductor *L1* vs. time (in secs)

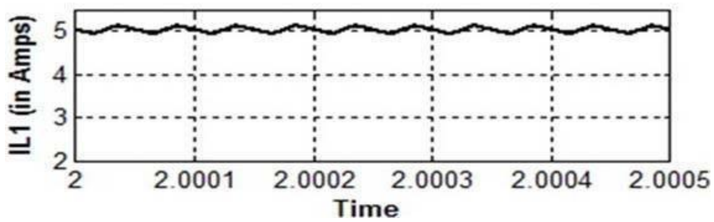


Fig.17. Current in the inductor *L1* vs time (inAmps)

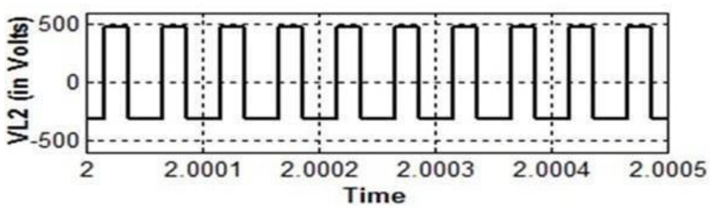


Fig. 18. Voltage at the inductor*L2*vs time (insec)

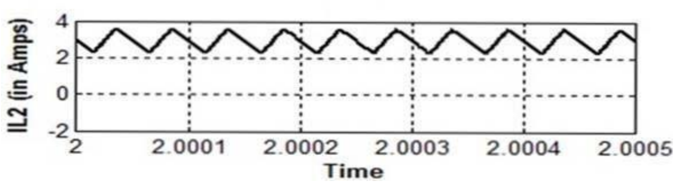


Fig. 19. Current through inductor *L*2 (in Amps) versus time (in secs)

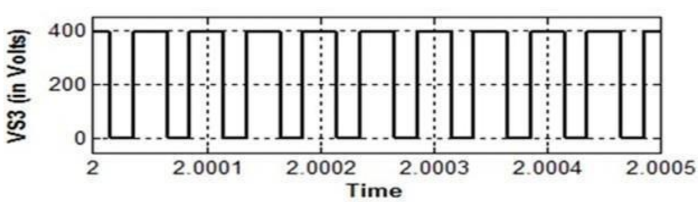


Fig. 20. Voltage at the switch *S3* vs time (in secs)

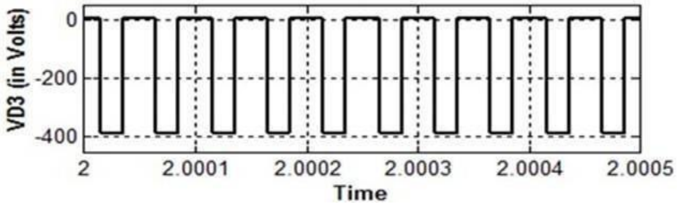


Fig.21. Voltage at the diode D3 vs time (in secs)

II. CONCLUSION

This paper presents thetransformer less DC-DC boost converter. This configuration is able to produce the very high output voltages even at a minimum duty ratio. This converter is capable of delivering one low output voltage and the other high output voltage being the solar PV as input energy source. These multiple output voltages can be fed to different loads and mostly suitable for DC micro grid applications. The voltage gains have been compared at different duty cycles at both low and high voltage buses. The voltage across the inductors and the current flowing through them are also presented. The simulation studies have been carried out in the MATLAB environment.

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