ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 3, Issue 9, September 2017

Performance Evaluation of Multi Input BUCK BOOST DC-DC Converter

[1] G.Sravani, [2] Y.Paramesh, [3] G.Kishor [4] V.Harinath
[1][2][4] UG student, G.Pulla Reddy Engineering College, Kurnool
[3] Associate Professor, G.Pulla Reddy Engineering College, Kurnool

Abstract: **-- Nowadays, electricity along with power electronics has become essential part of our life. Power consumptions are increasing every year due to industrialization in our country. DC-DC converter topologies such as buck, boost, buck-boost, cuk converters provide us with ability to step up and step down the input DC voltage precisely. DC-DC converter is needed to convert directly to the desired voltage from the renewable energy sources such as solar cell and Fuel cell. In this paper a four input buck-boost DC-DC converter is analyzed. A four input system will be used to improve efficiency, performance and to reduce cost and component count. To validate the results a four input buck-boost DC-DC converter will be simulated using MATLAB/Simulink.**

Keywords: DC-DC converters, Multi input, Buck-Boost converter

I. INTRODUCTION

Electrical energy can be transferred to any place. According to law of conservation of energy, it can be converted to other forms of energy such as light, heat and kinetic energy [5]. The country's economic factors greatly depend on Electric Energy. As electricity demand is raising day by day and decaying nature of conventional energies like nuclear, thermal etc which produces pollutants, so we need to go with alternate energy resources. Even more importantly, renewable energy produces little or no waste. Renewable energies are of clean and inexhaustible. Solar energy becomes more popular because of its simple structure [6]. Batteries, ultra-capacitors, and flywheels are the most common energy storage mechanisms used to hybridize energy systems. [1]. To meet the present demands, instead of using number of individual converters, we can use multiple sources which can improves efficiency and reduce the cost and size [3]. As the technology is advancing and apparatus cost [8] is decreasing along with the improvement of Reliability, their applications are expanding in industrial, commercial, residential, military, aerospace and utility environments. Many power semiconductor devices, converter topologies, analytical and simulation techniques, electrical machine drives, control and estimation techniques are contributing to this advancements [7].In general, a dc-dc converter is required to integrate each energy related component into the system. Integrating each energy source with a DC-DC converter is expensive, bulky, less efficient, and hard to control [2]. This configuration allows for only unidirectional power flow.This type of converter can operate both in continuous and discontinuous modes.Hence in this paper, a multi input dc-dc converter is analyzed and simulated.

II. DC-DC CONVERTERS

A d.c chopper is astatic device(switch)used to obtain variable d.c voltage from a source of constant d.c voltage source. chopper is d.c equivalent of an a.c transformer, since they behave in identically.DC chopper offers greater efficiency,faster response,lower maintanance,small size,smooth control and lower cost. choppers widely used in trolley cars,battery-operated vehicles,traction-motor control,control of a large number of motors from a common bus,marine hoists ,fork lift trucks,mine haulers. The basic DC-DC converters are buck, boost and buck-boost converters.

III. MULTI INPUT BUCK-BOOST DC-DC CONVERTER

The basic block diagram of multi input buck boost converter is as shown in Fig.1. The four inputs are from different sources like Fuel cell, Solar Energy, Battery and from other non renewable sources.

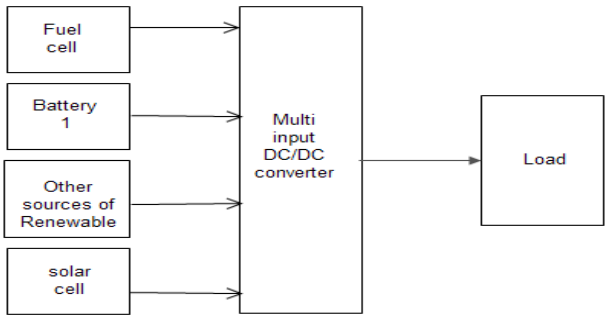

Fig.1. Block diagram of Multi input DC-DC converter

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
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Fig.2 shows the circuit diagram of multi input buck-boost DC-DC converter. The switch realization is done with voltage bidirectional switches.

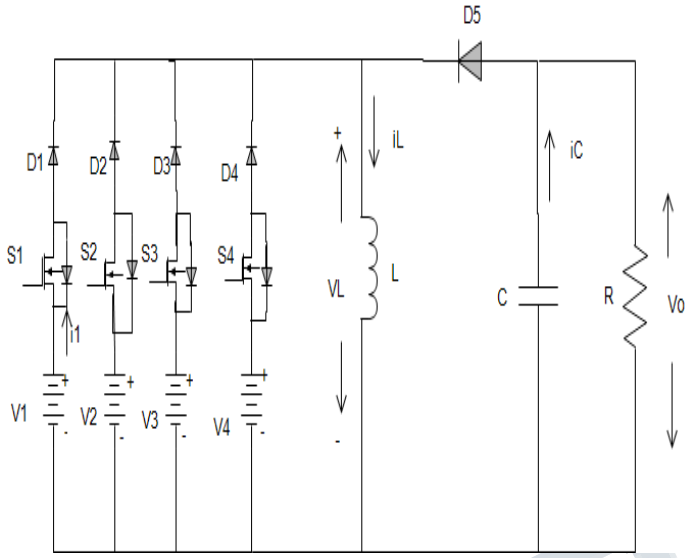

Fig.2. Basic circuit diagram of multi input buck-boost DC-DC converter.

When the switch S_1 is ON Inductor get charge from V_1 source. When the switch S_2 is ON Inductor get charge from V_2 source. Similarly N-number of voltages will charge the Inductor when particular channel switch is ON. The pulse patterns of the four switches are shown in Fig.3.

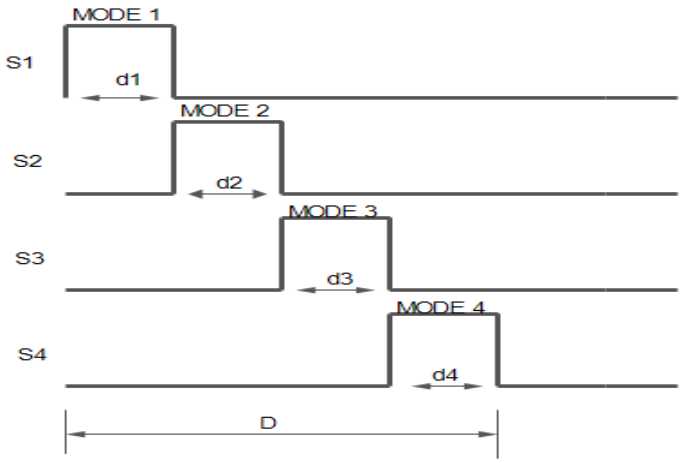

Fig.3. Pulse pattern for multi input Buck-Boost DC-DC converter.

IV. EQUIVALENT CIRCUTS FOR THE DIFFERENT MODES OF OPERATIONS

Mode 1: When S_1 is ON

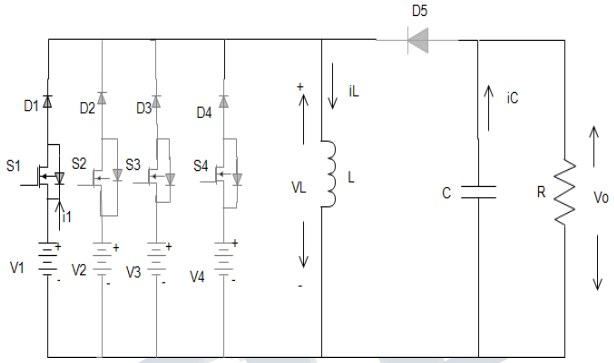

Fig.4. Equivalent circuit for Mode 1

Mode 2: When S_2 is ON

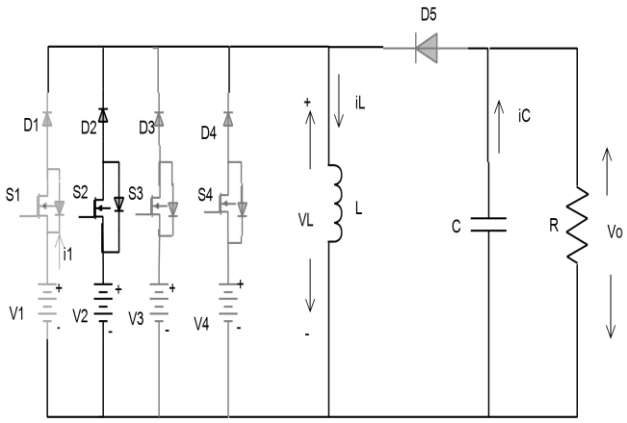

Fig.5. Equivalent circuit for Mode 2

Mode 3: When S_3 is ON

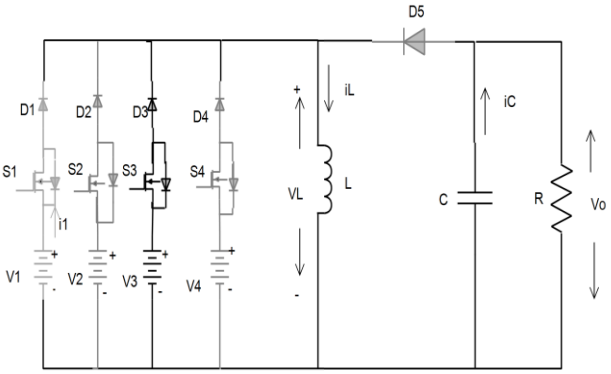

Fig.6. Equivalent circuit for Mode 3

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International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
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Mode 4: When S_4 is ON

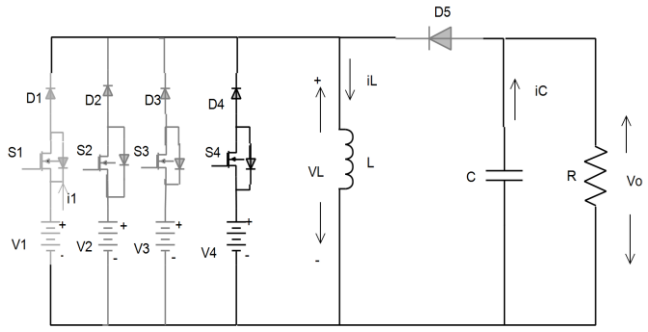

Fig.7. Equivalent circuit for Mode 4

Mode 5: When all switches are OFF

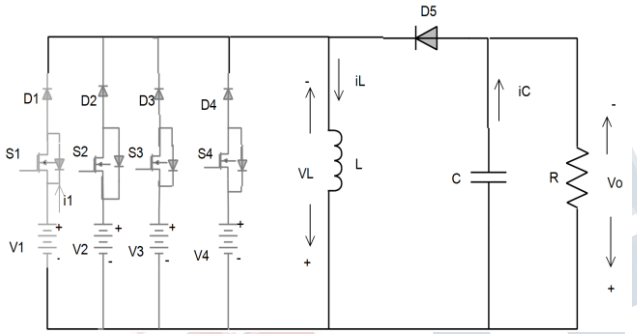

Fig.8. Equivalent circuit for Mode 5

V.SIMULATION MODEL AND RESULTS OF MULTI INPUT BUCK-BOOST DC-DC CONVERTER

The Multi input DC-DC converter is simulated in MATLAB and the Simulink diagram is as shown in Fig.9.

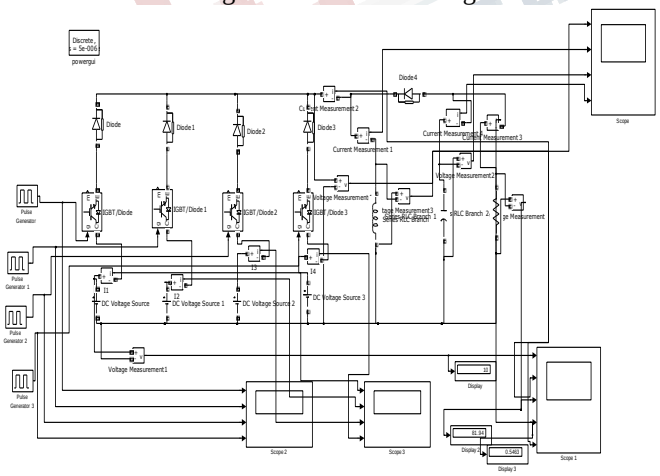

Fig.9. Simulink model of multi input DC-DC converter

Vg_1, Vg_2, Vg3 and Vg_4 are the respective gate pulses of four switches S_1, S_2, S_3 and S_4 in total time period all switches are turned ON, no two switches should not trigger at same instant. S_1, S2, S3 and S_4 should trigger sequentially at switching frequency of 10 KHz. The switching signals for switches S_1, S_2, S_3, S_4 of multi input buck-boost dc-dc converter in boost mode is shown in the Fig.10.

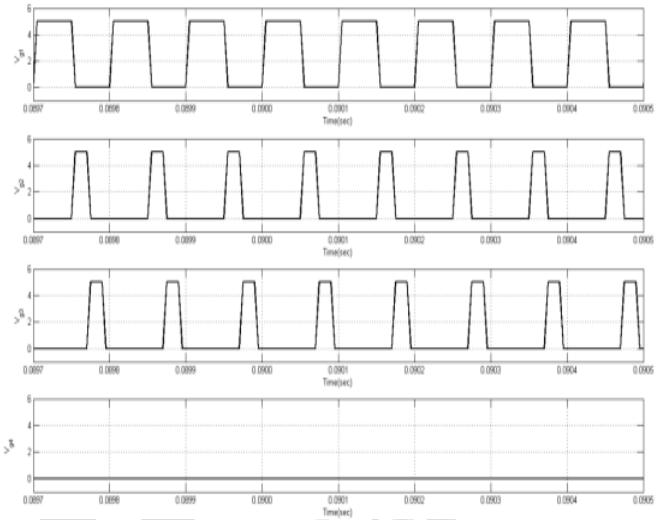

Fig.10. Switching signals of multi input buck-boost DC-DC converter (boost mode)

The voltage across the inductor is as shown in Fig.11.
The input current of each input voltage source in boost mode is as shown in Fig.12. The output current of multi input buck-boost DC-DC in boost mode as shown in Fig.13.

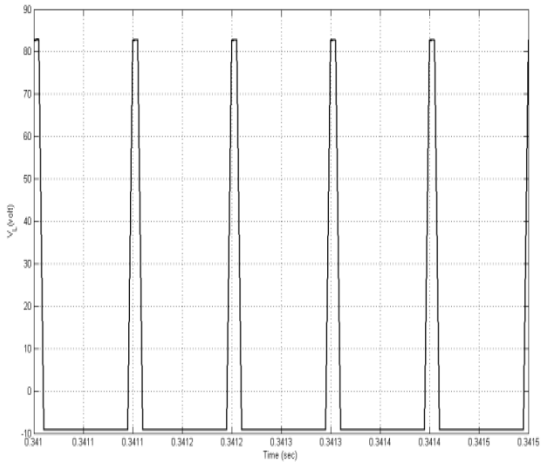

Fig.11. Inductor voltage of multi input buck-boost DC-DC converter (boost mode)

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
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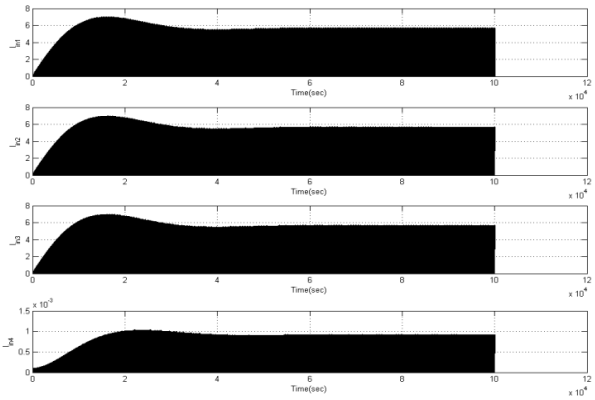

Fig.12. input current of multi input buck boost DC-DC converter

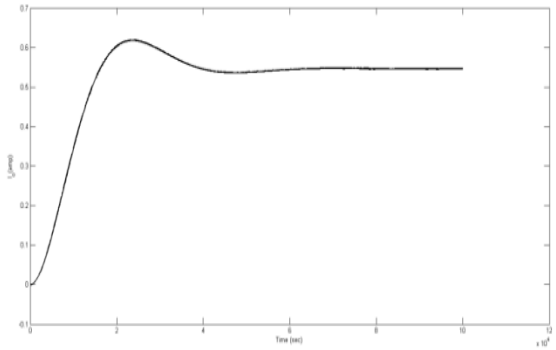

Fig.13. output current of multi input buck-boost dc-dc converter (boost mode) using MATLAB

The output current will settle in 0.6msec.Under steady state conditions output current ripple is 0.0016A.The frequency of ripple is same as switching frequency.

The output current ripple of multi input buck-boost DC-DC in boost mode as shown in Fig.14.

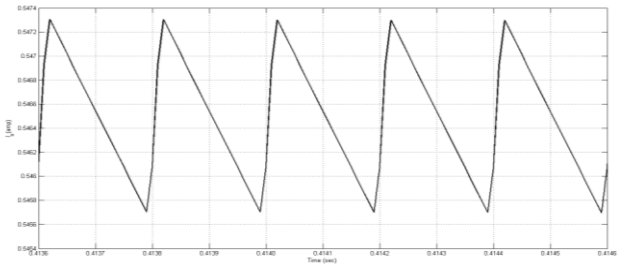

Fig.14. output current ripple of multi input buck-boost DC-DC converter (boost mode)

The output voltage of multi input buck-boost dc-dc in boost mode as shown in Fig.15.

The output voltage attains value of 82V in 0.6msec.Under steady state conditions output voltage ripple is 0.13V .The frequency of ripple is same as switching frequency.

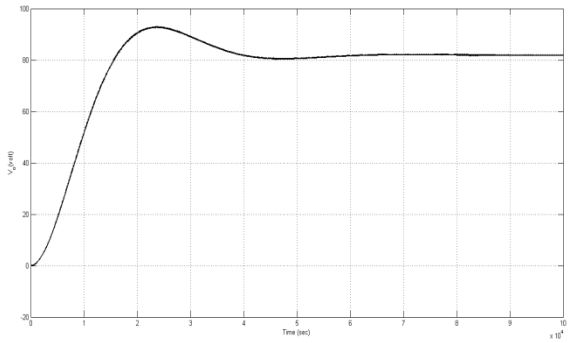

Fig.15. output voltage of multi input buck-boost DC-DC converter (boost mode)

The output voltage ripple of multi input buck-boost DC-DC in boost mode as shown in Fig.16.

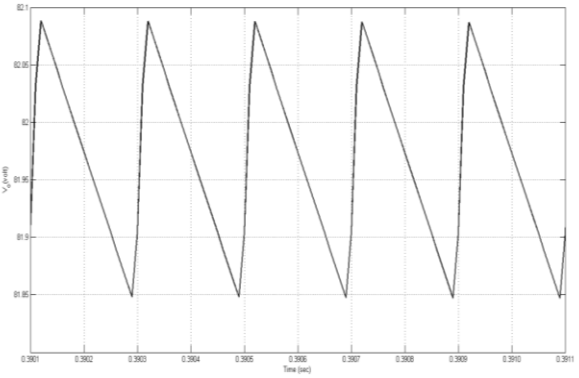

Fig.16.Output voltage ripple of multi input buck-boost DC-DC converter (boost mode) using MATLAB

The switching signals for switches S_1, S2, S3, S4 of multi input DC-DC buck boost converter in buck mode is shown in Fig.17.

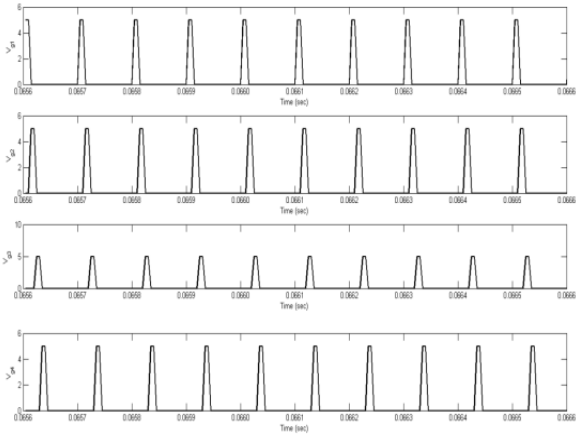

Fig.17. switching signals of multi input buck-boost DC-DC converter (buck mode)

ISSN (Online) 2395-2717

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The Inductor voltage in buck mode as shown in Fig.18.

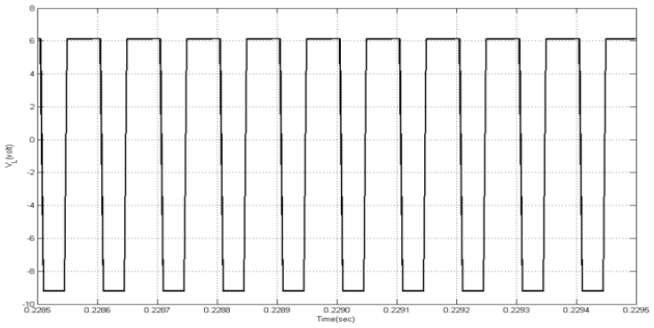

Fig.18. Inductor voltage of multi input buck-boost DC-DC converter (buck mode)

The input current of each input voltage source in buck mode as shown in Fig.19.

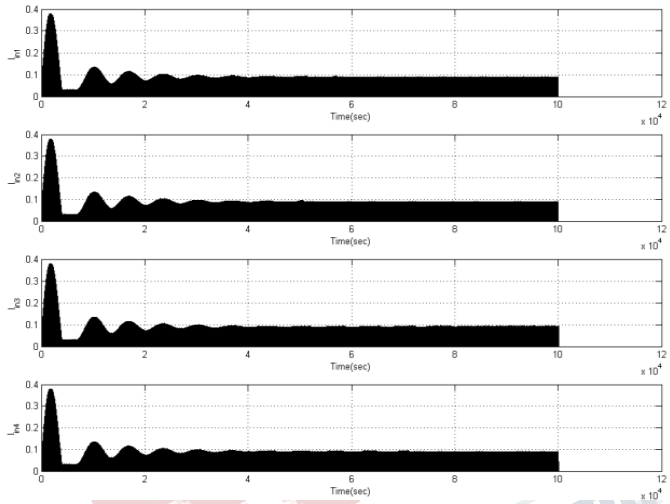

Fig.19. the input current of each input voltage source of multi input buck-boost DC-DC converter (buck mode)

The output current in buck mode is shown in Fig.20.

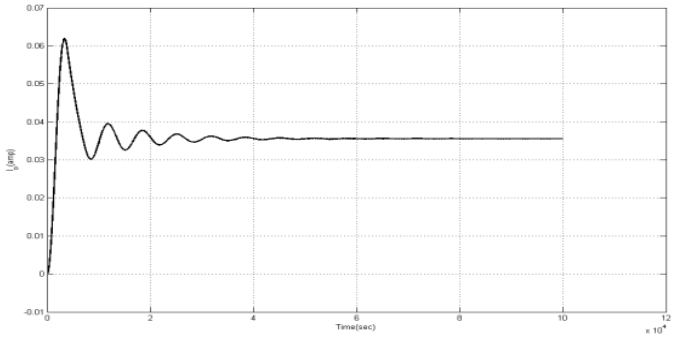

Fig.20. output current of multi input buck-boost DC-DC converter (buck mode)

The output current will settle in 0.6msec.Under steady state conditions output current ripple is 0.0016A.The frequency of ripple is same as switching frequency.

The output current ripple of multi input buck-boost DC-DC in buck mode as shown in Fig.21.

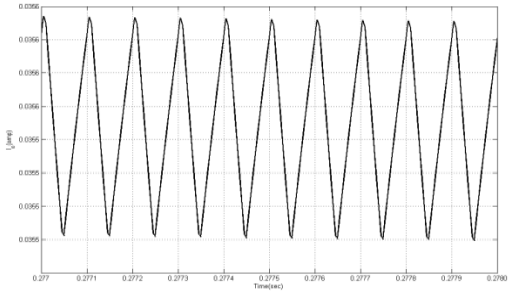

Fig.21. output current ripple of multi input buck-boost DC-DC converter (buck mode)

The output voltage of multi input buck-boost DC-DC in buck mode as shown in Fig.22.

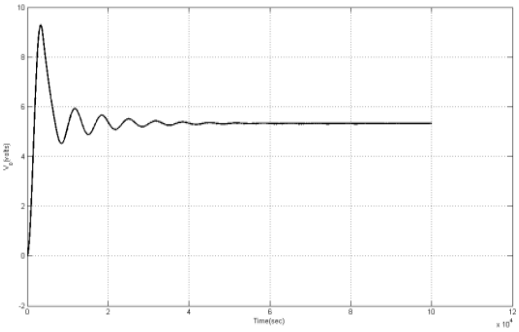

Fig.22. output voltage of multi input buck-boost DC-DC converter (buck mode)

The output voltage attains value of 5.33V in 0.6msec.Under steady state conditions output voltage ripple is 0.01V .The frequency of ripple is same as switching frequency.

The output voltage ripple of multi input buck-boost DC-DC in buck mode as shown in Fig.23.

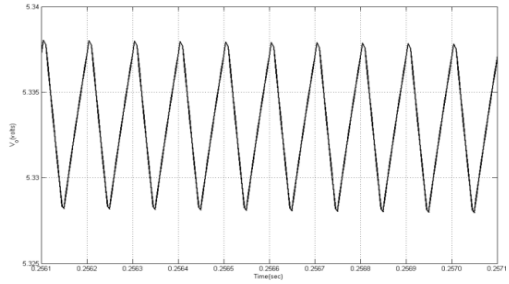

Fig.23.Output voltage ripple of multi input buck-boost DC-DC converter (buck mode)

Output voltage calculations:

ISSN (Online) 2395-2717

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$T_1=d_1T$
$T_2=d_2T$
$T_3=d_3T$
$T_4=d_4T$
$T= T_1+ T_2+ T_3+ T_4+T_{OFF}$
T_1=Turn ON time for S_1 switch
T_2=Turn ON time for S_2 switch
T_3=Turn ON time for S_3 switch
T_4=Turn ON time for S_4 switch
T_{OFF}=Turn OFF time
$D= d_1+ d_2+ d_3 + d_4$
D=Total duty ratio
d_1=duty ratio of S_1 switch
d_2=duty ratio of S_2 switch
d_3=duty ratio of S_3 switch
d_4=duty ratio of S_4 switch
From the voltage second balance equation

$$[L\frac{di}{dt}(d1T + d2T + d3T + d4T) + L\frac{di}{dt}(1 - d1 - d2 - d3 - d4)T] = Vin(d1 + d2 + d3 + d4)T + (-Vo)((1 - d1 - d2 - d3 - d4)T)$$

Average voltage across inductor is zero

$$[L\frac{di}{dt}(d1T + d2T + d3T + d4T) + L\frac{di}{dt}(1 - d1 - d2 - d3 - d4)T] = 0$$

$$\therefore Vin(d1 + d2 + d3 + d4)T = (Vo)(1 - d1 - d2 - d3 - d4)T$$

Then $Vo = \frac{Vin(d1+d2+d3+d4)}{1-d1-d2-d3-d4}$

Table. 1 shows duty ratio vs. efficiency calculations of multi input DC-DC converter. The duty ratio is maintained from 0.1 to 0.9 to attain buck and boost mode of operation. Fig.24 shows Duty ratio Vs. Efficiency graph. The converter attains a good efficiency at high duty ratio.

Table.1. Duty ratio Vs. Efficiency

D	Duty ratios of switches S_1,S_2,S_3,S_4							
	d_1	d_2	d_3	d_4	Output Voltage V_o	Output Current I_o	Input Current I_i	Efficiency (%η)
0.1	0.1	0.0	0.0	0.0	0.2226	0.00148	0.00736	00.44
0.2	0.1	0.1	0.0	0.0	1.5010	0.01001	0.01601	09.38
0.3	0.1	0.1	0.1	0.0	3.1450	0.020[illegible]	[illegible]	21.36
0.4	0.1	0.1	0.1	0.1	5.3380	0.03559	0.05694	33.36
0.5	0.2	0.1	0.1	0.1	8.4090	0.05606	0.10530	44.76
0.6	0.2	0.2	0.1	0.1	13.010	0.08676	0.20350	55.46
0.7	0.2	0.2	0.2	0.1	20.690	0.13800	0.43590	65.50
0.8	0.2	0.2	0.2	0.2	36.040	0.24030	1.15600	74.91
0.9	0.3	0.3	0.3	0.0	82.000	0.54690	5.35500	83.70
0.9	0.5	0.2	0.2	0.0	82.000	0.54690	5.35500	83.70
0.9	0.6	0.1	0.1	0.1	82.000	0.54690	5.35500	83.70

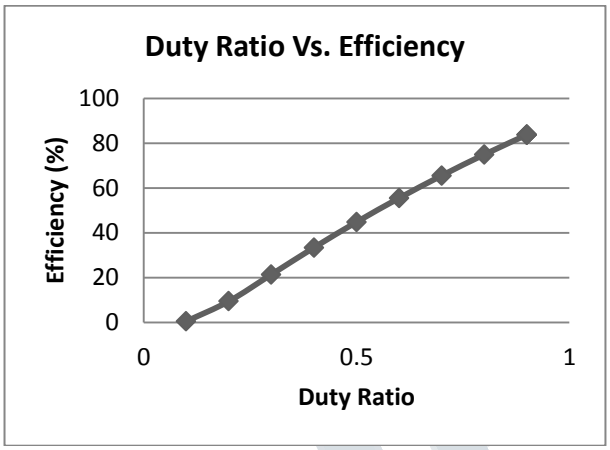

Fig.24. Graph for Duty ratio Vs. Efficiency

Table.2. Load vs. Efficiency

R_L ohms	V_i volts	I_i amp	V_o volt	I_o amp	Efficiency(%η)
1000	10	1.171	79.2	0.0792	53.56
600	10	1.735	85.64	0.1427	70.43
300	10	2.834	82.73	0.2758	80.5
150	10	5.355	82	0.5469	83.7
120	10	6.65	81.93	0.6828	84.12
100	10	7.938	82.03	0.8203	84.768
80	10	9.87	81.97	1.025	85.12
40	10	17.91	75.28	1.882	79.1

Load vs. Efficiency graph as shown in Fig.25.

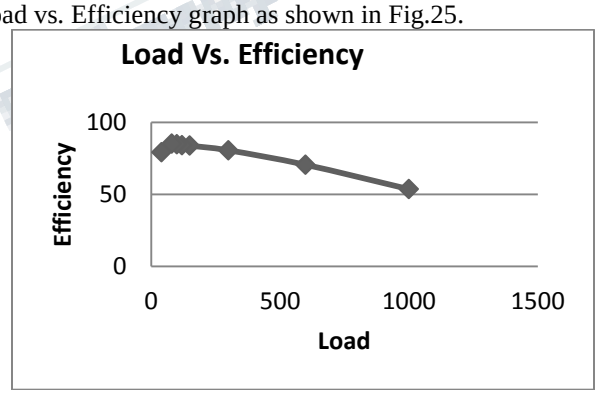

Fig.25 shows Load vs. Efficiency graph.

VI. CONCLUSION

The Multi input buck-boost DC-DC converter topologies were simulated through derivation by using four single pole single throw switches as a building block. This converter use only one inductor which reduces the converter size, component count and cost of the converter. The operating performances of the multi input DC-DC converter were simulated with constant input voltages with variable duty ratios. The proposed

converter provides efficient output voltage in buck and boost modes. It can be used with Ultra Capacitor, Battery, Photo voltaic system, Fuel cell system for renewable energy applications.

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