ISSN No:-2456-2165

Modified Common Ground Transformerless High Gain Dc-DcBuck-Boost Converter

[1]Vishak Ravi,
PG Scholar Dept of Electrical & Electronics Engg,
Mar Athanasius College of Engineering
Kothamangalam, Kerala

[2]Smitha Paulose (Professor)
Dept of Electrical & Electronics Engg,
Mar Athanasius College of Engineering
Kothamangalam, Kerala

[3]Mohitha Thomas (Professor)
Dept of Electrical & Electronics Engg,
Mar Athanasius College of Engineering
Kothamangalam, Kerala

[4]Binoj Thomas (Professor)
Dept of Electrical & Electronics Engg,
Mar Athanasius College of Engineering
Kothamangalam, Kerala

Abstract:- Enhancing the voltage ratio in a converter is a leading aim to improve its performance. Regarding this goal, a new topology of buck-boost converter is introduced. DC-DC converters are essential devices in many applications like UPS, solar energy, wind energy batteries, where their output voltage being constant. The converter offers a much higher voltage gain ratio in comparison to its relevant high gain buck-boost structures. The range of duty cycle has widened in this converter without adopting any transformers or coupled inductors in its configuration. The number of components is quite a few. There- fore, this converter is quite easy to be controlled. Furthermore, a common electrical ground is provided between the input and output ports. This has a high level of priority due to the conviction that, when a converter lacks this feature, another isolated device is required for controlling the power switches. This would considerably increase the costs of implementing such structures. As a result, their practical usage in several applications is highly limited. Hence, maintaining common electrical ground is another feature that must be considered in devising a converter. Hence, this structure is an appropriate choice to be utilized in several industrial applications. Results are obtained by simulating the system in MATLAB/SIMULINK R2020b.

Keywords:- *Buck-Boost Converter, Common electrical ground, Gain, Duty Cycle*

I. INTRODUCTION

DC-DC converters plays an important role in power electronics for numerous applications. uninterruptable power supplies (UPS), drives, renewable energy systems such as solar energy, and wind energy plants etc. have been announced as the most attractive applications that employ of DC-DC converters. Along with this notion, the voltage gain ratio also must be improved in order to extend the range of their duty cycle (D). This is because the scale of the duty cycle in the fundamental buck-boost converters is much confined. In this regard, improving voltage gain ratio in buck-boost converters attract a great deal of attention. Personal computers (PCs) have been serving among the fastest-growing devices from recent decades up to the present time, and, the future generation of electronics devices. One of the vital hardware components of a PC is Switched Mode Power Supply (SMPS). The main job of SMPS is to convert AC power to DC power, followed by several numbers of desirable dc voltages in order to convey the electric power to certain parts of the PC. After rectifying the received power, a proper regulator, such as a buck-boost DC-DC converter is essential. DC-DC converters are essential devices to be engaged in other applications, where the output voltage is required to be constant.

A suitable converter must have the lowest number of components possible in isolated or nonisolated structures. Itis obvious that one of the most crucial features in a converteris keeping electrical common ground. This has a high level of priority due to the conviction that, when a converter lacks this feature, another isolated device is required for controlling the power switches. Non-isolated converters are highly preferred owing to the absence of any leakage fluxes produced by the transformers in their structures. Regarding this aim, using voltage multiplier cells (so-called VMCs) is known as a quite effective approach to improve voltage gain ratio. Embedding cells in parallel or series can make a significant contribution to the improvement of voltage gain ratio. Moreover, the voltage stress across semi-conductors can be divided at low rates on each. Down the middle of these procedures, voltage lift techniques have also found their way toward DC-DC converters .The combination of this approach with VMCs yields a new definition known as voltage lift cells (VLC). The capability of increasing output voltage is significantly enhanced in both approaches. But granted, the extra number of components are much high, which increases the chance of having low efficiency in such structures.

With attention to the above mentioned features, this work offers a novel circuit architecture of a DC-DC power converter. voltage gain ratio is significantly enhanced. The number of components is much low. So, it represents the ease of controlling capability. More importantly, the common electrical ground is preserved. Converters are essential devices in many applications like UPS, solar energy, wind energy batteries, where their output voltage being constant. The modified converter offers a much higher voltage gain ratio in comparison to its relevant high gain buck-boost structures. The range of duty cycle has widened in this converter without adopting any transformers or coupled inductors in its configuration. The number of components is quite a few. Therefore, this modified converter is quite easy to be controlled. Furthermore, acommon electrical ground is provided between the input and output ports. This has a high level of priority due to the conviction that, when a converter lacks this feature, another isolated device is required for controlling the power switches. This would considerably increase the costs of implementing such structures. As a result, their practical usage in several applications is highly limited. Hence, maintaining common electrical groundis another feature that must be considered in devising a converter. Hence, this modified structure is an appropriate choice to be utilized in several industrial applications.

II. METHODOLOGY

Modified Common ground transformerless high gain dc-dc buck-boost converteris a combination of buck and boost mode of operations. Figure 1 shows the high gain dc-dc buck-boost converter. The topology consists of two power switches S_1 and S_2, inductances L_1 and L_2, capacitances C_1 and C_2, diodes D_1 and D_2 and load resistor R_0.

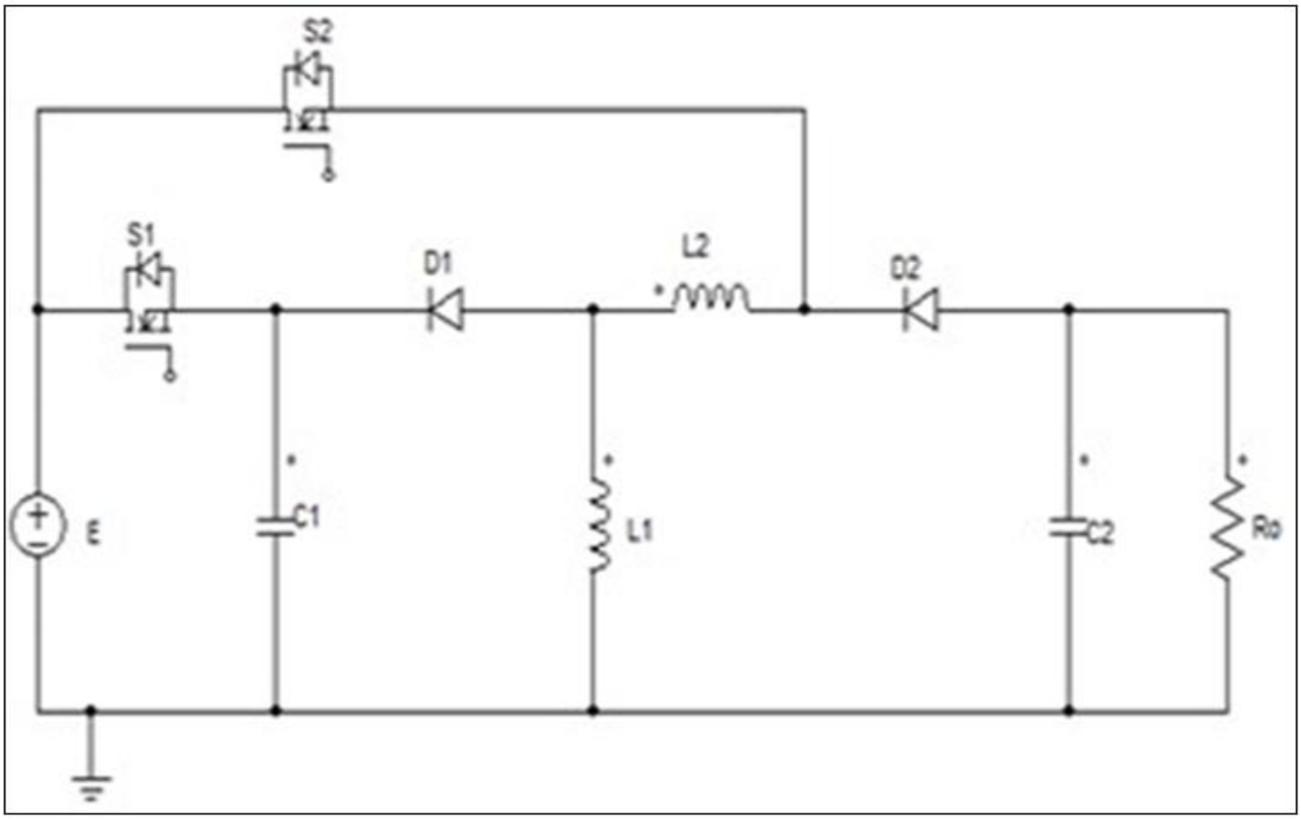

Fig 1 Modified Common Ground Transformerless High Gain Dc-Dc Buck-Boost Converter

The DC power source is supplied to the capacitor C_1 through S_1 and inductor L_2 through S_2.

A. Modes of Operation

For this converter there are two modes of operation. In mode1, the switches $S_1$and S_2 are turned on and diodes D_1 and D_2 become reverse biased simultaneously. While in mode 2,the power switches $S_1$and S_2 are both blocked simultaneously, though diodes D_1 and D_2 are conducting.

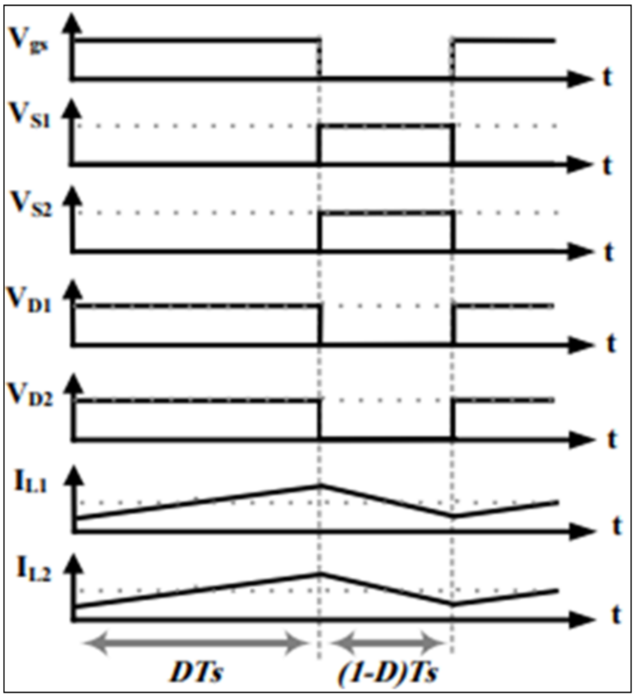

Fig 2 Theoretical Waveforms of Modified Buck-Boost Converter

- *Mode 1 (0-Dt$_s$) :*

In this mode, the switches $S_1$and S_2 are turned on and diodes D_1 and D_2 become reverse biased simultaneously. Capacitor C_1 charged by the input DC power source V_{in}. Meanwhile L_2 charged through the S_2. C_2 discharges its energy to the resistive load in the converter. Figure 3.6 shows the operating circuit of mode 1.

$$V_{C1} = V_{in} \quad (1)$$

$$L_1 \frac{di_{L1}}{dt} + L_2 \frac{di_{L2}}{dt} = V_{in} \quad (2)$$

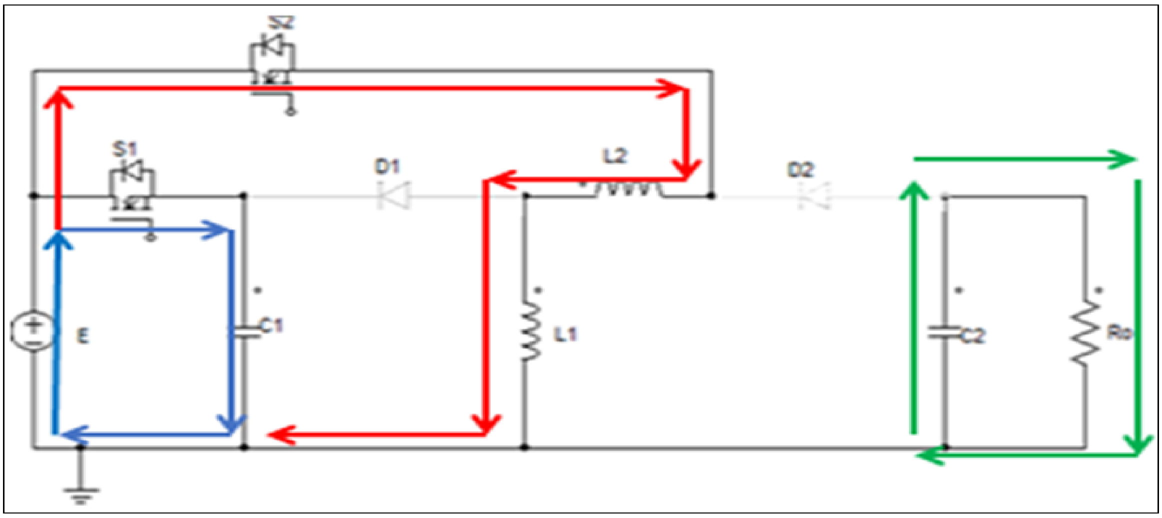

Fig 3 Operating Circuit of Mode 1

- *Mode 2 (DT$_s$ T$_s$):*

In this mode, the power switches $S_1$and S_2 are both blocked simultaneously, though diodes D_1 and D_2 are conducting. C_1 discharges. L_1 and L_2discharges its energy to C_2. Figure 3.7 shows the operating circuit of mode 2.

$$L_1 \frac{di_{L1}}{dt} = -V_{C1} \quad (3)$$

ISSN No:-2456-2165

$$L_2 \frac{di_{L2}}{dt} = -V_{C2} + L_1 \frac{di_{L1}}{dt} \quad (4)$$

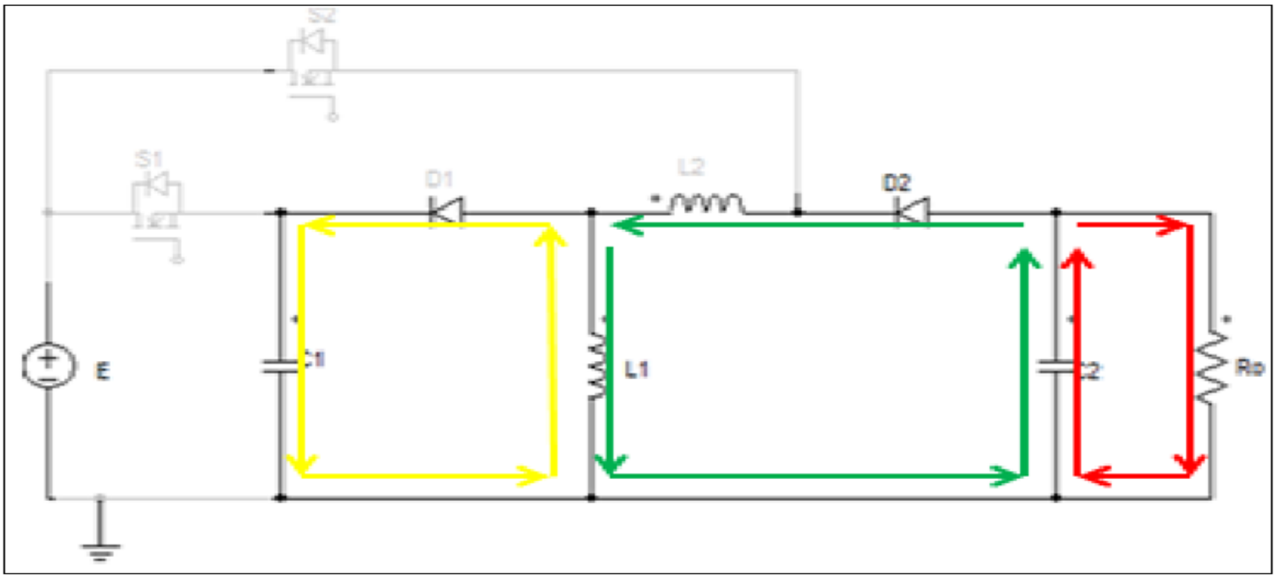

Fig 4 Operating Circuit of Mode 2

B. Design of Components

The input voltage is taken as V_{in} = 50. The load resistance is set as 4Ω and output voltage is taken as V_0 = -11.63V. switching frequency, f_s = 50kHz. So time period, T_s =$\frac{1}{}$ = 0.00002 sec.

➢ *Load Resistor, R0:*

$$R_o = \frac{{V_o}^2}{P_o} = \frac{-11.63^2}{225} = 0.601\Omega \quad (5)$$

Choose the value of load resistor as R0= 4 Ω

➢ *Duty ratio D:*

$$\frac{V_o}{V_{in}} = \frac{D(D-2)}{(1-D)^2} = \frac{-11.63}{50} = 0.2 \quad (6)$$

So, the value of Duty ratio (D)= 0.2

➢ *Inductor, L1:*

$$I_0 = \frac{P_o}{V_0} = \frac{225}{11.63} = 19.34A \quad (7)$$

$$I_{L1} = \frac{I_0}{(1-D)^2} = \frac{19.34}{(1-0.2)^2} = 30.68A \quad (8)$$

$$L_1 = \frac{D * V_{in}}{f_s * \Delta i_{L1}} \quad (9)$$

ΔiL1 = 3.2% of IL1 = 3.2% of 30.68 = 0.98A

Therefore,

$$L_1 = \frac{0.2 * 50}{50000 * 0.98} = 0.2mH \quad (10)$$

So, the value of inductor is set as L1 = 0.5mH.

➢ *Inductor, L_2:*

$$I_{L2} = \frac{I_0}{(1-D)} = \frac{19.34}{1-0.2} = 24.175A \quad (11)$$

$$L_2 = \frac{D * V_{in}}{(1-D)f_s * \Delta i_{L2}} \quad (12)$$

ΔiL2 = 5% of IL2 = 5% of 24.175 = 1.2A

Therefore,

$$L_2 = \frac{0.2 * 50}{(1-0.2) * 50000 * 1.2} = 0.2mH \quad (13)$$

So, the value of inductor is set as L_2 = 0.5mH.

➢ *Capacitor, C_1 :*

$$V_{C1} = \frac{D * V_{in}}{(1-D)} = \frac{0.2 * 50}{1-0.2} = 12.5V \quad (14)$$

$$C_1 = \frac{D * I_0}{(1-D) * f_s * \Delta V_{C1}} \quad (15)$$

ΔV_{C1} = 1.28% of V_{C1} = 1.28% of 12.5 = 0.16V

ISSN No:-2456-2165

Therefore,

$$C_1 = \frac{0.2 * 19.34}{(1-0.2)*50000*0.16} = 600\mu F \qquad (16)$$

Choose the value of capacitor is as C_1 = 220μF

➢ *Capacitor, C_2 :*

$$V_{C2} = \frac{D*(2-D)*V_{in}}{(1-D)^2} = \frac{0.2*(2-0.2)*50}{(1-0.2)^2} = 28.125V$$
(17)

$$C_2 = \frac{D * I_0}{f_s * \Delta V_{C2}} \qquad (18)$$

Therefore,

$$C_2 = \frac{0.2 * 19.34}{50000 * 0.12} = 644\mu F \qquad (19)$$

Choose the value of capacitor is as C_2 = 220μF

III. SIMULATIONS AND RESULTS

Simulation parameters for the modified buck-boost converter is given in Table 1. A dc input voltage, Vin of 50V gives an ac output voltage, V0 of -11.63V for an output power, Po of 225W. The switches are MOSFET/Diode with constant switching frequency of 50kHz. The simulation results of the modified buck-boost converter are shown in the following figures. Figure 5 shows the input voltage and input current. It can be seen that the input voltage Vin is 50V and the input current iin is 0.7554A. The switching frequency is chosen to be 50kHz.

Table 1 Simulation Parameters of Modified Buck-Boost Converter

Parameters	Buck mode
Input Voltage V_{in}	50 V
Output load R_0	4 Ω
Duty ratio D	0.2
Inductances L_1, L_2	0.5 mH
Capacitances C_1, C_2	220µF
Switching frequency f_s	50 kHz

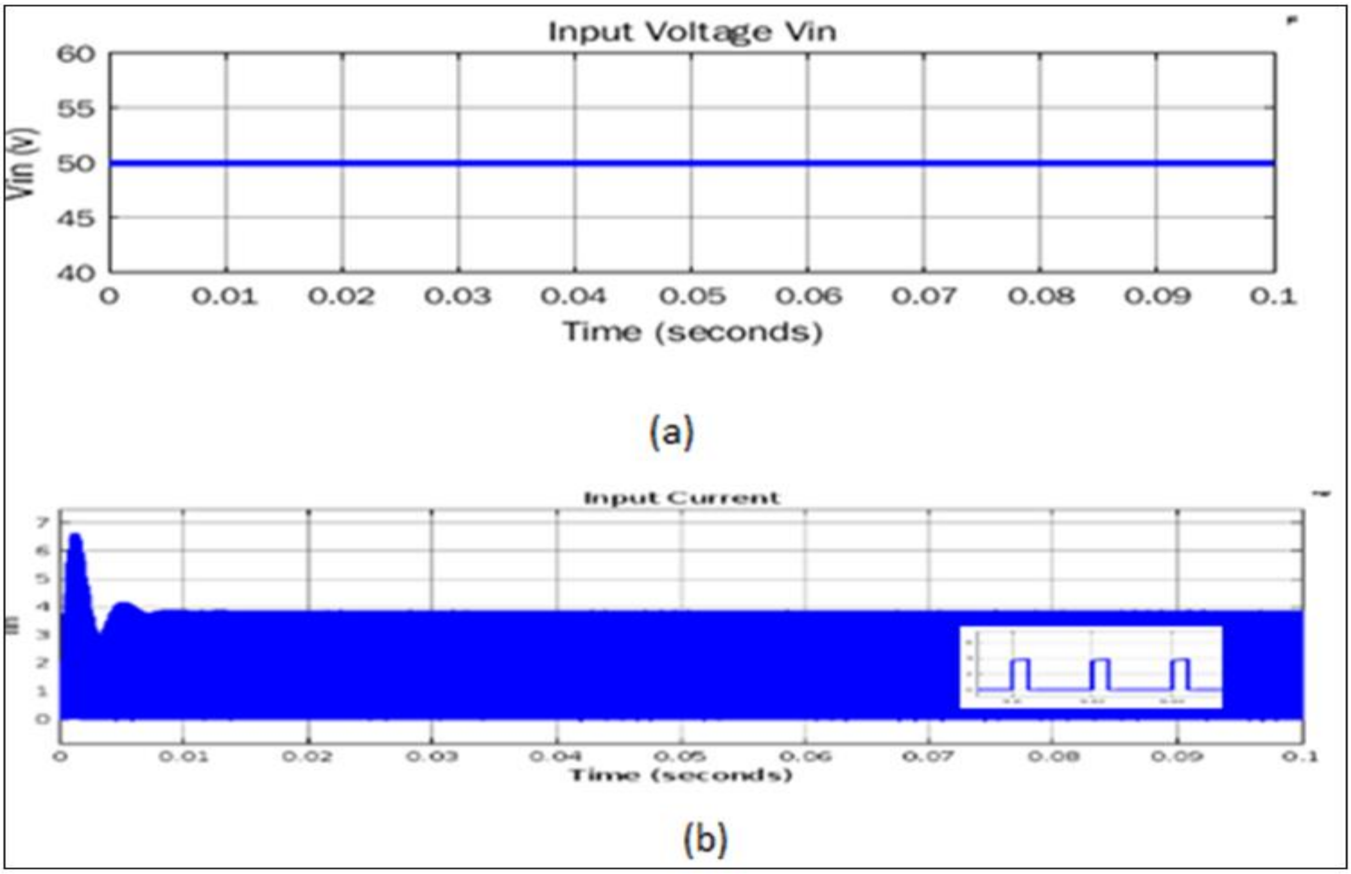

Fig 5 (a) Input Voltage (V_{in}) and (b) Input Current (i_{in})

Figure 6 shows the output voltage and output current. Itcan be seen that the output voltage V_0 is -11.63V and the output current i_0 is -2.907A.

ISSN No:-2456-2165

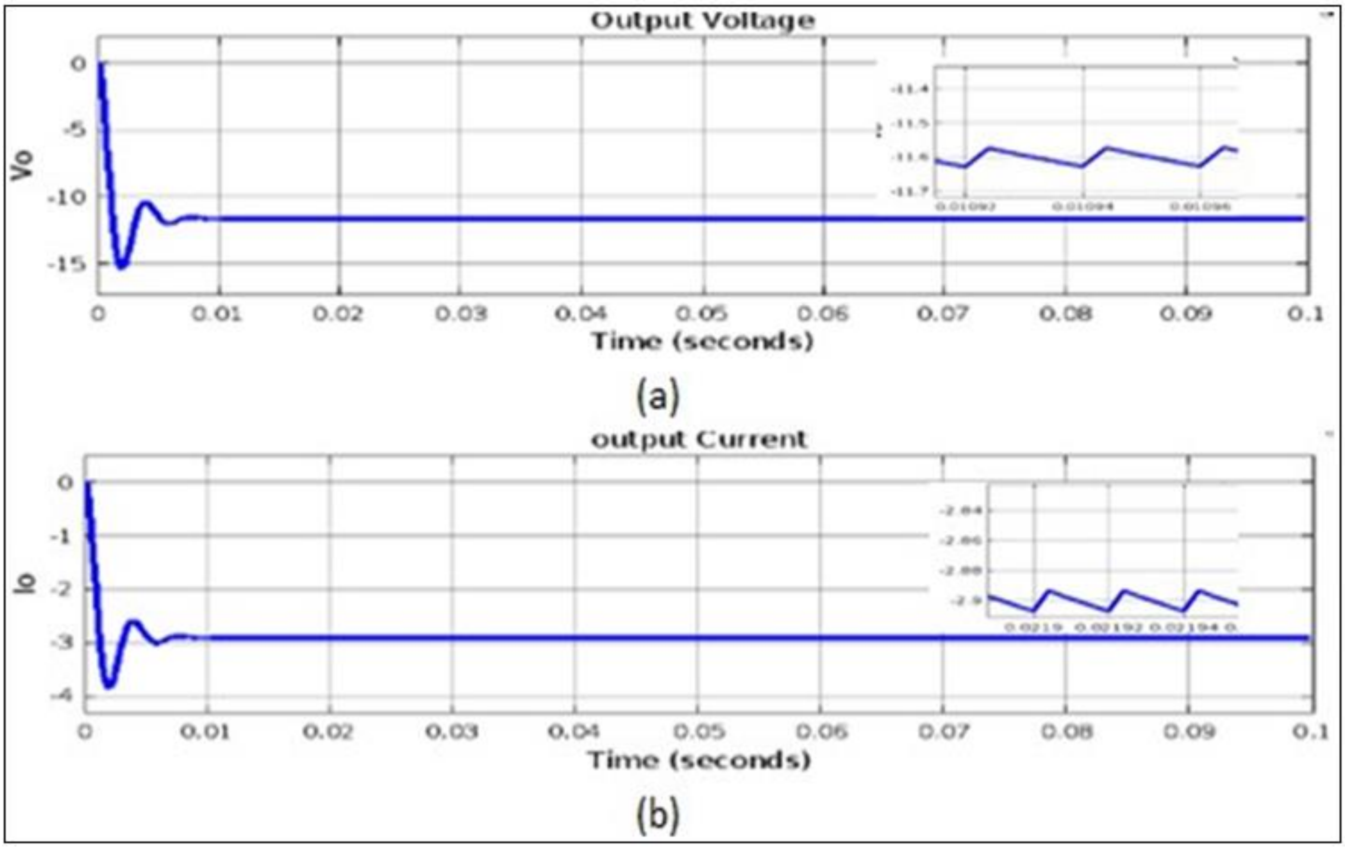

Fig 6 (a) Output Voltage (V_0) and (b) Output Current (i_0)

Figure 7 shows the gate pulse and voltage across switch S_1 .The voltage across the switch V_{S1} is 40V.

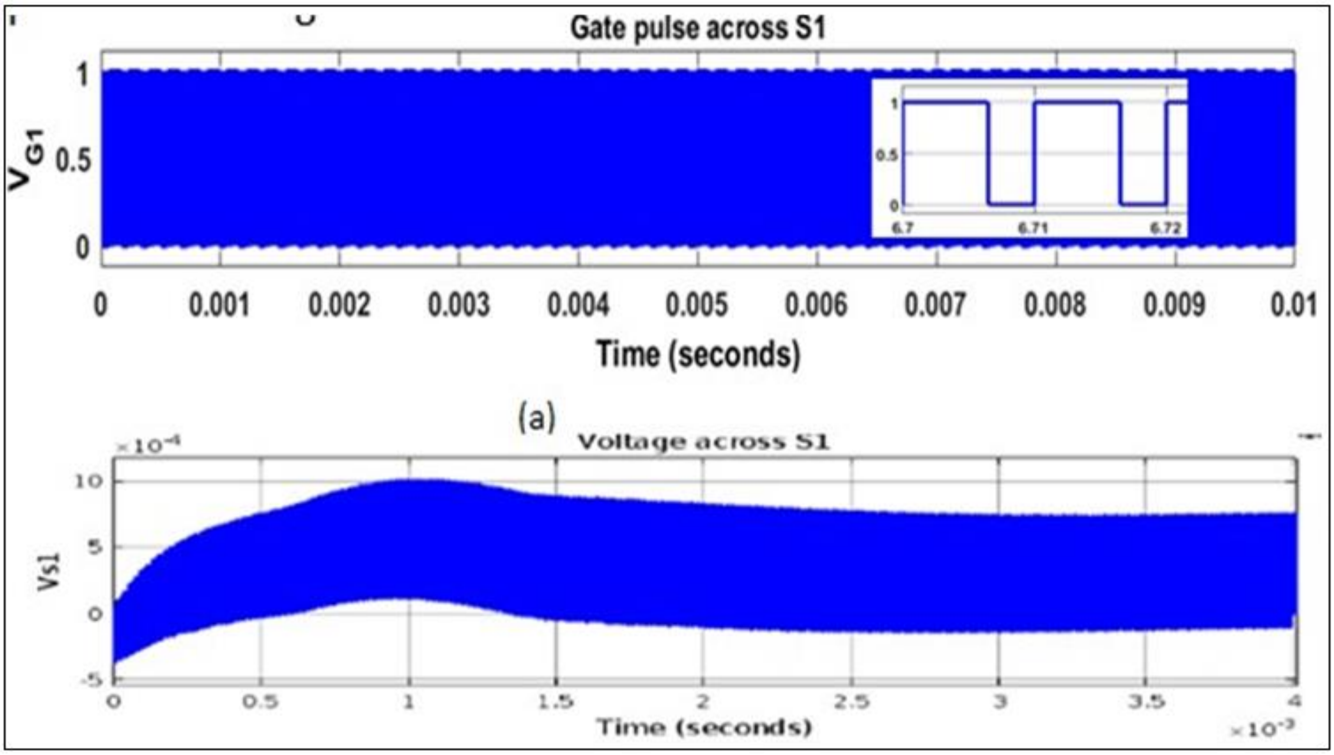

Fig 7 (a) Gate pulse of S_1 (b) Voltage across S_1(V_{S1})

Figure 8 Shows the Gate Pulse and Voltage Across Switch S_2.The Voltage Across the Switch V_{S2} is 60V.

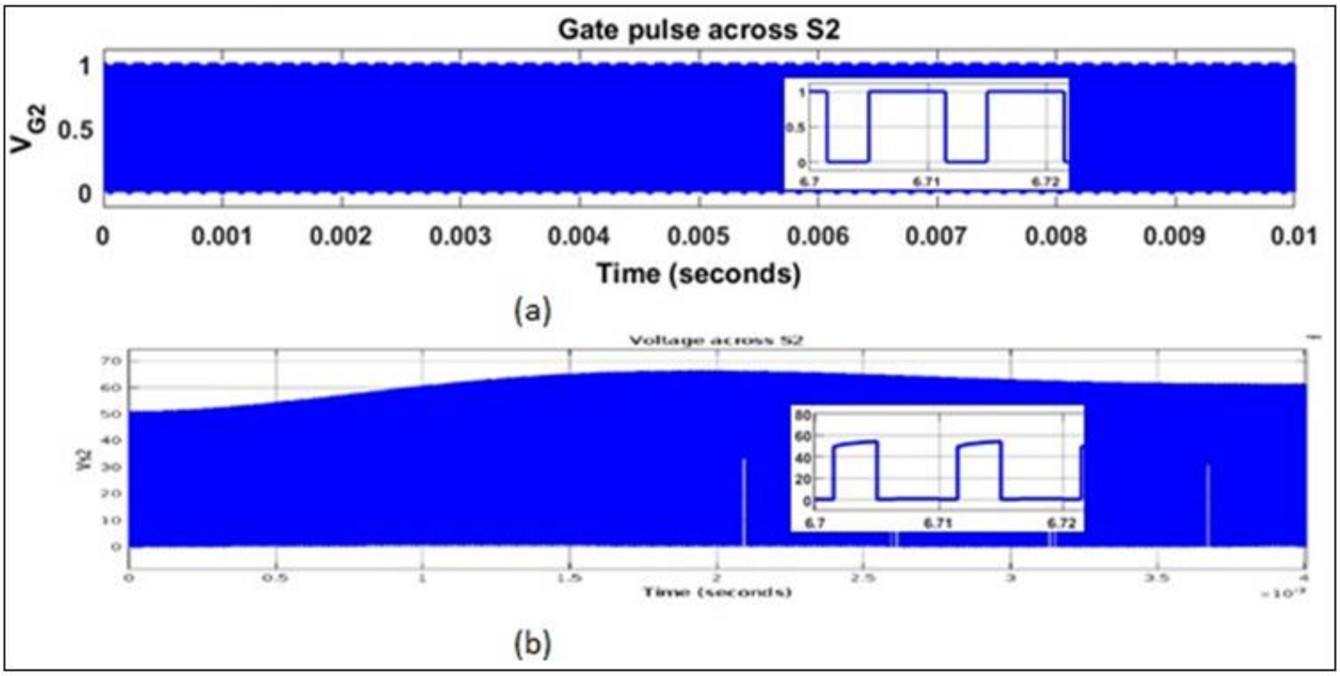

Fig 8 (a) Gate Pulse of S_2 (b) Voltage Across S_2(V_{S2})

Figure 9 shows the current through inductors L_1 and L_2. It can be seen that the current through inductor i_{L1} is 3.462A and current through inductor i_{L2} is 3.449A.

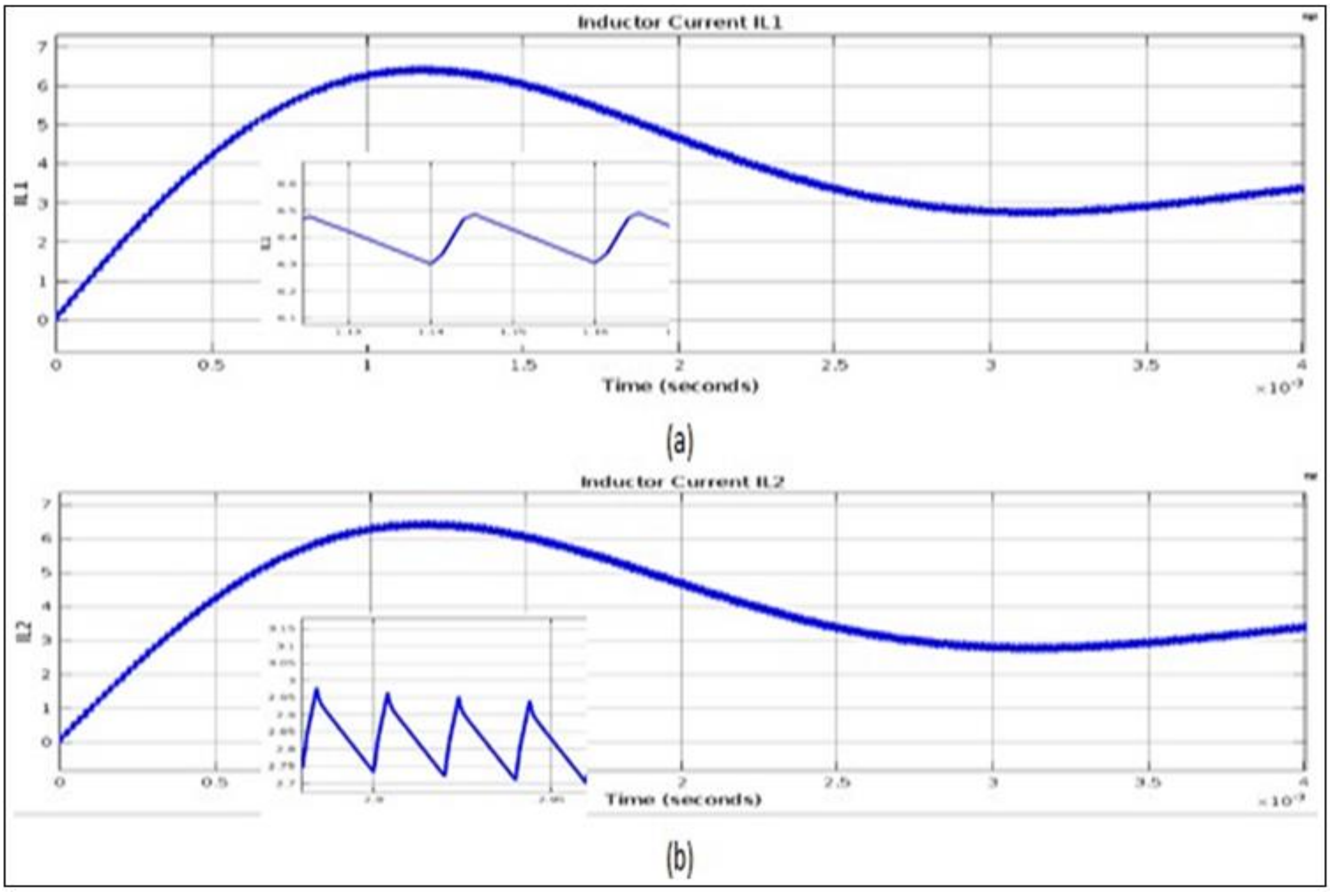

Fig 9 (a) Current through inductance (i_{L1}) and (b)Current Through Inductance (i_{L2})

Figure 10 shows the voltage across capacitor $C_1$and C_2. The value obtained for V_{C1} = 50V and Δ V_{C1} = 0.0007V. The value obtained for V_{C2} = -11.63 and Δ V_{C2} = 0.06V.

ISSN No:-2456-2165

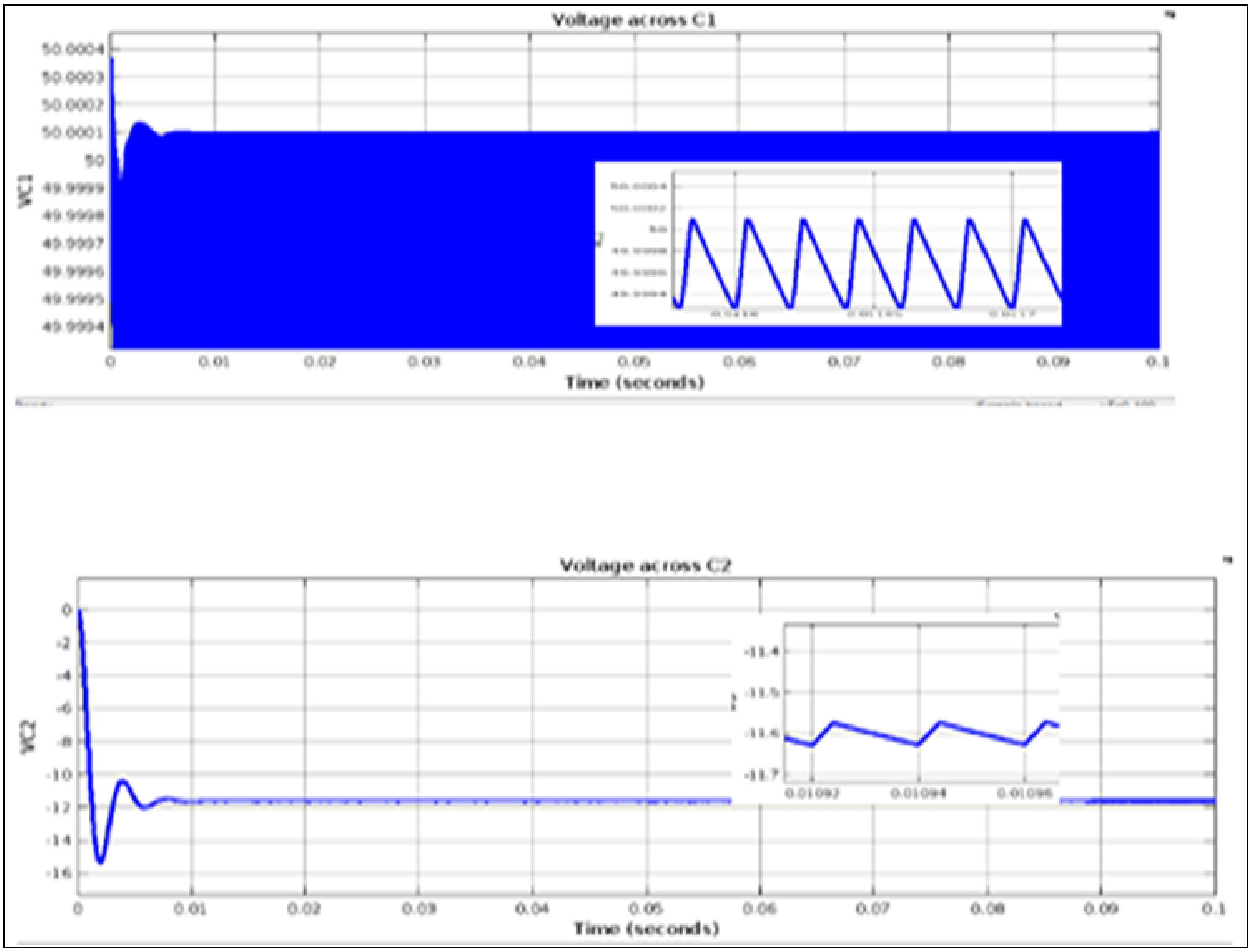

Fig 10 (a) Voltage Across Capacitor C_1 (V_{C1}), (b)Voltage Across Capacitor C_2 (V_{C2}))

IV. PERFORMANCE ANALYSIS

The analysis of modified buck- boost converter is carried out by considering parameters like efficiency, duty ratio and switching frequency.

A. *Efficiency Vs Output Power*

Efficiency of a power equipment is defined at any load as the ratio of the power output to the power input. The efficiencytells us the fraction of the input power delivered to the load. Figure 11 shows the efficiency characteristics of R load.

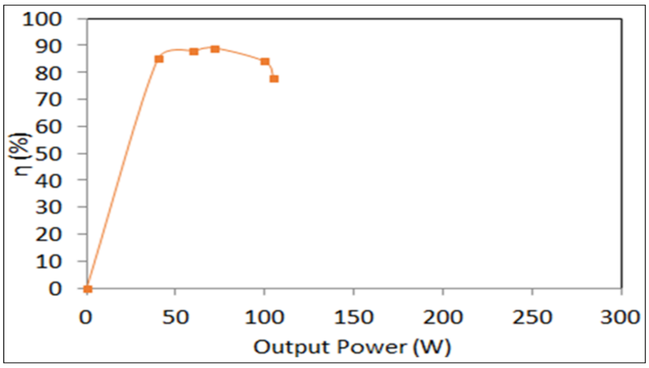

Fig 11 Efficiency Vs Output Power for R Load

The maximum efficiency of proposed converter for R load is around 89% at power output of 167W. And its efficiency decreases as the output power increases.

B. *Gain Vs Duty Ratio*

The plot of Gain of the modified buck-boost converter as a function of duty ratio shown in figure 12. The gain increasesas the duty ratio is varied.

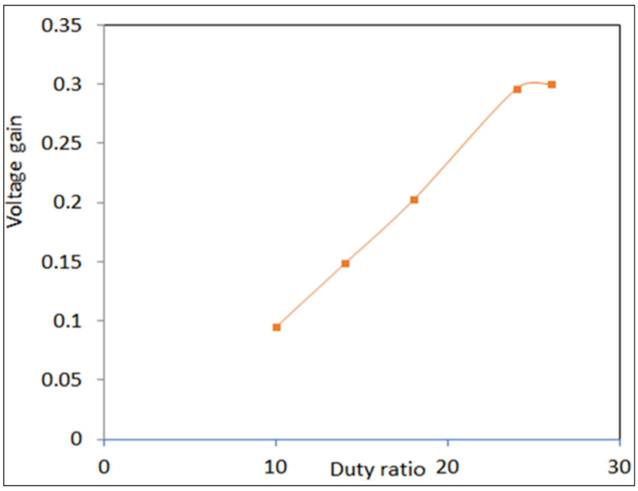

Fig 12 Gain Vs Duty Ratio

ISSN No:-2456-2165

From the figure, its clear that modified converter has less voltage gain. So modified converter perform better as a buck converter.

C. Output Voltage Ripple Vs Switching Frequency

The plot of Output voltage ripple as a function of switching frequency is shown in figure 13. The output voltage ripple is decreased as the switching frequency is increased. Modified buck boost converter has less output voltage ripple.

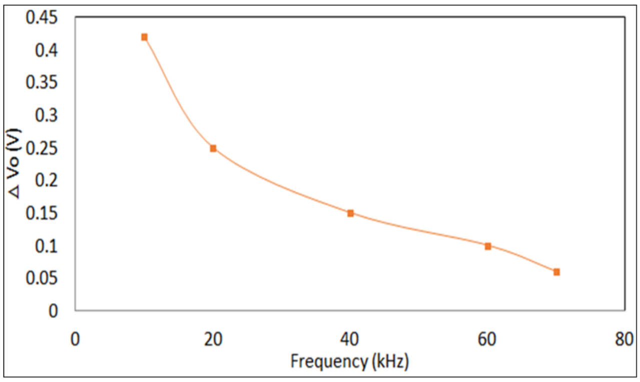

Fig 13 Output Voltage Ripple Vs Switching Frequency

D. Output Voltage Ripple Vs Duty Ratio

The plot of Output voltage ripple as a function of dutyratio is shown in figure 14. The output voltage ripple is increased as the duty ratio is increased. Modified converterhas less output voltage ripples.

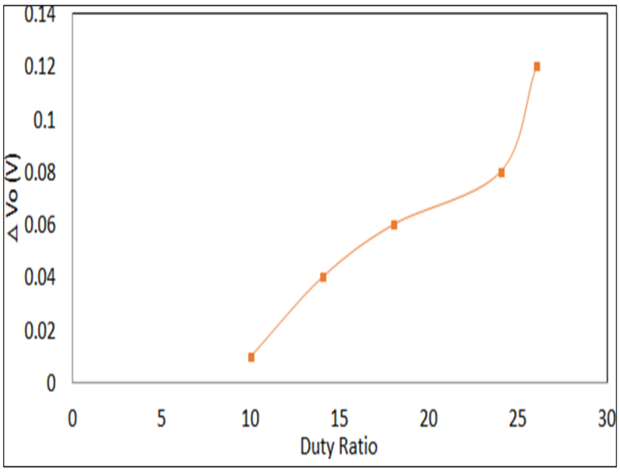

Fig 14 Output Voltage Ripple Vs Duty Ratio

V. COMPARATIVE STUDY

The comparison between between Common ground trans- formerless buck -boost converter & modified converter is givenin table 5.3. On the comparison it can be observed that, number of components are same both converters. Keeping same values for input voltage & switching frequency as 50V & 50kHz, the required output voltage is decreased from -28.125V to -11.63V and hence, gain also decreased from 0.52 to 0.2625. Output voltage ripple decreased to 0.06V from 0.08V in modified converter.

Table 2 Common Ground Transformerless Buck-Boost Converter & Modified Converter

Parameters	Common ground transfomer-less buck boost converter	Modified Converter
No. of switches	2	2
No. of inductor	2	2
No. of capacitor	2	2
No. of diode	2	2
Voltage gain	0.52	.2625
Output Voltage Ripple	0.08 V	0.06V
Output Current Ripple	0.027A	0.02 A
Voltage stress across switch	1.25v, 1.56v	1.35,1.52
Input current ripple	0.6 A	0.25 A

Table 3 shows the component wise comparison between modified converter & other converters. Comparison is based on the components used in the different converters. From table 3 it can be observed that, the number of total components used in modified converter is comparitively lesser than other converters.

Table 3 Comparison between Modified Converter & other Converters

Converters	Modified buck boost converter	Buck-Boost converter based on ZETA converter	Single-switch buck-boost DC/DC converter	KY Buck-Boost converter	Interleaved converter
Switches	2	1	2	1	1
Inductors	2	3	2	3	2
Capacitors	2	4	2	4	3
Diode	2	2	2	2	2

VI. EXPERIMENTAL SETUP WITH RESULT

For the purpose of implementing hardware, the input voltageis reduced to 5V and the switching pulses are generated using TMS320F28335 processor. The switches used are MOS-FET IRF3205. Driver circuit is implemented using TLP250H, which is an optocoupler used to isolate and protect the microcontroller from any damage and also to provide required gating to turn on the switches. Experimental setup of modifiedmodified buck-boost converter is shown in Figure 15. Input 5Vwith 0.03094A DC supply is given from DC source. Switching pulses are taken from TMS320F2833 5microcontroller to driver circuit. Thus an output voltage of -0.447V, 50kHz is obtained from power circuit that is shown in Figure 16. Outputvoltage of converter is taken from the DSO oscilloscope.

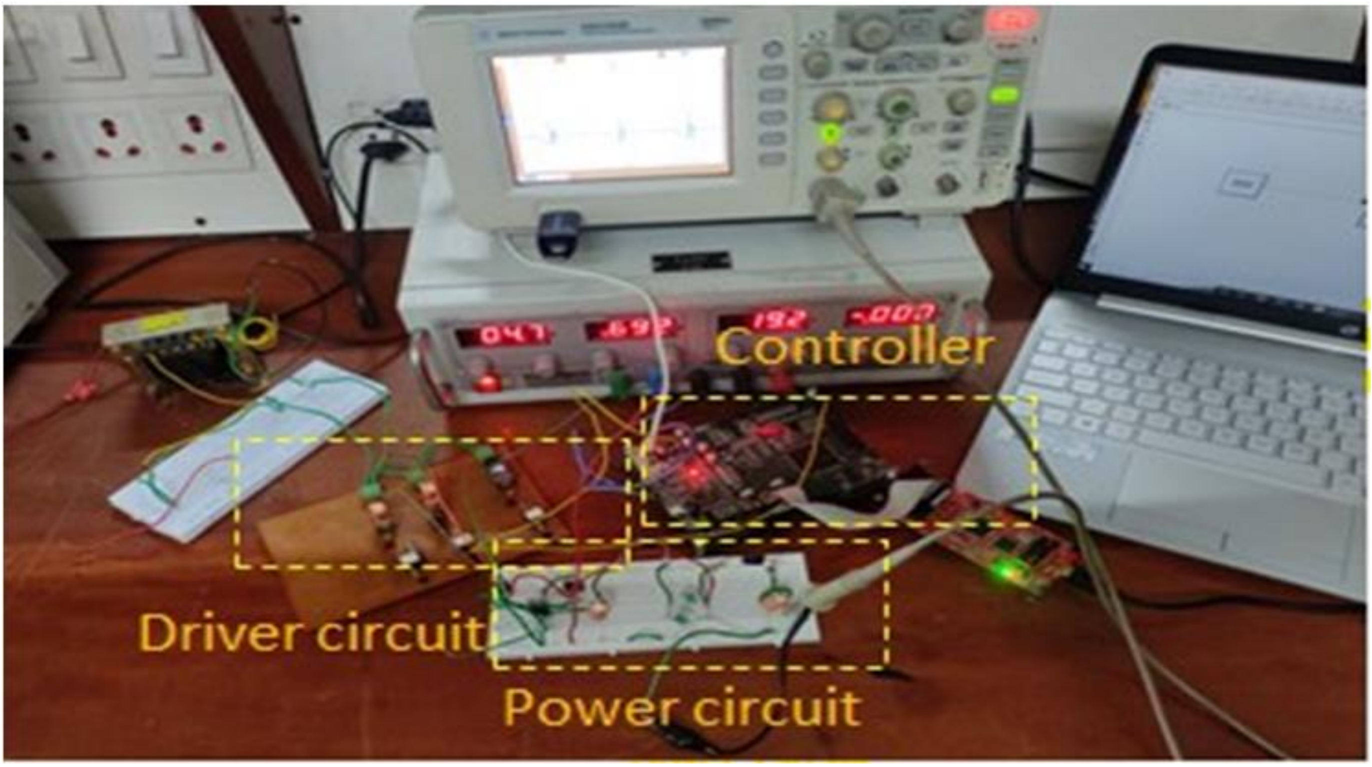

Fig 15 Experimental Setup

Fig 16 Output Voltage of Proposed Converter

VII. CONCLUSION

A modified buck-boost converter that offers a better voltagegain ratio is introduced here. The range of duty cycle has widened in this converter without adopting any transformers or coupled inductors in its configuration. The number of components is quite a few. Therefore this converter is quite easy to be controlled. Also a common electrical ground is provided between the input and output ports. The waveforms detected via simulation results are coincided with those of expected from time-domains. Hence, these waveforms have successfully verified the proper behaviour of the suggested converter under buck state mode of operation. Due to these features, this converter can be utilized in applications where their output ports required to be constant such as renewable energies and SMPSs.

REFERENCES

[1]. Seyed Hossein Hosseini, Masoud Farhadi and Reza Ghazi, ”A Common ground Transformer-less High Gain DC-DC Buck-Boost Converter”, ***12th Power Electronics, Drive Systems, and Technologies Conference (PEDSTC)***, 2021
[2]. R. Ghazi, S. H. Hosseini and S. K. Movahhed, ”A Novel High Gain Single-Switch DC-DC Buck-Boost Converter with Continuous Input and Output Power”, ***24th Electrical Power Distribution Conference (EPDC)***, 2019
[3]. M. Eydi, S. H. Hosseini, and R. Ghazi, ”A New High Gain DC-DC Boost Converter with Continuous Input and Output Currents”, ***10th Int. Power Electron. Drive Syst. Technol. Conf.***, pp. 224229, 2019
[4]. S. Farzamkia, A. Khoshkbar-Sadigh, H. Iman-Eini, and S. H. Hosseini, ”A Flexible Step-up Modular Multilevel Converter for High-PowerDrive Application”, ***IEEE Transportation Electrification Conference Expo (ITEC)***, 2020