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# A Modified Reduced Current Ripple Dc-Dc Buck-Boost Converter

Rahul C R[1], Prof.Veena Mathew [2]
[1](Department of EEE, M A College of Engineering, Kerala, India.)
[2](Department of EEE, M A College of Engineering, Kerala, India.)

***Abstract :*** *In this paper, a modified reduced current ripple DC-DC buck-boost converter, which can be applied for wide range of voltage. The current ripples in the output and input side can be reduced. Reduced current ripple of power electronics supplies has positive effect on efficiency and on the lifespan of sensitive power devices. The DC-DC buck-boost converter are commonly used to deliver higher load voltage from given low voltage source and vice versa. The conventional boost converter has disadvantages are requires a higher duty ratio even for realizing the moderate voltage gain, unable to reach expected levels of voltage gain at extreme duty ratios on account of excessive losses, and the efficiency on full load is low due to higher switching losses. To eliminate some of these limitations, higher-order boost pulse width modulated (PWM) converters are utilized. The DC-DC buck-boost converter are used in many applications such as self-regulating power supplies, battery power system, adaptive control, power amplification etc. The buck-boost converter is simulated in MATLAB/Simulink on a laboratory scale-down 20 to 60V, 50W prototype converter.*

***Keywords:*** *Buck-Boost converter, Fifth-order converter, Reduced current ripple, Resonating circuit, LCS Cell.*

## I. Introduction

Reduced current ripple of power electronics supplies has positive effect on efficiency and on the lifespan of sensitive power devices. Also components used in power electronics converters in a broad range of applications demand low current ripples to achieve higher efficiencies and to prevent their premature damage, this is the case for instance, of electrolytic capacitors, batteries, and fuel cells. DC-DC boost converters are most commonly used to deliver higher load voltages from given low voltage source. The conventional boost converter has disadvantages are requires a higher duty ratio even for realizing the moderate voltage gain, unable to reach expected levels of voltage gain at extreme duty ratios on account of excessive losses, and the efficiency on full load is low due to higher switching losses. To eliminate some of these limitations, higher-order boost pulse width modulated (PWM) converters are utilized. These converters give the higher voltage gain but at higher switching frequencies, the full-load efficiency is still a limitation.

For improvement in efficiency of these converters, soft switching schemes are implemented. The two schemes which are Zero voltage switching (ZVS) during turn-on and Zero current switching (ZCS) during turn-off. These schemes are selected on the basis of device used i.e, IGBT or MOSFET. Even though efficiency is improved using these techniques, they still suffer from some limitations. The ZCS turn-off suffers from limitations such as rise in losses during conduction, converter circuit diode subjected to higher voltage stress and conduction losses increase due to presence of the main switch in series with the resonant inductor. Some of these limitations are eliminated using the soft transition methods such as zero-voltage/zero-current transition (ZVT/ZCT) techniques [4]. To realize better efficiency at the full load condition. The additional network produces both the voltage amplification and the soft switching for the MOSFET [2].

The modified reduced current ripple buck-boost converter is proposed in this paper. The converter uses the energy–transferring capacitor to store energy, and there is no abruptly changing voltage on it. The rest of the paper is organized as follows. The operating principle and steady state analysis of the proposed converter are described in following section.

## II. Proposed Converter Topology

As the converter is shown in Fig. 1, the buck-boost converter consisting of an input voltage $V_{in}$, four switches $S_1$, $S_2$, $S_3$, and $S_4$ four diodes $D_1$, $D_2$, $D_3$, and $D_4$, four inductor $L_1$,$L_2$, $L_3$, and $L_4$, three capacitors $C_1$, $C_2$, and $C_0$ and one resistive load R. For steady-state theoretical analysis, it is assumed that all components are ideal and the proposed converter operates in CCM.

The converter can be operated in both buck and boost mode by adjusting duty ratio of $S_3$ and $S_4$. For the buck mode introducing one diode connected anti parallel to diode $D_3$. For the buck and boost operation these two diodes are controlled by two switches. Duty ratios of two switches are change, it can operate in either buck or boost mode. The proposed converter exhibits four operating modes in boost mode and two operating mode in buck mode. Equivalent circuits of boost mode operation are shown in Fig. 2 to Fig. 5 and buck mode operation are shown in Fig. 6 and Fig. 7.

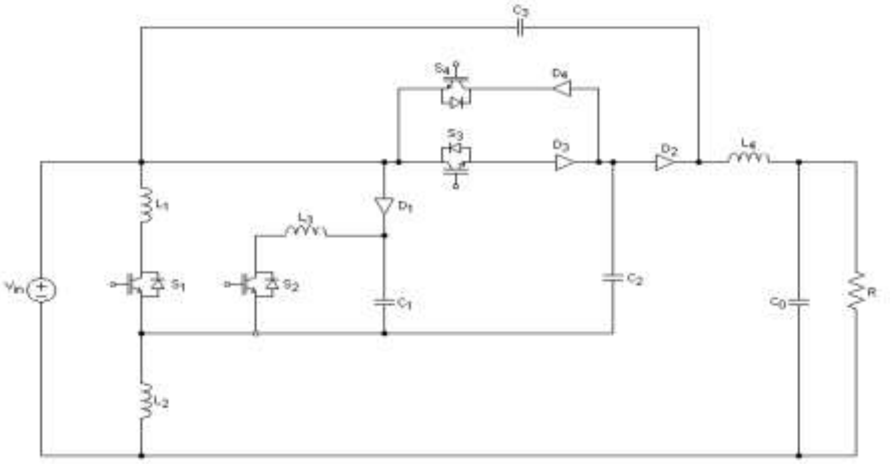


**Fig. 1.** Circuit diagram of modified reduced current ripple DC-DC Buck-Boost Converter.

**A. Boost Mode**

**1.1.1 Mode-1**

This mode is initiated by turning on of the switch $S_2$. The voltage across the resonating inductor is almost constant. The resonating inductor has current linearly increases and the resonating capacitor is charged to supply voltage. At the end of this mode, this current becomes zero and the diode $D_3$ goes to off state at zero current switching (ZCS). The voltage starts building up next mode of operation.

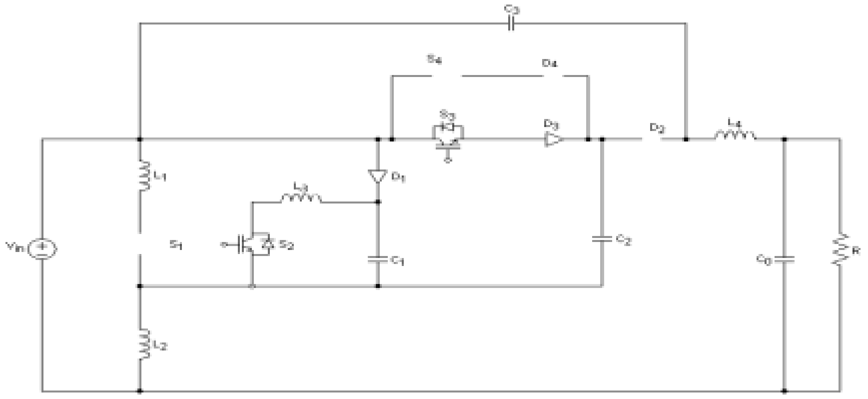


**Fig. 2.** Mode-1 equivalent circuit.

**1.1.2 Mode-2**

In this mode the switch $S_2$ is in on state and hence the inductor $L_1$ and $L_3$ is resonating with the capacitor $C_1$ . The voltage across the main switch starts decreasing at the end of this mode this become zero. At that moment the voltage across the main diode $D_3$ also reaches to full voltage. In this mode the voltage across the main diode $D_2$ starts decreasing and finally reaches to zero by the time when the voltage across the main switch reaches to zero. At the end of this mode both the main switch and diode $D_2$ are ready for zero voltage transition.

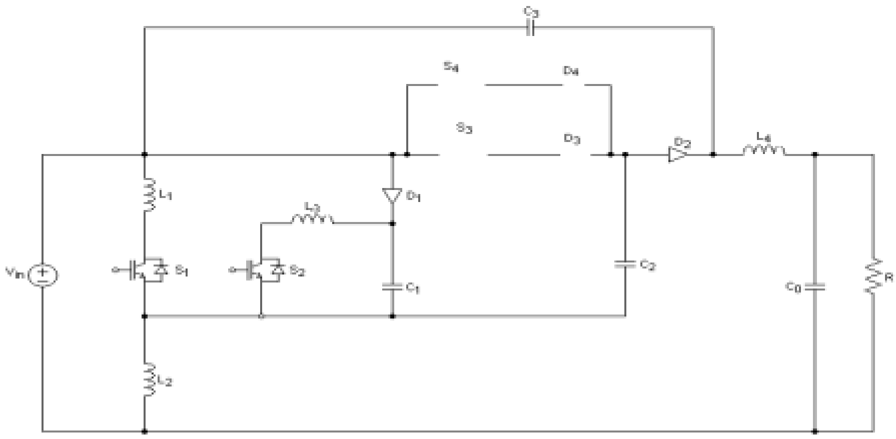


**Fig. 3.** Mode-2 equivalent circuit.

### 1.1.3 Mode-3

During this mode $D_2$, $S_2$ are in ON state and the anti-parallel diode of the main switch start conducting the negative current. During this mode the auxiliary switch and resonating inductor is carrying a constant current. This mode is going end when the main switch gate signal is released and the switch is ready for zero voltage turn on transition.

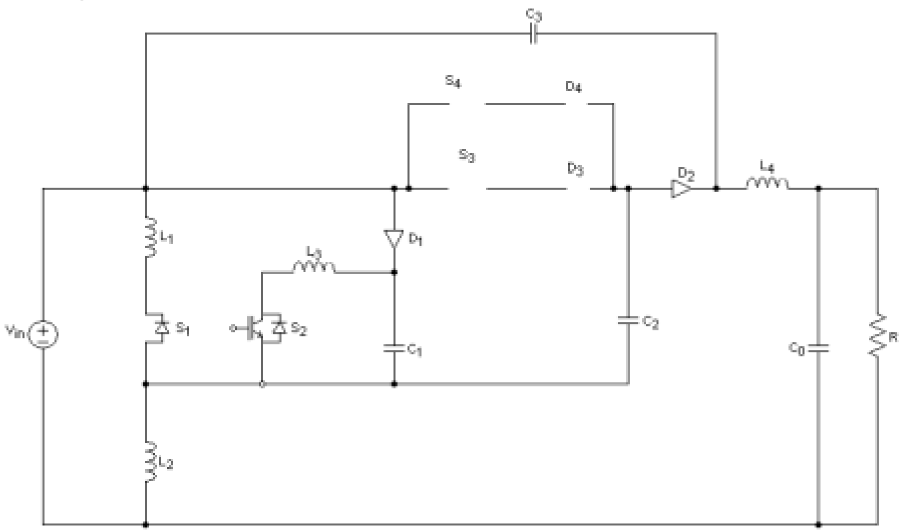


**Fig4.** Mode-3 equivalent circuit.

### 1.1.4 Mode-4

During this mode anti-parallel diode of main switch carry the negative current and main switch gate signal is released. Although main switch gate signal is present the negative current still flows through its anti-parallel diode until the auxiliary switch turns off. At the end of this mode the auxiliary switch must be turned off.

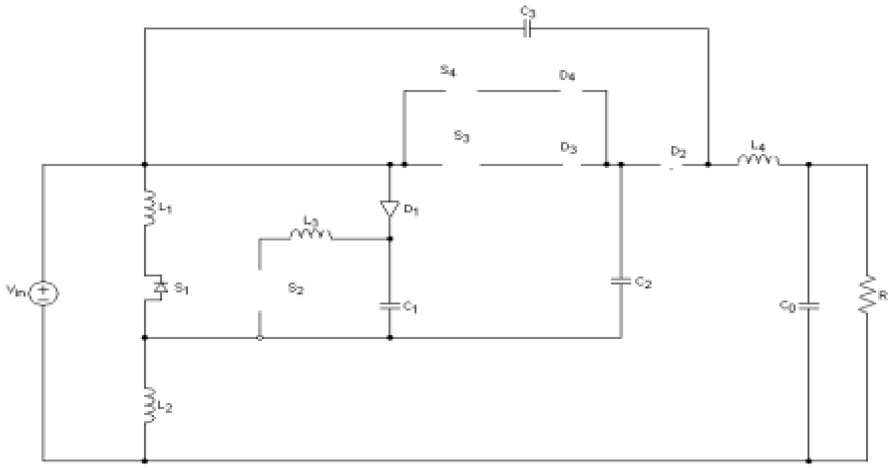


**Fig. 5.** Mode-4 equivalent circuit

**B. Buck Mode**

**1.2.1 Mode-1**

Initially the main switch $S_1$ is on and other switches are off state. The inductors $L_1$ and $L_2$ are stored the energy.

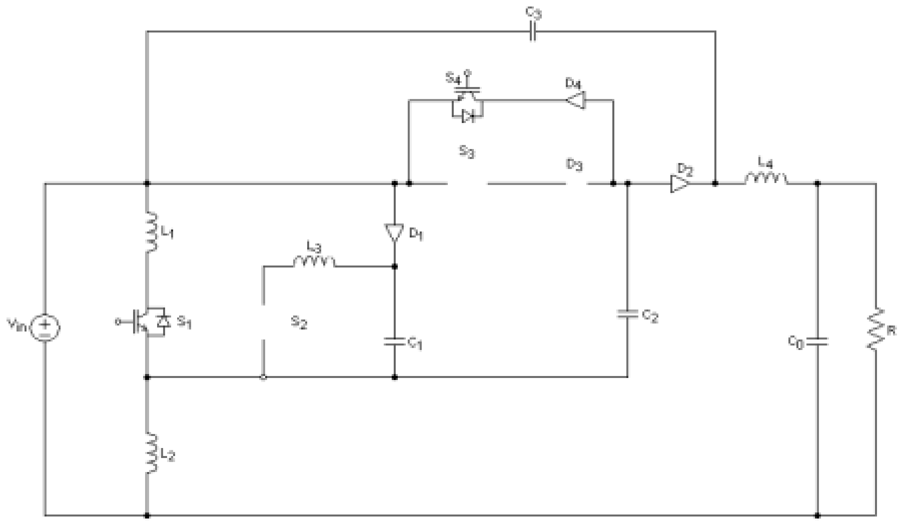


**Fig. 6.** Mode-1 equivalent circuit.

**1.2.2 Mode-2**

In this mode S1, $S_2$ and $S_2$ switches are on state. If the diode $D_2$ and $D_4$ are conducting in forward biased. The output voltage is less that of input voltage.

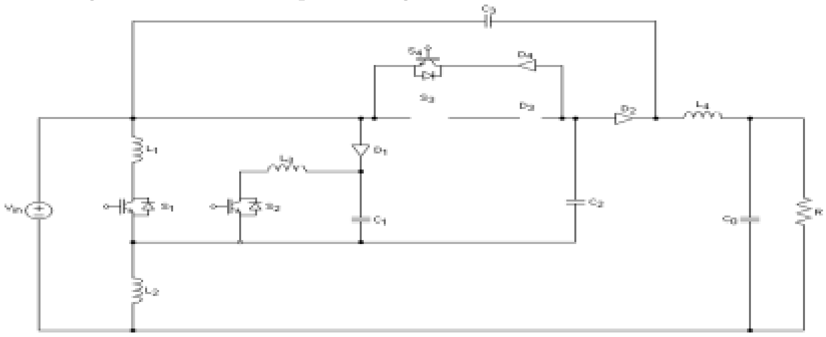

**Fig. 7.** Mode-2 equivalent circuit.

## III. Design Of Modified Reduced Current Ripple Buck-Boost Converter

The power stage components of a modified reduced current ripple buck-boost converter are designed as per the input parameters given in table 1.

$$L_1=[V_{in}D/(f_s\Delta i_{L1})] \quad (1)$$

$$L_4=[(V_gD)/(f_s\Delta i_{L2})] \quad (2)$$

$$C_2=[(2-D)V_{in}]/[(1-D)Rf_s\Delta V_{c1}] \quad (3)$$

$$C_3=[(2-D)V_{in}]/[Rf_s\Delta V_{c2}] \quad (4)$$

$$C_4=[(1-D)V_0D]/[8L_2(2-D)f_s\Delta V_{c3}]) \quad (5)$$

In order to design the resonant inductors ($L_2$, $L_3$) and capacitor ($C_1$) elements, the auxiliary switch duty ratio was fixed to the desired value (0.1 ~ 0.15) and then the inductor and capacitor values are obtained based on normalized load.

## IV. Simulation Parameters

A 50Watt prototype modified reduced current ripple buck-boost converter system has been designed to verifying. The converter is supplied from a 20V and the desired load voltage is 60V in boost mode and 14V in buck mode. The parameters of the designed converter to meet the specification are shown in table 1.

**Table –1** Parameters of the circuit

| Parameters | Step-up Mode | Step-down Mode |
|---|---|---|
| $V_{in}$ | 20V | 20V |
| $V_o$ | 60V | 14V |
| $F_s$ | 40KHz | 40KHz |
| $D_1$ | 0.5 | 0.5 |
| $D_2$ | 0.15 | 0.15 |
| $D_3$ | 0.9 | 0.01 |
| $D_4$ | 0.01 | 0.9 |
| $L_1$ | 150µH | 150µH |
| $L_2$ | 50µH | 50µH |
| $L_3$ | 1.5µH | 1.5µH |
| $L_4$ | 4.5µH | 4.5µH |
| $C_1$ | 50nF | 50nF |
| $C_2$ | 47µF | 47µF |
| $C_3$ | 47µF | 47µF |
| $C_4$ | 100µF | 100µF |
| R | 100Ω | 10Ω |

## V. Simulation Model And Results

The circuits are drawn in Matlab/Simulink software. The simulink model of reduced current ripple DC-DC buck-boost converter is shown in Fig. 8.

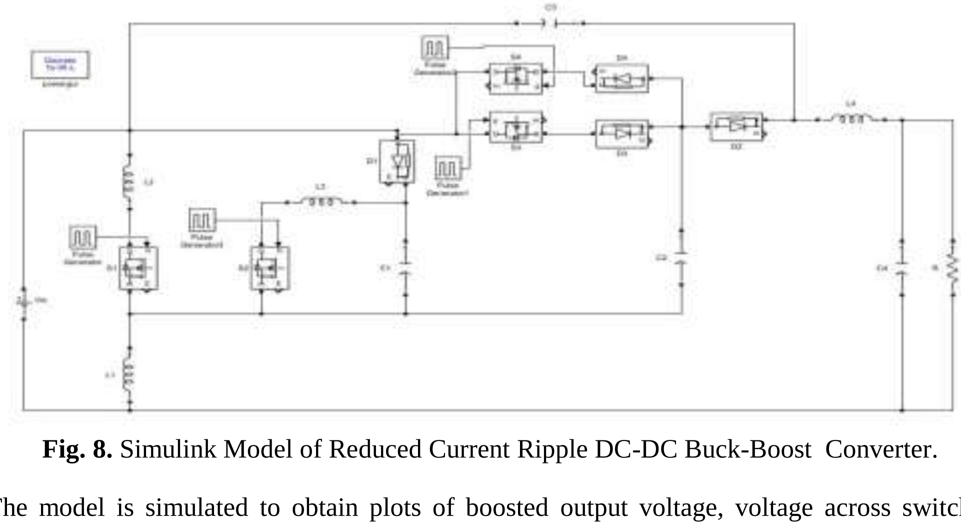

**Fig. 8.** Simulink Model of Reduced Current Ripple DC-DC Buck-Boost Converter.

The model is simulated to obtain plots of boosted output voltage, voltage across switches, voltage across capacitor and current through inductor are shown in following figures.

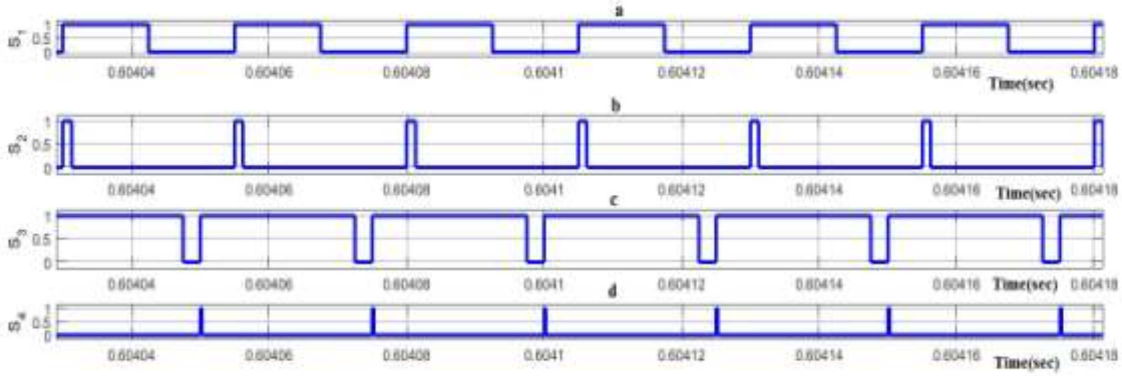


**Fig. 9. (a)** Gate pulse of $S_1$ **(b)** Gate pulse of $S_2$ **(c)** Gate pulse of $S_3$ **(d)** Gate pulse of $S_4$.

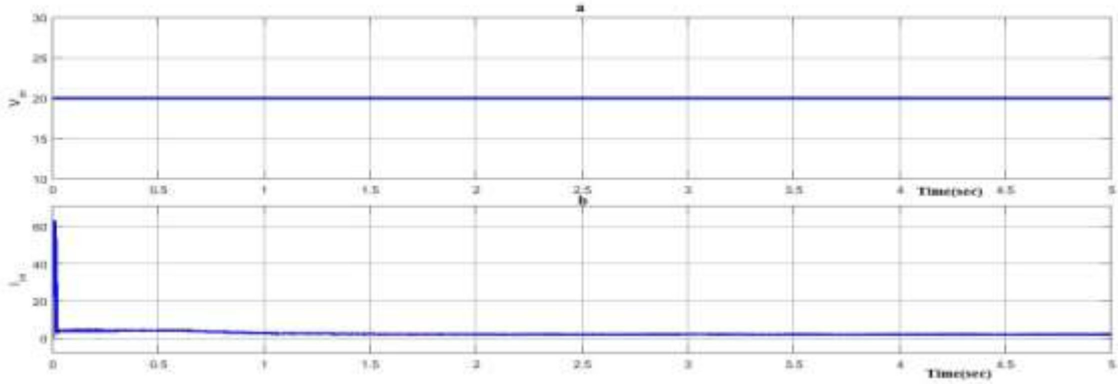


**Fig. 10. (a)** Input voltage $V_{in}$ **(b)** Input current $I_{in.}$

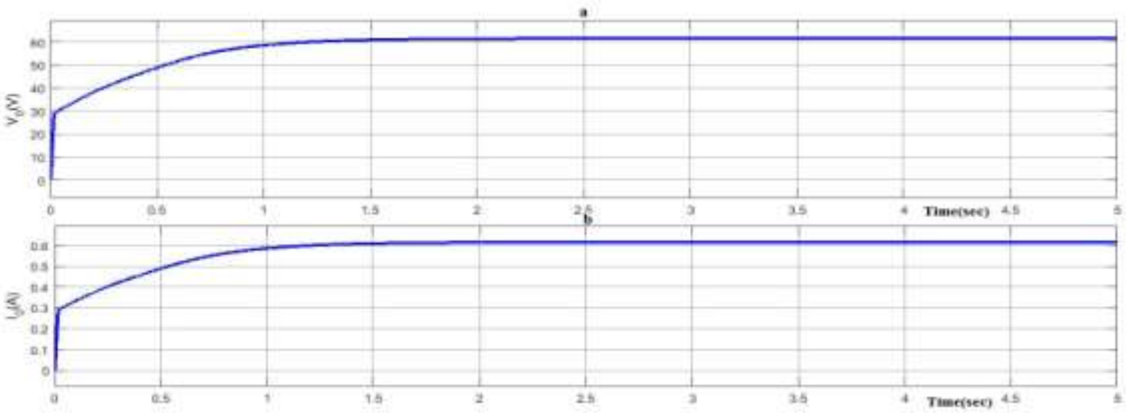


**Fig. 11. (a)** Output voltage $V_o$ **(b)** Output current $I_o$

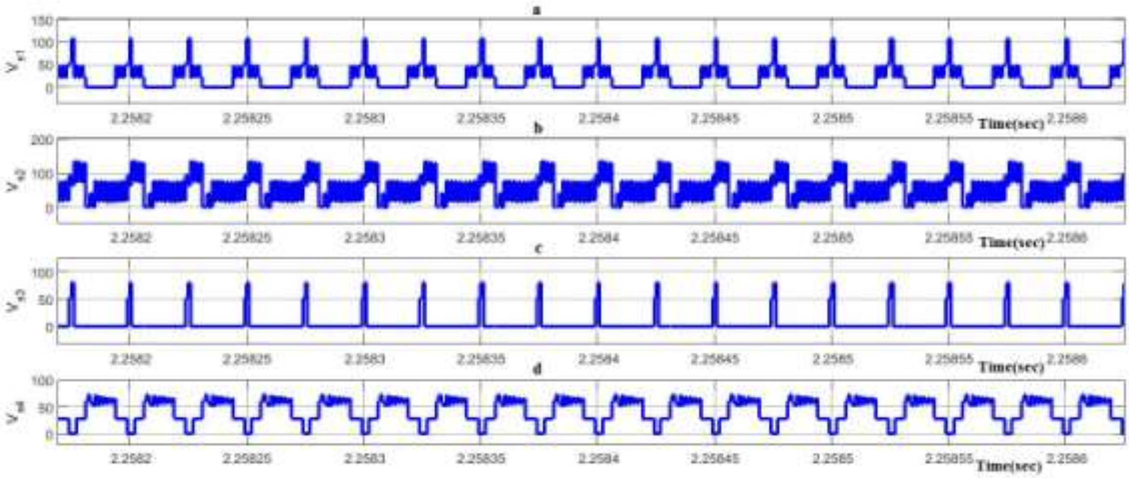


**Fig. 12. (a)** Voltage Stress across switch $S_1$ **(b)** Voltage Stress across switch $S_2$ **(c)** Voltage Stress across switch $S_3$ **(d)** Voltage Stress across switch $S_4$.

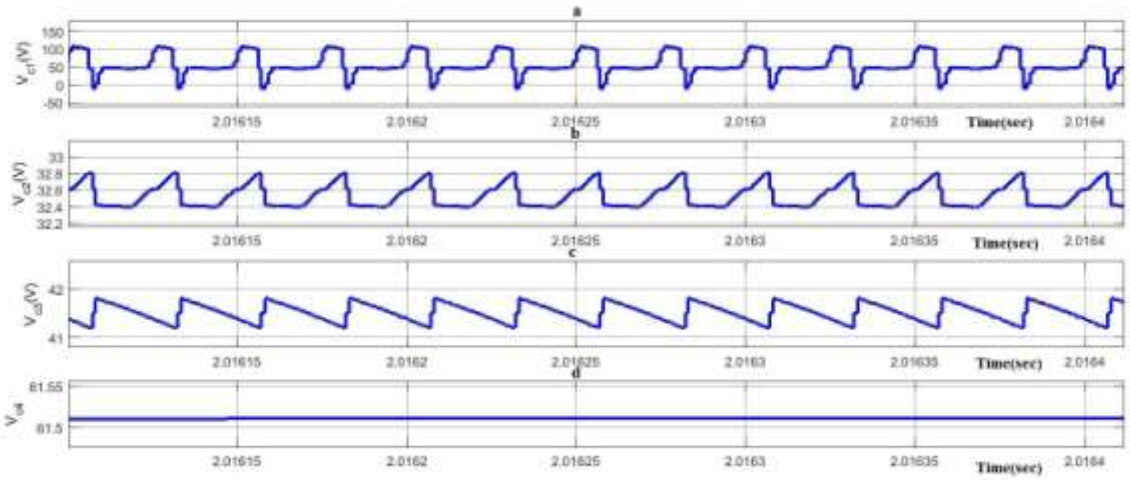


**Fig. 13. (a)** Voltage across $C_1$ **(b)** Voltage across $C_2$ **(c)** Voltage across $C_3$ **(d)** Voltage across $C_4$.

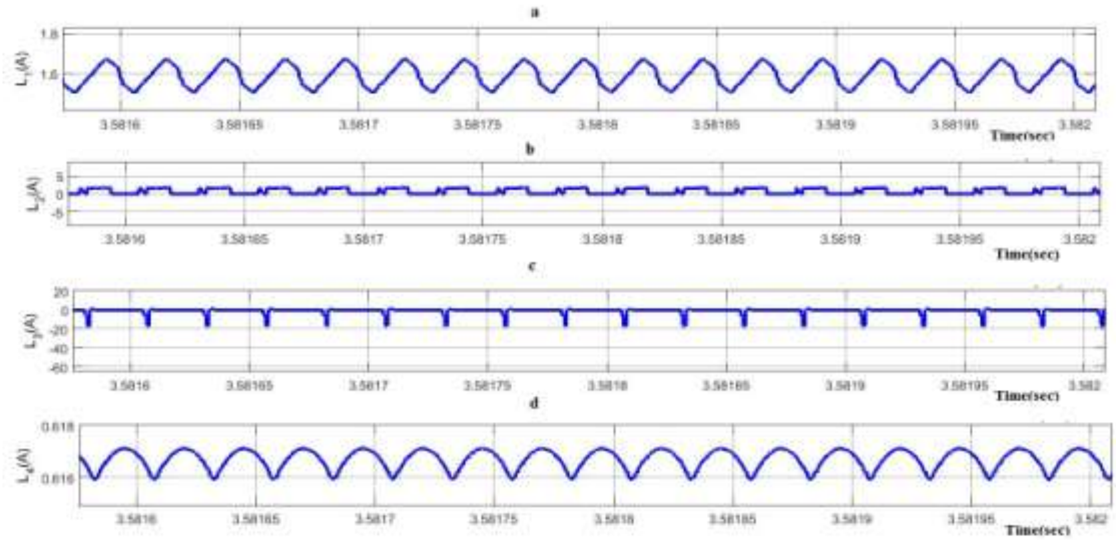


**Fig.14. (a)** Inductor current $L_1$ **(b)** Inductor current $L_2$ **(c)** Inductor current $L_3$ **(d)** Inductor current $L_4$.

The model is simulated to obtain plots of buck output voltage, voltage across switches, voltage across capacitor and current through inductor are shown in following figures.

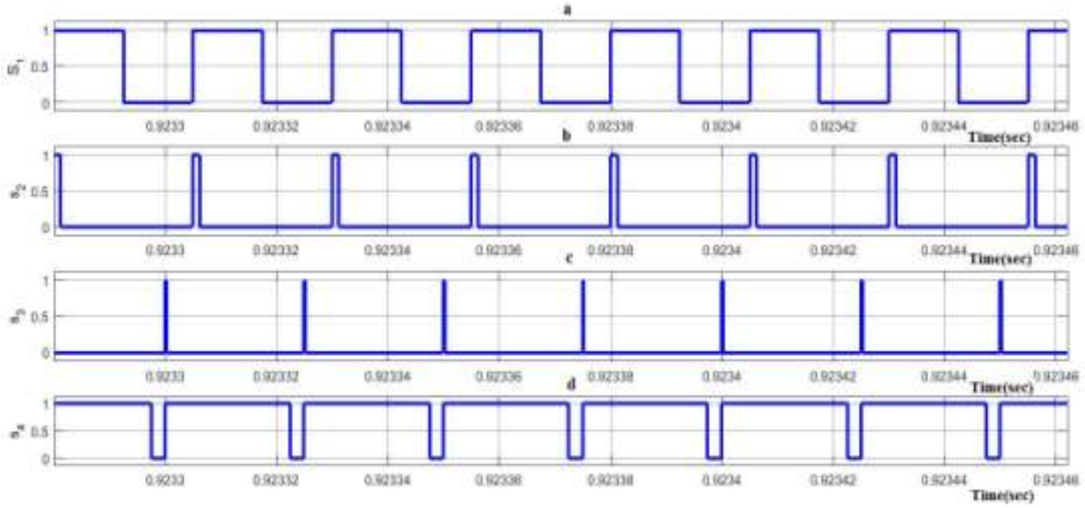


**Fig. 15. (a)** Gate pulse of $S_1$ **(b)** Gate pulse of $S_2$ **(c)** Gate pulse of $S_3$ **(d)** Gate pulse of $S_4$.

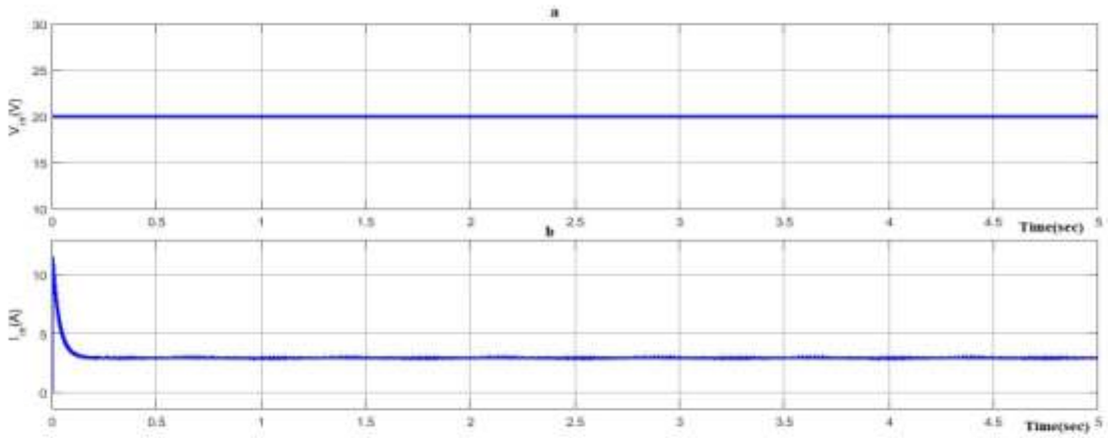


**Fig. 16. (a)** Input voltage $V_{in}$ **(b)** Input current $I_{in}$.

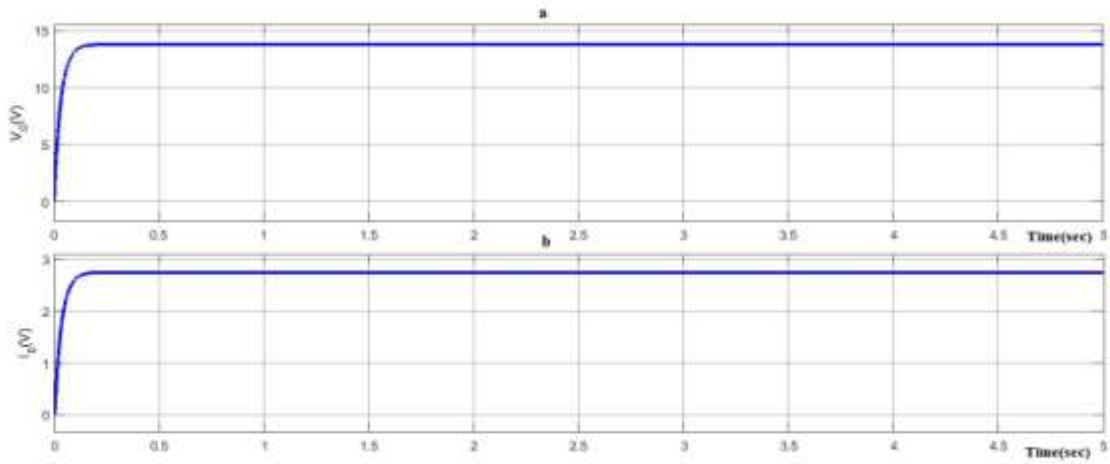


**Fig. 17. (a)** Output voltage $V_o$ **(b)** Output current $I_o$


**Fig. 18. (a)** Voltage Stress across switch $S_1$ **(b)** Voltage Stress across switch $S_2$ **(c)** Voltage Stress across switch $S_3$ **(d)** Voltage Stress across switch $S_4$.

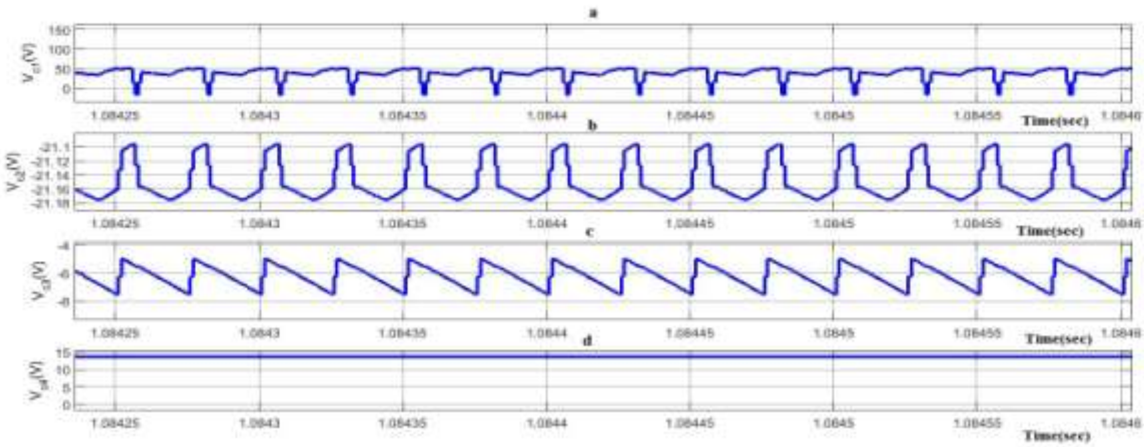


**Fig. 19. (a)** Voltage across $C_1$ **(b)** Voltage across $C_2$ **(c)** Voltage across $C_3$ **(d)** Voltage across $C_4$.

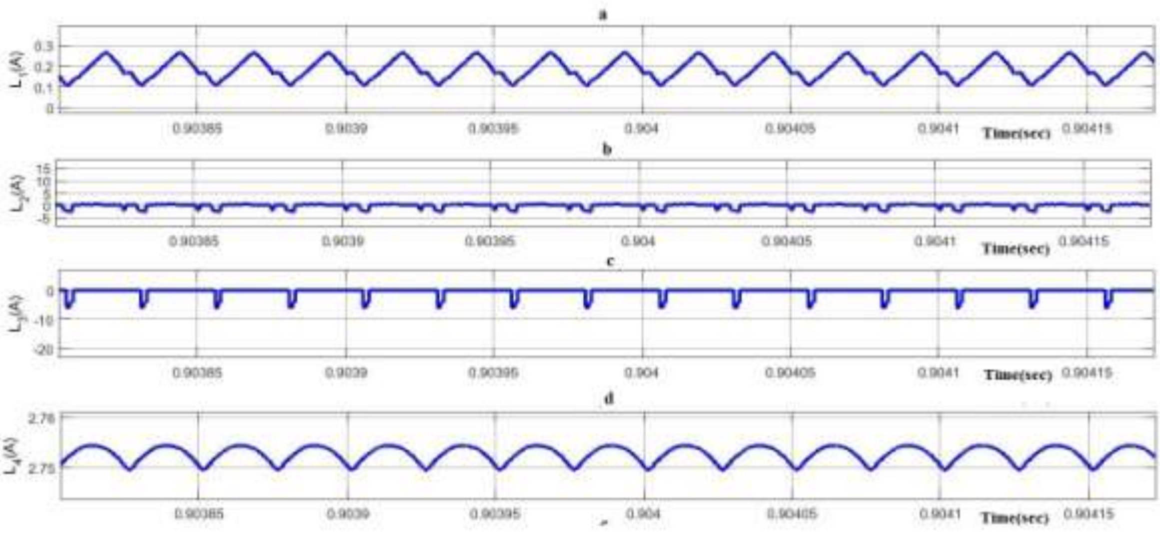


**Fig.20. (a)** Inductor current $L_1$ **(b)** Inductor current $L_2$ **(c)** Inductor current $L_3$ **(d)** Inductor current $L_4$.

Simulation of the proposed circuit gave output voltages 60V in boost mode and 14V in buck mode for an input voltage of 20V. From the simulation results we can see that the proposed converter can be used for both buck and boost operation.

## VI. Conclusion

The Modified reduced current ripple DC-DC buck-boost converter is simulated using MATLAB/Simulink software. The Modified reduced current ripple DC-DC buck-boost converter has been found to be yielding improved efficiency as compared to ZVT fifth order boost converter. The advantage of the converter is that it can be operated in buck and boost mode. The duty ratio of the switches $S_3$ and $S_4$ are interchange to operate in buck or boost mode. The one limitation of converter is that, when boost mode duty ratio of $S_3$ remains constant and $S_4$ varying up to 0.24 and buck mode $S_4$ duty ratio remains constant and $S_3$ duty ratio varying up to 0.1. The DC-DC buck-boost converter are used in many applications such as self-regulating power supplies, battery power system, adaptive control, power amplification etc.

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