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A Non-Isolated Converter Based on SEPIC Converter

Ninu Joy[1], Mohitha Thomas[2], Emlin Anto[3]

Professor, Dept. of EEE, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India[1,2]

PG Student [PE], Dept. of EEE, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India[3]

ABSTRACT: With increasing interest to environmental problems, the energy available from the fuel cell systems is greatly focussed on low environmental issues and clean energy. Fuel cells are an effective alternative to replace fuels in energy power systems. Therefore, fuel cells are appropriate as power supplies for telecom backup facilities and hybrid electric vehicles. Fuel cell have high efficiency and are small in size. In this a non-isolated buck boost converter is presented that uses only one main switch. The converter has the following advantages like higher voltage gain, higher efficiency and low input current. The voltage gain of the converter is higher than the classic converters like buck-boost, SEPIC, ZETA, CUK converters. The gain of the converter is 2.14 and efficiency is more making it suitable for low power applications. The performance study of the converter is carried out with MATLAB/SIMULINK R2017a.

KEYWORDS: SEPIC, transformer less buck-boost converter, voltage gain, voltage stress

I.INTRODUCTION

In recent years, environmental troubles, such as climate change and global warming by increased emissions of carbon dioxide, are very important. With increasing attention to environmental problems, energy achieved from the fuel cell systems is focused on the low environmental effects and clean energy. Fuel cells are an effective alternative to replace fuels in emergency power systems and vehicles. Fuel cells can be used as clean energy by users with low emissions of carbon dioxide. Due to steady operation with renewable fuel supply and high effectiveness and efficiency, the fuel cell has been recognized increasingly as a suitable alternative source. There are some problems of this fuel such as high costs, but they have brilliant features such as high efficiency and small size. Due to this, the fuel cell is appropriate as power supplies for telecom back-up facilities and hybrid electric vehicles. However, the voltage levels of these sources are too low and unpredictable unstable, varying with climate conditions such as solar irradiance and temperature. Therefore, high voltage gain converters are required for photovoltaic cell and fuel cell systems. But, the efficiency and the voltage gain of the classic boost converter are limited with large duty cycle and the losses of the diode and switch, and the equivalent series resistance of inductors and capacitors.[2]

In order to obtain the high efficiency and high voltage gain, many high step-up dc-dc converters have been proposed and in order to use the low duty cycle, adding a new control method is a good choice [3,4]. In switched-capacitor converters, the input voltage is used to provide energy and the switched-capacitors are linked in series and supply energy to the load. Thus, the source voltage can be multiplied [5]. Using switched-capacitors converters is the one method for voltage gain improvement. However, many switched-capacitor cells are needed to achieve high voltage, which makes the circuit complex. The major problem of the switched-capacitor cells is voltage stress of the switches. In [6,7] high voltage gain dc-dc converters with a coupled-inductor are proposed. The leakage inductance of the coupled inductor is so important that it cause high voltage spikes and adds the voltage stress. In [8] a transformer less buck boost converter with high voltage gain is proposed. The stress of the switch and diode in the converter is high. Hence, the losses of the converter will be high. In [9], a non-inverting buck–boost converter for fuel-cell system using three power switches and with a voltage gain 2D/1-D is proposed. However, the number of switches seems high. In [10] a high conversion ratio bidirectional dc–dc converter is proposed. However, this converter have five power switches which increase the conduction losses and the cost of the circuit and decrease the efficiency. In [11] a buck–boost converter based on KY converter is proposed. In this converter, two main switches are used and the voltage gain of the presented converter is 2D. In [12] a multi-output buck boost DC/DC converter is proposed. This converter has several output voltages, but, in the presented converter, many power switches have been used. In [13] a multi-output buck boost DC/DC converter is proposed. This converter has several output voltages, but, in the presented converter, many power switches have been used. Voltage stress of the switch is equal to the output voltage. The converter conduction and switching losses are high.

In this paper, a non-isolated buck-boost dc-dc converter with high step-up voltage gain and low voltage stress on the power switch is proposed. The voltage transfer gain of the proposed converter is higher than the classic buck-boost converter, SEPIC, CUK and ZETA converters. The structure of the proposed converter is simple; hence the control of the converter will be easy. In this converter only one main switch is used. The efficiency of the converter is high. The presented is appropriate for low voltage and low power applications. The proposed buck-boost converter is utilized in many applications like fuel-cell systems, car electronic devices, LED drivers and gadgets such as mobile phones and notebooks.

II.OPERATING PRINCIPLE OF THE CONVERTER

Fig. 1. shows the circuit topology of the non-isolated converter. The converter consists one main switch S, two diodes D_1 and D_2, three inductors L_1, L_2 and L_3, four capacitors C_1, C_2, C_3 and C_O and load R. To simplify the analysis of the new buck-boost converter, the following conditions were considered:

1) All capacitors are large enough hence the voltages of the capacitors can be seen as constant.

2) Semiconductor elements such as diodes and switch are ideal.

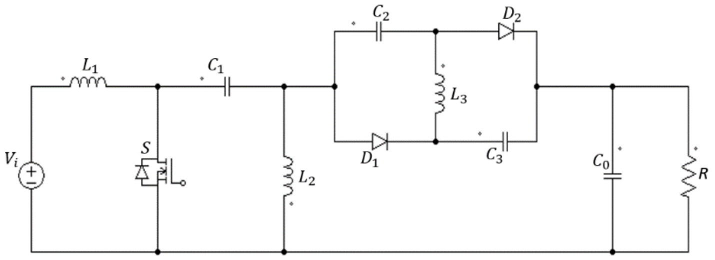

Fig. 1 Non-Isolated Buck-Boost Converter

The proposed converter can be used in the continuous conduction mode (CCM). The continuous conduction mode has two operating modes. The analysis of the converter at (CCM) is presented in detail as follows:

1) State [t_o, t_1]: During this time interval as shown in Fig. 2, the switch S is turned on and the diodes $D_1$and D_2 are off. The inductors L_1, L_2 and L_3 are magnetized linearly. The capacitors C_2, C_3 are charged by the capacitor C_1.

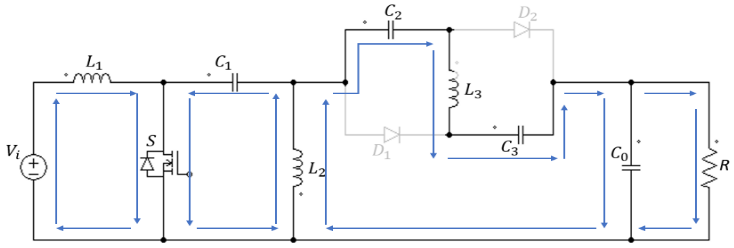

Fig. 2 Mode 1 operation of converter

2) State 2[t_1,t_2]: The current-flow path is shown in Fig. 3. During this time interval, switch S is turned OFF. Diodes D_1 and D_2 are turned ON. The L_1, L_2 and L_3 are demagnetized. The capacitor C_1 is charged by the inductor L_1. The capacitors C_2, C_3 are discharged.

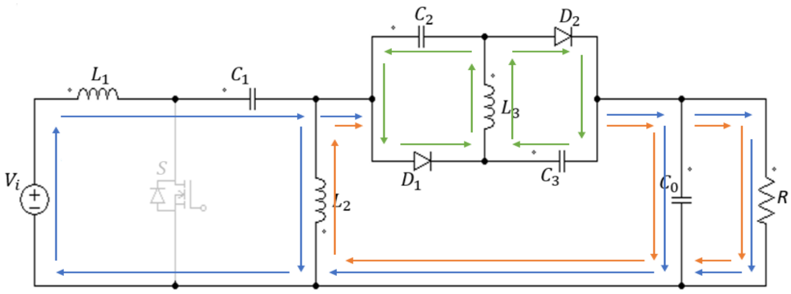

Fig. 3 Mode 2 operation of converter

The theoretical waveforms of the converter is illustrated in Fig.4.

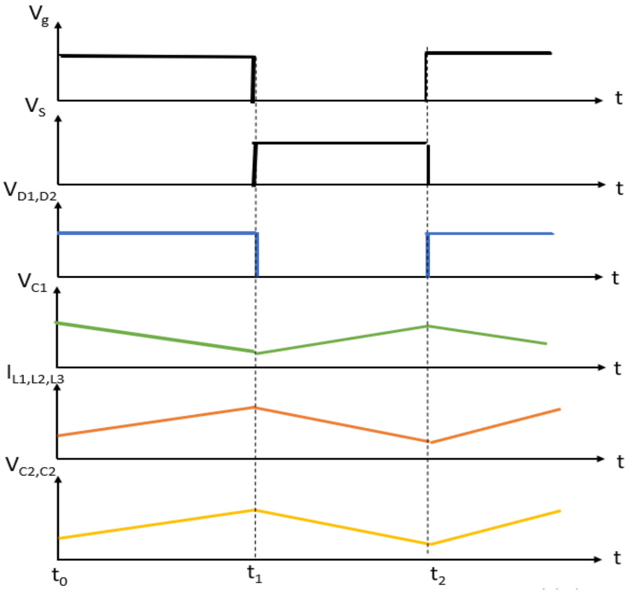

Fig.4 Theoretical waveform

III.DESIGN OF COMPONENTS

The input voltage is taken as 36V. The pulses are switched to a frequency 40kHz.The output voltage V_O=80V.

$$Conversion\ ratio, \frac{V_0}{V_i} = \frac{2D}{1-D}, \frac{80}{36} = \frac{2D}{1-D}$$

$$D = 0.526$$

A.INDUCTOR DESIGN

The values of inductors are,

$$L_{1,2,3} \geq \frac{V_i * D}{\Delta I_{L_{2,3}} * f_5} \geq \frac{36 * 0.526}{0.56 * 40 * 10^3} \geq 845\mu F$$

The value of inductor is set as L1 =900µH and L2,3 =1mH.

B. CAPACITOR DESIGN

Assume voltage ripple $\Delta V_{C1}=\Delta V_{C2}=\Delta V_{C3}=35\%\ V_0$

$$C_{1,2,3,0} \geq \frac{D * T_s * V_0}{R * \Delta V_{C_1}} c \geq \frac{0.526 * 80}{32 * 0.35 * 40 * 10^3} \geq 93mF$$

The value of capacitor C_1, C_2, C_3 is set at 100 µF and C_0 is set at 1mF.

C. LOAD RESISTOR

The output power is taken as P0= 200W and V0= 80V.

$$R_0 = \frac{V_0^2}{P_0} = \frac{80^2}{200} = 32\Omega$$

IV.SIMULATION AND RESULTS

The performance study of the non-isolated buck-boost converter is carried out using MATLAB/SIMULINK R2017a. The Simulink model of the converter is shown in fig 5. The control of the switch is given by the pulse generator.

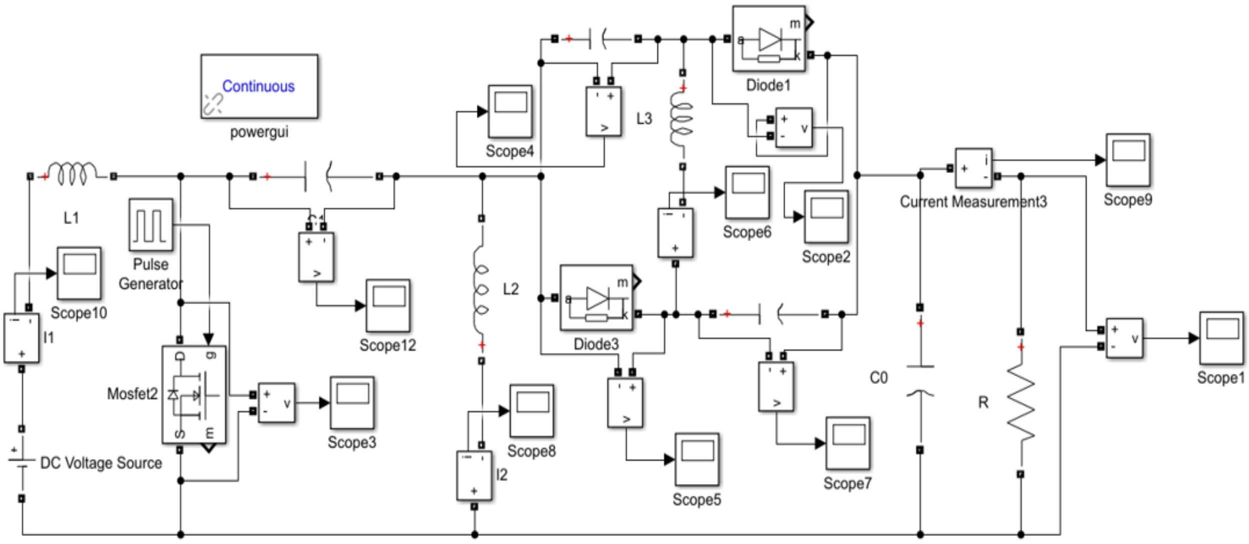

Fig.5 Simulink model of the proposed converter

Simulation parameters for the non-isolated buck-boost converter is given in Table. An input voltage $V_i$of 36V gives an output voltage V_O of 80V for an output power P_O of 200W. The switches are MOSFET/Diode with constant switching frequency of 40kHz. The duty cycle of switches is taken as D= 0.526.

Table1. Simulation Parameters

Parameters	Specifications
Input Voltage (V_i)	36V
Output Voltage (V_0)	80V
Switching frequency (f_s)	40kHz
Output Power (P_0)	200W
Resistance(R_0)	32Ω
Inductor (L_1)	900 µH
Inductors (L_2, L_3)	1mH
Capacitors (C_1, C_2, C_3)	100 µF
Capacitor (C_0)	1mF

The simulation results of the non-isolated buck boost converter are shown in the following figures. Fig 6 shows the input voltage V_i is 36V and the input current I_{in} is 5.174A. The switching frequency is chosen to be 40kHz and the duty ratio of S is equal to 0.526.

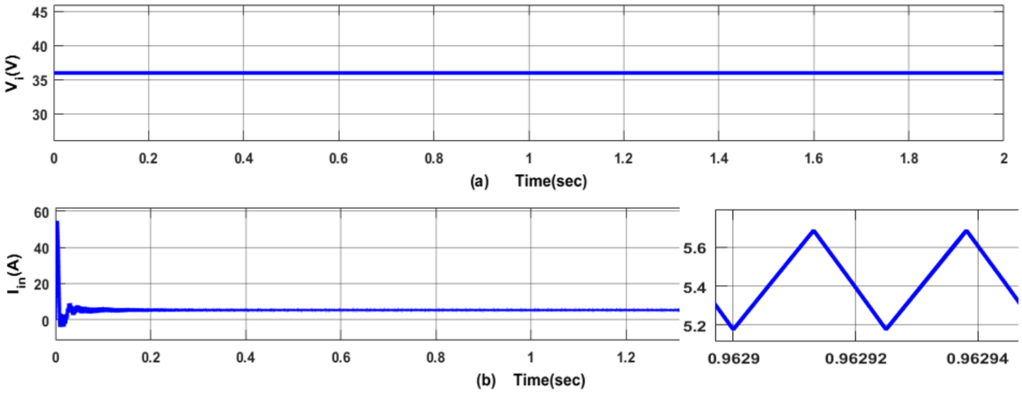

Fig.6 (a)Input voltage V_i, (b)Input current I_{in}

Figure 7 shows gate pulse of switch and voltage across S is seen as 75.32V.

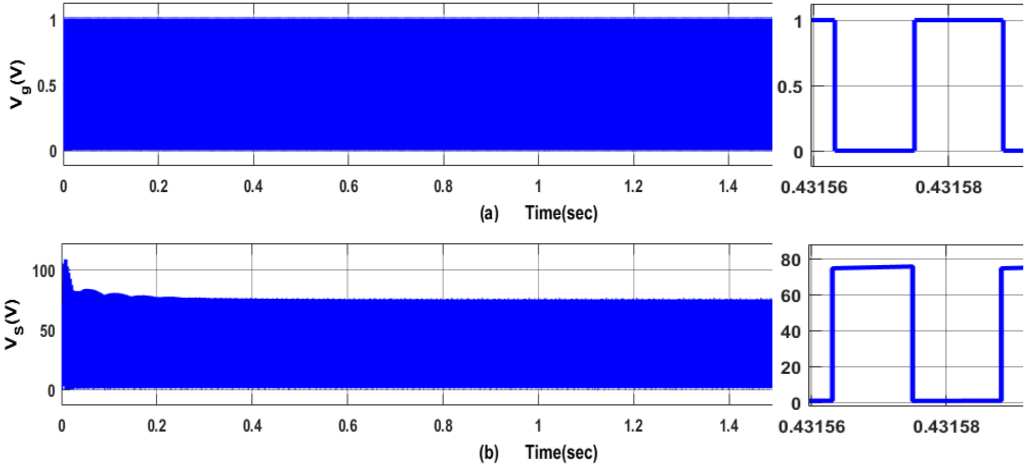

Fig 7. (a) Gate Pulse to switch S and (b) Voltage Stress of S

In figure 8 it is seen that the current through the inductors is I_{L1}=5.174A and ΔI_{L1}=0.518A, I_{L2}=2.145A and ΔI_{L2}=0.46A, I_{L3}=2.145A and ΔI_{L3}=0.46A.

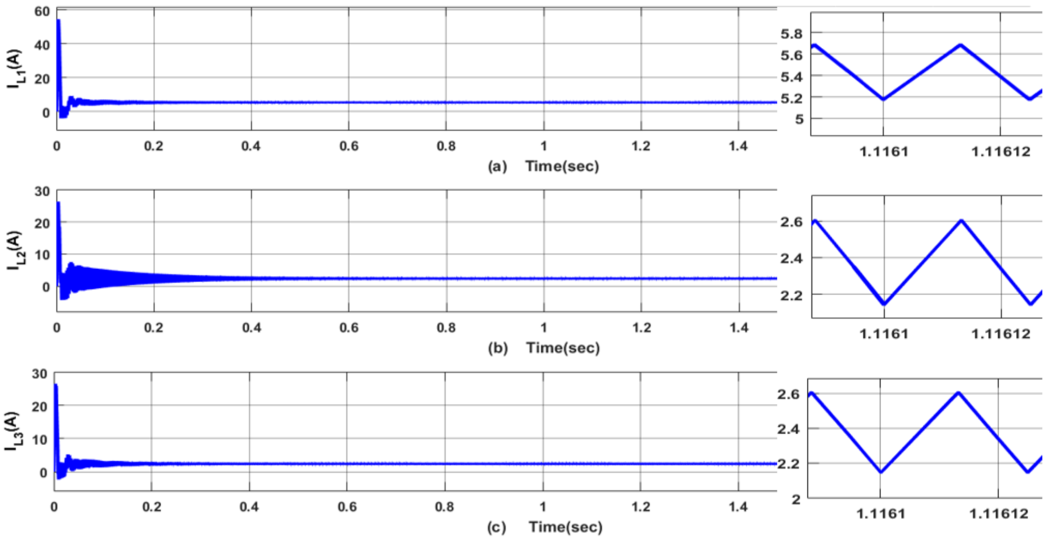

Fig.8 Inductor currents (a)I_{L1}, (b)I_{L2}, (c)I_{L3}

The voltage across capacitors with magnitudes V_{C1}=36.32V and ΔV_{C1}=0.63V, V_{C2}=36.32V and ΔV_{C2}=0.63V, V_{C3}=37.85V and ΔV_{C3}=0.31V is shown in figure 9.

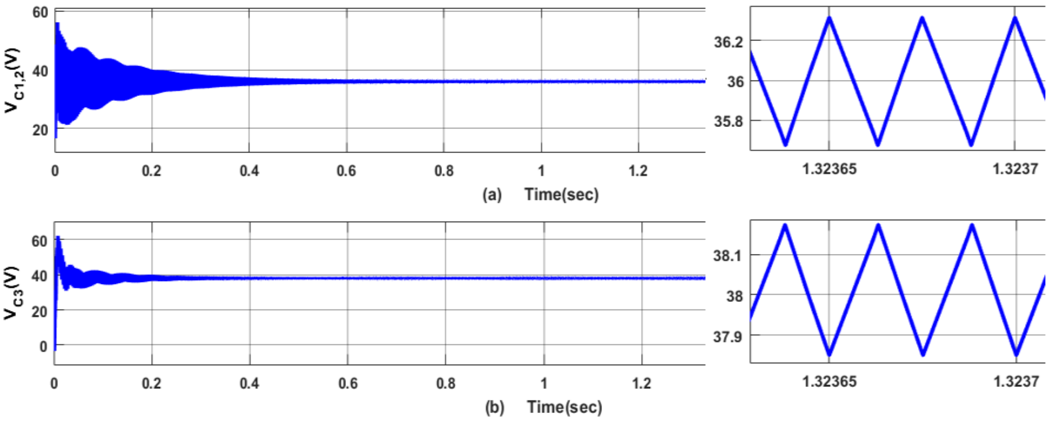

Fig.9 (a)$V_{C1,2}$, (b)V_{C3}

Figure 10 shows the voltage through the diodes D_1 and D_2 is 73.52V.

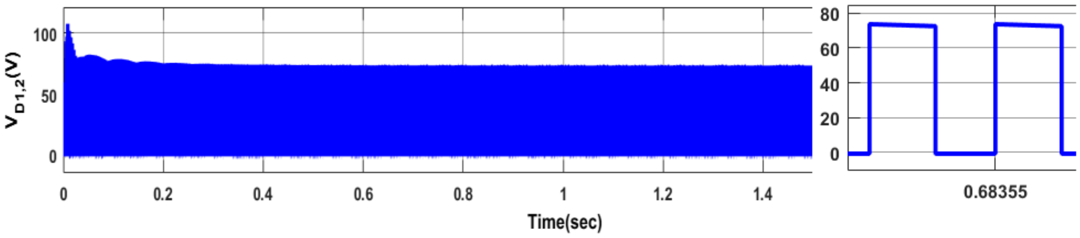

Fig. 10 Voltage across diodes $D_1$and D_2

The output voltage, V_O=76.06 V having a ripple of 0.06V and the output current, I_O=2.377A with current ripple 0.002A is shown in figure 11.

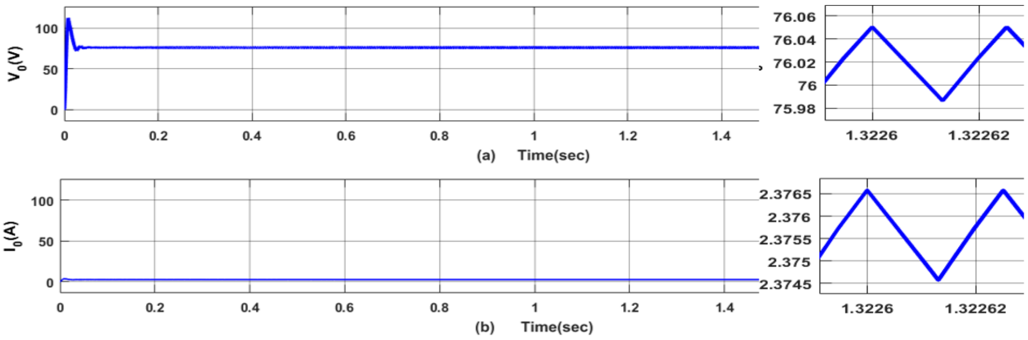

Fig.11 (a)Output voltage V_O and output current I_O

V. ANALYSIS FROM RESULTS

The analysis for the proposed converter were carried out based on efficiency, duty ratio, switching frequency etc. From the plot of efficiency Vs output power, Fig 12, it can be inferred that the converter is suitable for low power applications. Fig 13. shows the voltage gain variation with the duty ratio. It is seen that the converter conversion ratio increases with duty ratio.

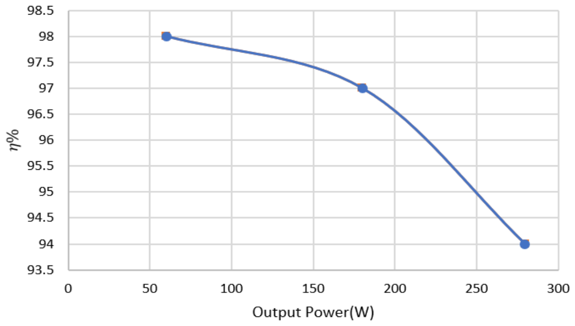

Fig.12 Efficiency Vs Output Power

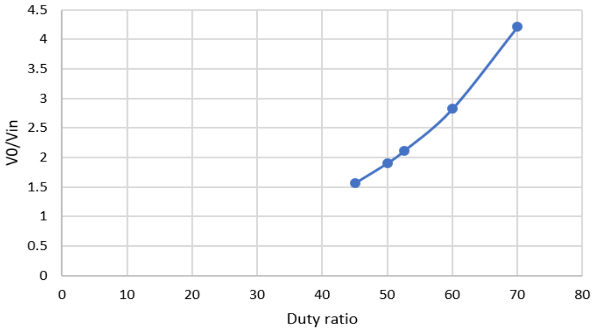

Fig. 13 Voltage Gain Vs Duty Ratio

The output voltage ripple as a function of frequency is shown in Fig.14. It shows thatan increase in switching frequency decrease the output voltage ripple.The plot of output voltage ripple as a function of duty ratio is shown in Fig.15. This shows that the output voltage ripple increases as the duty ratio increases.

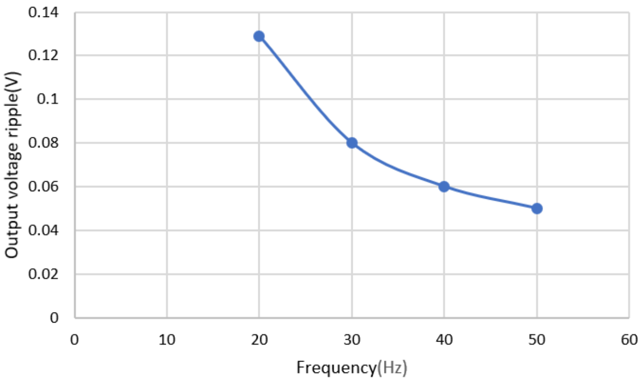

Fig.14 Output Voltage Ripple Vs Frequency

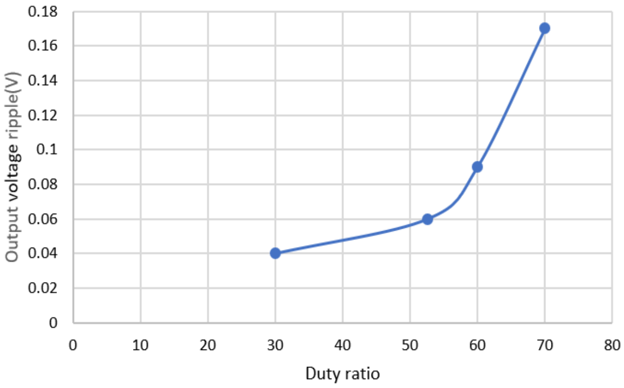

Fig. 15 Output Voltage Ripple Vs Duty Ratio

VI.CONCLUSION

In this paper, a non-isolated buck boost dc-dc converter based SEPIC converter is presented. The structure of the presented buck-boost converter is simple. In the proposed converter, only one main switch is utilized, which decreases the conduction loss of power switch and improves efficiency. The step-up voltage gain of the proposed buck-boost converter is higher than that of the classic boost, buck-boost, CUK, SEPIC and ZETA converters. The proposed converter has simple structure; therefore, the control of the presented converter will be easy. The buck-boost converters is utilized in many applications like gadgets such as mobile phones and notebooks, fuel-cell systems, car electronic devices and LED drivers.

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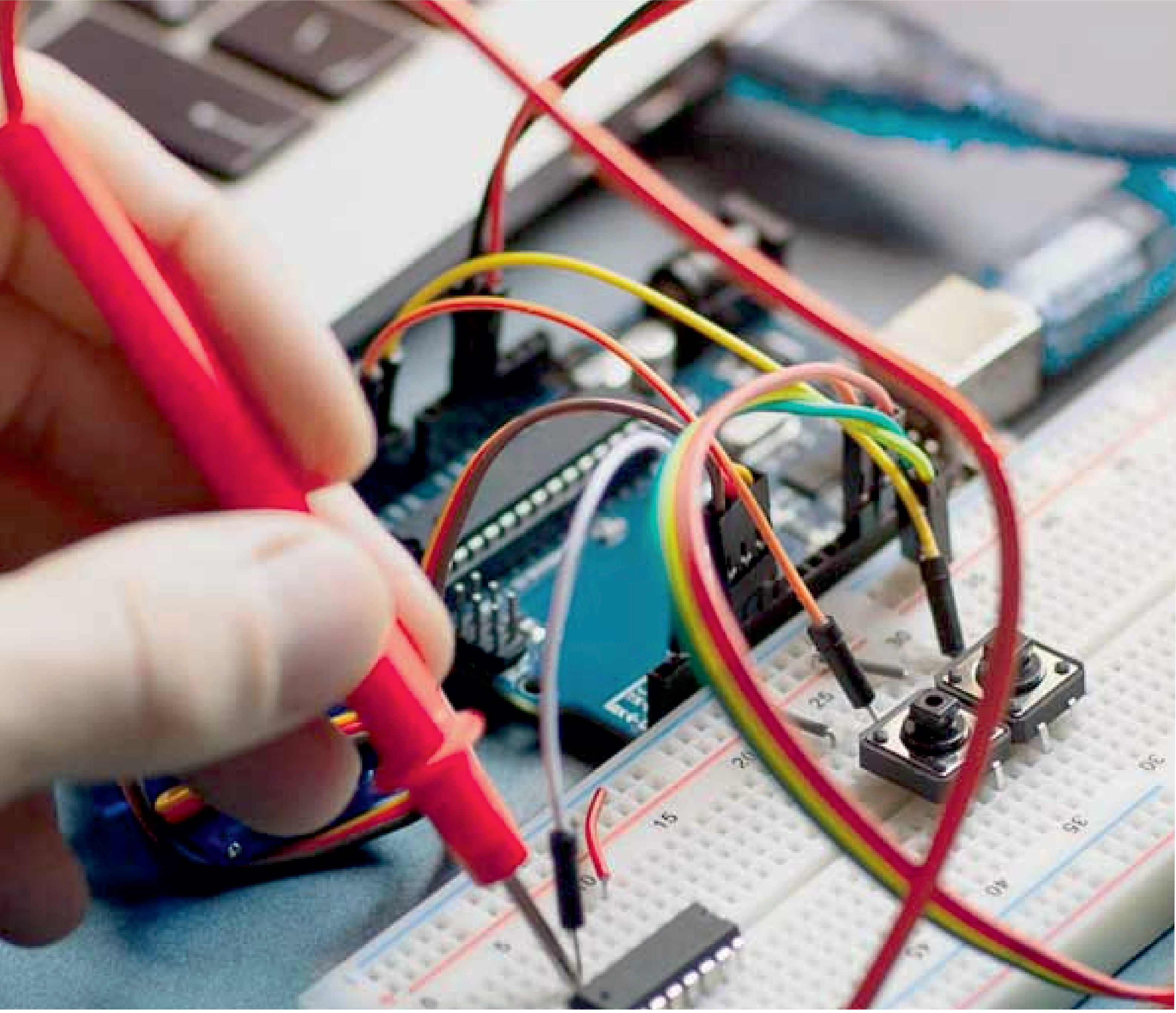

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