Comparative Analysis and Simulation Study of Non-Isolated High Gain Boost Converters

Gayathri Devi Ramaraj, Booma Nagarajan

Abstract: ***Renewable Energy has become the prodigious alternative in the future compared to the Non-Renewable which are abating with time. Solar power is clean, pollution free and in profusion. A Boost Converter with a high gain can be one solution towards to obtain the maximum efficiency. A comparative analysis is done between SEPIC and KY Boost Converter (KYBC) to identify the best converter with maximum efficiency using MATLAB Simulation. The Voltage conversion ratio is high for KYBC and also suited for low power applications. The simulation results also reveal that the KYBC is best suited in terms of high gain and less voltage and current ripple.***

Keywords: Renewable Energy, SEPIC Converter, KY Boost Converter (KYBC)

I. INTRODUCTION

Renewable Energy plays a vital role in today's power generation and also leads to Distributed Generation, Micro-grid and Smart cities. Researchers have been constantly working on the Converters to obtain better voltage gain and efficiency with reduced ripple in both voltage and current [1]. A converter is an electric power converter that changes the voltage or current of an electrical power source. DC-to-DC converters are electromechanical device that converts the dc voltage from one value to another value. Renewable Energy Systems requires a high gain boost converters for most of the applications. This could be effectively done implementing the boost converter [2]-[3]. The major drawback of the converter is the pulsating output currents, which tend to cause a large ripple in the output voltage. The ripples in the output can be reduced by implementing the converter with the interleaved concept. SEPIC converter finds its applications in SMPS and in high quality input power requirements [4]-[7].

A new converter named KY converter derives its name from its founder K. I. Hwu and Y. T. Yau [7]. The KY converter is a step up DC-DC converter with transient response operating in CCM always with low voltage ripple, non-pulsating current and the KY converter provides a larger voltage gain than the conventional boost converter[8].To overcome the drawbacks in Boost Converter, aKY converter along with synchronous rectified boost converter is used[9].And the other way is to use the capacitor with large capacitance and low equivalent series resistance (ESR), is to add an LC filter, and the other way is to increase the switching frequency [10]-[13].

The efficiency of power converters with the conventional hard switching technique is poor due to the switching losses which occur during the switching transitions. As the voltage level of the application increases, the switch has to block more voltage during the turn off process which further increases the switching losses, thereby resulting in poor efficiency. The switching losses can be nullified through Zero Voltage Switching (ZVS) or Zero Current Switching (ZCS) or combination of both, popularly known as soft switching techniques. Researchers have been working on the different converters topologies comparison [14]-[18]. This paper compares the SEPIC converter and KYBC with respect to parameters such as high voltage gain, reduced voltage and current ripple through simulations under the conditions of identical input voltage, frequency and duty cycle using MATLAB/Simulink.

II. MODES OF OPERATION OF KY BOOST CONVERTER

KY Boost Converter (KYBC), as the name implies, is a dc-dc converter employed to boost the input dc voltage. It is well known that a dc-dc converter can be operated in two modes of operation, namely continuous conduction mode (CCM) and discontinuous conduction mode (DCM). CCM is preferred in many applications as it possesses certain advantages such as reduction in ripple current [11] and fast transient response. Ripple free current is achieved at both the input and output in KYBC due to the presence of inductors at both the ports. Thus, unlike the conventional boost converter which can achieve ripple free current only at the input, KYBC can achieve ripple free current at both the input and output [2] when it operates in CCM mode. Hence, the KYBC has the capability to replace the conventional boost converter where the application demands high performance output response. Due to the aforementioned merits of KY boost converter, its' efficiency is very high. The circuit of KYBC is shown in Fig.1. KYBC suits best for low power applications such as digital camera, laptops etc. The presence of surge current in high power applications limits the use of conventional KYBC at high power but using soft switching techniques combined with the suppression of surge currents, this issue can be solved [6].

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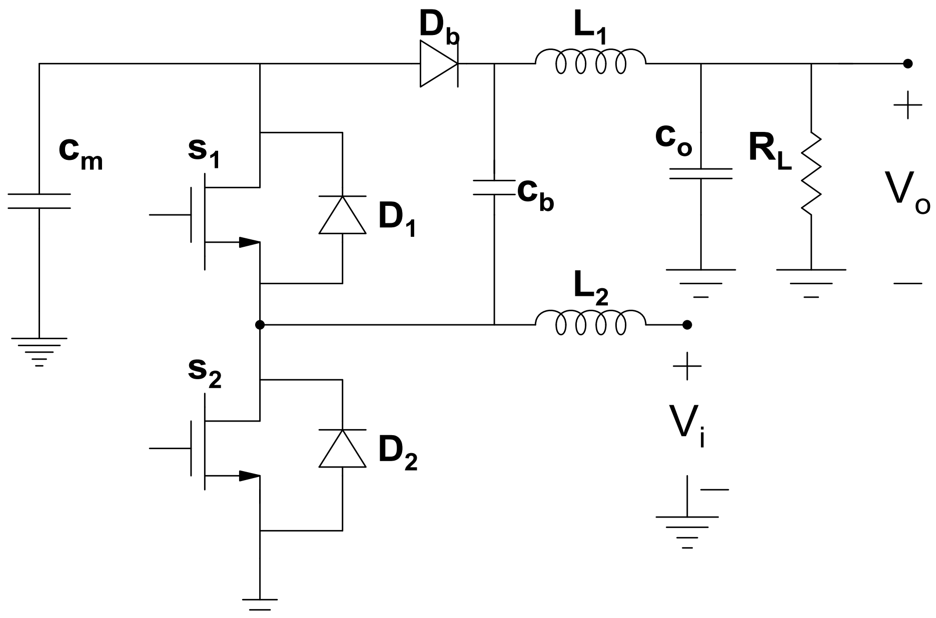

Fig. 1 KY Boost Converter

Mode 1

In this mode of operation, switch S_1 remains off and S_2 remains on. The diode D_b gets forward biased as the capacitor C_b is connected to ground through its' negative terminal. It is evident from the circuit, that in this mode of operation, the capacitor C_m discharges and C_b charges. Magnetizing current flows through L_1 and demagnetizing current flows through L_2since the voltage across L_1 is the input voltage V_i and the voltage across L_2 is the output voltage V_o The difference between the current in the inductor L_1 and load (R_L) current flows through the capacitor Co. The sum of the capacitor current I_{Cb} and the current in the inductor I_{L2} flows through the capacitor C_m.

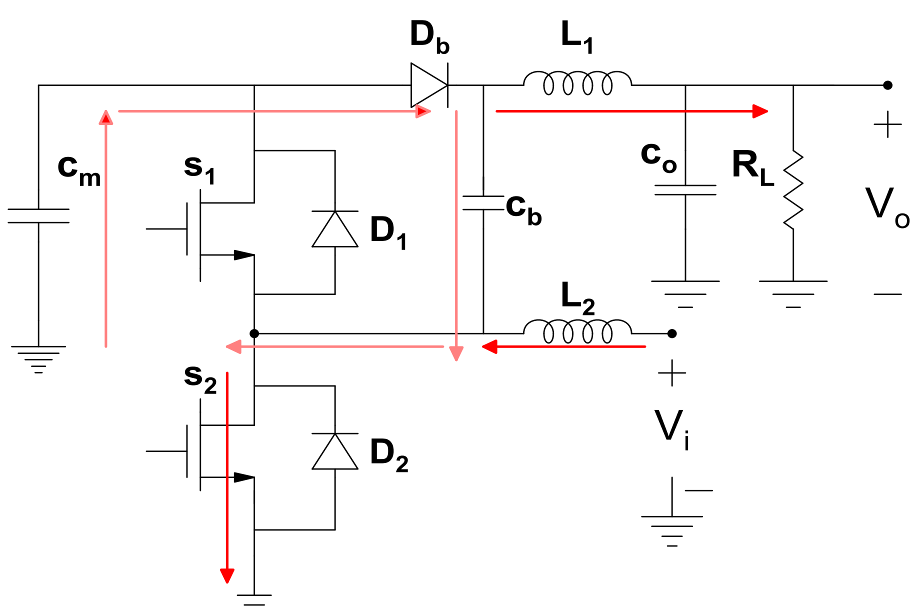

Fig. 2 MODE 1-KY Boost Converter

$\frac{L_0 \partial i_{L0}}{\partial t} = v_{Cm} - v_0$ --------1

$L_i \frac{\partial i}{\partial t} = v_i$--------------------2

$\frac{C_0 \partial v_0}{\partial t} = v_{L0} - \frac{v_0}{R_L}$-----------3

$\frac{c_m \partial v_{cm}}{\partial t} = -i_{cb} - i_{L0}$-----4

Mode 2

In this mode of operation, switch S_1 remains on and S_2 remains off. The diode D_b gets reverse biased. It is evident from the circuit, that in this mode of operation, the capacitor C_b discharges and C_m charges. Demagnetizing current flows through L_1 and the magnetizing current flows through L_2 since the voltage across L_1 is the input voltage V_{cm} and the voltage across L_2 is the difference between the output voltage V_o and twice of V_{cm}. The difference between the current in the inductor I_{L1} and load (R_L) current flows through the capacitor Co. The current in C_m is the sum of the inductor currentI_{L1} and $-I_{Lo}$.

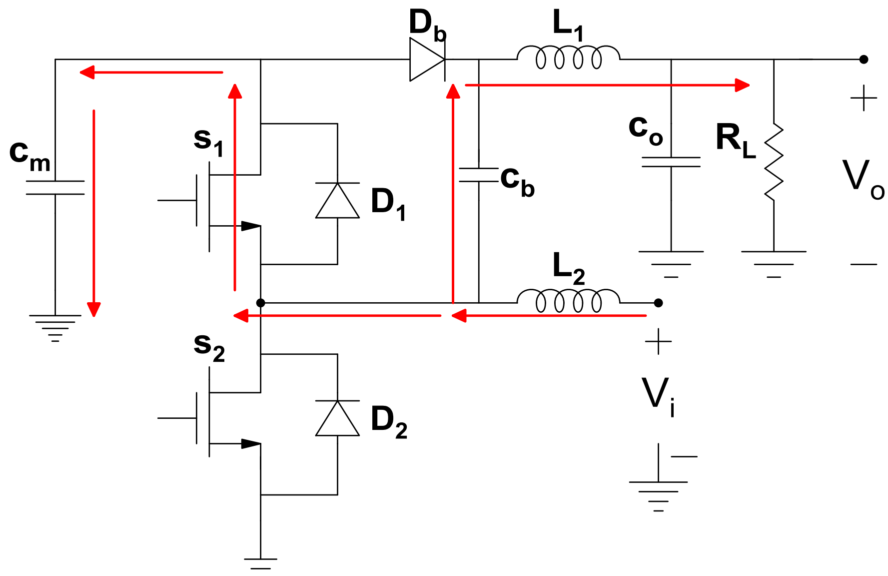

Fig. 3 MODE 2 -KY Boost Converter

$\frac{L_i \partial i_{L0}}{\partial t} = v_i - v_{cm}$ ----------------6

$\frac{L_0 \partial i_{L0}}{\partial t} = 2v_{Cm} - v_0$--------------7

$\frac{C_0 \partial v_0}{\partial t} = i_{L0} - \frac{v_0}{R_L}$------------------8

$\frac{C_m \partial v_{Cm}}{\partial t} = i_{L_i} - i_{L_0}$--------------9

$\frac{v_0}{v_i} = \frac{2-D}{1-D}$-------------------------10

III. SEPIC CONVERTER

Another kind of dc-dc converter that has the capability of providing buck-boost operation while maintaining the same polarity of output voltage as that of input is SEPIC converter (Single ended primary inductance convertor). It is a modification of basic boost and cuk convertor but the main drawback of cuk convertor is that it inverts the voltage. SEPIC has an advantage of providing non-inverted output voltage (as same that of input) by series coupling capacitor. It is superior to other convertors in terms of its switching losses, ripple, transient time and output noise. It consists of two inductors and a coupling capacitor for providing positive regulated DC voltage which can be less (buck operation) or more (boost operation) than the input voltage. It can operate in the buck mode or the boost mode by appropriately controlling the duty ratio of the controllable switch, for example, transistor. The output voltage can be increased by increasing the turn on time of the controllable switch (since the duty ratio is increases). The greater the percentage of duty cycle, greater will be inductor charging which increases the output voltage [10].

Basic Operation

Fig 4. represents the basic circuit of sepic convertor. Capacitor C_{OUT} represents the output capacitor whereas the inductors L1 and L2 can be individual inductors or can be coupled inductors. Capacitor C1 represents the AC coupling capacitor, with the controllable switch being power MOSFET represented by S in Fig.4 and the uncontrollable switch being diode D1. It is operating in continuous conduction mode (CCM) [8] – [10]. Both turn ON and turn OFF process is mentioned below.

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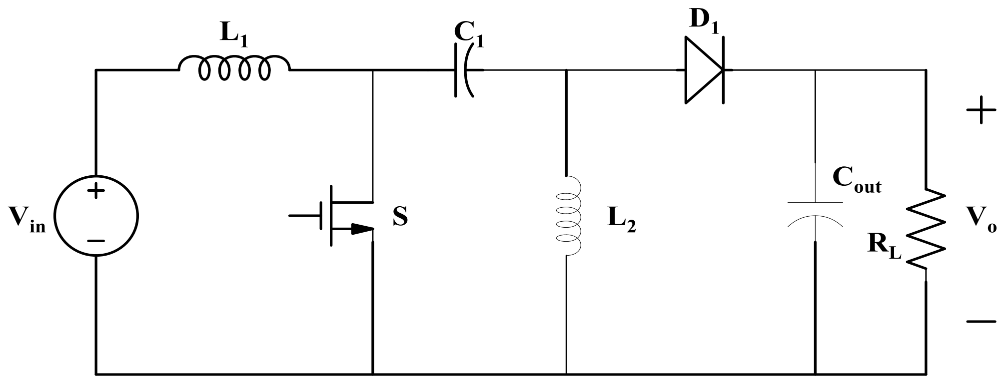

Fig. 4 SEPIC Converter

Turn ON Process

Once the gate pulse is provided, MOSFET (S) turns on, the coupling capacitor discharges through the inductor L_2. The inductor L_2gets charged by the coupling capacitor and the inductor L_1 gets charged by input voltage. Diode D_1 is reverse biased. The output is maintained by output capacitor C_{OUT} ($V_{C_{OUT}}$=V_{out}). Fig 2 shows Turn ON process of sepic

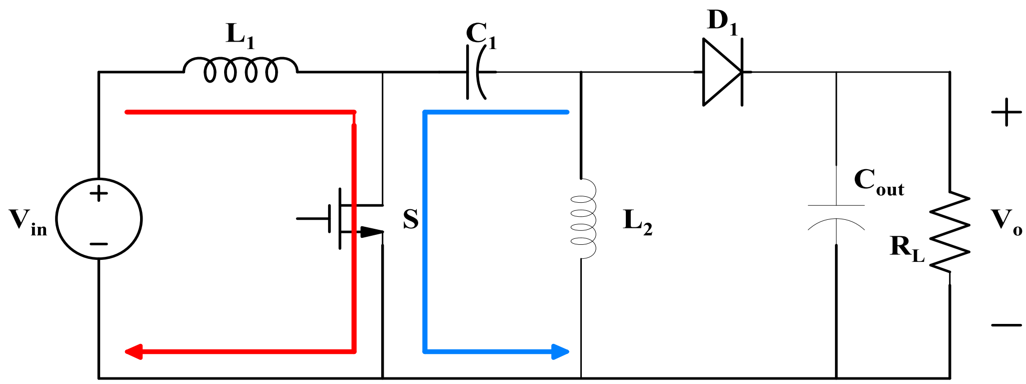

Fig. 5 Turn ON process

Turn OFF Process

Once the gate pulse is removed, MOSFET (S) turns off, the charged inductor L_1provides energy (discharges) to the load through the diode and charges the output capacitor. The output voltage is maintained across L_2 (V_{L_2}= V_{out}) .Both coupling and output capacitor gets recharged to provide load current and charge inductor L_2 when S is ON. Here fig 3 shows the turn OFF process of sepic convertor

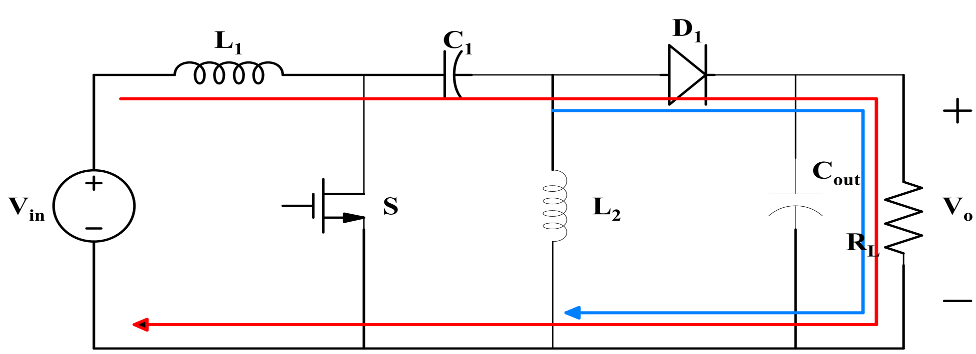

Fig. 6 Turn OFF process

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Design Parameters

During turn on:

$V_{in} = V_{L_1}(on)$---11

During turn off:

$V_{L1} = V_{C1} + V_{Out} - V_{in}$--12

Output Voltage $v_o = \frac{D*v_i}{1-D}$ ----------------------------13

Where D is Duty cycle

$D = \frac{V_O+V_d}{V_i+V_O+V_d}$---14

Ripple Current $\Delta I = I_{in}*40\% = I_{out}\frac{v_o}{v_i}*40\%$--------15

Ripple Voltage ΔV= 1% of v_i--------------------------16

Inductance $L_1=L_2=L = \frac{v_i}{\Delta I*f} * D$ ------------------------17

Coupling Capacitance C_1 depends on I_C ,$I_{C(rms)} = I_{out} * \sqrt{\frac{V_O+V_d}{v_i}}$ -----18

Coupling Capacitance $C_1 = \frac{I_{out}*D}{\Delta V*f}$ ------------------------------19

Load current $I_L = I_{in}$ --20

Load resistance $R_L = \frac{P_o}{V_o}$ --21

IV. SIMULATION AND RESULTS:

Both the SEPIC Converter and KYBC are validated through the simulations using MATLAB/Simulink with the input voltage of 150V, frequency f= 25 kHz and a duty cycle of 50% for both the converters. The simulated waveforms of output voltage, voltage ripple and current ripple are shown in Fig.7, Fig.8 and Fig.9 respectively.

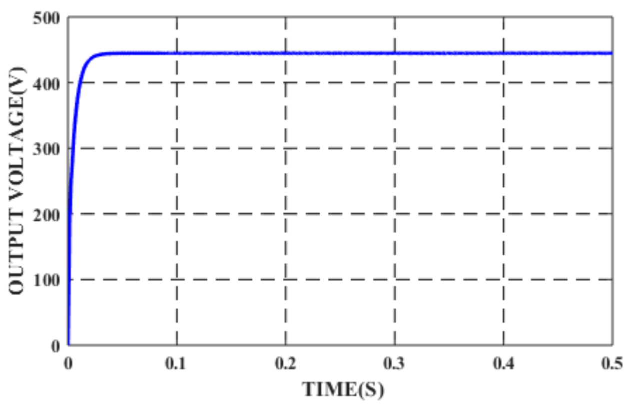

Fig.7(a)

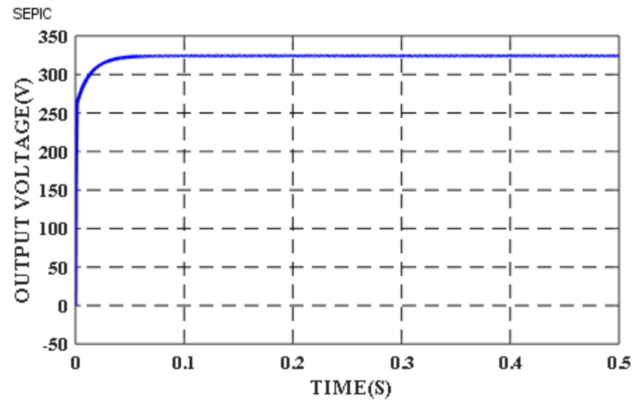

Fig.7(b)

Fig. 7 Output Voltage waveform of (a) KYBC (b) SEPIC Converter

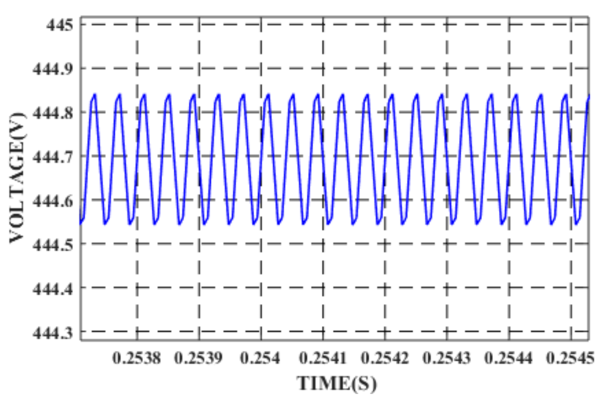

Fig.8(a)

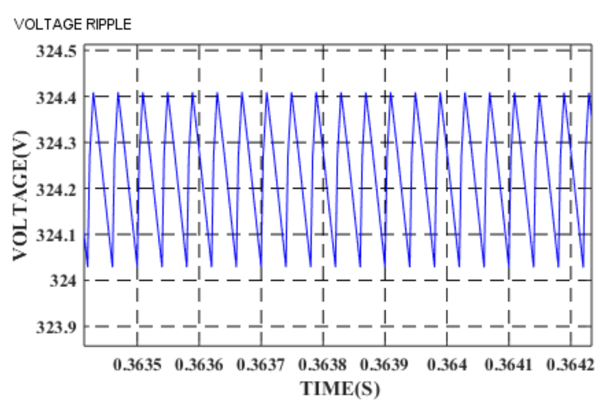

Fig.8(b)

Fig. 8 Voltage Ripple (a) KYBC (b) SEPIC Converter

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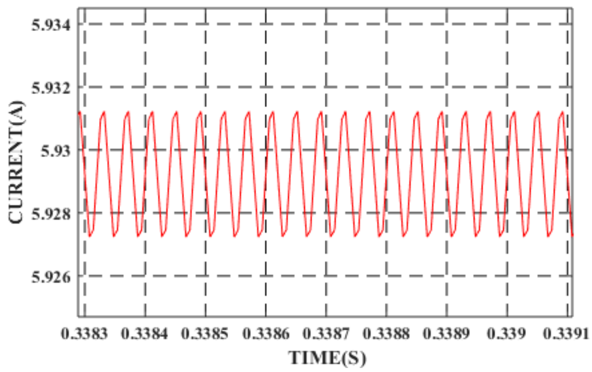

Fig. 9(a)

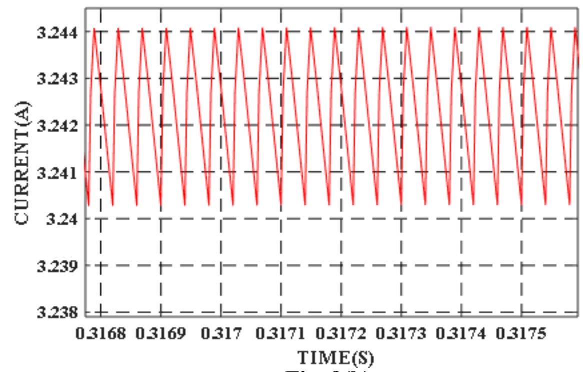

Fig. 9(b)

Fig. 9 Current Ripple (a) KYBC (b) SEPIC Converter

Fig. 8 and 9, shows the voltage ripple and current ripple of both the converters from which it's identified that the ripple of KYBC is lesser compared to that of the SEPIC.

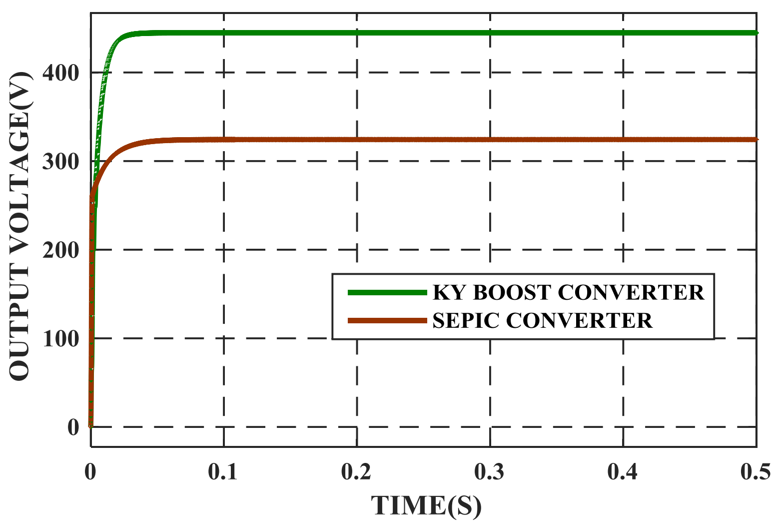

Fig. 10 Comparison Waveform of KYBC and SEPIC Converter

By comparing Fig.7 and Fig.10, it can be concluded that the load (output) voltage of KYBC is higher compared to that of SEPIC which leads to high gain for the same value of input voltage. Also both current ripple and voltage ripple gets reduced in KY Boost converter.

Table. 1 Comparison of Parameters from Waveforms of KYBC and SEPIC Converter

PARAMETERS	SEPIC CONVERTER	KY BOOST CONVERTER
OUTPUT VOLTAGE(V)	324	444
GAIN	2.16	2.96
VOLTAGE RIPPLE (V)	0.3798	0.2524
CURRENT RIPPLE (A)	0.0038	0.0033

From the waveforms and the comparison table, it is obviously clear that KY Boost Converter has the best performance in terms of higher output voltage as well as the reduction in both the current and voltage ripples.

V. CONCLUSION

KY Boost Converter and SEPIC Converter are simulated, compared and the results are tabulated above. The simulations have been performed by keeping identical input voltage for both the converters and the duty cycle of 50% and the results are taken for voltage and current ripple, also the comparison of their output voltages. The results ensure the high gain performance of KY Boost Converter and also the reduced ripples for both voltage and current. Hence, KY Boost Converter can be one ideal best suited High gain converter for Renewable Applications.

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