IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

DUAL OUTPUT COMMON GROUND QUADRATIC BOOST CONVERTER WITH LOW DUTY RATIO

[1]Saflana N A, [2]Smitha Paulose, [3]Neetha John, [4]Neema S, [5]Ninu Joy

[1]PG Scholar, [2,3,4,5]Professors

[1]Department of EEE, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India

Abstract: A high-gain DC-DC converter is essential in the generation of energy from non-conventional energy resources. Renewable energy applications like solar PV arrays and fuel cells produce insufficient output voltage. In practical applications, to meet the energy demands, the output voltage of the converter must be increased. The traditional boost converter is unsuitable for very high voltage gain because it provides high voltage gain at a high duty ratio. As a result, transient response problems and reverse recovery issues arise. Therefore, a dual output common ground quadratic boost converter with lower duty cycle has been designed. In this converter, the voltage stress on switching components is reduced as the converter has only one switch. Furthermore, the converter is more efficient and uses a constant input current, which is ideal for renewable energy applications. Moreover, this converter provides high voltage gain at low duty ratio and common ground structure reduces leakage current and electromagnetic interference. The analysis of the converter is carried out and the results are obtained using MATLAB/SIMULINK R2017a. Hardware implementation is done with PIC16F877A micro-controller and the switch is driven along with its driver TLP250H. A prototype of the converter is also implemented and tested to verify the analysis.

***Index Terms* -Quadratic Boost Converter, Dual Output, Common Ground, High Gain.**

I. INTRODUCTION

Distributed power generation is remaining as the most demanding technology in this era, as considering an alternative way to generate power rather than using depleting energy resources is inevitable. The right solution to the current and future scenario is renewable energy sources. To replace the existing conventional energy sources and to drive the world without environment pollution, green energy is required. Apart from the availability of the energy sources at minimum cost or free, the energy conversion methods and storage of energy makes the feasibility of the utilization of green energy. The advent growth of power electronics increases the power conversion efficiency and reduces implementation cost. The nature of the availability of renewable energy source is random, and it delivers maximum power at certain conditions. So, there is a need for effective power conversion, energy storage system and maximum power point tracking control techniques. The power rating of renewable sources varies from few hundreds of watts to few hundreds of mega watts, and the application are classified into two. They are grid connected and stand-alone. Solar PV produce DC power and other renewable sources produces either AC or DC power output based on the method of energy conversion adopted. Batteries used in energy storage system requires a DC interface either to charge or to discharge to the load. So, to interface the two or more DC nodes at a different potential, DC-DC converter circuits are needed. Nowadays, high step-up DC-DC converters are used in renewable energy systems for achieving better performance. Boost converter produce high output for low input. It is a step up DC-DC power converter. It contain at least two semiconductors (a diode and a transistor) and at least one energy storage element(a capacitor, inductor or the two in combination). To reduce ripple, filter made of capacitors are normally added (sometimes in combination with inductor) to the such converters output and input side. The advantage of these type of converters are low input current ripple, low conduction losses, high efficiency and low voltage stress across switches. Boost converters are also used in high intensity head lamps in automobiles, uninterrupted power systems, motor drives and many others. The conventional boost converter is not suitable for a very high voltage gain as it achieves high gain at a high value of duty cycle. Transient response problems arises due to high duty ratio, also it doesn't provide enough time to discharge the energy in energy storage element through diodes. The efficiency of the converter depends on the number of components in the circuit, conduction time, as well as switching frequency. A new double stage boost converter with single switch has same voltage gain as the series connection of two boost converters and is termed as quadratic boost converter. A non inverting high gain DC-DC boost converter in[1] can be operated with a wide range of duty ratios avoiding operation at extreme values, and hence there is no problem related to reverse recovery time for diodes. However, the absence of common ground is one of the disadvantages of the converter. In[2] a single switch quadratic voltage gain converter is proposed, but inductor count is more and voltage stress on the switch is same as output voltage. Single inductor boost converter presented in[3] has common grounded input and output terminals, which is benefit to avoid the dv/dt issues and achieve reliable output. A transformerless buck boost converter based on ZETA converter[4] utilizes only one switch. So the converter offers low voltage stress across the switch. Therefore the low on state resistance of the main switch can be selected to decrease the losses of the switch. But it has high ripple in source current. A single switch with three inductor high voltage gain converter proposed in [5] has the output voltage inverted in nature. Common ground concept is in-cooperated in it. Dual output is taken from the converter for buck-boost applications[5]. Common ground concept reduces the problems of leakage current and electromagnetic interference. Hence the performance of the converter can be improved.

This paper analyze a converter topology with high gain using a single switch and comparatively low voltage stresses across the switch and other power components. A voltage multiplier cell with common ground is used in the circuit to improve the gain. Moreover, voltage gain is more than twice as compared with a conventional quadratic boost converter and quadratic boost converter presented in [2]. The problems caused due to leakage current and Electromagnetic interference are not present here and the control of circuit is very easy because circuit utilize only one switch. The circuit draws continuous input current with low ripple which is desirable for renewable energy applications and that reduces the cost of input filter. It is operated with a wide range of duty ratios avoiding operation at extreme duty ratio, and hence there is no problem related to reverse recovery time for diodes. Dual outputs are taken from this circuit for different voltage and power applications[6].

II. Methodology

Dual output common ground quadratic boost converter consist of only one switch S and six diodes D_1, D_2, D_3, D_4, D_5 and D_6, five capacitors C_1, C_2, C_3, C_4, and output filter capacitor C_0, two inductors L_1, and L_2 and load R_0 and R_1 . Fig. 1 shows dual output common ground quadratic boost converter.

Fig. 1. Dual output common ground quadratic boost converter

2.1 Modes of Operation

The proposed converter has two operating modes: the first mode analysed during switch on, and the second mode is during switch off. Fig. 2 shows the theoretical waveforms of proposed converter during mode 1 and mode 2.

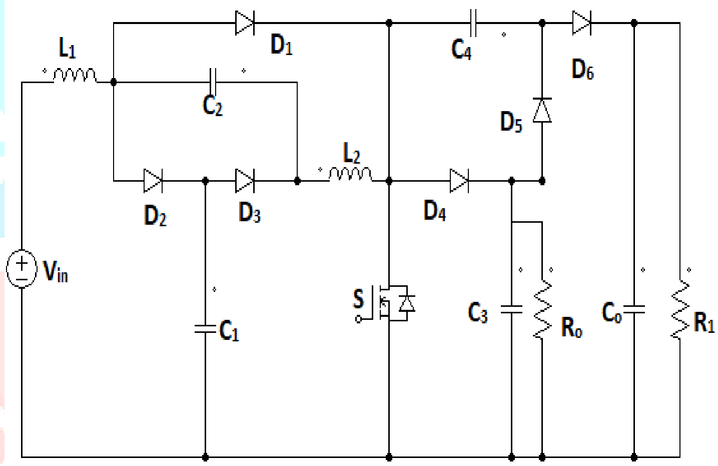


Fig. 2. Theoretical waveform of proposed converter

During mode 1, at time t_0, the switch S turned on. Diode D_1, D_3 and D_5 are forward biased and diode D_2, D_4 and D_6 are reverse biased. These diodes are reverse biased due to the polarity of capacitors and inductors. Hence, the voltage across inductor L_1 is equal to the input voltage Vin, and the inductor's current i_{L1} and i_{L2} rises to the peak value at the same time. Hence inductors store energy. Energy stored in capacitors C_1, C_3 and C_0 discharges. C_1 transfer energy to inductor L_2, C_3 transfer energy to C_4 and load R_0. C_0 feeds the load R_1. Fig. 3 shows the operating circuit of mode 1.

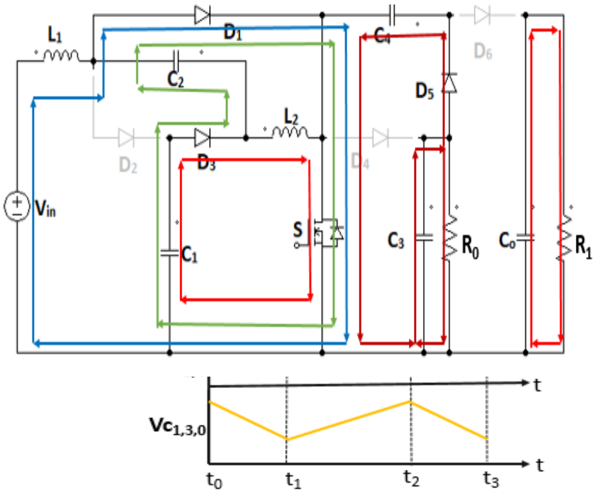


Fig. 3. Mode 1

During mode 2, at time t_1, switch is turned off, and three diodes D_2, D_4, D_6 are forward biased. L_1 and L_2 discharges. The inductor's current i_{L1} and i_{L2} decreases simultaneously. Energy stored in inductors are transferred to C_1, C_3 and C_0. The output capacitor C_0 discharges and feeds the load. The voltage across the capacitor C_3 and C_4 are equal. The voltage across output capacitor C_0 is the sum of voltage across the capacitor C_3 and C_4 and feeds the load. Fig. 4 shows the operating circuit of mode 2.

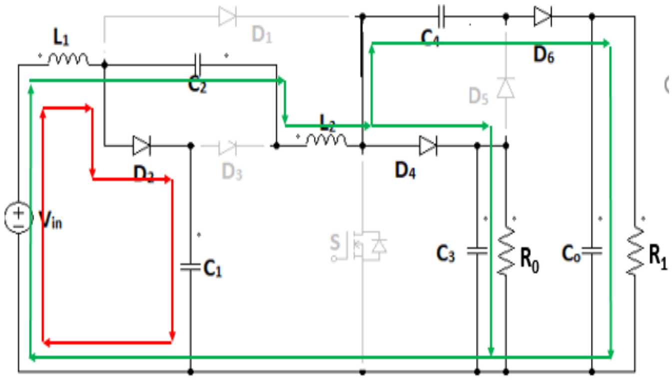


Fig. 4. Mode 2

2.2 Design of Components

In order to operate the converter, its components should be designed appropriately. It consist of designing the values of inductors and capacitors. For designing dual output common ground quadratic boost converter the input voltage is taken as 24V. The pulses are switched at the rate of 50kHz with duty ratio 0.3. The output voltage is take as 150V and the load resistance taken as 200Ω for both loads. The capacitor voltage ripple is taken as less than or equal to 1% of capacitor voltage and ripple in inductor current is take as less than or equal to 40% of inductor current. The voltage gain of the circuit is calculated by using (1) given below:

.

$$M = Vo/Vin \tag{1}$$

using (2) output current can be calculated.

$$Io = Vo/R \tag{2}$$

The inductors L_1 & L_2 are obtained by taking current ripple as 10% of I_{L1} and 30% of I_{L2} respectively. By substituting values to (4) & (6) it is approximated to 330μH each.

$$I_{L1} = \frac{2(2-D)Io}{(1-D)^2} \tag{3}$$

$$L_1 >= \frac{DVin}{\Delta I_{L1} fs} \tag{4}$$

$$I_{L2} = \frac{2Io}{1-D} \tag{5}$$

$$L_2 >= \frac{DVin}{(1-D)\Delta I_{L2} fs} \tag{6}$$

The capacitors C_1 & C_2 are obtained by taking voltage ripple as 1% of Vc. By substituting values to (8) capacitor values are approximated to 47μF for C_1 & C_2.

$$V_{C1} = V_{C2} = \frac{Vin}{1-D} \tag{7}$$

$$C_1 = C_2 >= \frac{2Dvo}{(1-D)R\Delta V_{c1} f_s} \tag{8}$$

The capacitors C_3 & C_4 are obtained by taking voltage ripple as 0.2% of Vc. By substituting values to (10) capacitor values are approximated to 47μF for C_3 & C_4.

$$V_{C3} = V_{C4} = \frac{2DVin}{(1-D)^2} \tag{9}$$

$$C_3 = C_4 >= \frac{DVo}{R\Delta V_{C3} f_s} \tag{10}$$

The output capacitors C_0 is obtained by taking voltage ripple as 0.1% of V_0. By substituting values to (11) output capacitor value is approximated to 100μF.

$$Co \geq \frac{(1-D)Vo}{R\Delta V_o f_s} \tag{11}$$

III. SIMULATIONS AND RESULTS

The dual output common ground quadratic boost converter is simulated in MATLAB/SIMULINK by choosing the parameters listed in Table 1. An input voltage Vin of 24V is given to get a required output voltage of 150V. The load resistance is given as 200Ω. The switch is MOSFET with constant switching frequency of 50kHz. The duty cycle of switch is taken as D= 0.3.

TABLE I

Simulation Parameters

Simulation Parameters	Specification
Input Voltge(V_{in})	24V
Switching Frequency	50kHz
Duty Ratio	0.3
Load resistance	200Ω
Inductors	330μH, 330μH
Capacitors	47μF, 47μF, 47μF, 47μF, 100μH

It can be seen that, an input voltage Vin of 24V and the input current I_{in} of 6.646A gives an output voltage V_{01} as 74.94V and V_{02} as 148.2V. The switching frequency is chosen to be 50 kHz and the duty ratio of S is equal to 0.3. Fig. 5 shows the input voltage and current. Thus, the voltage gain is obtained as 3.1 and 6.2 for output 1 and 2 respectively.

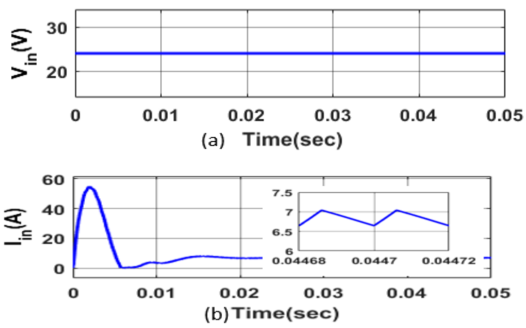


Fig. 5. (a) Input Voltage (V_{in}) and (b) Input Current (I_{in})

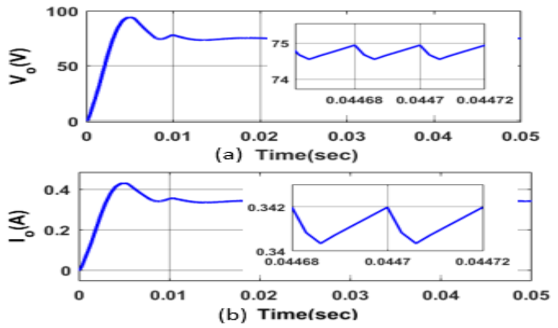


Fig. 6. (a) Output Voltage (V_{01}) (b) Output Current (I_{01})

Fig. 6 shows the output voltage V_{01} and output current I_{01} of the converter for load R_0. The converter output voltage is 74.94V and output current is 0.342A. The output voltage ripple is 0.39V and output current ripple is 0.0016A. Fig. 7 shows the output voltage V_{02} and output current I_{02} of the converter for load R_1. The converter output voltage is 148.2V and output current is 0.7412A. The ripple content in output voltage is 0.051V and output current is 0.00024A. Fig. 8 shows gate pulse and voltage across switch S. Voltage across switch S is 75.89V. Fig.9 shows the voltage across C_1 and C_2. The voltage across the capacitor C_1 is about 33.09V. The voltage ripple is 1.3V and voltage across the capacitor C_2 is about 28.59V. The voltage ripple is 0.8V. Fig. 10 shows the voltage across C_3 and C_4. The voltage across the capacitor C_3 is about 74.94V. The voltage ripple is 0.39V and voltage across the capacitor C_4 is about 73.25V and the voltage ripple is 0.34V.

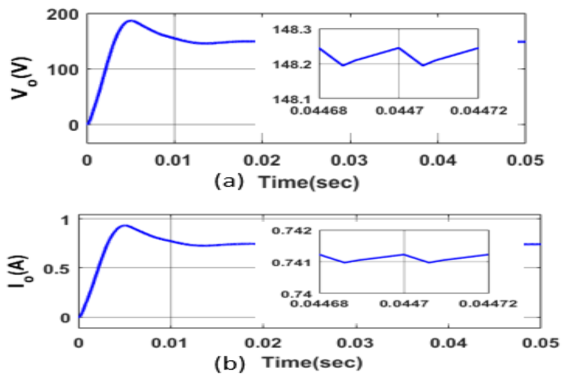


Fig. 7. (a) Output Voltage (V_{02}) (b) Output Current (I_{02})

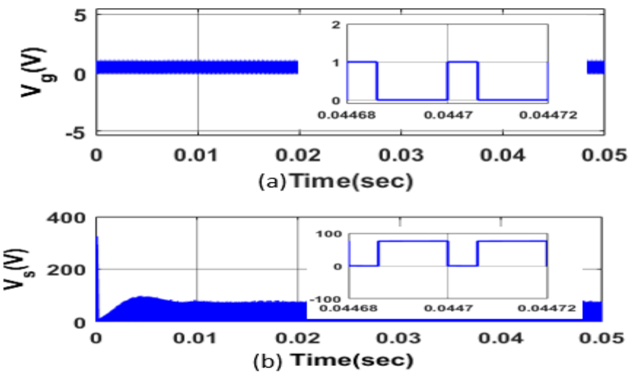
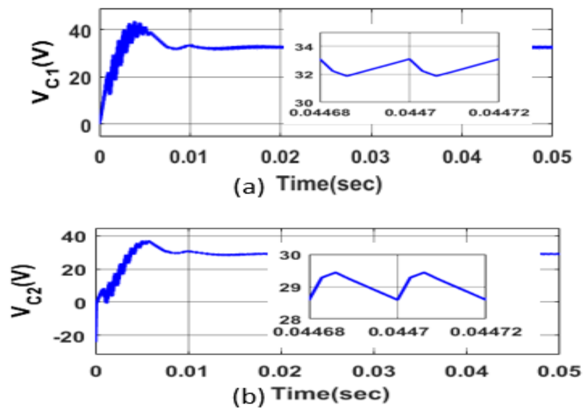


Fig. 8. (a) Gate Pulse to (S) and (b) Voltage Stress across (S)



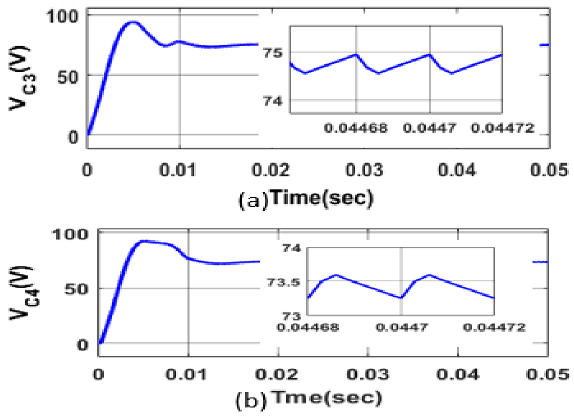


Fig. 9. (a) Voltage across Capacitor (C_1) and (b) Voltage across Capacitor (C_2) Fig. 10. (a) Voltage across Capacitor (C_3) and (b) Voltage across Capacitor (C_4)

Fig. 11 shows the currents through inductors L_1 and L_2. Current through inductor L_1 is equal to input current, and its about 6.646A and current through inductor L_2 is 2.53A. The ripple content in I_{L1} is 0.39A and I_{L2} is 0.52A.

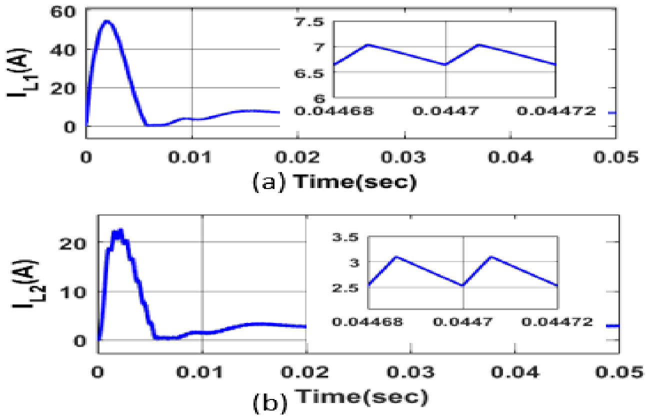
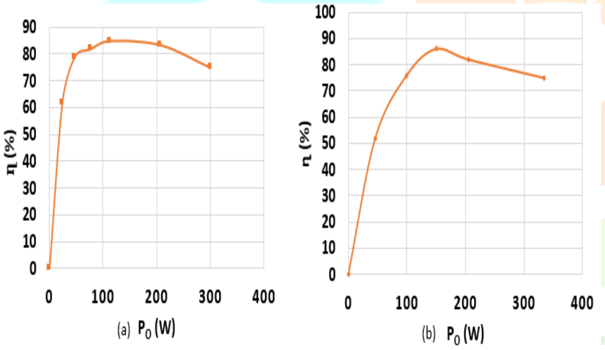


Fig. 11. (a) Inductor Current (I_{L1}) (b) Inductor Current (I_{L2})

IV. Performance Analysis

The analysis of dual output common ground quadratic boost converter are carried out by considering parameters like efficiency, voltage gain, output voltage ripple and duty ratio. The plot of efficiency Vs output power for R load and RL load is shown in Fig. 12. The dual output common ground quadratic boost converter's maximum efficiency is around 85% for R load and 86% RL load at 112 W output power.

The output voltage ripple Vs duty ratio is shown in Fig. 13(a). For duty ratio below 0.5, the ripple content is comparatively low for the converter whereas the ripple content in output voltage is high for duty ratio above 0.5. Therefore, duty ratio of 0.3 is chosen for feasible operation of the proposed converter. The analysis of output voltage ripple Vs switching frequency is shown in Fig. 13(b). According to the analysis the output voltage ripple decreases with increase in switching frequency of the converters.



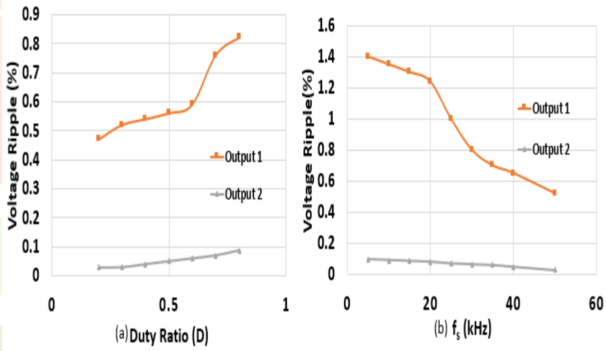


Fig. 12. Efficiency Vs Output Power (a) R Load and (b) RL Load Fig. 13. (a)Output Voltage Ripple Vs Duty Ratio and (b) Output Voltage Ripple Vs Switching Frequency

V. Comparitive Study

The comparison between non-inverting high gain DC-DC converter[1] and proposed dual output common ground quadratic boost converter is given in Table 2. From the comparison table it is clear that the dual output common ground quadratic boost converter has better performance than non-inverting high gain DC-DC converter. The number of components same for both the converters. The voltage gain of both the converters are approximately equal. Output voltage and output current ripple of proposed dual output common ground quadratic boost converter is lower than that of noninverting high gain DC-DC converter. The voltage stress across switch is same for both the converters.

TABLE II

Comparison between Non inverting quadratic boost converter[1] and Proposed converter

Parameters	*NIQBC[1]*	*Proposed converter*
No of switches	1	1
No of inductors	2	2
No of capacitors	5	5
No of diodes	6	6
Voltage Gain	6.4	6.2
Input Current	5.6A	6.646A
Output Current	0.7658A	0.7412A
Output Voltage	153.2V	148.2V
Output Current Ripple	0.088%	0.032%
Output Voltage Ripple	0.078%	0.034%
Voltage Stress across Switch	0.5Vo	0.5Vo

Table 3 shows the components wise comparison among dual output common ground quadratic boost converter and other DC-DC converter topologies. The no.of components of proposed converter and non inverting high gain converter are same. It shows that without adding any extra components the performance of proposed converter get improved. Inductor count is more in converter proposed in [2]. The no.of switches is higher in converter[3] than other converters.

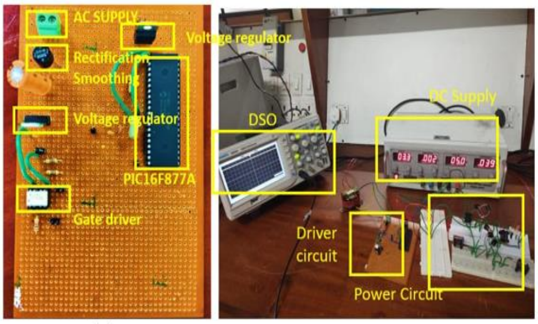
TABLE III

Components wise comparison among Dual output common ground quadratic boost converter and other DC-DC converter topologies

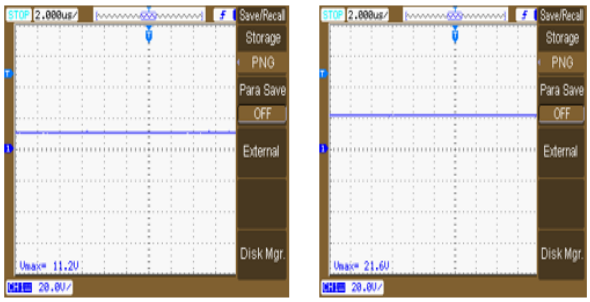
Title	*NIQBC[1]*	*SIQBC[2]*	*SIBC[3]*	*Proposed converter*
No of switches	1	1	2	1
No of inductors	2	3	1	2
No of capacitors	5	3	4	5
No of diodes	6	6	5	6

VI. Experimental Setup With Results

For the purpose of implementing hardware, the input voltage is reduced to 5V and the switching pulse generated using PIC16F877A micro-controller. The switches used are MOSFET IRFZ44N along with its driver TLP250H, which is an opto coupler used to isolate and protect the micro-controller from any damage and also to provide required gating to turn on the switch. Fig.14 (a) and (b) shows the interfacing circuit and experimental setup for dual output common ground quadratic boost converter respectively. Input 5V DC supply is given from DC source. Switching pulses are taken from interfacing circuit, which consist of PIC16F877A micro-controller and it's driver circuit. Thus, an output voltage of 11.2V and 21.6V with 50Hz frequency is obtained from power circuit that is shown in Fig. 15. Output voltage of the converter is taken from the DSO.



(a) (b)



(a) (b)

Fig. 14. (a) Experimental Setup, (b) Output Voltage of Proposed Inverter Fig. 15. (a) Output Voltage (for load R_0) and (b) Output Voltage (for load R_1)

VII. Conclusion

The dual output common ground quadratic boost converter provides numerous advantages in the field of photovoltaic applications. As the energy consumption is increasing day by day, conventional energy resources can be replaced by non conventional energy resources. Mainly a PV system can be implemented for domestic and industrial applications. Although to meet the required output voltage at the grid side a boost converter is needed to interface between PV cells and inverter. The dual output common ground quadratic boost converter has high an efficiency of 86% at lower duty cycle. The output voltage ripple and output current ripple is lower for this converter. The converter has wide voltage conversion ratio with continuous input current and also have high voltage step-up gain. It provides a voltage gain of 6.2 for an input voltage of 24V. The voltage multiplier cell with common ground enhances the performance of the converter by reducing the leakage current and eliminating the electromagnetic interference issues. This converter has simple topology and it can be used in renewable energy applications. Moreover, dual outputs are taken from the circuit, which make the circuit suitable for multiple purposes at the same time. Hardware is implemented using PIC16F877A micro-controller. The prototype converter section is tested and effectiveness of proposed converter experimentally verified.

References

[1] A. Mahmood, M. Zaid, J. Ahmad, M. A. Khan, S. Khan, " A Non Inverting High Gain DC-DC Converter with Continuous Input current",IEEE Access , vol. 9, pp.54710-54721, Apr. 2021.

[2] J. Ahmad, M. Zaid, A. Sarwar, M. Tariq and Z.Sarwer, "A New Transformerless Quadratic Boost Converter with High Voltage Gain,"Smart Science , vol.8, no.3, pp.163-183, Jul.2020.

[3] Shan Miao, Wei Liu, and J. Gao " Single Inductor Boost Converter with Ultra High Step up Gain, Lower Switches Voltage Stress, Continuous Input Current, and Common Grounded Structure",IEEE Transactions on Power Electronics , vol. 36, no. 7, pp. 7841-7852, Jul.2021.

[4] M. R. Banaei and H. A. F Bonab, " A High Efficiency Non-Isolated Buck Boost Converter based on ZETA Converter",IEEE Transactions on Industrial Electronics , vol. 67, no. 3, pp. 1991-1998, Mar.2020.

[5] A. Sarikhani, B. Allahverdinejad, H. Torkaman, "A Non Isolated Buck Boost DC-DC Converter with Single Switch", 2018 9th Annual Power electronics,Drives Systems and Technologies Conference(PEDSTC) ,vol. 18, no. 1, pp.53861-4699, Apr.2018.

[6] G. Chen , Z. Jin, Yan Deng , Xiangning He, and Xinlin Qing, "Principle and Topology Synthesis of Integrated Single-Input Dual-Output and Dual-Input Single-Output DCDC Converters", IEEE Transactions on Industrial Electronics ,vol. 65, no. 5, pp.3815-3825, May.2018.

[7] Dongwon Kwon, and Gabriel A. Rincn-Mora, "Single-Inductor Multiple-Output Switching DCDC Converters", IEEE Transactions on Circuits and Systems,vol. 56, no. 8, pp.614-618, Aug.2009.

[8] S. Miao, F. Wang and X. Ma, "A New Transformer-less Buck-Boost Converter with Positive Output Voltage," IEEE Transactions on Industrial Electronics, vol. 63, no. 5, pp. 2965-2975, May 2016.

[9] M.R Banaei and S.G. Sani, "Analysis and Implementation of a New SEPIC-Based Single-Switch Buck-Boost DC-DC Converter with Continuous Input Current," IEEE Transactions on Power Electronics, vol. 33, no. 12, pp. 10317- 10325, 2018.

[10] M.R Banaei and H.A.F Bonab, “A Novel Structure for Single Switch Non isolated Transformer-less Buck-Boost DC-DC Converter,” IEEE Transactions on Industrial Electronics, vol.64, no. 1, pp. 198-205,Jan. 2017.