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Original Article

Design of Single Switch Improved High Gain Boost Converter with Reduced Voltage Stress

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Abstract: *This paper describes the design of single switch improved high gain boost converter (SSIHGBC) with increased voltage gain and reduced voltage stress across the semiconductor switch as well as overall converter losses. High gain converters play a crucial role in numerous power supply applications, and the proposed SSIHGBC is tailored to enhance efficiency while minimizing voltage stress on components, making it particularly suitable for renewable energy systems and low power electronic devices. The proposed topology is a member of the family of the non-isolated category with a common ground feature and can operate in a wide range of duty ratios, and is able to provide the required voltage gain. In this proposed circuit configuration, a dual voltage boost cell was formed by incorporating two capacitors in series with two inductors of a conventional quadratic boost converter. Additionally, a capacitor was integrated with a second voltage boost cell. This special configuration increases the voltage gain as well as reduces the voltage stress across the switch. The simulation was performed in MATLAB software, and the experimental results agreed with the obtained output voltage gain. The proposed topology showed a peak efficiency of 93% at 22-W output power after considering the power losses in all the components of the circuit.*

Keywords: *DC-DC Converter, High Gain, Low Voltage Stress, Duty Ratio, High Efficiency.*

I. INTRODUCTION

Distributed energy sources are diverting the intention of power producers to fulfill their energy demands and mitigate energy crises. Different renewable energy sources such as wind, solar photovoltaic, fuel cell are commonly used sources, but solar photovoltaic attracted the intention of research in recent years because of its abundant availability. The output voltage of photovoltaic and fuel cell system is very low. Step up DC-DC converters are widely used in numerous power conversion applications and converting lower power DC levels to higher levels. In general, theoretically, the well-known traditional simple boost converter can achieve a high gain (i.e., 10 times) at a duty ratio near 90–95%, but practically, it is impossible to achieve due to the presence of parasitic resistance in passive components, as it limits the charging current in the inductor loop. Additionally, operating at a very high duty cycle may create a reverse recovery problem for the power diode, so it reduces the system performance by increasing the conduction loss of the converter, which further limits the system efficiency. This modified high gain boost is designed to overcome all these challenges; the operation of the boost converter is preferable at a lower duty ratio. The output voltage has been varied according to the switching speed of the MOSFET.

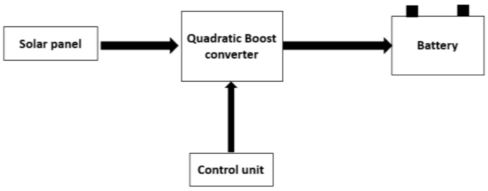
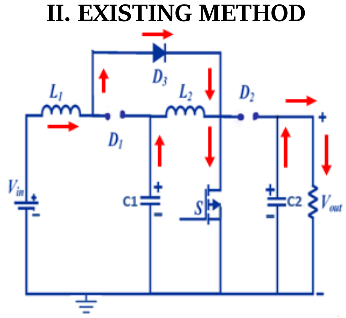


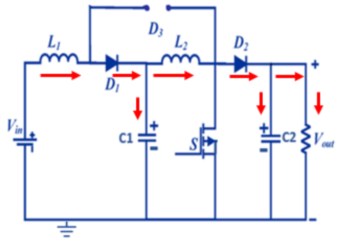
Figure 1: Block Diagram of High Gain Boost Converter

II. EXISTING METHOD



Mode 1

- D3 – Forward biased
- D1, D2 – Reverse biased
- Vin & C1 – Charge L1 & L2



Mode 2

- **D1D2 – Forward biased**
- **D3- Reverse biased**
- **L1 & L2 – Charge C1and C2 respectively.**

A. Limitation of existing method

- This boost converter has limited switching frequency because of the stress on the switch.
- The output voltage of the converter has ripple content. Which requires additional filter circuit.
- Existing boost converters introduce energy losses during the conversion process due to factors such as switching losses and voltage drops across semiconductor devices.
- These losses can reduce the overall efficiency of the system, leading to energy wastage and decreased battery life in applications like electric vehicles.

III. PROPOSED METHOD

In this Modified QBC two additional capacitor C1 & C2 are connected in series with the inductor L1 and L2 respectively, which plays a significant role in boosting the output voltage as well as reducing the voltage stress across the switch. The proposed topology is a member of the family of the non-isolated category with a common ground feature and can operate in a wide range of duty ratios, and is able to provide the required voltage gain.

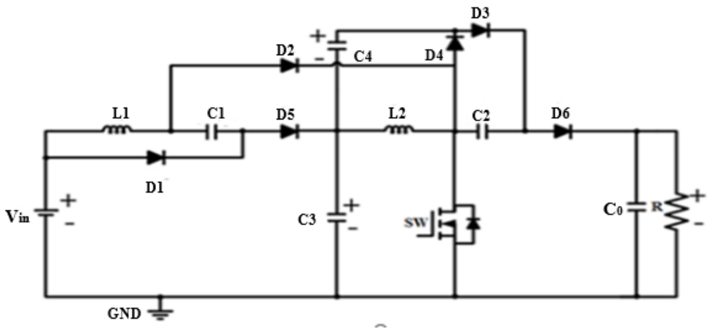
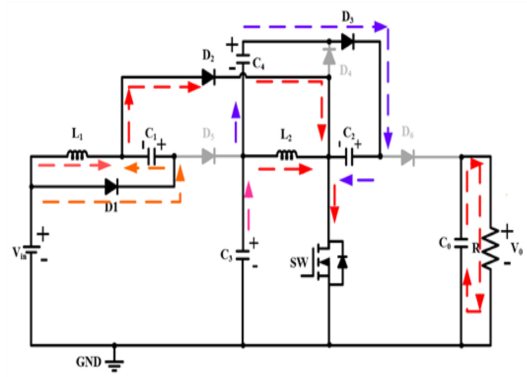


Figure 2: Circuit Diagram for Proposed High Gain Boost Converters

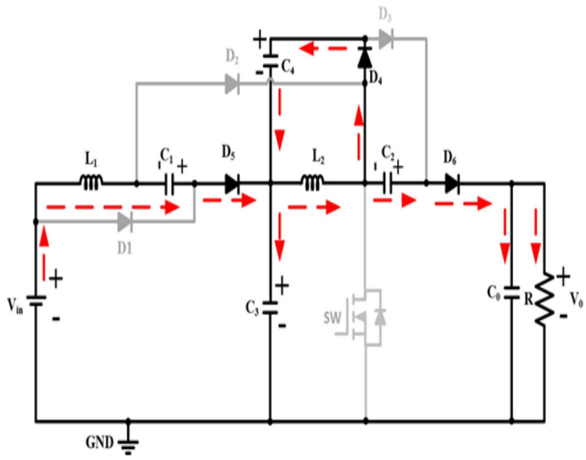
A. Modes of Operation

Mode 1:



The diodes D1, D2, and D3 will be forward biased. The diodes D4, D5, and D6 will be reverse biased during the first mode of operation. The inductor L1 and capacitor C1 are charged by the source voltage . The inductor L1 and capacitor C1 are charged by the source voltage , where capacitor C1 is supplied by the diode D1. In the second integrated voltage lift cell, the capacitor C3 transfers the energy directly into the inductor L2, and the capacitor C2 is charged by the summation of the voltage source supplied by the capacitors C3 and C4. On the other hand, the output capacitor Co transfer the necessary load current to the load.

Mode 2:



During this interval period, the switch was turned off, ideally with the withdrawal of the PWM signal. In this mode of operation, the energy is directly transferred from the source to the load through the passive component, and it transfers the energy to the other passive component (i.e., C3, C4). The diodes D1, D2, and D3 will be in reverse bias; on the other hand, the D5 and D6 will carry the necessary current for the load. The charging current for capacitor C4 is provided by the inductor L2 through diode D4.

B. Design Considerations

a) Design of Inductor

$$v_L = L1\frac{di_{L1}}{dt} = v_{in} \quad (1)$$

$$L_1 = \frac{v_{in}\,dt}{\Delta iL1} \quad (2)$$

$$V_{L2} = L2\frac{di_L}{dt} = V_{C3} \quad (3)$$

$$L_2 = \frac{v_{c3}\,dT}{\Delta iL1} = \frac{(2-d)v_{in}\,dT}{(1-d)\Delta iL1} \quad (4)$$

$$\Delta iL1 = \frac{v_{in}dT}{L1} \quad (5)$$

$$\Delta iL2 = \frac{v_c dT}{L_2} = \frac{(2-d)v_{in}dT}{(1-d)L_2} \quad (6)$$

b) Design of capacitor

The capacitor was designed using voltage across each capacitor Vcx, the charging current flowing through it, the duty cycle, and the switching frequency respectively.

$$c_1 = \frac{\Delta Q_1}{\Delta V_{c1}} = \frac{\Delta I_{c_1}\,dT}{\Delta V_{c1}} = \frac{(2-d)\,dV_0}{(1-d)^2\Delta V_{c1}\,f_{s(s)}R} \quad (7)$$

$$c_2 = \frac{\Delta Q_2}{\Delta V_{c2}} = \frac{\Delta I_{C2}\,dT}{\Delta V_{c2}} = \frac{dV_0}{(1-d)^2\Delta V_{C2}\,f_{s(s)}R} \quad (8)$$

$$c_3 = \frac{\Delta Q_3}{\Delta V_{c3}} = \frac{\Delta I_{C3}\,dT}{\Delta V_{c3}} = \frac{dV_0}{(1-d)^2\Delta V_{C3}\,f_{s(s)}R} \quad (9)$$

$$c_0 = \frac{\Delta Q_0}{\Delta V_{c0}} = \frac{\Delta I_{C0}\,dT}{\Delta V_{c0}} = \frac{dV_0}{\Delta V_{C0}\,f_{s(s)}R} \quad (10)$$

C. Simulation Model of Proposed Method

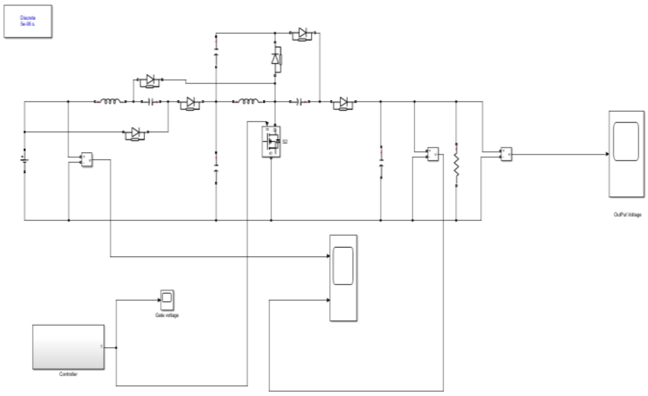


Figure 3: Simulation Circuit Diagram for Modified Quadratic Boost Converter

If V_S=12V, δ=0.5 then the output voltage is given by 180V for the duty cycle 0.5 whereas the simulation output is 400V for the 48v input voltage. The simulation output of quadratic boost converter is shown below in Fig.

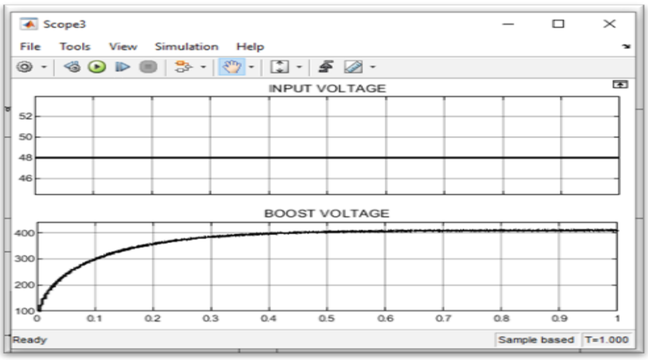


Figure 4: Simulation Output

a) Efficiency

Duty Ratio	Input voltage (V)	Input Current (A)	Output Voltage (V)	Output Current (A)	Efficiency (%)
0.2	12	0.5	50	0.076	63%
0.5	12	1.2	120	0.093	78%
0.6	12	2	180	0.125	93%

b) Performance Comparision

Topology	Switch	Diode	Capacitor	Input Voltage	Output Voltage	Duty Ratio	Efficiency
Conventional boost converter	1	1	1	12	35	0.7	62%
Quadratic boost converter (QBC)	1	3	2	12	95	0.7	74%
Modified QBC [Proposed method]	1	6	4	12	180	0.6	93%

IV. CONCLUSION

In conclusion, the proposed modified high gain quadratic boost converter offers a promising solution for a wide range of applications in sustainable green energy and high voltage systems. By incorporating a dual voltage boost cell and integrating additional capacitors, the circuit achieves increased voltage gain while simultaneously reducing voltage stress on the switch. Its ability to operate across a wide range of duty ratios ensures adaptability to various load conditions and voltage requirements. Overall, the proposed converter presents a significant advancement in the field of DC-DC conversion, offering improved voltage regulation, efficiency, and reliability. Its potential applications span across renewable energy systems, electric vehicles, power supplies, and beyond, contributing to the ongoing efforts towards sustainable and efficient energy solutions.

A. Acknowledgment

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