ENHANCED GAIN QUADRATIC BOOST CONVERTER FOR RENEWABLE ENERGYAPPLICATIONS

Ms. Aisha Mol M.S , PG Scholar
Dept of Electrical & Electronics Engg, Mar Athanasius College of Engineering
Kothamangalam, Kerala, India

Prof. Beena M.Vargheese
Dept of Electrical & Electronics Engg, Mar Athanasius College of Engineering
Kothamangalam, Kerala, India

Dr.Siny Paul
Dept of Electrical & Electronics Engg, Mar Athanasius College of Engineering
Kothamangalam, Kerala, India

Prof. Jeena Joy
Dept of Electrical & Electronics Engg, Mar Athanasius College of Engineering
Kothamangalam, Kerala, India

Dr. Jisha Kuruvilla
Dept of Electrical & Electronics Engg, Mar Athanasius College of Engineering
Kothamangalam, Kerala, India

Dr. Sija Gopinathan
Dept of Electrical & Electronics Engg, Mar Athanasius College of Engineering
Kothamangalam, Kerala, India

Abstract—The use of renewable energy is increasing and decreasing the use of dangerous fossil fuels.It is inefficient to link fuel cells or photovoltaic (PV) panels in series and parallel to meet the grid's energy needs from renewable sources. From now on, the combination of step-up dc–dc converters and attractive renewables will fulfill load requirements in several low-power applications.The quadratic boost converter is more often used than the buck and buck-boost converters due to the demand of voltage gain.Using a traditional quadratic boost converter to achieve high gain at a high duty ratio will result in increased voltage, stress, and lower efficiency.The suggested converter is made to produce high gain at a lower duty ratio and lower voltage stress.A voltage multiplier cell added to the rear end of this construction reduces the voltage stress across the switches.By modeling the converter in Matlab/SIMULINK R2020b, results are obtained.According to the simulation findings, the suggested high-gain converter achieves a maximum operating efficiency of 89% while delivering high-gain and reducing voltage stresses in switching devices.The hardware prototype was developed with an output of 10.8V and an input of 2V using a microcontroller TMS320F28027F.

***keywords*—**Voltage multiplier cell (VMC), Gain, Efficiency, Switched inductor, Pulse-width modulation (PWM).

I. INTRODUCTION

The utilizing various renewable energy sources has gained significant appeal in recent times because of concerns about climate change and the ongoing depletion of fossil fuels.As a result, it's critical to make an energy transition.To fulfill the worldwide sustainable strategic goals.Power electronic converter technology has advanced and provided a potential solution in this area.Power generated on a local or big scale may be delivered to the power grid using renewable energy sources.Since the voltage obtained from a photovoltaic source is known to be intermittent, a powerful electronic boost converter is essential to the intermediate system's ability to raise the input voltage.The fundamental design of boost-buck-boost converters may be used to increase the converter's low input voltage to the appropriate level by applying pulse width modulation (PWM) control.

To fulfill the grid's energy requirements from renewable sources, photovoltaic (PV) or fuel cell connections must be connected in series and parallel [2].Step-up dc-dc converters and renewables will meet load demand in many low-power applications [3].Because of the need for voltage gain, the standard boost converter is preferred over the buck and buck-boost converters. Nonetheless, a typical boost converter only achieves ten times the voltage increase at an impractical duty ratio.Furthermore, utilizing an excessive duty ratio while accounting for parasites results in high current loads on the components, poor efficiency, and significant reverse recovery concerns [4].Taking into account the aforementioned difficulties, this results in a voltage conversion ratio of just four times.

Non-isolated converters employ a number of voltage boosting tactics, including voltage multipliers, connected inductors, and switching inductors, to increase the gain of DC-DC converters.Another way to improve the converter's boosting capabilities is to connect a Z-network between the power supply and the switching devices. Another circuit that mixes common Z-Source networks in various ways is designed to increase the lower boosting capacity of a Z-source DC-DC converter [5]. Extreme duty cycles increase power switches' conduction losses, lowering their efficiency. The Z network circuit is complicated by the huge, hefty components.To address this issue, a converter with a restricted duty cycle for boosting is designed with a straightforward structure and minimal voltage gain [6]. Switched capacitor-based Z-source converters [7] provide a higher voltage gain than typicalZ-source converters. Additionally, it uses smaller inductors

compared to other converters, resulting in a more compact circuit. However, there is a higher tension between switches and diodes.

In an effort to achieve high voltage gain, several converter topologies have been devised in the last ten years to circumvent the limits imposed by a host converter [8]–[10].Furthermore, the use of voltage-boosting methods allows these converter topologies to be divided into isolated and nonisolated categories.Separated converters use a high-frequency transformer to adjust the voltage gain by changing the number of turns; however, a higher number of turns causes the converter's size and cost to rise.

The most practical way to get around the aforementioned restrictions is to use an enhanced quadratic boost converter[1] that has fewer components and less voltage stress on the apparatus.The input and loadside share a common ground facility and a continuous source of current.using the same PWM pulse for both switches, and consequently, the converter Control is easy.A thorough examination of the quadratic best converter under steady-state circumstances is conducted.

In this paper an improved gain quadratic boost converter with excellent conversion efficiency is proposed to solve the aforementioned restrictions.By adding a voltage multiplier cell to the output side, this converter is created.The voltage gain of the proposed converter is increased by the voltage multiplier cell.Additionally, to decrease input current and input voltage triple, decrease output current and output voltage triple.The converter has two modes of operation and is evaluated in continuous conduction mode.To validate the aforementioned properties of the proposed circuit, which more clearly illustrates the circuit's efficacy, simulations have been run.

II. METHODOLOGY

The enhanced gain quadratic boost converter is derived by adding a voltage multiplier cell to the outputside of quadratic boost converter.The enhanced gain quadratic boost converter comprises of a single switch S, inductor L_1 and L_2, capacitor C_1- C_4, diodes D_1 -D_5 and a load resistor R_O. Figure 1 shows the enhanced gain quadratic boost converter withlow voltage stress.

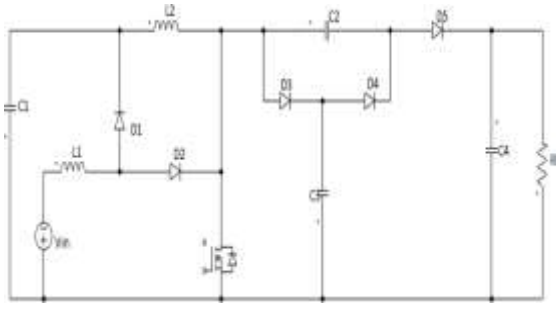

Fig. 1. Enhanced Gain Quadratic Boost Converter

A. Modes of Operation

The proposed converter operates in continuous current mode.There are two operating modes in one switching cycle.Both modes provide positive output voltage.

1) Mode 1 : In mode 1, switch S, diodes D_2, and D_4 are switched on, while diodes D_1, D_3, and D_5, are turned off.Currently, the source charges the inductors L_1, and L_2.Capacitor C_1, charges, capacitors C_2 and C_3 discharge.Current Both inductors rise linearly.The output capacitor C_4 charges the load.Figure 2 depicts the operational circuit of mode 1.

$$V_{IN} - V_{L1} = 0 \quad (1)$$

$$V_{C1} - V_{L2} = 0 \quad (2)$$

$$V_{C3} - V_{C2} = 0 \quad (3)$$

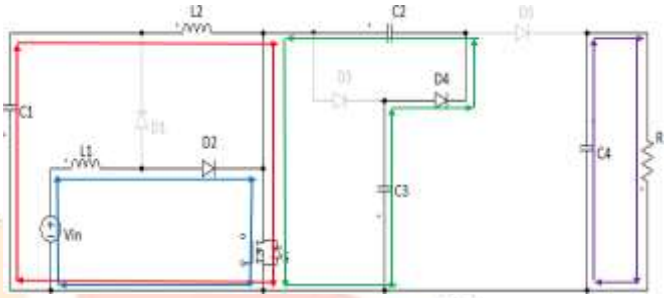

Fig. 2. Mode 1

2) Mode 2 :In mode 2, the switch S is turned off along with diodes D_2 and D_4 while diodes D_1, D_3 and D_5 are switched on.Currently, there are discharges from the inducers L_1 and L_2, as well as charges from capacitors C_1, C_3, and C_4.Therefore,the capacitor voltages V_{C1}, V_{C3}, and V_{C4} grow, but V_{C2} declines. Both I_{L1} and I_{L2} decrease linearly. Figure 3 depicts the operational circuit of mode 2.

$$V_{IN} - V_{L1} - V_{C1} = 0 \quad (4)$$

$$V_{IN} - V_{L1} - V_{L2} - V_{C3} = 0 \quad (5)$$

$$V_{IN} - V_{L1} - V_{L2} + V_{C2} - V_{C4} = 0 \quad (6)$$

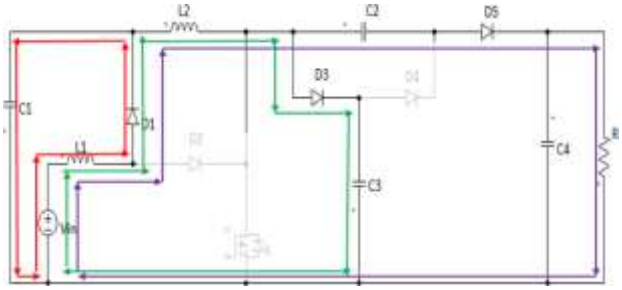

Fig. 3. Mode 2

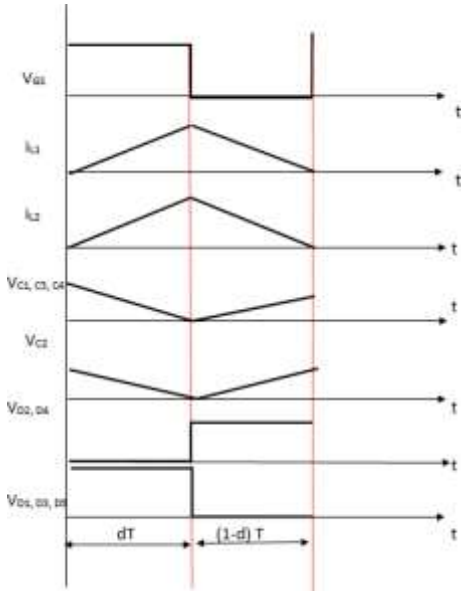

Fig. 4. Key waveform of a converter

B. Design of Components

In order to operate a converter properly, its components should be designed appropriately. It consists of design of capacitor,inductor,and resistive load.We assume that the input voltage is 40V. The output voltage is assumed to be 250V, while the output power is 200W. 50 kHz is the switching frequency.After solving equation (7) output current equals 0.8A.

$$I_O = \frac{P_O}{V_O} \tag{7}$$

The duty ratio is found using (8) and is equivalent to 0.43. In (9) the load resistor value is set to 300Ω.

$$\frac{V_0}{V_{IN}} = \frac{2}{(1-D)^2} \tag{8}$$

$$R = \frac{V_0^2}{P_0} \tag{9}$$

The value of inductors and capacitors are designed from following equations.

$$L_1 \geq \frac{D * V_{IN}}{f_s * \Delta i_L} \tag{10}$$

$$L_2 \geq \frac{D * V_{IN}}{f_s * \Delta i_L * (1-D)} \tag{11}$$

The capacitor's design primarily takes into account the maximum permissible voltage ripple across it and the voltage stress. By calculating voltage ripple as 5% of the voltage across corresponding capacitors, the capacitors C_1, C_2, C_3 and C_4 are obtained. The approximate values of capacitors for C_1, C_2,C_3 and C_4 are 47µF by changing the values in the following equations.

$$C_1 \geq \frac{D * 2 * I_O}{f_s * \Delta V_{C1} * (1-D)} \tag{12}$$

$$C_2, C_3 \geq \frac{2 * I_0 * D}{V_O D} \quad f_s * \Delta V_{C2}, \Delta V_{C3} \tag{13}$$

$$C_3 \geq \frac{V_O D}{f_s * \Delta V_{C3} * R} \tag{14}$$

$$C_4 \geq \frac{V_O D}{f_s * \Delta V_{C4} * R} \tag{15}$$

III. SIMULATIONS AND RESULTS

MATLAB/SIMULINK is used to simulate the enhanced gain quadratic boost converter by selecting the parameters given in Table 1. The MOSFET switch maintain a consistent switching frequency of 50 kHz. power switch is controlled using duty ratio of 0.43.

TABLE I
SIMULATION PARAMETERS QUADRATIC BOOST CONVERTER

Parameters	Values
Input Voltage V_{IN}	40V
Output Load R	300Ω
Switching Frequency f_s	50 kHz
Inductors L_1,L_2	500 μH, 1400 μH
Capacitors C_1,C_2,C_3,C_4,	47 μF
Duty Ratio	0.43

An output of 233V can be obtained with a dc input voltage of 40V. Figure 5 illustrates the display of the source voltage and current. The voltage and current of the converter's output can be observed in Figure 6. The gate pulse and switching voltage across switch S. are displayed in Figure 7. Switch S has a voltage stress of 188.7V. The voltage across capacitors

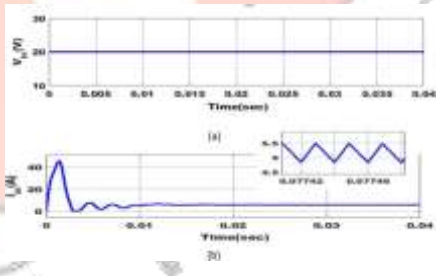

Fig. 5. (a) Input Voltage (V_{IN}) and (b) Input Current (I_{IN})

V_{C1} is 680.5V ,V_{C2} is 115.5V,V_{C3} is 117.9V and V_{C4} is obtained as 233.4V which is shown in Figure 8.

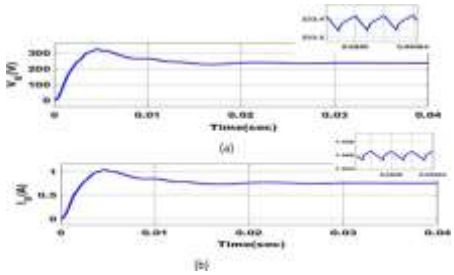

Fig. 6. (a) Output Voltage (V_O) and (b) Output Current (I_O)

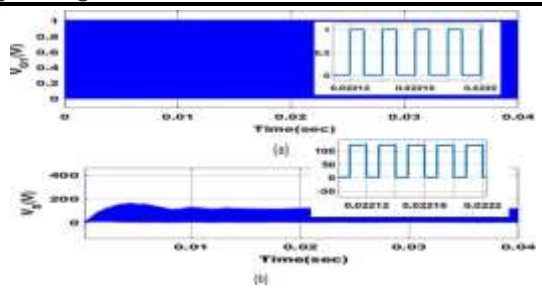

Fig. 7. (a) Gate Pulse ofS_1 , (b) V_{S1}, (c) Gate Pulse ofS_2 ,(b) V_{S2}

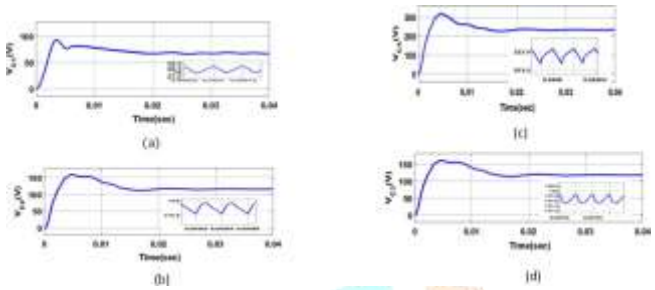

Fig. 8. Voltage across Capacitors (a)V_{C1}, (b)V_{C2}, (c)V_{C3}, (d)V_{C4}

IV. PERFORMANCE ANALYSIS

The power input to output ratio of a electrical equipment determines its efficiency at various load. The efficiency versus output power for a enhanced gain quadratic boost converter with R and RL loads is presented in Figure 9. For R and RL loads, the maximum converter efficiencies are 90.78% and 88.23% respectively.

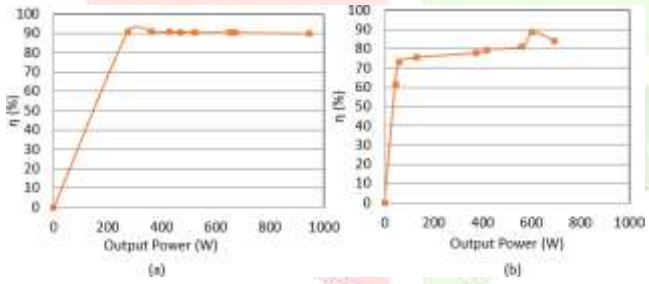

Fig. 9. Efficiency of converter Vs Output Power for (a) Resistive load, (b) Resistive-Inductive load

The graph of Voltage gain VS duty ratio is shown in figure 10. The graph of Output voltage ripple Vs duty ratio is shown in figure 11.

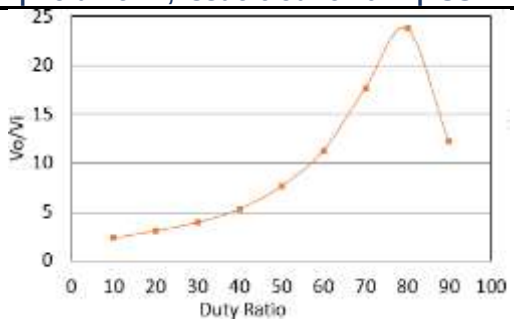

Fig. 10. Voltage Gain Vs Duty Ratio

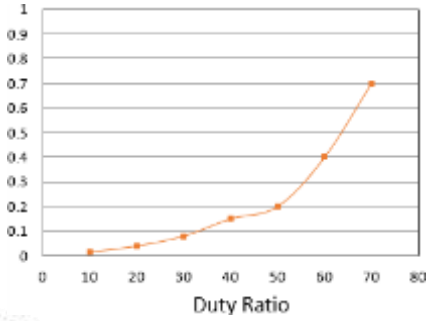

Fig. 11. Output Voltage Ripple Vs Duty Ratio

V. COMPARITIVE STUDY

The Comparison between quadratic boost converter and enhanced gain quadraticb oost converter is done by keeping the same output power P_O=200W ,input voltage V_{IN} =40V and switching frequency F_S=50kHz, and the loadas constant and is given in TableII. It is clear from the table II and III that the modified converter surpasses the standard quadratic boost converter in terms of gain.

TABLE II
COMPARISON WITH QUADRATIC BOOST CONVERTER AND ENHANCED GAIN QUADRATIC BOOST CONVERTER

Parameters	***Quadratic Boost Converter***	***Enhanced Gain QBC***
No of switches	1	1
No of diodes	3	5
No of inductors	2	2
No of capacitors	2	4
Efficiency	84%	88%
Output voltage ripple	1V	0.15V
Voltage gain	6	5.9
Output voltage	241V	233V
Output current ripple	.002A	.0005A V
Voltage gain equation	$\frac{1}{(1-D)^2}$	$\frac{2}{(1-D)^2}$
Voltage stress across switch	241V	118.7V

Due to the addition of a voltage multiplier circuit, the quadratic boost converter has more components. Thus, there was a reduction in stress across the switch. The utilization of a enhanced gain converter effectively reduces the ripple exist in both the output voltage and current. Table III presents the

results of a comparative analysis between various boost topologies and the suggested converter. After evaluating similar boost converters, it can be inferred that the suggested converter has exceptional performance in regards of voltage gain, switching voltage, and efficiency.

TABLE III
COMPARISON WITH ENHANCED GAIN QUADRATIC BOOST CONVERTER AND DIFFERENT DC-DC CONVERTER CIRCUITS

Converters	***Switched Capacitor dual switch Converter in[6]***	***Switched Capacitor based Z-Converter in[7]***	***Quadratic Boost Converter in[1]***	***Enhanced Gain QBC***
Switches	2	1	1	1
Diodes	4	4	3	5
Inductors	1	2	2	2
Capacitors	3	5	2	4
Voltage Gain	$\frac{3-2D}{1-2D}$	$\frac{2}{1-2D}$	$\frac{1}{(1-D)^2}$	$\frac{2}{(1-D)^2}$

VI. EXPERIMENT RESULTS

The source voltage is lowered to 2V, inorder to facilitate hardware implemention .While the TMS320F28335 controller is employed to generate the switching pulses. MOSFETIRF540 switches are utilized, and IN 5817 diodes are used. The TLP250H optocoupler, which is used to provide the necessary gating to turn on the switch and to isolate and shield the microcontroller from harm, is used to implement the driver circuit. The TLP250H is used in the development of an interface circuit to supply the gating voltage needed to activate the switches. Fig. displays the single switch high gain buck boost converter experimental setup. 13(a).Input: DC source provides a 1.57V DC supply. The TMS320F28027F microcontroller provides the switching pulses to the driver circuit.

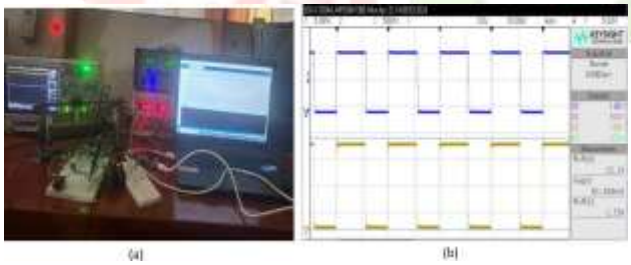

Fig. 12. (a) Experimental Setup (b) Switching Pulses

The TMS320F28027F microcontroller provides the switching pulses to the driver circuit. The TMS320F28027F controller, as shown in Figure 13(b), generates pulses that are integrated into an interface circuit, which amplifies the pulse to activate the switch. Consequently, the power circuit depicted in Figure 14 yields an output voltage of 10.8V, 50kHz. The converter's output voltage is measured using a DSO oscilloscope.

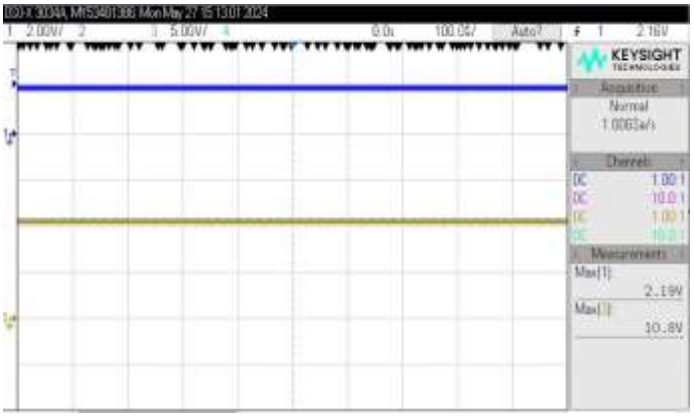

Fig. 13. Output Voltage of Converter

VII. CONCLUSION

The proposed enhanced gain quadratic boost converter with minimal voltage stress across switches.This structure is consist of an voltage multiplier cell. In comparison to current boost DC-DC converters, the suggested converter provides high Gain and reduced voltage stress across switching devices.Simulated and analyzed the suggested converter.The simulation shows that the converter achieves an efficiency of 88% with an output power of 200W.The suggested architecture has several advantages, including high voltage gain, high efficiency, decreased voltage stress across the switch, low output voltage and current ripple, and low input voltage.The suggested converter is controlled by TMS320F28027F microcontroller.The 200W converter prototype delivers predicted performance at a voltage of 10.8V, taking into account component drops. These qualities make the given architecture an ideal interface for renewable energy applications.

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