A Novel Interleaved High-Voltage Gain Boost Converter for Solar PV

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For PV systems,converter with an MPPT controller is being developed to get the photovoltaic array's maximum output. A Novel converter is developed from the existing two-phase interleaved boost converter. The PV array's current should be drawn with minimum ripple as possible.The contribution of this research is that a solar array's output voltage is less and it has to be increased to feed high-power applications or integrate with the grid. However, this must be done efficiently while drawing the maximum amount of power from the PV array. Many approaches has been developed for increasing the output voltage of a solar PV source, however these have limits due to low efficiency, more complexity, and expense. It is possible to achieve large Voltage boost ratios with maximum efficiency and economical of the overall photovoltaic system with the proposed DC-DC converter. The proposed converter is also appropriate for high or Variable power applications.

Keywords: Photovoltaic system, MPPT controller, Voltage Stress

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1. Introduction

The photovoltaic system is seen as a unique solution to the present energy shortages. Because this technology is recyclable and has a long service life, it is widely used and is largely pollution-free. The high–efficiency interface is required to deliver PV energy to the load. In this paper, we propose a two-stage switched capacitor and linked inductor high boost interleaved boost converter. The MPPT controller is also used to increase the efficiency of solar PV systems. When compared to previous ways, this method produces a high voltage gain with a low duty ratio, and the voltage across the switch is considerably reduced, reducing ripple and conduction loss. Two-stage switched capacitors increase voltage gain while also maximising the inductor's performance. The passive clamping circuit causes the primary switches to be switched off,Zero voltage and zero current switching are conceivable due to the inductor's intrinsic loss.Due to leakage inductance the current drop rate is controlled the problem of reverse recovery of the diode is addressed, and efficiency is increased.

With the current global energy constraint, many academics are focusing on renewable energy options. One of the most extensively used renewable energy technologies is the photovoltaic (PV) system. In a PV system, two significant challenges arise: PV output voltage fluctuates with respect to weather conditions and results in low conversion efficiency. A DC-DC novel step-up converter is required to compensate for the low voltage characteristic.These converters were widely used in a variety of applications, including high–intensity discharge lights in vehicle headlamps, Uninterruptible Power Systems (UPS), and the system of communication and power. The conventional converter has been used to achieve a high voltage gain, but it has the drawback of voltage stress on the switches, making it unsuitable for low voltage devices.The total efficiency degrades when the duty ratio approaches unity.and the existing converters which are not able to meet the application's requirements [1-3], [17].

Many topologies with a low duty ratio have been proposed to achieve significant step-up voltage gain [4]. The DC-DC flyback converter generates a large voltage gain with a simple construction. The voltage stress on the active switches is considerable due to the transformer's leakage inductance, and many techniques have been used to reduce voltage stresses on active switches. [5],[6] & [17].

Isolated voltage-type converters, such as a full-bridge phase-shifted converter, can already give significant step-up gain by adding transformer turns, but additional research is required. Electrolytic capacitors are required to reduce input current ripples.Other isolated type converters can attain high efficiency and good step-up conversion, such as the active clamp dual boost and full-bridge active clamp boost converters.[7],[8].

A switched-capacitor-based converter was proposed to increase conversion efficiency and obtain a significant voltage conversion ratio [9], [10]. However, This method results in a high transient current and significant conduction loss in the switch,and it also necessitates the use of more The circuit is complicated because it uses switched-capacitor cells to obtain a very high step-up conversion [11], [18].

Many soft-switching techniques based on switched-capacitor have been developed to reduce electromagnetic interference and switching loss [12], [19]. Another method for attaining large step-up gain by altering the turn ratio is the coupled-inductor technique [13]. As they resonate together, the parasitic capacitor and coupled-leakage inductor's inductance will produce a snub circuit and be utilised to absorb voltage ringing on the output diode. The two active switches, along with various protection circuits, add to the circuit's cost and complexity.

Interleaved voltage doubler circuits with automatic current sharing capability were presented for global power factor correction, and decreased active switch stress was employed to boost low-line efficiency. The diode stress, on the other hand, remains extremely high, and the voltage gain is insufficient. To obtain high step-up voltage ratios, a high step-up converter and an ultra-step-up converter have been developed, but the diode voltage stress remains high [14].

The PV power generation system's key issues are its low conversion efficiency and its changing weather conditions. PV systems should be used to their greatest potential at all times to enhance its efficiency. There are numerous MPPT algorithms. have been proposed to address this [15], [16], and [20]. In this reasearch, a novel two-phase interleaved boost converter is cascaded together, with the added benefit of automated current sharing capability. This method will give improved efficiency by reducing voltage stress on switches and diodes.

2. Proposed System

The proposed converter with an MPPT controller for large step-up conversion as shown in

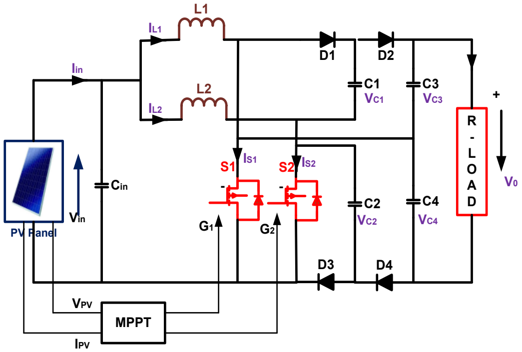


Fig 1: Proposed DC-DC Converter with High Voltage Gain

L_1, L_2	-	Magnetizing Inductances
D_1, D_2, D_3, D_4	-	Clamp diodes
C_1, C_2	-	Clamp capacitors
C_3, C_4	-	Output capacitors
S_1, S_2	-	Main Switches

Two capacitors and two diodes are added to the novel interleaved boost converter. The stored energy in the partial inductor is stored in one of the capacitors, and the stored energy of the other capacitor is transported to the output to acquire higher voltage during the energy transfer period.When compared to existing interleaved converter, the proposed converter will achieve double the voltage gain, and obtain less voltage stess on both diodes & switches. The suggested converter is equipped with an MPPT controller, which allows it to automatically track for the highest MPP and provide higher conversion ratios.The main purpose of this converter is to provide high voltage gain, and when the duty cycle is more than 0.5, a steady-state analysis is done.

(i) Mode 1

In this mode when $t_0 \leq t < t_1$, The D1, D2, D3, and D4 switches are turned off, while the S1 and S2 switches are turned on. The current flow path is depicted in Figure 2. In L1 and L2, both iL1 and iL2 are strengthened to store energy. Diodes D1 and D3 have their voltages clamped to VC1 and VC2 of the capacitor voltage, respectively, while diodes D4 and D2 have their voltages clamped to the capacitor voltage (V_{C4} –V_{C2}) and (V_{C3}-V_{C1}).

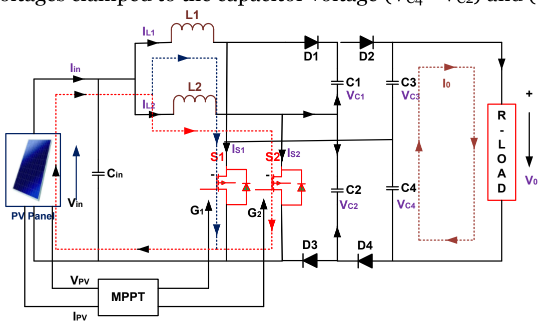


Fig 2: Operating circuit of Mode-1

C3 and C4 load power are supplied by capacitors, and the appropriate equation is shown below.

$$V_{in} = L_1 \frac{di_{L1}}{dt} = L_2 \frac{di_{L2}}{dt} \qquad (1)$$

$$C_1 \frac{dV_{c1}}{dt} = C_2 \frac{dV_{c1}}{dt} = 0 \qquad (2)$$

$$C_3 \frac{dV_{c3}}{dt} = C_4 \frac{dV_{c4}}{dt} = -(\frac{V_{c3}+V_{c4}}{R}) \qquad (3)$$

(ii) Mode 2:

In this mode when $t_1 \le t < t_2$, Switch S2 is disabled, however switches S1, D2, and D3 remain operational. In Fig 3, the capacitor C1 and the inductor L2 stored energy are released to the load and C3 of the output capacitor, respectively, while a portion of the inductor L2 stored energy is held in C2.This mode's capacitor voltage is $V_{C3}=V_{C2}+V_{C1}$, which makes iL_2 decrease linearly and iL_1 increase continuously.

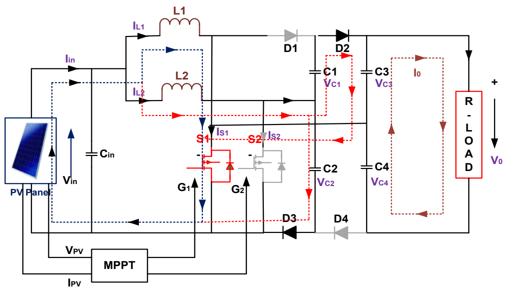


Fig 3: Operating circuit of Mode-2

The equation corresponding to this is shown below.

$$V_{in} = L_1 \frac{di_{L1}}{dt} \qquad (4)$$

$$V_{in} - V_{c2} = L_2 \frac{di_{L2}}{dt} \qquad (5)$$

$$C_1 \frac{dV_{c1}}{dt} = I_{C2} - I_{L2} \qquad (6)$$

$$C_2 \frac{dV_{C2}}{dt} = I_{C1} + I_{L2} \qquad (7)$$

$$C_3 \frac{dV_{C3}}{dt} = -I_{C1} - (\frac{V_{c3}+V_{c4}}{R}) \qquad (8)$$

$$C_4 \frac{dV_{C4}}{dt} = -(\frac{V_{c3}+V_{c4}}{R}) \qquad (9)$$

(iii) Mode 3

In this mode when $t_2 \le t < t_3$, S1 and S2 are both turned on, and the rest of the operations are the same as in mode 1.

(iv) Mode 4

When $t_3 \le t < t_4$, In this mode of operation, switch S2 continues to conduct while switch S1 is shut OFF.
The diodes D1 and D4 were also put through their paces. The energy retained in inductor L1 and C2 is released to the load and C4 output capacitor,while the output capacitor is being charged. $V_{C4}=V_{C2}+V_{C1}$. This makes i_{L1} decrease linearly and i_{L2} remains increasing continuously.

$$L_1 \frac{di_{L1}}{dt} = V_{in} - V_{C4} + V_{C2} = V_{in} - V_{C1} \quad (10)$$

$$V_{in} = L_2 \frac{di_{L2}}{dt} \quad (11)$$

$$C_1 \frac{dV_{C1}}{dt} = i_{C2} + i_{L1} \quad (12)$$

$$C_2 \frac{dV_{C2}}{dt} = i_{C1} - i_{L1} \quad (13)$$

$$C_3 \frac{dV_{C3}}{dt} = -(\frac{V_{C3} + V_{C4}}{R}) \quad (14)$$

$$C_4 \frac{dV_{C4}}{dt} = -i_{C2} - (\frac{V_{C3} + V_{C4}}{R}) \quad (15)$$

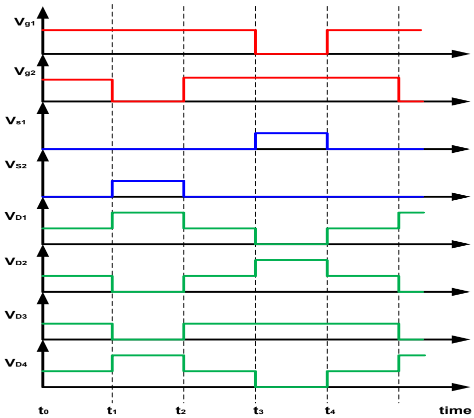


Fig 4: Operating waveforms

The proposed converter's operations are simple to implement and symmetric. Low voltage stress is achieved with the use of four diodes and two active switches, as well as continuous current sharing as seen in Figure 4 essential operating waveforms.

2.1 Voltage Stress Analysis

To make voltage stress analysis of the converter components easier, assume that the capacitor voltage ripple can be ignored. The voltage strains on the solid-state power switches S1 and S2 can be calculated directly from the operating modes. The following criteria determine the volt second relationship between inductors L1 and L2.

$$DV_{in} + (1-D)(V_{in} - V_{C1}) = 0$$

and

$$DV_{in} + (1-D)(V_{in} - V_{C2}) = 0 \quad (16)$$

The capacitor V_{C3} and V_{C4} can be obtained by using the following relationship

$$V_{C3} = V_{C1} + V_{C2} = \frac{2}{1-D} V_{in}$$

and

$$V_{C4} = V_{C1} + V_{C2} = \frac{2}{1-D} V_{in} \quad (17)$$

As a result, the converter's output voltage is.

$$V_0 = V_{C3} + V_{C4} = \frac{4}{1-D} V_{in} \quad (18)$$

Hence, the interleaved boost dc-dc converter's voltage conversion ratio is

$$M = \frac{V_0}{V_{in}} = \frac{4}{1-D} \quad (19)$$

Hence, The voltage stress on the solid-state power switches S1 and S2 are caused by the operating modes.

$$V_{S1} = V_{S2} = \frac{1}{1-D} V_{in} \quad (20)$$

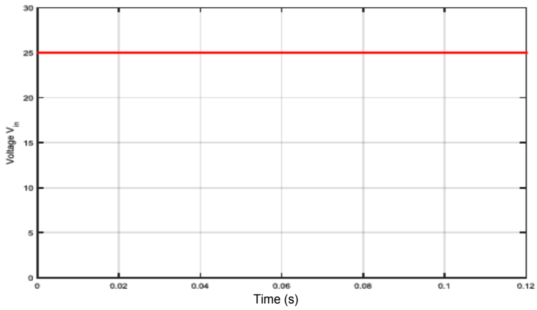
By substituting Voltage stresses on active solid-state power switches are calculated using the output voltage equation under the above circumstance. As a result, the voltage stress on power switches is increased.

$$V_{S1} = V_{S2} = \frac{V_0}{4} \quad (21)$$

According to the above equation,the voltage stress of the proposed converter's power switches is equal to one-fourth of the output voltage. As a result, the proposed converter will be used for devices having lower voltage ratings and it further reduce switching and conduction losses.

3. Simulation Results

The proposed converter will use 25V input and a 400V output with a power rating of 400W. when the Switching frequency 40HZ Both switches S1 and S2 are having an equal duty ratio of 0.75.The construction of this novel interleaved converter will reduce input & output ripples, and inductor size by increasing the switching



frequency.

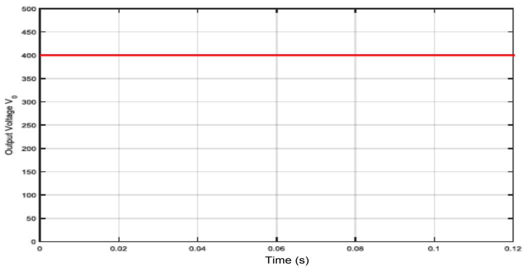


Fig 5 Input and Output Voltage

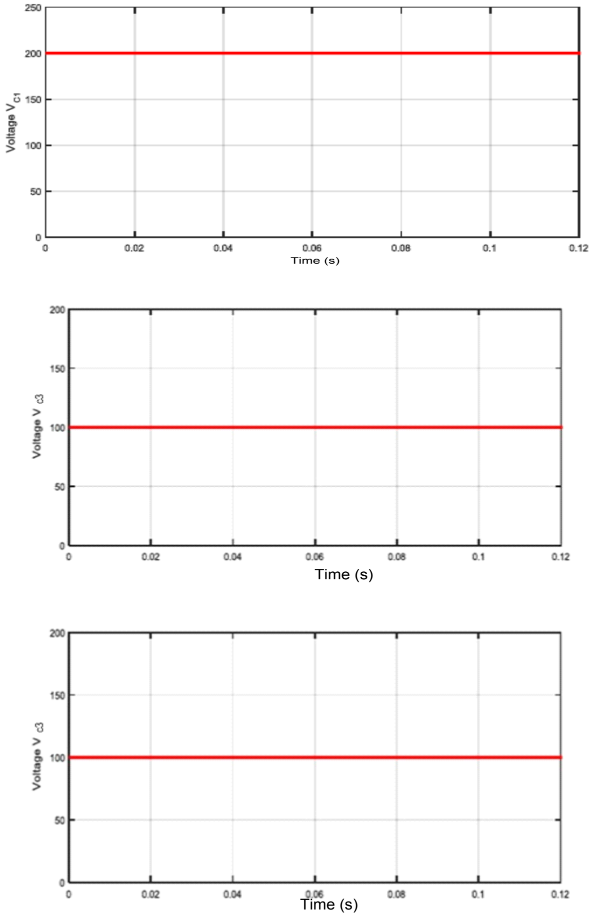
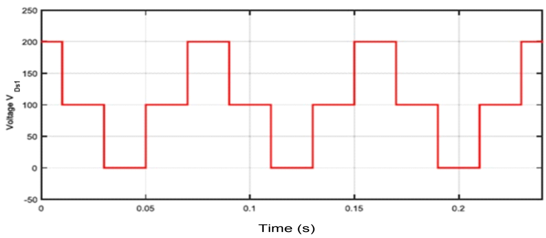


Fig 6 Results obtained for blocking capacitor & Output capacitor



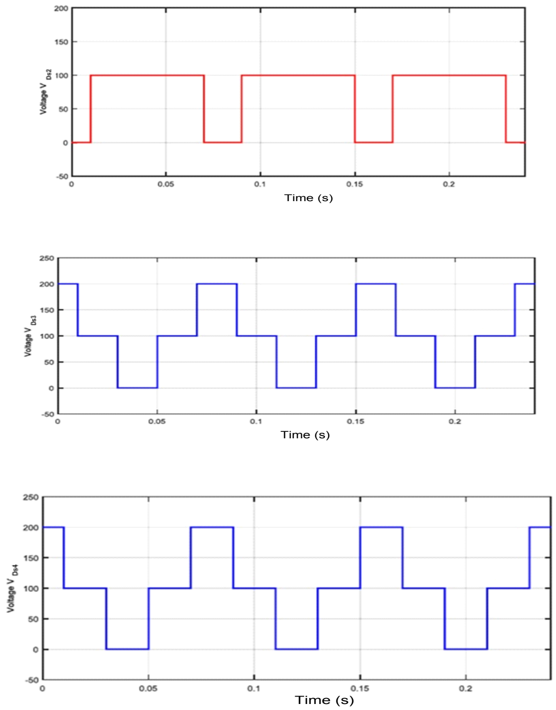


Fig 7 Voltage stress on VDS1, VDS2, VDS3, VDS4.

Figure 5 shown input and output voltages of our suggested approach. The waveforms of the blocking and output capacitors are shown in Figure 6. The voltage stress on the active switch is 1/4 of the output voltage , as shown in Figure 7.The distribution of power losses is investigated, and it is found that substantial losses occur in switches, diodes, and inductors. We presented a converter in this research to reduce Voltage stress on switches and diodes, resulting in lower losses.

4. Performance Analysis

The performance of proposed converter is compared with the existing converters which is discussed in the literature.Table 1 shows a comparison of voltage gain and normalised voltage stress in active switches.

Table 1 Comparison of the proposed converter's voltage gain and voltage stress to that of other converters

	Voltage gain			**Voltage stress**		
Duty Ratio	0.5	0.6	0.7	0.5	0.6	0.7
Voltage Doubler	4	5	6	0.5	0.5	0.5
High Step-Up Ratio Converter	5	6.1	7	0.4	0.43	0.45
Proposed Converter	8	10	14	0.25	0.25	0.25

The proposed converter characteristic curve, as well as a comparison of voltage gains normalised voltage stress, of existing converters are also shown in Figure 8 and Figure 9.

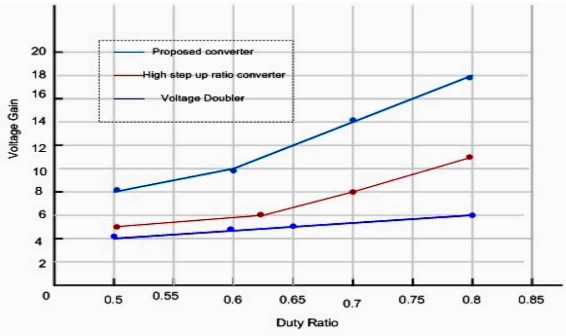


Fig 8. Duty ratio vs Voltage gain

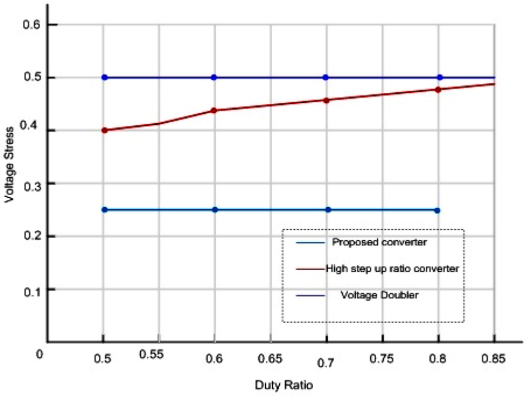


Fig 9. Active Switches Normalized Voltage Stress

The proposed boost converter may produce higher voltage gain than other existing boost converters Figure 8,and lower voltage stress for active switches Figure 9.This proposed converter is more suitable for applications that require more voltage gain and can achieve higher efficiency by using switching components with lower voltage ratings.

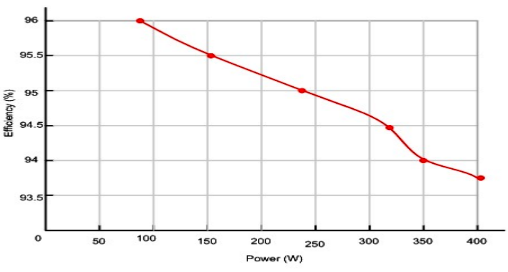


Fig 10 Proposed Converter Efficiency

This recommended converter, when combined with the MPPT controller, may attain a maximum efficiency of 96 percent, as shown in Figure 10. The proposed converter with MPPT controller may obtain 2.4 times more PV power than a converter that does not employ the MPPT algorithm. Our proposed converter with an MPPT controller is functional and capable of extracting the maximum quantity of electricity from the PV system, according to the results.

5. Conclusion

This research looked at a converter for PV systems that used an MPPT controller. The MPPT algorithm was created to get the most power out of the PV array. The recommended converter is based on an existing two-phase interleaved boost converter.. Not only does it produce significant voltage gain, but it also does it with a lower duty cycle. This paves the way for MOSFETs having low voltages and diodes to reduce both conduction and switching losses. Without adding any additional circuitry, the converter also has consistent automatic current sharing capabilities. The proposed converter with the MPPT controller has a greater conversion efficiency when compared to a traditional converter, and it is also validated using a 25V input and 400V output rating. The results show that this approach is particularly useful for situations requiring a large step-up voltage gain.

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