

# An Implementation of High Step-Up Conversion through Interleaved Boost Converter with Voltage Multiplier for Renewable Energy System

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**ABSTRACT:** A new high step-up converter, which is proper for renewable energy system, is deliberate in this paper. During a voltage multiplier section composed of switched capacitors and coupled inductors, a conventional interleaved boost converter obtains high step-up increase without operating at tremendous duty ratio. The configuration of the anticipated converter not only reduces the current pressure but also constrains the input current undulation, which decreases the conduction wounded and lengthens the lifetime of the input source. In addition, due to the lossless passive clamp routine, leakage energy is used to the output mortal. Hence, large voltage spikes diagonally the main switches are alleviated, and the efficiency is enhanced. Even the low voltage pressure makes the low-voltage-rated MOSFETs be adopted for reductions of transfer losses and cost. Finally, the sample circuit with 40-V input electrical energy, 380-V output, and 1000-W output power is operated to verify its routine. The maximum efficiency is 97.1%.

**KEYWORDS:** Boost-flyback converter, high step-up, photo-voltaic (PV) system, voltage multiplier module.

## I. INTRODUCTION

NOWADAYS, renewable energy is gradually more valued and employed international because of energy deficiency and environmental contamination. Renewable energy systems produce low voltage output, and thus, high step-up dc/dc converters have been commonly in employment in many renewable energy applications such fuel cells, wind power generation, and photovoltaic (PV) systems. Such systems convert energy from renewable sources into electrical energy and convert low voltage into high voltage via a step-up converter, which can convert energy into energy using a grid-by-grid inverter or dc microgram. A typical renewable energy system that consists of renewable energy sources, a step-up converter, and an inverter for ac application. The high step-up exchange may require two-stage converters with cascade arrangement for enough step-up gain, which decreases the usefulness and increases the cost. Thus, a high step-up converter is seen as an important stage in the system because such a arrangement requires a sufficiently high step-up conversion with high efficiency. Theoretically, conventional step-up converters, such as the progress converter and flyback converter, cannot complete a high step-up exchange with high effectiveness since of the resistances of fundamentals or leakage inductance; also, the energy stresses are huge. Thus, in recent years, several novel high step-up converters have been developed. Despite these advances, high step-up single-switch converters are unsuitable to operate at weighty load given a large input current ripple, which increases transference losses

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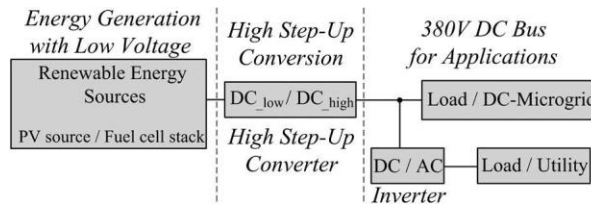


Fig. 1. Typical renewable energy system.

The conformist interleaved boost converter is an admirable aspirant for high power applications and power factor adaptation. regrettably, the step-up gain is boundless, and the voltage stresses on semiconductor components are toward output voltage.

Hence, based on the abovementioned considerations, modifying a conventional interleaved boost converter for high step-up and high-power application is a fitting come close to. To integrate switched capacitors into an interleaved improve converter may make voltage gain reduplicate, but no service of coupled inductors causes the step-up voltage expand to be limited. Oppositely, to incorporate only attached inductors into an interleaved boost converter may make voltage gain higher and adjustable, but no employ of switched capacitors causes the step-up voltage gain to be common.

Thus, the synchronous employment of united inductors and switched capacitors is a better concept; besides, high step-up gain, high efficiency, and low voltage stress are achieved even for high-power applications. The projected converter is a conventional interleaved boost converter incorporated with a voltage multiplier element, and the voltage multiplier module is composed of switched capacitors and coupled inductors. The together inductors can be considered to extend step-up gain, and the switched capacitors suggest extra voltage adaptation ratio. In addition, when one of the switches turns off, the energy stored in the magnetizing inductor will relocate via three personal paths; thus, the current division not only decreases the conduction losses by lower valuable current but also makes currents all the way through some diodes decrease to zero after they turn off, which improve diode reverse recovery losses.

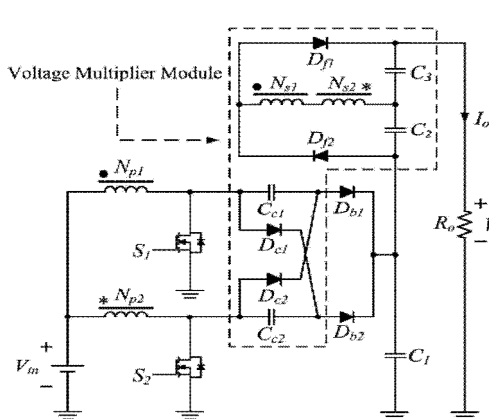


Fig. 2. Proposed high step-up converter.

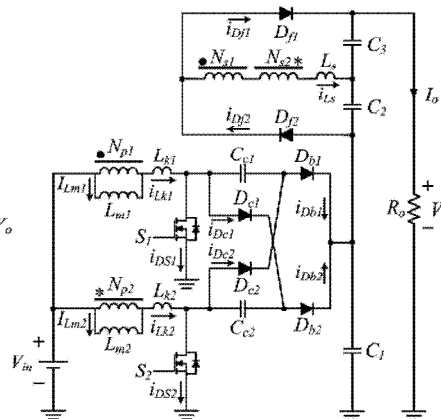


Fig. 3. Equivalent circuit of the proposed converter.

The advantages of the anticipated converter are as follows.

- 1) The anticipated converter is characterized by low input current undulate and low conduction losses, which increases the duration of renewable energy sources and makes it appropriate for high-power applications.
- 2) The converter achieves the high step-up achieve that renewable energy systems entail.
- 3) Due to the lossless passive clamp concert, leakage power is cast-off to the output terminal. Hence, large voltage spikes crossways the major switches are alleviated, and the competence is enhanced.
- 4) Low outlay and high competence are achieved by service of the low-voltage-rated influence switch with low  $R_{DS(ON)}$ ; also, the voltage stresses scheduled main switches and diodes are significantly lesser than output voltage.
- 5) The innate arrangement of the anticipated converter makes some diodes reduce conduction losses and lessen diode reverse recuperation losses.

## II. OPERATING PRINCIPLES

The anticipated high step-up interleaved converter with a voltage multiplier component is shown in Fig. 2. The voltage multiplier component is poised of two coupled inductors and two switched capacitors and is inserted among a predictable interleaved boost converter to form a adapted boost flyback ahead interleaved structure. When the switches twirl off by twirl, the segment whose switch is in OFF state performs as a flyback converter, and the further segment whose switch is in ON state performs as a ahead converter. Primary windings of the coupled inductors with  $N_p$  turns are engaged to diminish input current undulate and secondary windings of the coupled inductors with  $N_s$  turns are coupled in series to enlarge voltage gain. The twirl ratios of the coupled inductors are the identical. The coupling references of the inductors are denoted by “.” and “□”.The comparable circuit of the anticipated converter is shown in Fig. 3, where  $L_{m1}$  and  $L_{m2}$  are the magnetizing inductors;  $L_{k1}$  and  $L_{k2}$  symbolize the leakage inductors;  $L_s$  represents the series escape inductors in the secondary side;  $S_1$  and  $S_2$  denote the power switches;  $C_{c1}$  and  $C_{c2}$  are the switched capacitors; and  $C_1$ ,  $C_2$ , and  $C_3$  are the output capacitors.  $D_{c1}$  and  $D_{c2}$  are the clamp diodes,  $D_{b1}$  and  $D_{b2}$  symbolize the output diodes for boost operation with switched capacitors,  $D_{f1}$  and  $D_{f2}$  symbolize the output diodes for flyback–forward procedure, and  $n$  is defined as turn ratio  $N_s/N_p$ .

In the circuit analysis, the future converter operates in continuous conduction mode (CCM), and the duty cycles of the power switches during steady operation are superior than 0.5 and are interleaved with a  $180^\circ$  phase shift. The key steady waveform in one switching period of the anticipated converter contains six. modes, which are depicted in Fig. 4, and Fig. 5 shows the topological stages of the circuit

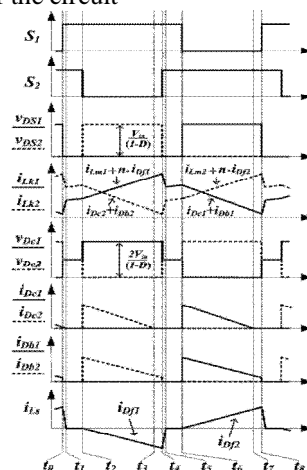


Fig. 4. Steady waveform of the proposed converter in CCM.

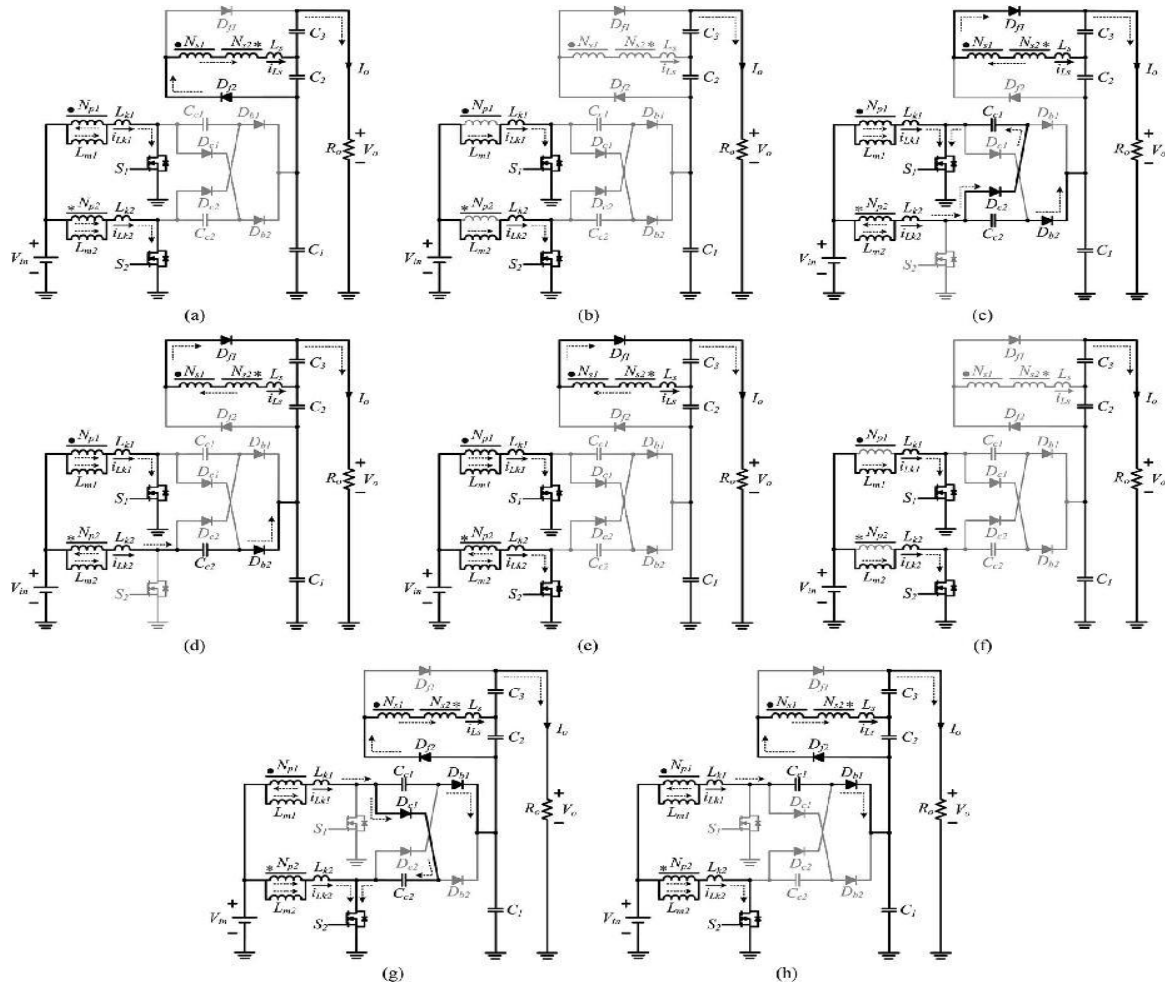


Fig. 5. Operating modes of the proposed converter. (a) Mode I [ $t_0, t_1$ ]. (b) Mode II [ $t_1, t_2$ ]. (c) Mode III [ $t_2, t_3$ ]. (d) Mode IV [ $t_3, t_4$ ]. (e) Mode V [ $t_4, t_5$ ]. (f) Mode VI [ $t_5, t_6$ ]. (g) Mode VII [ $t_6, t_7$ ]. (h) Mode VIII [ $t_7, t_8$ ].

**Mode I [ $t_0, t_1$ ]:** At  $t = t_0$ , the power switch  $S_2$  remains in ON state, and the other power switch  $S_1$  begins to turn on. The diodes  $D_{c1}$ ,  $D_{c2}$ ,  $D_{b1}$ ,  $D_{b2}$ , and  $D_{f1}$  are reverse biased, as shown in Fig. 5(a). The series outflow inductors  $L_s$  quickly discharge the stored energy to the output terminal via flyback–forward diode  $D_{f2}$ , and the current through series leakage inductors  $L_s$  decreases to zero. Thus, the magnetizing inductor  $L_{m1}$  still transfers energy to the secondary side of coupled inductors. The current through discharge inductor  $L_{k1}$  increases linearly, and the other current through outflow inductor  $L_{k2}$  decreases linearly.

**Mode II [ $t_1, t_2$ ]:** At  $t = t_1$ , both of the power switches  $S_1$  and  $S_2$  remain in ON state, and all diodes are reverse biased, as shown in Fig. 5(b). Both currents through outflow inductors  $L_{k1}$  and  $L_{k2}$  are amplified linearly due to charging by input voltage source  $V_{in}$ .

**Mode III [ $t_2, t_3$ ]:** At  $t = t_2$ , the power switch  $S_1$  remains in ON state, and the other power switch  $S_2$  begins to

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turn off. The diodes  $D_{c1}$ ,  $D_{b1}$ , and  $D_{f2}$  are overturned biased, as shown in Fig. 5(c). The energy stored in magnetizing inductor  $L_{m2}$  transfers to the resultant side of together inductors, and the current during series outflow inductors  $L_s$  flows to output capacitor  $C_3$  via flyback–forward diode  $D_{f1}$ . The voltage stress on power switch  $S_2$  is clamped by clamp capacitor  $C_{c1}$  which social group the output voltage of the boost converter. The input voltage source, magnetizing inductor  $L_{m2}$ , leakage inductor  $L_{k2}$ , and clamp capacitor  $C_{c2}$  release energy to the output terminal; thus,  $VC_1$  obtains a twice over output voltage of the boost converter.

*Mode IV* [ $t_3$ ,  $t_4$ ]: At  $t = t_3$ , the current  $i_{Dc2}$  has in nature decreased to zero due to the magnetizing current division and hence, diode annul recovery losses are alleviated and conduction losses are decreased. Both power switches and all diodes remain in before states except the secure diode  $D_{c2}$ , as shown in Fig. 5(d).

*Mode V* [ $t_4$ ,  $t_5$ ]: At  $t = t_4$ , the power switch  $S_1$  remainder in ON state, and the other power exchange  $S_2$  begins to turn on. The diodes  $D_{c1}$ ,  $D_{c2}$ ,  $D_{b1}$ ,  $D_{b2}$ , and  $D_{f2}$  are reversed biased, as shown in Fig. 5(e). The series leakage inductors  $L_s$  quickly release the stored energy to the output incurable via flyback– forward diode  $D_{f1}$ , and the current during series leakage inductors decreases to zero. Thus, the magnetizing inductor  $L_{m2}$  still transfers energy to the secondary side of attached inductors. The current during leakage inductor  $L_{k2}$  increases linearly, and the other current during leakage inductor  $L_{k1}$  decreases linearly.

*Mode VI* [ $t_5$ ,  $t_6$ ]: At  $t = t_5$ , both of the power switches  $S_1$  and  $S_2$  linger in ON state, and all diodes are reversed biased, as shown in Fig. 5(f). Both currents during leakage inductors  $L_{k1}$  and  $L_{k2}$  are increased linearly due to charging by input voltage source  $V_{in}$ .

*Mode VII* [ $t_6$ ,  $t_7$ ]: At  $t = t_6$ , the power switch  $S_2$  remains in ON state, and the other power switch  $S_1$  begins to turn off. The diodes  $D_{c2}$ ,  $D_{b2}$ , and  $D_{f1}$  are reversed biased, as shown in Fig. 5(g). The energy stored in magnetizing inductor  $L_{m1}$  trans-fers to the secondary side of coupled inductors, and the current through series leakage inductors flows to output capacitor  $C_2$  via flyback–forward diode  $D_{f2}$ . The voltage stress on power switch  $S_1$  is clamped by clamp capacitor  $C_{c2}$  which generation the output voltage of the boost converter. The input voltage foundation, magnetizing inductor  $L_{m1}$ , leakage inductor  $L_{k1}$ , and clamp capacitor  $C_{c1}$  discharge energy to the output terminal; thus,  $VC_1$  obtains twice output voltage of the boost converter.

*Mode VIII* [ $t_7$ ,  $t_8$ ]: At  $t = t_7$ , the current  $i_{Dc1}$  has obviously decreased to zero due to the magnetizing current distribution, and therefore, diode reverse recovery losses are alleviated and conduction sufferers are decreased. Both power switches and all diodes remain in previous states apart from the clamp diode  $D_{c1}$ , as shown in Fig. 5(h).

### III. BOOST CONVERTER

A **boost converter (step-up converter)** is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Figure 1. If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much. The two configurations of a boost converter, depending on the state of the switch  $S$ .



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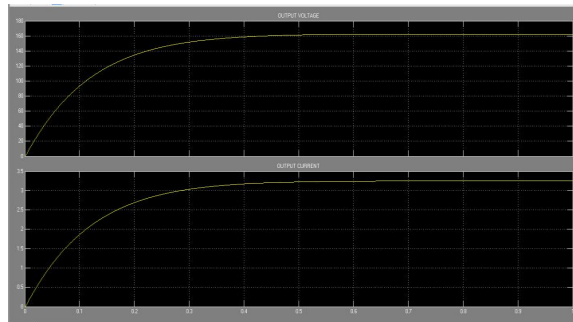
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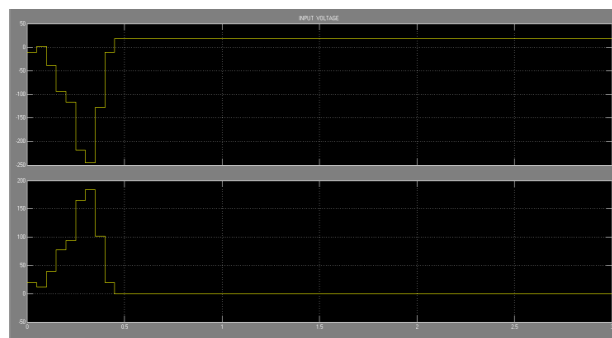
The basic principle of a Boost converter consists of 2 distinct states (see figure 2):

- in the On-state, the switch S (see figure 1) is closed, resulting in an increase in the inductor current;
- in the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R. This results in transferring the energy accumulated during the On-state into the capacitor.
- The input current is the same as the inductor current as can be seen in figure 2. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

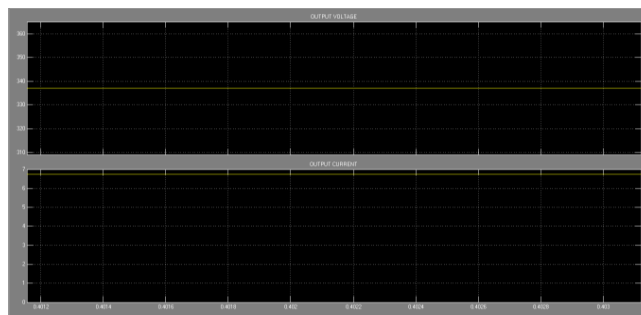
**OPEN LOOP OUTPUT SCOPE**



**CLOSED LOOP INPUT SCOPE**



**CLOSED LOOP OUTPUT**



(a) When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some

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energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

(b) When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current flow towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

### Continuous mode

When a boost converter operates in continuous mode, the current through the inductor never falls to zero. It shows the typical waveforms of currents and voltages in a converter operating in this mode. The output voltage can be calculated as follows, in the case of an ideal converter (i.e. using components with an ideal behaviour) operating in steady conditions

During the On-state, the switch S is closed, which makes the input voltage appear across the inductor, which causes a change in current flowing through the inductor during a time period (t) by the formula:

### Discontinuous mode

If the ripple amplitude of the current is too high, the inductor may be completely discharged before the end of a whole commutation cycle. This commonly occurs under light loads. In this case, the current through the inductor falls to zero during part of the period (see waveforms in figure 4). Although slight, the difference has a strong effect on the output voltage equation. It can be calculated as follows:

## IV. CONCLUSION

This paper has presented the imaginary analysis of steady state, related consideration, recreation results, and experimental results for the projected converter. The proposed converter has successfully implemented an efficient high step-up conversion during the voltage multiplier module. The interleaved formation reduces the input current ripple and distributes the current through each element. In addition, the lossless passive clamp function recycles the leakage energy and constrains a large voltage spike across the power switch. Meanwhile, the voltage stress on the power switch is constrained and much lesser than the output voltage (380 V).

Furthermore, the full-load competence is 96.4% at  $P_o = 1000W$ , and the highest competence is 97.1% at  $P_o = 400 W$ . Thus, the anticipated converter is apposite for high-power or renewable energy applications that require high step-up conversion.

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