International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 18
December 2016

# Step-Up High Performance High Interlace Converter with Renewable Energy System Voltage Multiplier

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## ABSTRACT

The main aim of this project is analysis and design of interleaved converter for grid connected solar applications. The system proposes a voltage multiplier module composed of switched capacitors and coupled inductors, A conventional interleaved boost converter obtains high step-up gain without operating at extreme duty ratio. The configuration of the proposed converter not only reduces the current stress but also constrains the input current ripple, which decreases the conduction losses and lengthens the lifetime of the input source. In addition, due to the lossless passive clamp performance, leakage energy is recycled to the output terminal. Hence, large voltage spikes across the main switches are alleviated , and the efficiency is improved.

**KEY WORDS: High step up, photovoltaic system, Voltage multiplier module, grid, interleaved converter**

## I.INTRODUCTION:

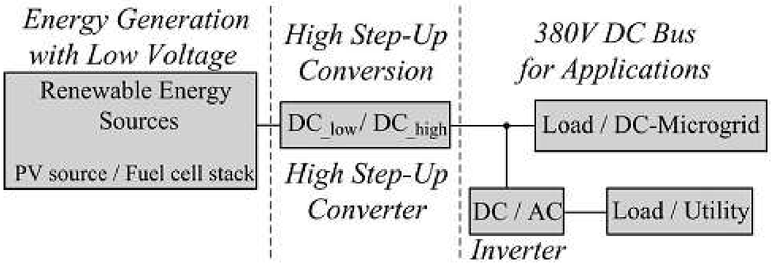


**Fig. 1. Typical renewable energy system.**

The high step-up conversion may require two-stage converters with cascade structure for enough step-up gain, which decreases the efficiency and increases the cost. Thus, a high step-up converter is seen as an important stage in the system because such a system requires a sufficiently high step-up conversion with high efficiency. Theoretically, conventional step-up converters, such as the boost converter and flyback converter, cannot achieve a high step-up conversion with high efficiency because of the resistances of elements or leakage inductance; also, the voltage stresses are large. Thus, in recent years, many novel high stepup converters have been developed . Despite these advances, high step-up single-switch converters are unsuitable to operate at heavy load given a large input current ripple, which increases conduction losses. The conventional interleaved boost converter is an excellent candidate for high-power applications and power factor correction. Unfortunately, the step-up gain is limited, and the voltage stresses on semiconductor components are equal to output voltage. Hence, based on the aforementioned considerations, modifying a conventional interleaved boost converter for high step-up and high-power application is a suitable approach. To integrate switched capacitors into an interleaved boost converter may make voltage gain reduplicate, but no employment of coupled inductors causes the step-up voltage gain to be limited . Oppositely, to integrate only coupled inductors into an interleaved boost converter may make voltage gain higher and adjustable, but no employment of switched capacitors causes the step-up voltage gain to be ordinary .

The proposed converter is a conventional interleaved boost converter integrated with a voltage multiplier module, and the voltage multiplier module is composed of switched capacitors and coupled inductors. The coupled inductors can be designed to extend step-up gain, and the switched capacitors offer extra voltage conversion ratio. In addition, when one of the switches turns off, the energy stored in the magnetizing inductor will transfer via three respective paths; thus, the current distribution not only decreases the conduction losses by lower effective current but also makes currents through some diodes decrease to zero before they turn off, which alleviate diode reverse recovery losses.

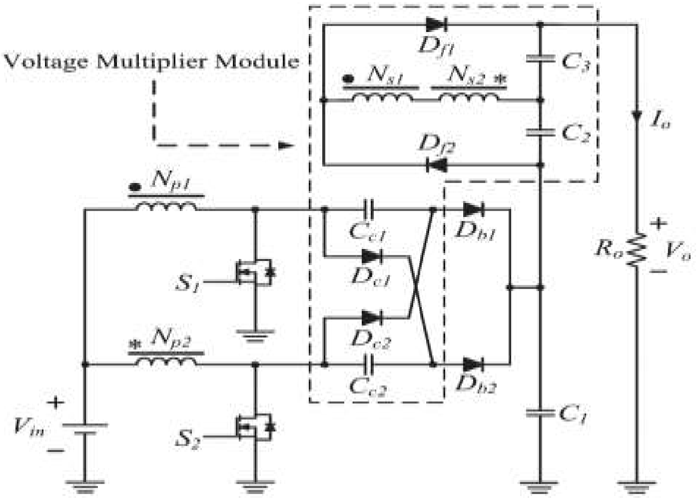


**Fig.2. Proposed high step-up converter.**

The advantages of the proposed converter are as follows.

1) The proposed converter is characterized by low input current ripple and low conduction losses,
2) The converter achieves the high step-up gain that renewable energy systems require.
3) Due to the lossless passive clamp performance, leakage energy is recycled to the output terminal.

4) Low cost and high efficiency are achieved by employment of the low-voltage-rated power switch with low RDS(ON); also, the voltage stresses on main switches and diodes are substantially lower than output voltage.

The inherent configuration of the proposed converter makes some diodes decrease conduction losses and alleviate diode reverse recovery losses.

## II. OPERATION OF PROPOSED SYSTEM

The proposed high step-up interleaved converter with a voltage multiplier module is shown in Fig.2. The voltage multiplier module is composed of two coupled inductors and two switched capacitors and is inserted between a conventional interleaved boost converter to form a modified boost–fly back–forward interleaved structure. When the switches turn off by turn, the phase whose switch is in OFF state performs as a fly back converter, and the other phase whose switch is in ON state performs as a forward converter. Primary windings of the coupled inductors with Np turns are employed to decrease input current ripple, and secondary windings of the coupled inductors with Ns turns are connected in series to extend voltage gain. The turn ratios of the coupled inductors are the same. The coupling references of the inductors are denoted by “·” and “∗”.

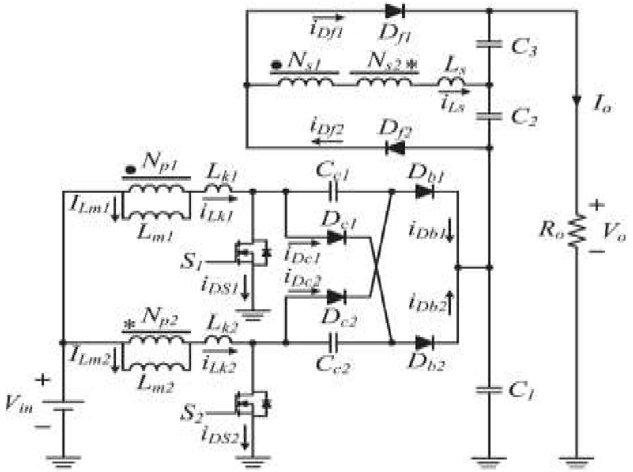


**Fig. 3. Equivalent circuit of the proposed converter**

The equivalent circuit of the proposed converter is shown in Fig.3, where Lm1andLm2are the magnetizing inductors; Lk1andLk2represent the leakage inductors; Ls represents the series leakage inductors in the secondary side;S1andS2denote the power switches; Cc1andCc2are the switched capacitors; andC1, C2, and C3 are the output capacitors.Dc1 andDc2 are the clamp diodes,Db1andDb2represent the output diodes for boost operation with switched capacitors, Df1 andDf2 represent the output diodes for fly back–forward operation, and n is defined as turn ratio Ns/Np. In the circuit analysis, the proposed converter operates in continuous conduction mode (CCM), and the duty cycles of the power switches during steady operation are greater than 0.5 and are interleaved with a $180^{\circ}$ phase shift.

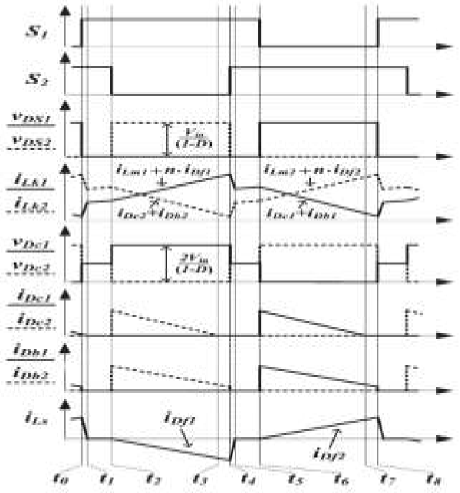
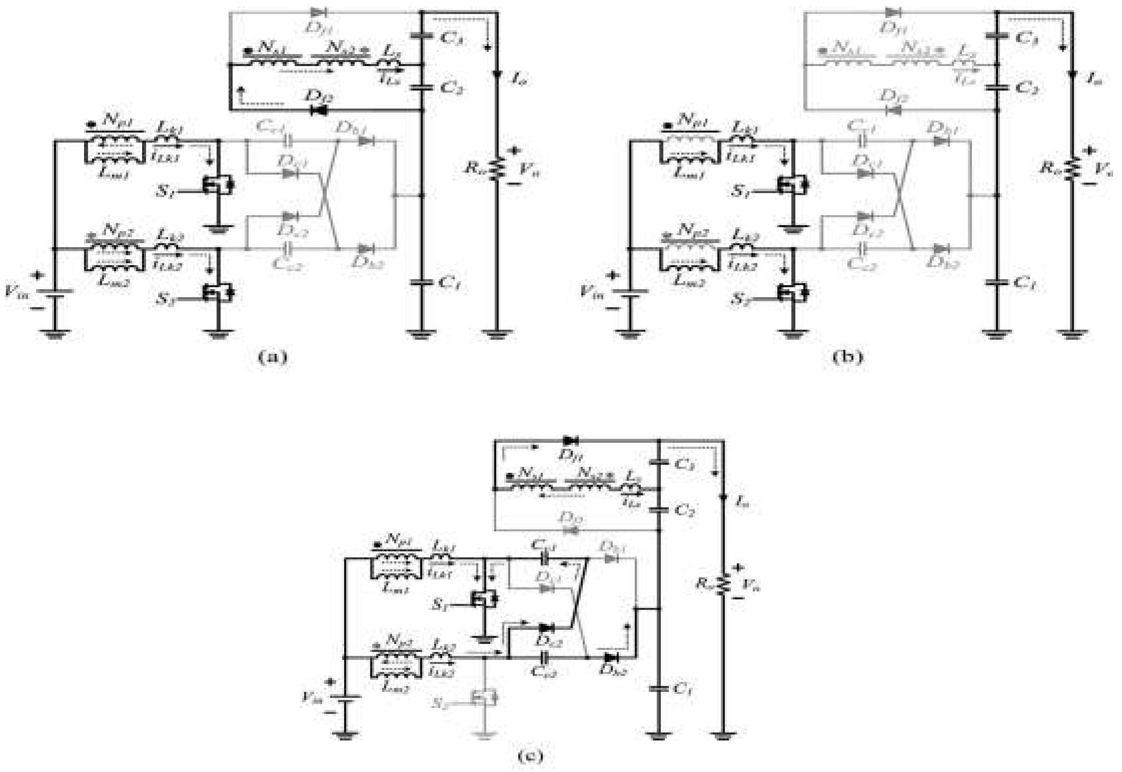


**Fig.4. Steady waveform of the proposed converter in CCM.**

The key steady waveform in one switching period of the proposed converter contains six modes, which are depicted in Fig.4, and Fig.5 shows the topological stages of the circuit.



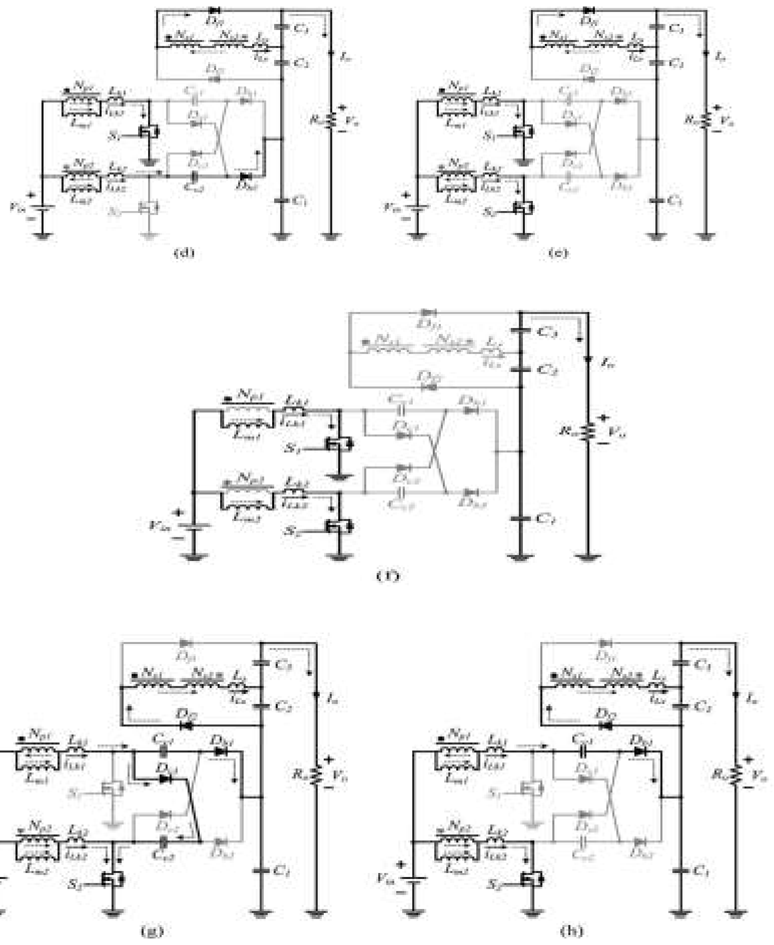

(d) (e) (f) (g) (h)

Fig 5. Operating modes of the proposed converter. (a) Mode I[to,t1]. (b) Mode II [t1,t2]. (c) Mode III [t2,t3]. (d) Mode IV [t3,t4]. (e) Mode V [t4,t5]. (f) Mode VI[t5,t6]. (g) Mode VII [t6,t7]. (h) Mode VIII[t7,t8]

**Mode I[t0,t1]:** At t=t0, the power switch S2remains in ON state, and the other power switchS1begins to turn on. The diodesDc1, Dc2, Db1, Db2, and Df1 are reversed biased, as shown in Fig.5(a). The series leakage inductors Ls quickly release the stored energy to the output terminal via fly back– forward diode Df2, and the current through series leakage inductors Ls decreases to zero. Thus, the magnetizing inductor Lm1 still transfers energy to the secondary side of coupled inductors. The current through leakage inductor Lk1increases linearly, and the other current through leakage inductor Lk2 decreases linearly.

**Mode II[t1,t2]:** At t=t1, both of the power switches S1 andS2remain in ON state, and all diodes are reversed biased, as shown in Fig.5(b). Both currents through leakage inductors Lk1 andLk2 are increased linearly due to charging by input voltage source Vin.

**Mode III[t2,t3]:** At t=t2, the power switch S1 remains in ON state, and the other power switchS2begins to turn off. The diodes Dc1, Db1, and Df2 are reversed biased, as shown in Fig.5(c). The energy stored in magnetizing inductor Lm2 transfers to the secondary side of coupled inductors, and the current through series leakage inductors Ls flows to output capacitorC3via fly back–forward diodeDf1. The voltage stress on power switchS2is clamped by clamp capacitor Cc1which equals the output voltage of the boost converter. The input voltage source, magnetizing inductorLm2, leakage inductor Lk2, and clamp capacitorCc2release energy to the output terminal; thus,VC1 obtains a double output voltage of the boost converter.

**Mode IV[t3,t4]:** At t=t3, the current iDc2 has naturally decreased to zero due to the magnetizing current distribution, and hence, diode reverse recovery losses are alleviated and conduction losses are decreased. Both power switches and all diodes remain in previous states except the clamp diodeDc2, as shown in Fig.5(d).

**Mode V[t4,t5]:** At t=t4, the power switch S1 remains in ON state, and the other power switch S2 begins to turn on. The diodesDc1, Dc2, Db1, Db2, and Df2 are reversed biased, as shown in Fig. 5(e). The series leakage inductors Ls quickly release the stored energy to the output terminal via fly back–forward diodeDf1, and the current through series leakage inductors decreases to zero. Thus, the magnetizing inductor Lm2 still transfers energy to the secondary side of coupled inductors. The current through leakage inductorLk2 increases linearly, and the other current through leakage inductorLk1decreases linearly.

**Mode VI[t5,t6]:** At t=t5, both of the power switches S1 andS2remain in ON state, and all diodes are reversed biased, as shown in Fig.5(f). Both currents through leakage inductors Lk1 andLk2 are increased linearly due to charging by input voltage source Vin.

**Mode VII[t6,t7]:** At t=t6, the power switch S2 remains in ON state, and the other power switchS1begins to turn off. The diodesDc2,Db2, andDf1are reversed biased, as shown in Fig. 5(g). The energy stored in magnetizing inductorLm1transfers to the secondary side of coupled inductors, and the current through series leakage inductors flows to output capacitor C2 via fly back–forward diodeDf2. The voltage stress on power switchS1is clamped by clamp capacitorCc2which equals the output voltage of the boost converter. The input voltage source, magnetizing inductorLm1, leakage inductor Lk1, and clamp capacitorCc1release energy to the output terminal; thus,VC1 obtains double output voltage of the boost converter.

**Mode VIII[t7,t8]:** At t=t7, the current iDc1has naturally decreased to zero due to the magnetizing current distribution, and hence, diode reverse recovery losses are alleviated and conduction losses are decreased. Both power switches and all diodes remain in previous states except the clamp diodeDc1, as shown in Fig.5(h).

## III. SIMULATION RESULTS

Here the simulation carried by two different cases they are

1) high step-up interleaved converter with a voltage multiplier module

2) PV as input source of proposed converter with inverter module

Case-1 High step-up interleaved converter with a voltage multiplier module

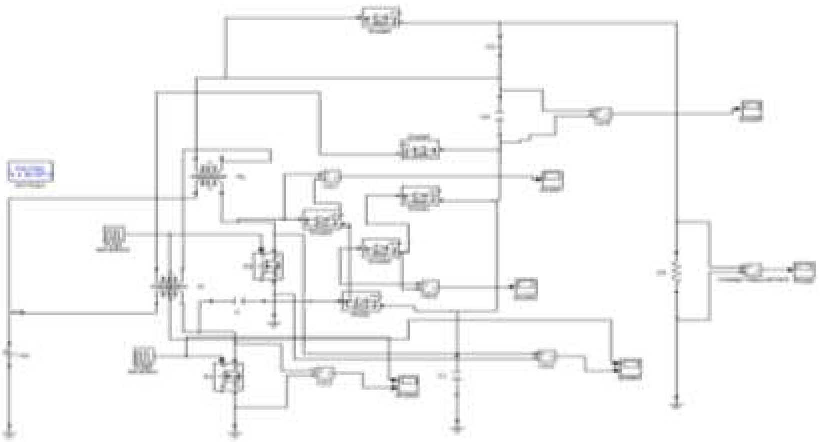


Fig.6. Simulink model of conventional high step-up interleaved converter with a voltage multiplier module

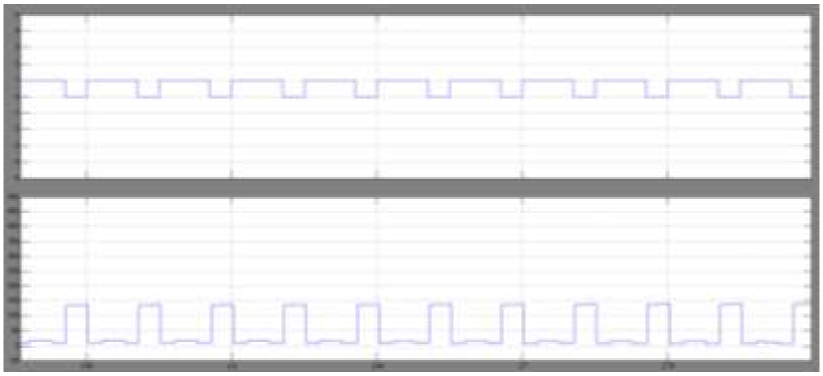


Fig.7. power switch S1 gating pulse and output voltage

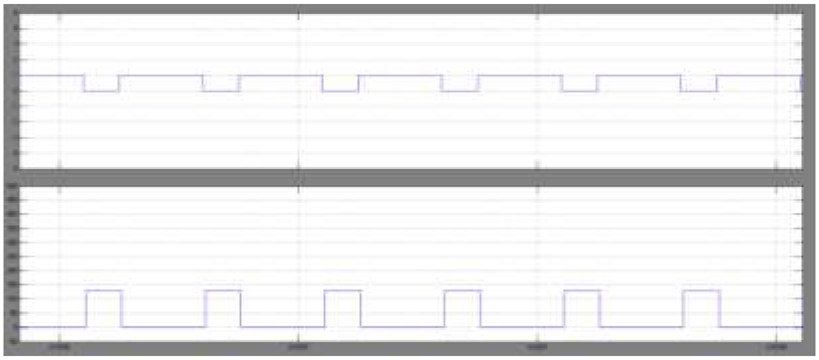


Fig.8.power switch S2 gating pulse and output voltage

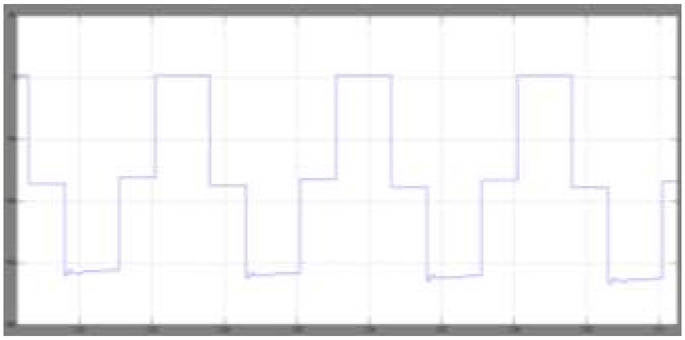


Fig.9. shows the simulated output waveform voltage across switched capacitor

Case-2 proposed converter with AC load

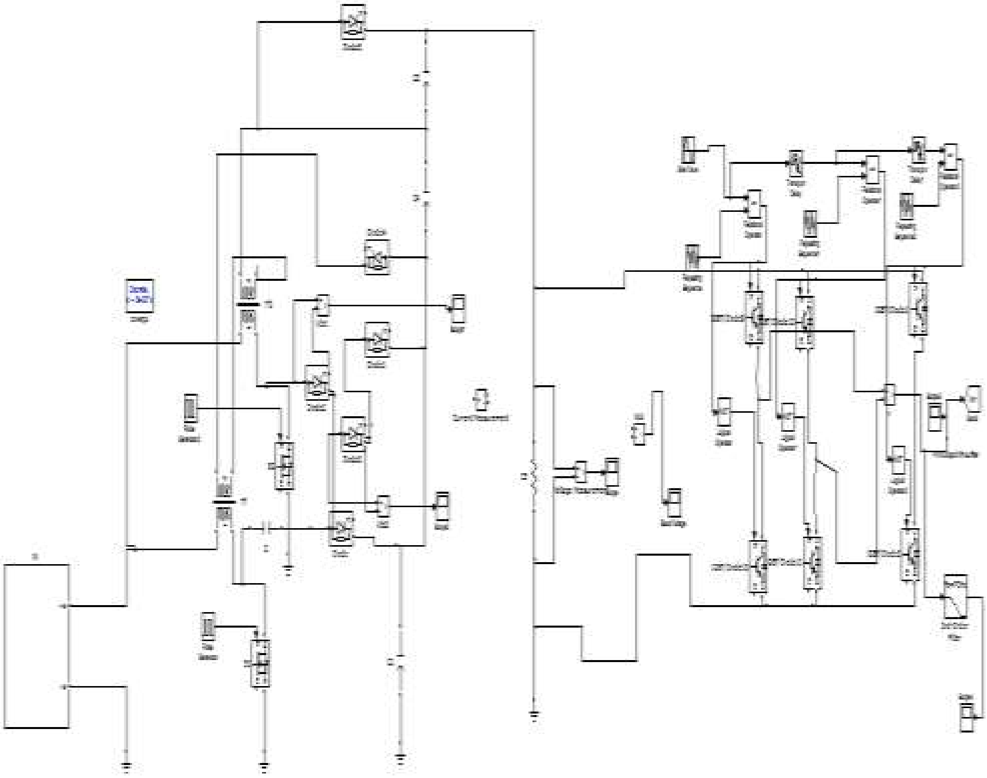


Fig.12. Simulink model of PV as input source of proposed converter with inverter module

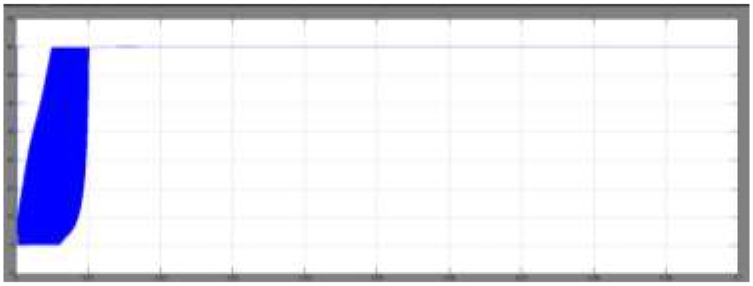


Fig.13. shows simulated PV output voltage

Fig.14. shows Input voltage of proposed inverter

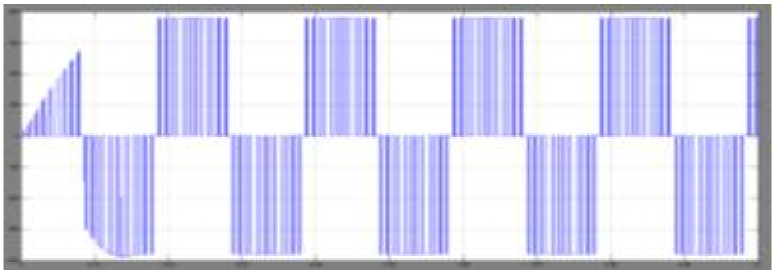


Fig.15. shows output voltage of proposed inverter without filter

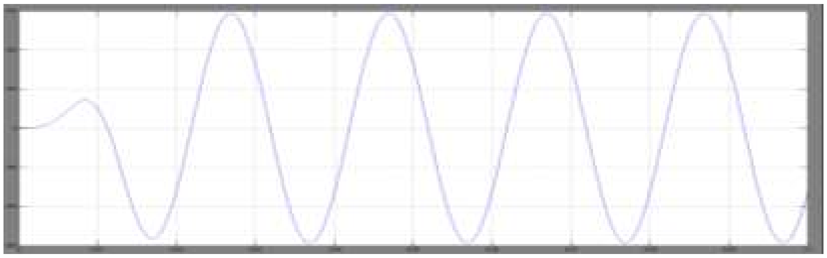


Fig.16. shows output voltage of proposed inverter with filter

## CONCLUSION

This project has presented the theoretical analysis of steady state, related consideration, simulation results. The proposed converter has successfully implemented an efficient high step-up conversion through the voltage multiplier module. The interleaved structure reduces the input current ripple and distributes the current through each component. 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 restricted and much lower than the output voltage (380 V).

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