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A Novel High Step-Up Interleaved Converter with Voltage Multiplier Circuit for PV Systems

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***Abstract* –** A novel high step-up converter, which is suitable for photovoltaic system is proposed in this project. Through a voltage multiplier module composed of switched capacitors and coupled inductors, the proposed converter obtains high step-up gain. The proposed converter not only reduces the current stress. But also constrains the input current ripple, which decreases the conduction losses and the efficiency gets improved.

Keywords - Boost–fly back converter, high step-up, photo-voltaic (PV) system, voltage multiplier module.

I. INTRODUCTION

Nowadays, renewable energy is increasingly valued and employed worldwide because of energy shortage and environmental contamination [1] – [10]. Renewable energy systems generate low voltage output, and thus, high step-up dc/dc converters have been widely employed in many renewable energy applications such fuel cells, wind power generation, and photovoltaic (PV) systems. Such systems transform energy from renewable sources into electrical energy and coert low voltage into high voltage viaa step-up converter, which can convert energy into electricity using a grid-by-grid inverter ordc micro grid.Fig.1shows 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 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.

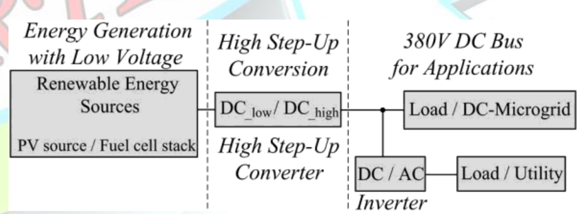

Fig. 1.Typicalrenewableenergysystem

Theoretically, conventional step-up converters, such as the boost converter and fly back 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 step-up converters have been developed.

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Despite these advances, high step-up single-switch converter s are unsuitable to operate at heavy load given a

Large input current ripple, which increases conduction losses.

The conventional inter leaved 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 fore mentioned considerations, modifying a conventional inter leaved boost converter for high step-up and high-power application is a suitable approach. To integrate switched capacitors into an inter leaved 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 inter leaved boost converter may make voltage gain higher and adjustable, but no employment of switched capacitors causes the step-up voltage gain to be ordinary. Thus, the synchronous employment of coupled inductor s and switched capacitors is a better concept; moreover, high step-up gain, high efficiency, and low voltage stress are achieved even for high-power applications.

The proposed converter is a conventional inter leaved 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 turnoff, which all eviate diode reverse recovery losses.

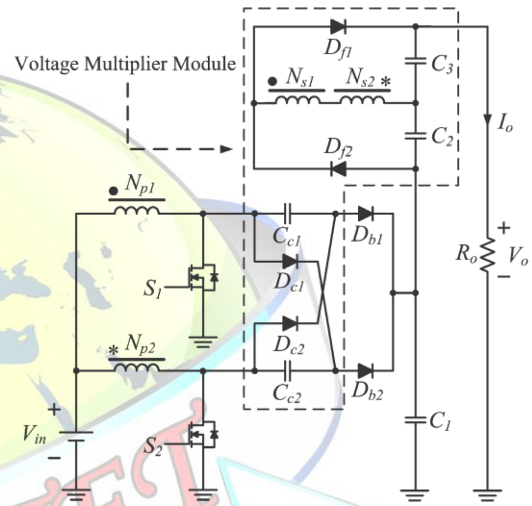

Fig.2. Proposed high step-up converter

II. ADVANTAGES OF THE PROPOSED CONVERTER

The advantages of the proposed converter are as follows.

1) The proposed converter increases the life time of renewable energy sources and makes it suitable for high-power applications.

2) Due to the lossless passive clamp performance, leakage energy is recycled to the output terminal. Hence, large voltage spikes across the main switches are reduced and the efficiency is improved.

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3) The converter achieves the high step-up gain that renewable energy systems require.

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

5) The inherent configuration of the proposed converter makes some diodes decrease conduction losses and all eviate diode reverse recovery losses.

III.OPERATINGPRINCIPLES

The proposed high step-up inter leaved 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–flyback–forward inter leaved structure. When the switches turn off by turn, the phase whose switch is in OFF state performs as a flyback converter, and the other phase whose switch is in ON state performs as a forward converter.

Primary windings of the coupled inductors with N_p turns are employed to decrease input current ripple, and secondary windings of the coupled inductors with N_s 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“*”.

The equivalent circuit of the proposed converter is shown in Fig.3,where $L_{m1}$and $L_{m2}$are the magnetizing inductors; $L_{k1}$and L_{k2} represent the leakage inductors; L_s represents the series leakage 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} represent the output diodes for boost operation with switched capacitors, D_{f1} and D_{f2} represent the output diodes for flyback–forward operation and n is defined as turn ratio N_s/N_p.

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 areinterleavedwitha180°phase shift. 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.

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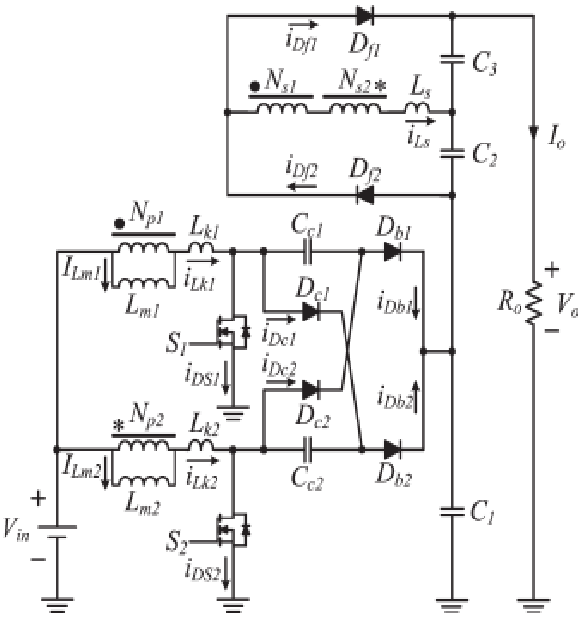

Fig.3.Equivalent circuit of the proposed converter

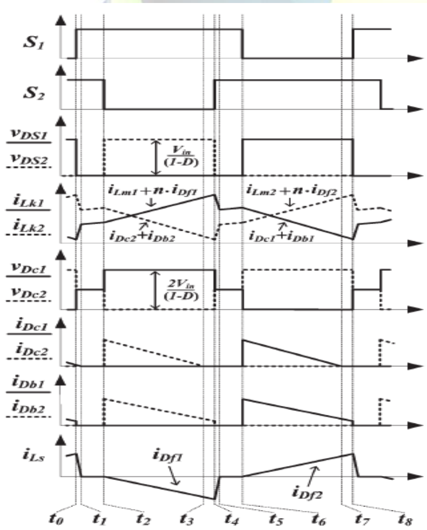

Fig.4.Steady waveform of the proposed converter in CCM

IV. STEADY-STATEANALYSIS

The transient characteristics of circuitry are disregarded to simplify the circuit performance analysis of the proposed converter in CCM, and some formulated assumptions are as follows.

1) All of the components in the proposed converter are ideal.

2) Leakage inductors $Lk1$, $Lk2$, and L_S are neglected.

3) Voltages on all capacitors are considered to be constant because of infinitely large capacitance.

4) Due to the completely symmetrical interleaved structure, the related components are defined as the corresponding symbols such as $D_{C1}$and D_{C2}defined as D_C.

A. Step-Up Gain

The voltage on clamp capacitor C_C can be regarded as an output voltage of the boost converter; thus, voltage V_{Cc} can be derived from the equation

$$Vcc = \frac{1}{1-D} V_{in} \tag{1}$$

When one of the switches turns off, voltage Vc_1 can obtain a double output voltage of the boost converter derived from

$$Vc1 = \frac{1}{1-D} Vin + Vcc = \frac{2}{1-D} V_{in} \tag{2}$$

The outputs filter capacitors C_2 and $C_3$are charged by energy transformation from the primary side. When $S_2$is in ON state and$S_1$is in OFF state, $Vc_2$is equal to the sum of the induced voltage of Ns_1 and the induced voltage of Ns_2, and when S_1 is in ON state and S_2 is in OFF state, Vc_3 is also equal to the sum of the induced voltage of Ns_1 and the induced voltage of Ns_2. Thus, voltages Vc_2 and Vc_3 can be derived from

$$Vc2 = Vc3 = n\,Vin\left(1+\frac{D}{1-D}\right)=\frac{n}{1-D}V_{in} \quad (3)$$

The output voltage can be derived from

$$V0 = Vc1 + Vc2 + Vc3 = \frac{2n+2}{1-D}V_{in} \quad (4)$$

In addition, the voltage gain of the proposed converter is

$$\frac{V_0}{V_{in}} = \frac{2n+2}{1-D} \quad (5)$$

B. VOLTAGE STRESS ON SEMI CONDUCTOR COMPONENT

Voltage ripple on capacitor was ignored to simplify the voltage stress analysis of the components of the proposed converter. The voltage stress on power switch S was clamped and derived from

$$Vs1 = Vs2 = \frac{2}{1-D}Vin = \frac{1}{2n+2}V_0 \quad (6)$$

This equation represents low-voltage-rated MOSFET with low RDS(ON)can be adopted for the proposed converter to reduce conduction losses and costs.These voltage stresses can be derived from

$$VDc1 = VDc2 = \frac{2}{1-D}Vin = \frac{1}{n+1}V_0 \quad (7)$$

$$VDb1 = VDb2 = Vc1 - Vc2 = \frac{2}{1-D}Vin = \frac{1}{2n+2}V_0 \quad (8)$$

Although the voltage stress on the diode *Df* increases as the turn ratio *n* increases, the voltage stress on the diodes *Df*is always lower than the output voltage.

V. DESIGN AND EXPERIMENT OFPROPOSED CONVERTER

A 1-kW prototype of the proposed high step-up converter is tested. The electrical specifications are *V*in = 40 V, *Vo* = 380 V, and *fs*= 40 kHz. The major components have been chosen as follows: Magnetizing inductors *Lm*1 and *Lm*2 = 133 μH; turn ratio *n* = 1; power switches *S*1 and *S*2 areIRFP4227; diodes *Dc*1 and *Dc*2 are BYQ28E-200; diodes *Db*1, *Db*2, *Df*1, and *Df*2 are FCF06A-40; capacitors *Cc*1, *Cc*2, *C*2, and *C*3 = 220 μF; and *C*1 = 470 μF.

The design consideration of the proposed converter includes component selection and coupled inductor design, which are based on the analysis presented in the previous section. In theproposed converter, the values of the primary leakage inductors of the coupled inductors are set as close as possible for current sharing performance, and the leakage

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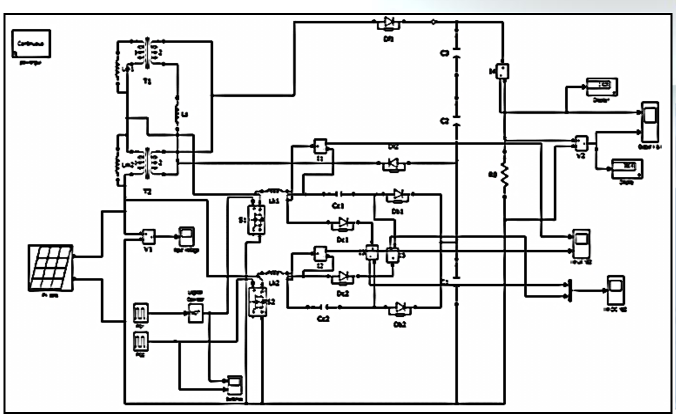
inductors $Lk1$ and $Lk2$ are 1.6 μH. Due to the performances of high step-up gain, the turn ratio n can be set as one for the prototype circuit with 40-V input voltage and 380-V output to reduce cost, volume, and conduction loss of the winding. Thus, the copper resistances which affect efficiency much can be decreased.

V. DESIGN PARAMETERS

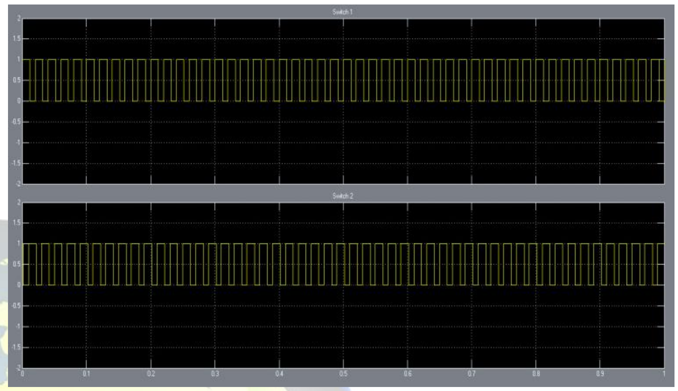
PARAMETER	VALUE
Input Voltage	40 V DC
Output Voltage	380 V DC
Switching Frequency	40 KHz
Magnetizing Inductors (Lm1 & Lm2)	133 µH
Capacitors (Cc1, Cc2, C2 & C3)	220 µF
Capacitor (C1)	470 µF
Output Power	1000 W

VI. MATLAB SIMULATION DIAGRAM



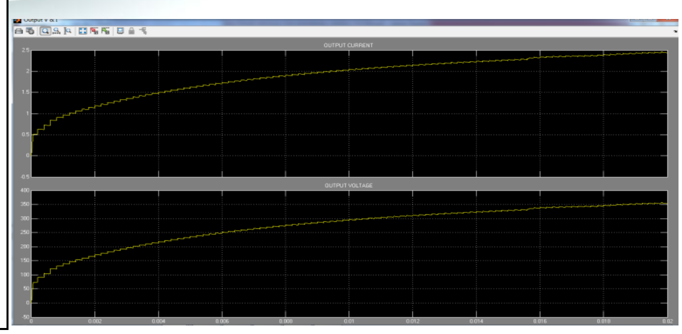
VII. WAVEFORMS

a) Switching Pulses:



b) Current Through Leakage Inductances:

c) Output Current and Output Voltage:



VIII. CONCLUSION

This paper has presented the theoretical analysis of steady state, related consideration, simulation results, and experimental results for the proposed converter. The proposed converter has successfully implemented an efficient high step-up con- version through the voltage multiplier module. The interleaved structure reduces the input current ripple and distributes the cur- rentthrougheach 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 (380V).Furthermore, the full-load efficiency is 96.4% at P_O=1000W, and the highest efficiency is 97.1% at P_O=400W.Thus, the proposed converter is suitable for high-power or renewable energy applications that need high step-up conversion.

REFERENCES

[1] J. T. Bialasiewicz, "Renewable energy systems with photovoltaic power generators: Operation and modeling," IEEE Trans. Ind. Electron., vol. 55,no. 7, pp. 2752–2758, Jul. 2008.

[2] T. Kefalas and A. Kladas, "Analysis of transformers working under heavily saturated conditions in grid-connected renewable energy systems,"IEEE Trans. Ind. Electron., vol. 59, no. 5, pp. 2342–2350, May 2012.

[3] Y. Xiong, X. Cheng, Z. J. Shen, C. Mi, H. Wu, and V. K. Garg, "Prognostic and warning system for power-electronic modules in electric, hybridelectric, and fuel-cell vehicles," IEEE Trans. Ind. Electron., vol. 55, no. 6,pp. 2268–2276, Jun. 2008.

[4] A. K. Rathore, A. K. S. Bhat, and R. Oruganti, "Analysis, design and experimental results of wide range ZVS active-clamped L–L type currentfedDC/DC converter for fuel cells to utility interface," IEEE Trans. Ind.Electron., vol. 59, no. 1, pp. 473–485, Jan. 2012.

[5] T. Zhou and B. Francois, "Energy management and power control of ahybrid active wind generator for distributed power generation and gridintegration," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 95–104,Jan. 2011.

[6] C. T. Pan and C. M. Lai, "A high-efficiency high step-up converter withlow switch voltage stress for fuel-cell system applications," IEEE Trans.Ind. Electron., vol. 57, no. 6, pp. 1998–2006, Jun. 2010.

[7] R. J.Wai and R. Y. Duan, "High step-up converter with coupled-inductor," IEEE Trans. Power Electron., vol. 20, no. 5, pp. 1025–1035, Sep. 2005.

[8] S. K. Changchien, T. J. Liang, J. F. Chen, and L. S. Yang, "Novel highstep-up DC–DC converter for fuel cell energy conversion system," IEEETrans. Ind. Electron., vol. 57, No. 6, pp. 2007–2017, Jun. 2010.

[9] Y. P. Hsieh, J. F. Chen, T. J. Liang, and L. S. Yang, "Novel high step-up DC–DC converter with coupled-inductor and switched-capacitor techniques for a sustainable energy system," IEEE Trans. Power Electron.,vol. 26, no. 12, pp. 3481–3490, Dec. 2011.

[10] C. Evangelista, P. Puleston, F. Valenciaga, and L.M. Fridman, "Lyapunov designed super-twisting sliding mode control for wind energy conversion optimization," IEEE Trans. Ind. Electron., vol. 60, no. 2, pp. 538–545, Feb. 2013.

