A High Step-Up Converter With Voltage-Multiplier Modules For Sustainable Energy Applications

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Abstract-*This paper proposes a novel isolated high step-up converter for sustainable energy applications. Through an adjustable voltage-multiplier module, the proposed converter achieves a high step-up gain without utilizing either a large duty ratio or a high turns ratio. The voltage-multiplier modules are composed of coupled inductors and switched capacitors. Due to the passive lossless clamped performance, leakage energy is recycled, which alleviates a large voltage spike across the main switches and improves efficiency. Thus, power switches with low levels of voltage stress can be adopted for reducing conduction losses. In addition, the isolated topology of the proposed converter satisfies electrical-isolation and safety regulations. The proposed converter also possesses continuous and smooth input current, which decreases the conduction losses, lengthens life time of the input source, and constrains conducted electromagnetic-interference problems.*

I. INTRODUCTION

Energy is essential to our society to ensure our quality of life and to underpin all other elements of our economy. However, many developed countries have widely employed fossil fuels for the development of industry, economy and technology, which increase carbon emissions and the international price of oil. Hence, renewable-energy sources are becoming increasingly important and are being utilized worldwide to solve energy-shortage problems and to alleviate environmental-protection issues [1]-[10].

The block diagram of a typically sustainable energy system is shown in Fig. 1. The rated voltage of renewable-energy sources (such as photovoltaic sources or fuel-cell stacks) are at low levels, so that an intermediate converter with a sufficiently high step-up conversion and high efficiency is essentially required in this kind of system. Literature [11]-[23] indicates that some high step-up DC/DC converters have been proposed and are widely utilized in many renewable-energy applications.

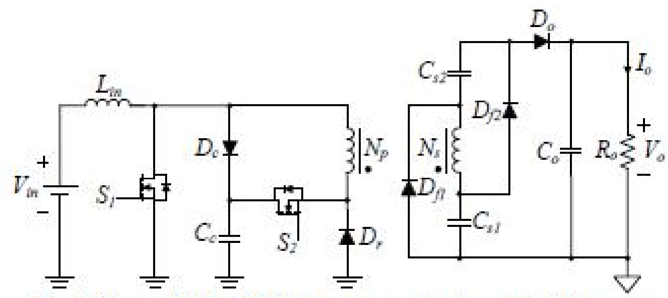


Fig. 2. Proposed isolated high step-up converter for sustainable energy applications.

II. OPERATING PRINCIPLE OF PROPOSED CONVERTER

The equivalent circuit of the proposed isolated converter is shown in Fig. 3, where L_{in} is the input inductor, L_m is the magnetizing inductor, L_k is the leakage inductor, S_1 and S_2 denote the power switches, C_c is the clamp capacitor, C_{s1} and C_{s2} are the switched capacitors, and C_o is the output capacitor. D_c is the clamp diode and D_r is the regenerative diode; D_{f1} and D_{f2} represent the diodes of flyback-forward, and D_o represents the output diode. The turns ratio N_s/N_p is

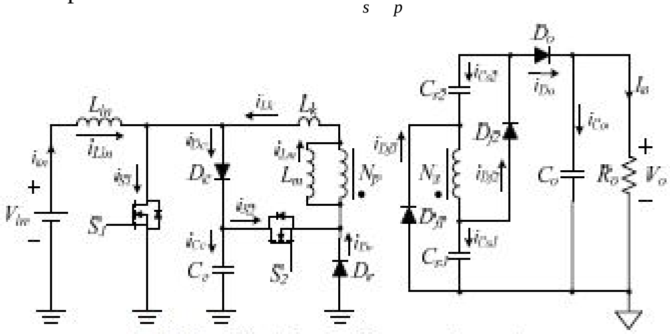
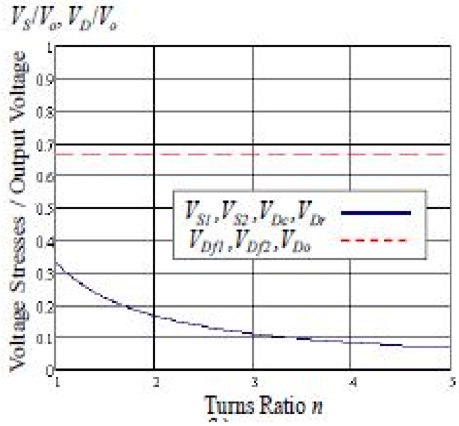


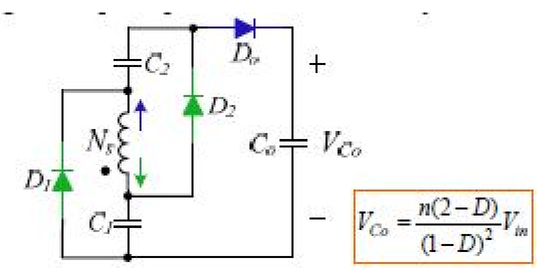
Fig. 3. Equivalent circuit of proposed converter.

III. EXTENTION OF VOLTAGE MULTIPLIER MODULE

The proposed isolated converter, the voltage-multiplier modules in the secondary side can be extended by symmetrically multiplicative design. The symmetrically multiplicative design satisfies requirements for low output ripple; examples of these (quintuple-rectifier circuit, septuple-rectifier circuit and nonuple-rectifier circuit, etc.) are shown in Fig. 9, where Ns represents the secondary side of the coupled inductor, and VCo indicates the supplied voltage of output capacitors in the secondary side.

TURNS RATIO





(a) Triple-rectifier circuit

TABLE I
PERFORMANCE COMPARISONS AMONG ISOLATED HIGH STEP-UP CONVERTERS

High Step-Up Isolated Converters	Converter in [25]	Converter in [26]	Proposed Converter
Voltage Gain	$\frac{n}{1-D}$	$\frac{n(2-D)}{1-D}$	$\frac{n(2-D)}{(1-D)^2}$
Voltage Stress on Switch	$\frac{V_o}{n}$	$\frac{(1-D)V_o}{n(2-D)}$	$\frac{(1-D)V_o}{n(2-D)}$
Maximum Voltage Stress on Diode	V_o	$\frac{V_o}{2-D}$	$\frac{V_o}{2-D}$
PWM Control	Normal	Easy	Easy
Input Current Ripple	Large	Large	Normal
Circuit Topology			
Converter in [25]	Active-clamp forward-flyback converter		
Converter in [26]	Double-ended forward-flyback converter		
Proposed Converter	Cascade double-ended boost-forward-flyback converter		

IV. EXPERIMENTAL RESULTS

A 500W prototype converter with high step-up ratio has been implemented and tested. Tables II and III show the specifications and circuit components, respectively, used in the proposed isolated converter.

Prototype Specification	
Input Voltage V_{in}	40 V
Output Voltage V_o	380 V
Maximum Output Power P_o	500 W
Switching Frequency f_s	50 kHz

V. CONCLUSION

This paper has presented the theoretical analysis of steady-state and experimental results for the proposed converter, which successfully demonstrates its performance. A prototype isolated converter has been successfully implemented with a high step-up ratio and high efficiency for sustainable energy applications. The presented circuit topology inherently makes the input current continuous and smooth, which decreases the conduction losses, lengthens the life time of the input source, and constrains conducted EMI problems. In addition, the lossless passive clamp function recycles the leakage energy and constrains/lowers the voltage spikes across the power switches. Meanwhile, the voltage stress on the power switch is restricted and is much lower than the output voltage Vo, which is 380 V. Furthermore, the full-load efficiency is 90.67% at Po =500 W, and the maximum efficiency is 94.71% at Po = 200 W. Thus, the proposed converter is suitable for renewable-energy applications that need high step-up conversion and have electrical-isolation requirements.

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