# 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.

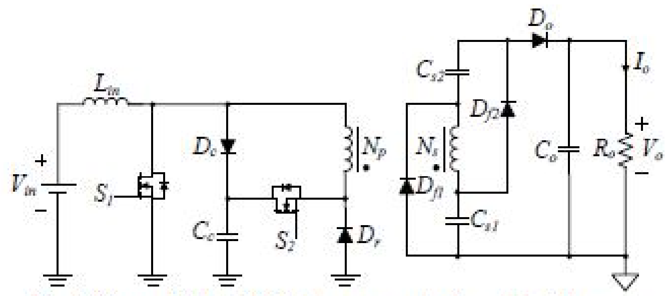


Fig. 2. Proposed isolated high step-up converter for sustainable energy applications.

## II. OPERATING PRINCIPLE OF PROPOSED CONVERTER

The equivalent circuit of the proposed isolated converter is shown in Fig. 3, where Lin is the input inductor, Lm is the magnetizing inductor, Lk is the leakage inductor, S1 and S2 denote the power switches, Ccis the clamp capacitor, Cs1 and Cs2 are the switched capacitors, and Co is the output capacitor. Dc is the clamp diode and Dr is the regenerative diode; Df1 and Df2 represent the diodes of flyback-forward, and Dorepresents the output diode. The turns ratio Ns/Np is

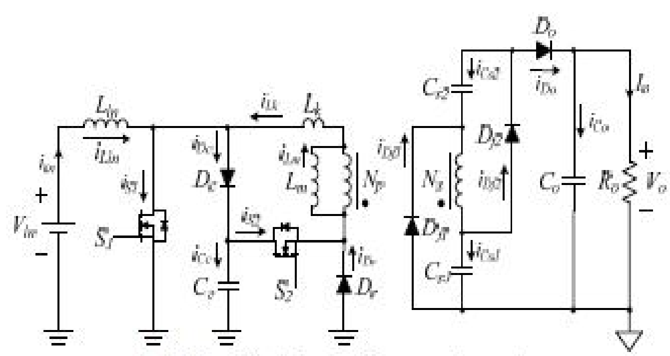


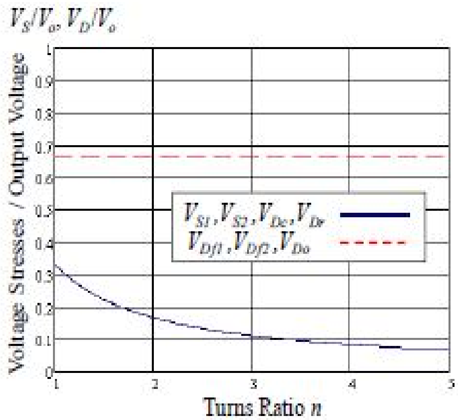
Fig. 3. Equivalent circuit of proposed converter.

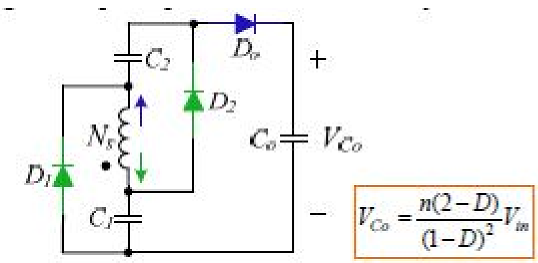
## III. EXTENTION OF VOLTAGE MULTIPLIER MODULE

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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