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An Improved Dual Switch Converter with Passive Lossless Clamping

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ABSTRACT: High step-up voltage gain dc/dc converters are widely used in applications such as lasers, X-ray systems, fuel cell energy conversion systems, and high-intensity-discharge lamp ballasts for automobile headlamps. Various topologies have been developed to provide a high step-up voltage gain without an extremely high duty ratio .Isolated DC-DC converters contain high frequency transformers, they have some disadvantages both in volume and conversion efficiency .The transformerless high step-up voltage gain converters have become the research hotspot. Traditional transformerless high step-up voltage gain converters bring some drawbacks: converters are large, voltage stress of the power devices is very high, and voltage gain is still limited. This work is based on active dual switch converter with passive lossless clamping which has following advantages are high voltage conversion ratio, low voltage stress across switches, converter has very strict requirement of the device parameters consistency. This work discuss the steady state analysis in practical conditions that the two inductors, the two parasitic capacitors and the switching speed of the two power switches are exactly equal. Passive lossless clamping is adopted to balance the voltage across the switches and to suppress the resonance.

KEYWORDS*:* Dual switch converter, parasitic capacitor, resonance

I.INTRODUCTION

As a result of the massive consumption of oil, coal, gas and other fossil energy, we inevitably face the threat of the exhaustion of non-renewable energy source. What is more, the usage of fossil energy has generated a large amount of exhaust gas, result in global surface temperature increase. Facing the double pressure from natural resources and environment. More and more researchers concentrate on exploring the renewable energy sources, such as the photovoltaic power generation, fuel cell stacks and so on . The output voltage of the fuel-cell stack is lower than 40 V due to the cost and reliability issues in the household stand-alone power generation applications; it is required to be boosted to nearly 400V before being inverted into a 220V AC output [1]. In order to prevent the happening of hot spot and multiple peaks maximum power point tracking, a new structure of the distributed photovoltaic grid-connected power generation is proposed, which connect each individual PV cell (the output voltage ranges from 20V to 40V) to the grid through a micro-inverter, it also calls for high step-up and high-efficiency converters to realize the integrated PV modules [2].
Affected by the equivalent series resistance (ESR) of the devices, traditional Boost converters cannot provide a high voltage gain. Otherwise, the extremely narrow turn-off time will bring large peak current and considerable conduction and switching losses [3]. Various topologies have been developed to provide a high step-up without an extremely high duty ratio. The isolated converters can boost the voltage ratio by increasing the turn ratios of the high frequency transformer [4-6]. However, the leakage inductor should be handled carefully, otherwise it will cause voltage spike across the power switches and the cost in isolated topologies is high with multi-stage DC/AC/DC power conversion and isolated sensors or controllers. In order to achieve high step-up voltage gain with high efficiency, transformerless converters have been extensive researched. The transformerless converters can be generalized as the coupled inductor type and non-coupled inductor type. A number of coupled inductor based high step-up converters has been developed, by increasing the turn ratios of the coupled inductor, which is similar to that in isolated converters, high voltage-conversion ration can be achieved [7-10]. Unfortunately, the leakage inductance of the coupled inductor is inevitable, like the isolated

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Converters, it may cause high voltage spikes which will add the voltage stress. By combining the conventional Boost converter with the Flyback converter, the outputs of the Boost and Flyback converters are in series to generate the high output voltage in the integrated Boost-Flyback converters, while the voltage balance of the output capacitors should be taken into consideration with the series structure. The non-coupled inductor type can achieve high voltage gain with minimized magnetic components [11-13]. The switched-inductor Boost converter can provide a high voltage-conversion ratio, but the voltage stress on the power MOSFET is relatively high. Although the cascade Boost converter could provide a high step-up voltage, the topology is very complex, the efficiency would deteriorate after a multi-stage transformation and it exist a stability problem of the cascaded system.

Transformerless high step-up voltage gain converter, and gives out the working principle in ideal situation, the proposed converter is consisted of two inductors and two power switches which share the same operation signal, the topology is very simple. However, the converter has a very strict requirement of the device parameters’ consistency. Considering the actual working status, this paper gives out the steady-state analysis in the situation that the two inductors, the two parasitic capacitors and the switching speed of the two MOSFETs are exactly equal; and then, a passive lossless clamp circuit is adopted to balance the voltage on the switches and suppress the resonance. Finally, according to the proposed circuit, a prototype rated at 100W has been established in the lab, and the experimental results verify the correctness of the analysis

II.DUAL SWITCH CONVERTER

Fig.1shows the solutions to suppress the resonance: D_1 and D_2, and a capacitor Cc is added to clamp the switches. Obviously, the potential voltage across points A and B in Fig.1 keeps constant; therefore, the converter may not introduce leakage current when applied in a microinverter PV system. In order to simplify the analysis, take Fig. 1(a) as an example. Assume that the inductance of $L1$ is smaller than $L2$, and the output capacitor is large enough that the output voltage can be treated as constant. Fig. 2 shows the two possible waveforms of the converter under CCM operation mode. The occurrence of Fig. 2(a) and (b) is determined by the charging speed of C_1 and C_2, which depends on the characteristics of switches and the relationship between the inductances of L_1 and L_2. In this case, parasitic capacitor C_2 charges faster, and D_1 opens faster than D_2

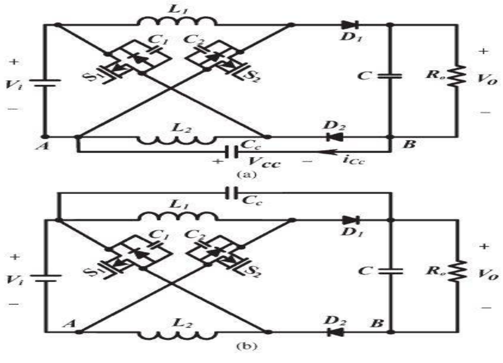

Fig.1 Dual switch converter

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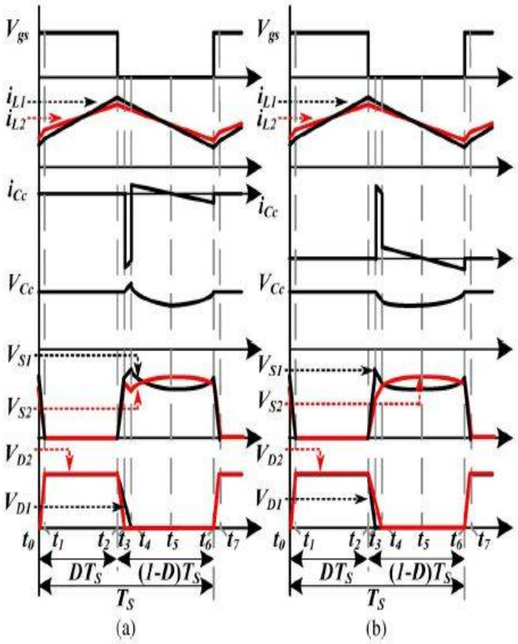

(a) (b)

Fig.2 waveform of the dual switch converter with clamping circuit under CCM operation

III.SIMULATION RESULTS

Simulation results are given to verify the correctness of the analysis. The simulation parameters are: input voltage V_i = 20V; output voltage V_o = 100 V; load: resistance load R = 100 Ω; inductance: L1 = 490 μH, L2 = 510 μH; parasitic capacitance of the switches: C_1 = 900 pF, C_2 = 800 pF; filter capacitor: C = 470 μF; and switching frequency: fs = 50 kHz.

COMPONENTS	PARAMETERS
Input voltage	20-40V
Output voltage	100V
Rated power	100W
Switching frequency	50KHz
L_1,L_2(inductors)	$500\mu H$
S_1,S_2(power MOSFETS)	IRFP650(with clamping)
D_1,D_2(Diodes)	SF23
Clamping capacitors(C_c)	$1\mu F/63V$(CBB capacitors))
C(filter capacitor)	$470\mu F/160V$

Table.1 utilized components and parameters of the converter

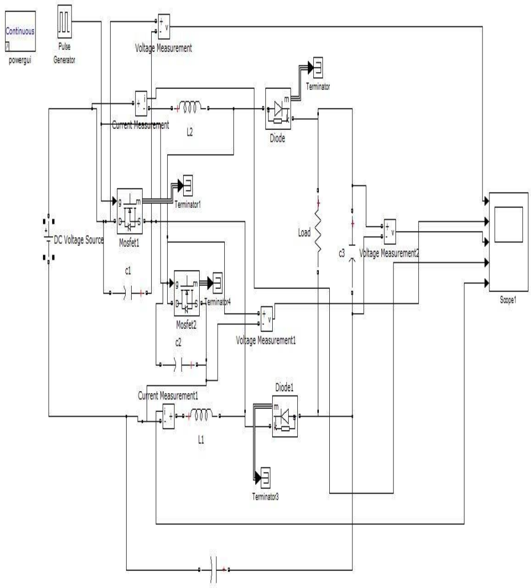

Fig.3 simulation model of dual switch converter

Fig.4 shows the simulation results of the converter with the proposed passive lossless clamping circuit. The capacitance of the clamping capacitor is 1μF. The waveforms from top to bottom is the switching signal V_{gs}, the inductor current i_{L1}, i_{L2}, and the voltage across the switch V_{S1}, V_{S2}, respectively. As shown, the resonance is suppressed and the voltage balance of two switches is realized, the voltage stress on the switches is 60 V (i.e., $(V_i + V_o)/2$)

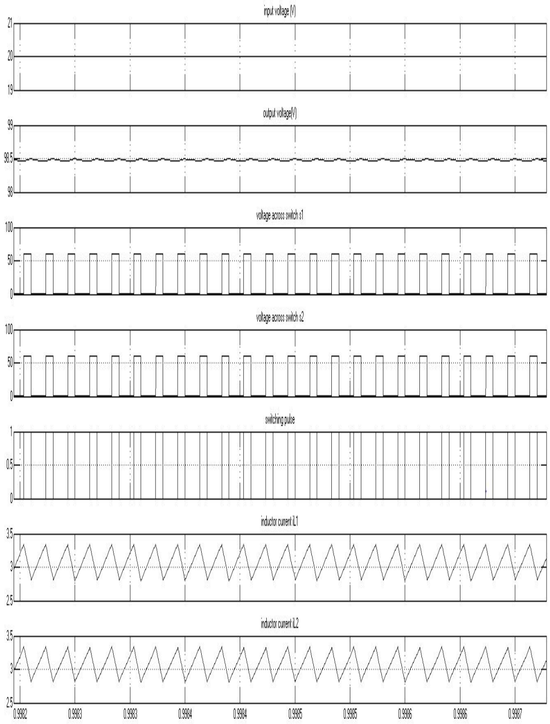

Fig.3 simulation results of dual switch converter

IV.CONCLUSION

This dual switch converter considering the practical operation conditions of the dual-switch converter illustrates the steady-state analysis on the conditions that the parameters of the devices are not exactly equal, and then a passive lossless clamping circuit has been proposed to balance the voltage on the switches and suppress the resonance. Simulation and experimental results have been given and verify the correctness of the analysis. With the passive lossless clamping circuits, low-voltage switches with small R_{ds}(on) can be utilized, and the efficiency of the converter can be improved. Compared with the two-stage boost converter, it has the same amount of power switches and passive components; however, the converter has such advantages.

1) The voltage stress across power devices is relatively low compared to the secondary stage of the two-stage boost converter.

2) The system stability of the cascade structure is another big issue; the proposed converter can avoid it. The voltage-conversion ratio remains high, thus making the converter more suitable for step-up dc–dc power conversion

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