높은 부스트 전압 이득 절연 DC-DC 컨버터

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A High Boost Voltage Gain Isolated DC-DC Converter

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ABSTRACT

The isolated boost DC-DC converter based on three switches in fuel cell applications is presented in this paper. The major advantages of the proposed converter are as follows: continuous input current; decrease one active switch and no use snubber circuit. The operating principles and analysis of the proposed converter have been discussed. A 400 W prototype has been tested in the laboratory to verify the performance of the proposed converter and a PID controller was used to clarify the DC output voltage at 400 V. The simulation and experimental results are shown to validate the theoretical analysis.

1. Introduction

Recently, the industrialization is developing, in addition it has decreased the natural resources, many environmental problems are posed. So, the using of new energy sources are very important, for example: fuel cells, solar photovoltaic[1]-[2]. But, the energy sources have a low-voltage DC and instability, hence the stepped up a high voltage level is necessary. In order to use it should be raised 200V or 400V DC voltage before it's inverted into 110V or 220V AC output voltage.

High boost DC-DC conversion techniques are required in many applications such as fuel cells (FCs), solar photovoltaic (PV) systems and uninterruptible power supplies (UPS). For these applications, a high boost voltage ratio with high conversion efficiency is necessary. Many high step-up DC-DC converters have been proposed to convert low voltages into a high DC bus voltage, such as isolated and non-isolated topologies.

For non-isolated topologies, many researchers have proposed a lot of converter, it can be classified: coupled inductor, a switched – capacitor, a switched inductor, a cascade topology and the mixture of them[3]-[4]. To provide the isolation between input and output terminal, improve the voltage boost ability, many isolated topologies have been discussed in[4]-[7] The CFFB DC-DC converters[7] are suitable for applications.

In this paper, a new isolated boost DC-DC converter is proposed. Compared to the conventional CFFB converter, the proposed converter uses one fewer active switch, one extra diode, and one extra capacitor. The operating principles, analysis for the proposed converter are discuss. To verify the analysis, simulation and experimental results are provided.

2. Operating Principle of the Proposed Isolated DC-DC converter.

The proposed isolated boost DC-DC converter is shown in Fig. 1. Which consists of a boost inductor (L_1) , three MOSFETs, one boost capacitor (C_1) , one diode (D_1) at the primary winding of the transformer , voltage doubler rectifier (VDR) implemented by two diodes (D_2 and D_3) and two capacitors (C_2 and C_3), and resistor load (R). The main major of the proposed converter are as follows: 1) the input current is continuous with low ripple; 2) it uses one fewer active switch and 3) the snubber circuit is not used. Thus, the three gate drivers are used in the proposed converter.

A circuit analysis of the proposed converter is performed under the following conditions: 1) the inverter operates in continuous conduction mode (CCM); 2) all devices are ideal and lossless; 3) the high-frequency transformer is an ideal transformer; 4) the voltage of the capacitors maintain a constant; and 5) D is the duty cycle of switch S_3.

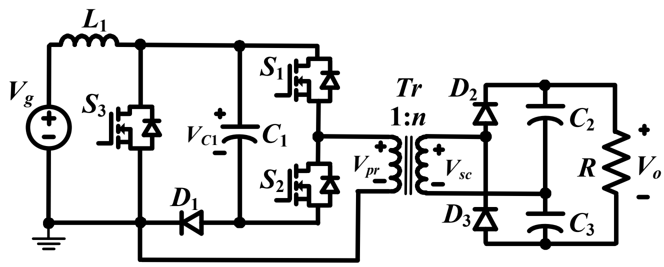

Fig. 1. Proposed three-switch isolated boost DC-DC converter.

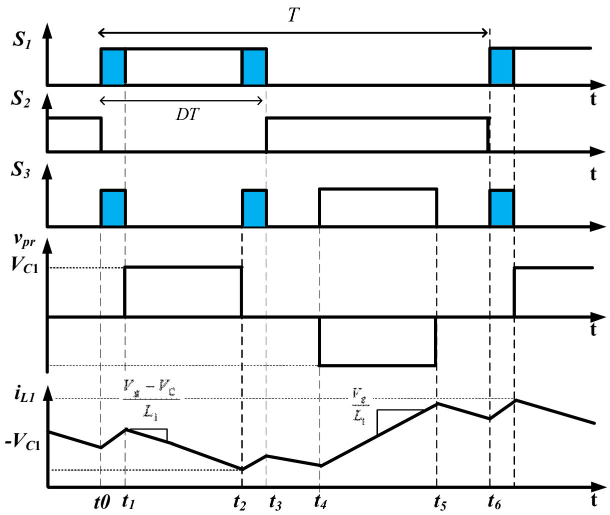

Fig. 2. Key waveforms of the proposed converter.

Stage 1–[t_0 – t_1, t_2 – t_3, Fig. 3(a)]: At t_0, S_1 and S_3 turn "ON". In this stage, S_2 is turned "OFF". The inductor L_1 is charged by the input voltage.

$$L_1 \frac{di_{L1}}{dt} = V_g, \tag{1}$$

Stage 2–[t_1 – t_2, Fig. 3(b)]: S_1 is turned on, S_2 and S_3 are turned off. The inductor L_1 is discharge. The primary voltage of the transformer is V_{c1}. We have:

$$L_1 \frac{di_{L1}}{dt} = V_g - V_{C1}, \tag{2}$$

Stage 3–[t_3 – t_4, t_5 – t_6, Fig.3 (c)]: In this time, only S_2 turns "ON". The inductor L_1 current is through D_1. The primary winding of the transformer is equal to zero. So, the secondary voltage of the transformer is zero; the D_2 and D_3 diodes are reverse-biased. We get:

$$L_1 \frac{di_{L1}}{dt} = V_g - V_{C1}, \tag{3}$$

Stage 4–[t_4 – t_5, Fig. 3(d)]: At t_4, when S_3 and S_2 turns "ON", S_1 remains "OFF"." The inductor L_1 is charged, while the capacitor C_1 is discharged. The primary voltage of the transformer is $-V_{c1}$. After passing through the step-up transformer, the secondary voltage is negative. We get:

$$L_1 \frac{di_{L1}}{dt} = V_g, \tag{4}$$

Use the volt-second balance law to the inductor L_1, from (1), (2) and (3), the capacitor C_1 voltage and output voltage can be approximated as

$$\begin{cases} V_{C1} \approx \dfrac{1}{1-D} V_g \\ G = \dfrac{V_o}{V_g} \approx \dfrac{2n}{1-D}, \end{cases} \tag{5}$$

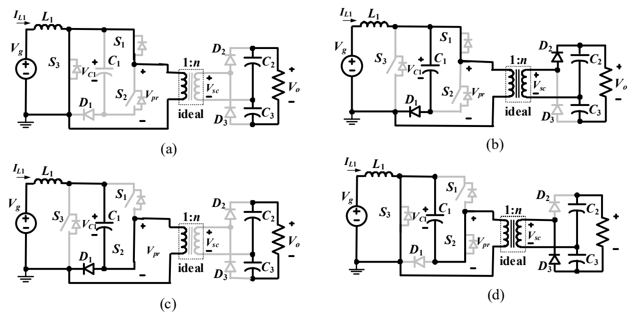

Fig. 3. Operation stages of the proposed converter.

3. Simulation and Experimental Results

3.1 Simulation Results

The proposed DC-DC converter is verified by using PSIM 9.1 simulation when the 40 V input voltage and the 400 W output voltage are as shown in Fig. 3. The frequency of switching is 10 KHz. The simulation parameters of the proposed converter is selected as the same Table I. These simulation results are agreeable with the theoretical analysis.

TABLE I

SIMULATION AND EXPERIMENTAL PARAMETERS

Input voltage range (V_g)		40 V
Output voltage (V_o)		400 V
Inductor (L_1)		1 mH
Transformer	Turn ratio	1:2.5
	Primary inductance	1.4 mH
	Leakage inductance	11 μH
Capacitors	C_1	220 μF
	$C_2 = C_3$	150 μF

Switching frequency	10 kHz
Resistive load (*R*)	600 Ω

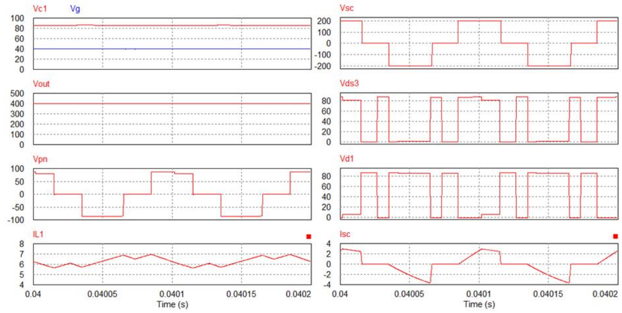

Fig. 3. Simulation results when V_g = 40 V.

3.2 Experimental Results

The experiment results with 250 W are implemented by using DSP kit TMS320F28335 with parameters experiments same as Table 1. The PWM signal is generated by TMS320F28335 through a isolated amplifiers (TLP250) and the gating signal is create to drive three MOSFETs. The primary and secondary windings of the transformer had designed 38 turns and 95 turns. The voltage C_1 voltage was 87 V and the input current is continuous.

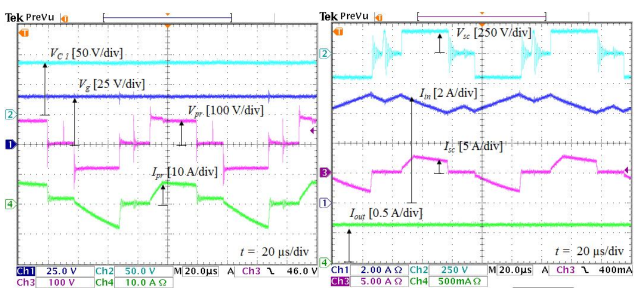

Fig. 4. Experimental voltage waveforms of the proposed converter when V_g = 40 V at the output power of 250 W.

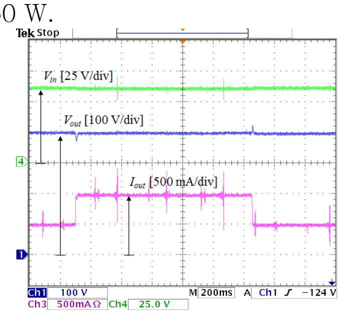

Fig. 5. Experiment with PID controller when the load changes from half load to full load.

4. Conclusion

A new isolated boost DC-DC converter has been presented in this paper and had the following characteristics: the input current is continuous, reduced one active switch, the primary and secondary voltage waveforms of the transformer does not change, and no snubber circuit. The operating principles and analysis of the proposed converter have been discussed. The proposed converter is applicable for fuel-cell applications with low-dc input voltage.

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