

A Novel Single-stage AC/DC Converter with ZVS Characteristic

Abstract. A novel single-stage AC/DC converter is proposed in this letter. The converter is designed by integrating a sepic circuit and a flyback circuit, the circuit work in the quasi-resonance state, and the switch is turned on in the zero voltage switching (ZVS) state, which decreased the switching losses of the converter

Streszczenie. Opisano nowy konwerter AC/DC. Układ pracuje w stanie quasi-rezonansu z przełączaniem przy zerowym napięciu. (Nowy konwerter AC/DC z przełączaniem przy zerowym napięciu)

Keywords: AC-DC converter.

Słowa kluczowe: konwerter AC-DC.

Introduction

Usually a PFC (power-factor-correction) must be added to an AC/DC converter to satisfy the standards such as IEEE 519 and IEC 61000-3-2[1]-[2]. But the costs of the two-stage AC/DC converter are very high, and the reliability is very low. So the single-stage AC/DC converter becomes a choice, but most single-stage converters cannot work with soft switching state, which increases the switching losses of the converter [3]-[4]. A novel single-stage AC/DC converter with ZVS characteristic is proposed in the letter to improve the efficiency of the single-stage AC/DC converter.

Single-stage AC/DC Converter

The converter proposed in the letter is shown in fig.1. Here L_1 , C_1 , D_6 , L_2 , Q , and C_3 form a sepic circuit, the flyback is in series with the sepic circuit, the switch Q is both one part of the sepic circuit and the flyback circuit. The sepic circuit works in the DCM state, which can realize the PFC function. The flyback circuit works in the quasi-resonance state, and the switch is turned on in the time when the first valley of V_{DS} comes, so the switch is turned on in the ZVS state. Here C_2 is the resonant capacitor, and L_{leak} is the leakage inductor of the transformer.

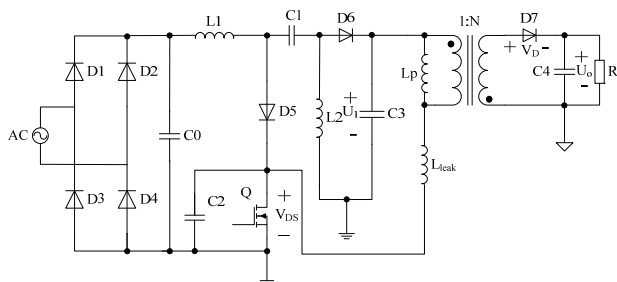


Fig.1. Proposed converter in the letter

Principle of The Converter

Here, the working frequency is constant; the output voltage of the converter is regulated through varying the duty cycle of the converter. The sepic converter can realize the PFC function if the equation (1) is satisfied [5].

(1)

$$\frac{2L_{eq}}{RT_s} < \frac{1}{2(M+1)^2}$$

Where L_{eq} is the equivalent inductor of L_1 and L_2 , T_s is the working period, and M is the transfer ratio of the peak value of the input voltage and the output voltage. For the flyback circuit, V_{DS} can be described as follows [6].

(2)
$$V_{DS}(t) = U_1 + \frac{1}{N}(U_0 + V_D)e^{-\frac{R_p}{2L_p}t} \cos\left(2\pi \frac{1}{2\pi\sqrt{L_p \cdot C_2}}t\right)$$

Here R_p is the resistor of L_p . From (2), V_{DS} has a minimum value, if the switch is turned on in this moment, the switch can be turned on in the ZVS state. The current of the components for the converter is shown in fig.2.

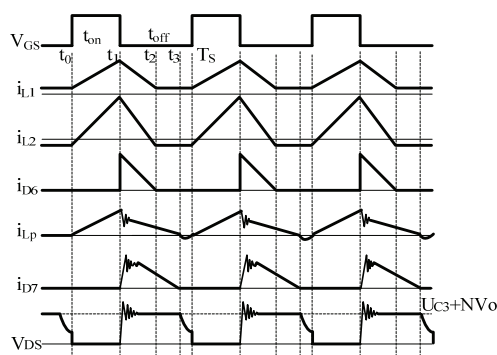


Fig.2. Working principle of the converter

Design and Experiment

In the laboratory, a 100 W prototype is presented. $f_s=100\text{kHz}$, the input voltage $U_i=311\sin(\omega L t)\text{V}$, the efficiency is set to 85%, $U_1=200\text{V}$, $U_0=48\text{V}$, then the parameters of the converter can be calculated as follows: $L_1=7.55\text{mH}$, $L_2=282\mu\text{H}$, $C_1=3\mu\text{F}$, $C_3=C_4=100\mu\text{F}$, $N=4$, $L_p=220\mu\text{H}$. Here to verify the converter proposed, the chip NCP1207 which is produced by On Semiconductor Company is adopted to control the converter. 7N60B is selected to be the main switch Q , and $D5\sim D7$ is F8L60.

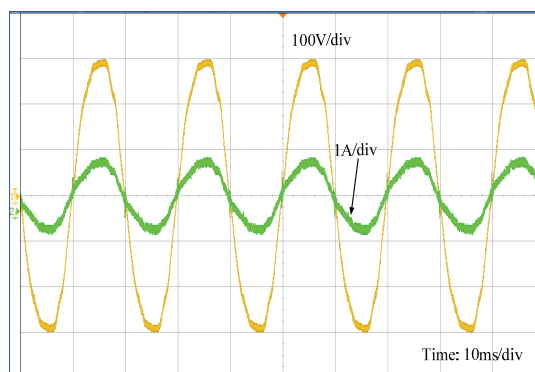


Fig. 3. Input voltage and input current

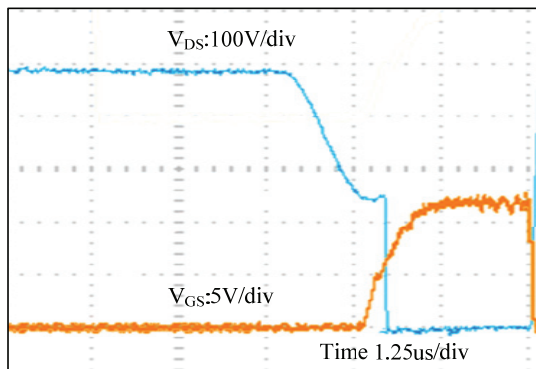


Fig. 4. Waveforms of V_{DS} and V_{GS}

Table 1. Test results of the converter

Output power(W)	Efficiency (%)	Power factor	THD
30	78	0.991	9
40	78.5	0.991	7.8
50	80	0.992	7.1
60	81	0.993	7.2
70	81.5	0.993	7.3
80	82	0.991	7.5
90	83	0.992	6.8
100	83	0.992	6.9

The experimental results are shown as follows. Fig.3 shows the waveforms of the input voltage and the input current, it's evident that the input current can follow the input voltage correctly. Fig.4 shows the waveforms of V_{DS} and V_{GS} , then Q is turned on in the time when the first valley of V_{DS} comes, the switch is turned on in the ZVS state. Table.1 shows the test results in the experiment. When the output power ranges from 30W to 100W, the power factor is always higher than 0.99, THD is within 10%, and the efficiency is higher than 78%.

Conclusion

The letter proposes a novel single-stage AC/DC converter, the converter is obtained by integrating the sepic

circuit and the flyback circuit and sharing with one switch. Since the switch works in the ZVS state, the switching losses decrease which improves the efficiency of the system. Since there is only one power stage, the costs decrease while the reliability increases. In the experiment, a 100W prototype proves the rightness of the analysis above, and the efficiency is as high as 83% in full load.

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