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Design and simulation of AC-DC constant current source with high power factor

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The design of high reliability, high efficiency, high power factor and low cost is the development trend of the current switching power supply. Traditional switching power supply, input current of rectifier filter circuit, which contains a large number of harmonics, will cause the power utilization efficiency decreased, low power factor and so on. In this paper, flyback topology with capacitor-less is used. The flyback switching converter controlled by ARM is designed for power factor correction, and its working principle is analyzed in detail. It can reduce the impact of high input ripple voltage caused by capacitor-less on the output voltage ripple and achieve constant current source, and to obtain high power factor by using program algorithm. Matlab/Simulink is used to verify the design, and the simulation results show that the scheme is feasible.

Keywords: Power factor correction; Flyback converter; Constant current source.

1. Introduction

In the field of traditional switching power supply, after the rectifier bridge is the electrolytic capacitor. These nonlinear elements make the AC input current waveform distorted, and produce harmonic interference, and reduce input power factor [1-2]. In order to improve power factor, reduce the current harmonic, there are two main methods at present: (1) Passive power factor correction [3]; (2) Active power factor correction [4-6]. This paper describes the design of a flyback AC/DC constant current source without input electrolytic capacitor, which generates the drive pulse control switch by ARM to reduce the output current ripple, to increase the input power factor, and to achieve the purpose of constant current output.

2. System composition and Working principle

High power factor AC-DC constant current source system composition diagram is shown in Figure 1. The system is composed of EMI circuit, auxiliary power circuit, flyback converter circuit, output rectifier filter circuit, output voltage sampling circuit, input voltage sampling circuit, ARM control circuit, and transformer isolation drive circuit.

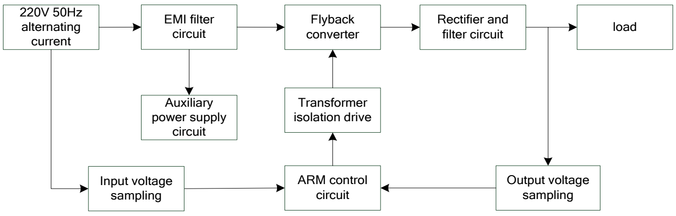


Fig. 1 system composition block diagram

220V, 50Hz, AC input through EMI filter circuit, which filter out interference signal. After rectification, the alternating current is changed into DC impulse voltage, One circuit enters into the flyback converter circuit and reduces voltage to supply the load, another circuit enters into the auxiliary power supply circuit to produce two auxiliary voltage. Two auxiliary voltages are supplied to system chip and control chip. ARM sampling the input voltage and the input current, and through program can produce PWM wave with adjustable duty ratio, which get through the isolation driving circuit to control flyback converter switch turn-on and turn-off, to achieve power factor correction and constant current output.

3. System design

3.1 Control strategy

When the flyback converter has no input filter capacitor, schematic diagram is shown in figure 2:

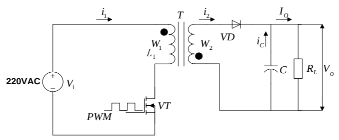


Figure. 2. The schematic diagram of flyback converter.

Flyback converter is working in the DCM mode, the input voltage is high pulse voltage, during the switch conduction period, high pulse input voltage acting on the inductor, has the following relationship, as in Eq. (1).

$$L_1 \frac{dT}{dt} = U_m \sin \omega_o \tag{1}$$

L_1 is the primary side of the transformer inductance, i_{L1} is transformer primary side current, U_m is the peak value of input voltage,ω_0 is power angle frequency, when the chopping frequency is much higher than the power frequency, during the switch tube conduction time, the input AC voltage can be considered unchanged. Integrating the two sides of the Eq. (1), we can get a formula about peak current I_{ip}, as in Eq. (2).

$$I_{iP} = \frac{dT}{L_1} U_m \sin \omega_o t \tag{2}$$

d is the switch duty cycle, d=ton/T, T is the chopping cycle, flyback converter is working in DCM mode, at the end of the switch tube conduction time, energy storage in the L_1 is W_i, as in Eq. (3).

$$W_i = \frac{1}{2} L_i I_{iP}{}^2 \tag{3}$$

The average input power from the above formula is P_i, as in Eq. (4).

$$P_i = \frac{d^2 T}{2L_1} U_m^2 \sin^2 \omega_o t \tag{4}$$

Output power is P_o, as in Eq. (5).

$$P_o = U_O I_O \tag{5}$$

By the total power conservation, $P_i\eta = P_o$, simultaneous equation (4) and (5), d can be get, as in Eq. (6).

$$d = \frac{1}{U_m \sin \omega_o t} \sqrt{\frac{U_o I_o * 2L_1 * f}{\eta}} \tag{6}$$

U_o and I_o are the set value, L_1 and f are hardware parameters, which can be considered constant value, d and $U_m \sin\omega_o t$ are inversely proportional, according to the duty cycle and the input sinusoidal voltage, the duty cycle is the smallest when the input voltage is maximum, the duty cycle is the maximum when the input voltage is smallest. According to the input voltage and duty relationship, write control program, after sampling input voltage and output voltage into ARM, through the procedure produces variable duty cycle pulse to control the main circuit switch of flyback converter in DCM mode, the output voltage ripple of the flyback converter without input filter capacitor is controlled to achieve the purpose of the constant current output.

3.2 Program Design

The system program flow chart is shown in Figure 3, ARM is used as the main control chip. After system power on, the initial duty cycle D_0 is given, then output voltage and input voltage are sampled, then read it, and judge whether open circuit, if the system is open circuit ,output duty ratio D is 0,and turn off the flyback converter main switch, if not, the program continue to run. By calculating, get the corresponding duty ratio of PWM wave with different width, by isolating drive circuit control the flyback converter switch, then continue to read the AD conversion results, followed by reciprocating, the normal running of the program.

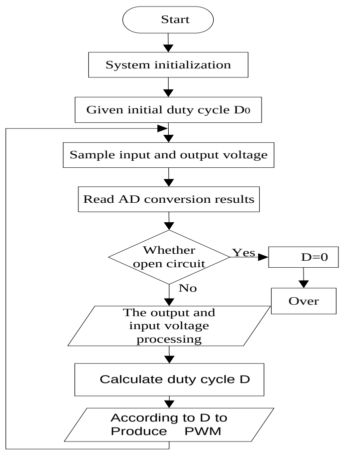


Fig.3 System program flow chart.

3.3 Hardware parameter design

Single-stage flyback converter’s input voltage range is 175V-265V, frequency is 50Hz, output voltage is 28V-38V and output current is 2.1A. The choice of reflection voltage V_{or} is 270V, .D=0.5, the ferrite core EC-35 can be used to design the flyback converter transformer, because the output power of the constant current source is 59W-80W. As Eq(7).

$$I_p = \frac{2P_o}{V_{in\min} D_{\max} \eta} \tag{7}$$

The V_{inmin}=175V in the formula, so I_p=2.18A. It is generalized from inductance calculation formula, as Eq(8).

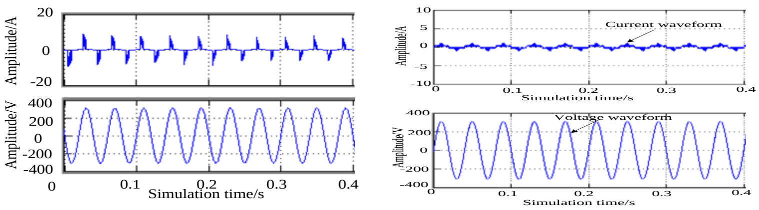
$$L_p = \frac{2P_o T}{I_p^2} \tag{8}$$

T is switching tube period. Bringing current and maximum output power of 8th calculating formula into 9th calculating formula, we will get Lp=765uF. The number of turns is calculated as Eq(9).

$$N_p = \frac{L_p I_p * 10^{-8}}{A_p \Delta B} \tag{9}$$

Ap is the cross section area of the transformer core, The Ap of EC35 core is 112mm2, △B is calculated by the general 0.25T, from 10th formula, the primary side is 63 turns. According to the calculation of reflected voltage, turns ratio is 7, so the vice side is 9 turns.

4. Simulation and verification



(a) (b)

Fig.4. Waveform of input voltage and the input current with capacitor and capacitor-less.

Based on the above parameters, the circuit with capacitor is carried out by Simulink. When input sinusoidal voltage gets through the rectifier filter circuit, the waveform of input voltage and input current are shown in Figure 4(a). Current waveform presents spike pulse shape, due to the lower power factor. This kind of current contains a large number of high harmonics, when flowing through the power grid, it will cause serious harmonic pollution, the voltage waveform distortion, even can cause the electric equipment heating damage.

After removing the input filter capacitor, in accordance with the new control method, the simulation waveforms are shown in Figure 4(b), the phase of the input current is similar to the input voltage, the power factor close to 1. The waveform of the output current is shown in Figure 5, the ripple is only 56mA. The designed output current target is 2.1A, and the stability of the constant current is 1%. Stability is higher than the market products, the result achieved the constant current effect, and simulation results verify the feasibility and integrity of the design ideas.

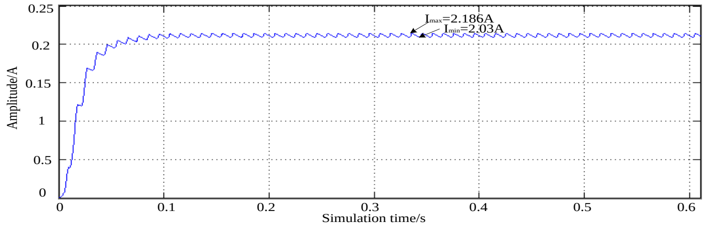


Fig.5. Waveform of the output current

5. Conclusion

This paper introduces the flyback converter with capacitor-less, It works in DCM mode to realize power factor correction, then using ARM programming to reduce the impact of input high pulse voltage on the output voltage ripple and achieve a stable output voltage. Finally, according to the hardware design parameters of the system and using Matlab/simulink to complete the simulation design. From the simulation results, it can be seen that the input voltage phase is the same to the output current and the power factor is close to 1, and the stability of current source's output current is high, to achieve the goal of power factor correction and output constant current.

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