The Design of AC-DC Converter Based on Double Closed Loop PFC

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Abstract. Based on the requirements of switching power supply design and application, this paper proposes a PFC AC-DC voltage stabilized power supply with two closed loops of current and voltage as the core. The modeling and analysis results show that the power factor is over 99% and the output DC voltage has high stability. The circuit has certain application and popularization value.

Keywords: Double Closed Loop Control, Boost Boost Circuit, Pfc

1. Introduction

With the development demand of energy saving and emission reduction and AC/DC converter, high power and low system loss and miniaturization have become its main development trend. Switching power supply has been widely used in many occasions because of its high working frequency and low loss. This paper analyzes and designs a AC-DC converter with high power factor by the method of single stage power factor correction. Through reasonable design of inductance, capacitance and voltage and current double closed loop controller, the AC-DC rectifier boost voltage regulator circuit function with power factor correction link is effectively realized. The feasibility and effectiveness of parameter design are verified by modeling and analyzing the AC/DC converter with MATLAB.

2. Overall system design

The main topology of switching power supply is transformed by three basic structures: boost, step down and lift voltage. In this design, the Boost converter is implemented by adding PFC control circuit. Boost converter is mainly caused by inductance to increase load voltage and capacitance to keep load voltage, so the output voltage of circuit can be higher than input voltage. Therefore, the key technology lies in the power factor correction (PFC), the voltage and current as the control target, and the dual closed loop control mode of current control loop and voltage control loop is selected. Among them, the inner loop is a current control loop, which makes the input current waveform close to sine wave, and is in the same phase as the input voltage signal, and the outer loop is a voltage control loop, so that it can maintain a stable voltage output. And has a good transient response. The overall block diagram of the designed AC-DC converter with double closed loop PFC is shown in figure 1. It is mainly composed of rectifier circuit, Boost boost circuit, voltage and current closed loop controller.
3. Main Link Design

3.1. Boost boost circuit

Compared with the topology of boost chopper circuit is relatively simple compared with the topology of other commonly used switching power supply. The input current can be easily adjusted by adjusting the inductance connected to the input end of the circuit. So the main circuit topology is composed of diode rectifier bridge and Boost boost chopper circuit[5].

![Figure 2. Main circuit topology.](image)

(1) MOSFET switching frequency is set to 20 kHz.; and The effective value Us the input voltage is 20-30 V, the output voltage is 36 V, the output current is 2 A, so the output power is 72 W.

(2) The determination[6] of inductance L and capacitance C:

Calculation of Inductance ripple current $\Delta I_L$

$$\Delta I_L = \frac{P_{out}}{\eta U_{inmin}} \gamma \sqrt{2} \tag{1}$$

Above, $U_{inmin}$ is the minimum effective voltage for input, get 20V; Efficiency $\eta = 0.9$; $\gamma$ is the current ripple rate of the inductor current, get 10%.

Calculation of $D_{min}$ Minimum duty cycle

$$D_{min} = 1 - \sqrt{2} \frac{U_{inmin}}{U_{out}} \tag{2}$$

Above, $U_{out}$ Represents the output voltage of the boost converter, take 36V.
Calculation of Inductance \( L \)
\[
L = \frac{U_{in\min}}{\Delta i f_{SW}} \sqrt{2D_{\min}} \tag{3}
\]

Above, \( f_{SW} \) is the operating frequency of the switch, take 20KHz.

Calculation of Capacitance \( C \)
\[
C \geq 2P_{out} \left( \frac{t_{hiu}}{u_{out} - (u_{out} - u_{drop})} \right) \tag{4}
\]

Above, \( u_{drop} \) is the voltage drop of the output voltage during the holding time, \( t_{hiu} \) the holding time, is 100ms.

Through the above calculation, we can get :0.53 mH, where 0.6 mH; capacitance is taken \( C \) considering the requirement of 10 times critical value and voltage stable output effect, it is more appropriate to take 20 mF.

3.2. Design of Dual Closed Loop PFC Controller

(1) Tracking control mode of current inner loop

The control methods of DC current include current peak control, average current control, predictive current control, fuzzy control, current hysteresis tracking control and so on. The current hysteresis control is based on the current peak control and the hysteresis logic control, and then the upper and lower thresholds are used to control the on-off of the switch tube. The current replacement control mode is relatively simple, easy to realize and robust.

(2) PFC circuit structure design

PFC circuit structure design adopts the PFC model of analog control. When used Boost the circuit works in the mode of continuous conduction. At this time, the input current is equivalent to the inductance current, which is sampled and controlled. Its amplitude is proportional to the sinusoidal signal of the same phase input voltage. The current hysteresis tracking control is added to the voltage loop, and the multiplier circuit is used to control the sinusoidal reference current signal, and the output voltage can be adjusted. Through calculation, \( K_p = 0.13 \), \( K_i K_p = 2.04 \).

![Figure 3. PFC Circuit structure block diagram.](image)

4. System Simulation and Debugging

According to the designed circuit parameters, a model is built in the simulation software for modeling and analysis. The input power supply voltage is set to 24 V, to adjust the load and carry out simulation test.
Figure 4. Simulation model of PFC AC-DC circuit with double closed loop.

(1) When the Uo peak voltage is 24 V, and the load resistance is equal to 18Ω, the steady-state waveform after 1 s is selected and the output is stable 36 V voltage.

Figure 5. AC-DC circuit of double closed loop PFC Ω18 simulation waveforms.

(2) When the Uo peak voltage is set to 24 V, and the load resistance is adjusted to 100Ω, the steady state waveform after 2.2 s is selected and the output is V voltage.
5. Conclusion
A set of AC-DC switching power supply is designed by using current and voltage double closed loop control in this paper. The modeling and simulation results show that the power factor of the system is over 99% and has a relatively stable voltage output, which realizes the expected design goal. At the same time, the system can be designed according to the needs of parameters to meet the needs of different occasions such as new energy vehicles, LED power supply and so on.

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