Research on Boost-Buck High-efficiency Semiconductor Lighting Driving Based on OCC Feedforward Technology

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Abstract. Semiconductor lighting has the characteristics of energy saving, high efficiency, long life and environmental protection. It is the product of “green lighting” and semiconductor luminescence technology, and CUK converter is widely used in semiconductor lighting drive. In this paper, the main features of CUK main circuit are discussed, and a new CUK high power and high efficiency semiconductor lighting control scheme is proposed, that is, the CUK drive system controlled by OCC feedforward technology. Then, the author makes a deep research on its work dynamics, such as SIMULINK and SIMPOWERSYSTEMS and other tools simulation analysis, and the corresponding relationship expression of its system dynamic performance is derived to achieve that the system has the characteristics of high efficiency, fast response, strong anti-interference and so on.

Introduction

CUK converter is also known as Boost-Buck converter, as shown in Fig. 1. It is one of the best topologies in semiconductor lighting drives, and is widely used [1-6], with both boost and buck output, maintaining the continuity of Boost-type converter input current with a wide input voltage range. It can easily achieve boost or buck by changing the duty cycle of the switch. Through serial in two inductors, the exchange ripple wave value becomes smaller, in practice, electromagnetic interference (EMI) filter does not need to be added. The drive system is small and the voltage is stable. Based on the traditional control, this paper presents a new scheme, OCC feedforward drive system.

Figure 1. Schematic diagram of CUK convertor

Basic Ideas and Implementation Scheme of OCC Feedforward Control

At present, most of the drive control is to linearize the obtained model equation firstly, and then use a feedback loop to control [7-10]. The OCC control technology is shown in Fig. 2. However, due to the dynamic characteristics of the filter, the controlled output voltage will be disturbed, and its anti-load disturbance capability is weak, and the power factor of the whole converter may decrease at light load. In view of these problems, this paper proposes OCC feedforward control

improvement strategy, as shown in Fig. 3.

Figure 2. Control strategy of CUK convertor for traditional OCC

Figure 3. Feedforward control improvement strategy of CUK convertor based on OCC

As can be seen from the figure above, the sampling voltage is taken from the system output voltage and a feedback signal at input terminal is added. OCC feedforward control improvement strategy using voltage feedforward control technology, the input voltage V_r is converted to get the synchronous current i_f signal, which is added with the input current i_r signal and sent to the comparator with the integrator output signal together, generating switch tube driver signal through RS trigger. The control strategy is changed from sampling of converter for the input voltage to the current signal i_f , which can effectively reflect the disturbance of the input voltage. The disturbance of input voltage can be suppressed by the adjustment of single cycle. If the input voltage v_r has a pulse transition, the current signal i_r obtained by the converter will produce a pulse ripple, and the output voltage will become larger, the feedback voltage signal V_f will fluctuate, which will increase the integral slope of the integrator, integration time will decrease, the duty cycle will be reduced accordingly, and the voltage has been stable output, to ensure a good anti-interference ability.

Analysis under the conditions of the previous assumption, the working waveform is shown in Fig.

4. Set a converter conversion rate k_b , that is $i_f = v_r k_b$, the following equation can be got by the working waveform:

$$v_r = L_s \frac{\Delta i_r}{T_s} + (i_r + i_f) \frac{V_f}{V_m} \quad (1)$$

Where L_s is equivalent inductance, Δi_r is the peak current variation within single cycle.

Figure 4. Work waveform based on OCC feedforward control improvement strategy

The equation below can be obtained combining $i_f = v_r k_b$ and the assumed conditions aforesaid:

$$v_r \left(1 - \frac{V_f}{V_m} k_b \right) = i_r \frac{V_f}{V_m} + L_s \frac{di_r}{dt} \quad (2)$$

Which can simplified as:

$$i_r = \frac{v_r \left(1 - \frac{V_f}{V_m} k_b \right)}{\frac{V_f}{V_m} + j\omega L_s} \quad (3)$$

From the equation above, the introduction of convertor conversion rate k_b reduces the effect of error amplifier output on the entire system, also achieves precise adjustment of the output voltage to overcome the deficiency of traditional converter and improve the performance of system in light load characteristics and power factor, as well as improves the anti-load disturbance capability. If the output feedback voltage V_f is much larger than the error signal, and the error signal is equal to the conversion rate, the impact of error signal can be ignored, that is the effect of error signal on the entire drive system is completely eliminated.

Simulation Results and Analysis

In order to verify the validity of feedforward control improvement strategy of CUK converter of OCC, SIMULINK and SimPower Systems tools in MATLAB software are used to set up CUK main circuit simulation model. The input voltage is sinusoidal 220V, 50Hz AC voltage, the load LED resistance is 20Ω, the output voltage is set to 20V, the capacitance C is 0.1μF, the inductance L_1 is 2.7mH, the output capacitance C_o is 470μF, the inductance L_2 is 300μH, the sampling resistance R_2 is 50kΩ, the sampling resistance R_1 is 150kΩ, the clock signal switching frequency is 20KHz. From the waveform in Fig. 5, it can be seen that the input current tracks the input voltage well, and the input current and input voltage distortion is very small, the overall system power factor is large and system utilization efficiency is high.

Figure 5. Work waveform of input voltage and current

In order to verify the input interference resistance ability of feedforward control strategy of CUK converter of OCC, in the system input voltage end, superimpose 10V, 100Hz sinusoidal signal and 12V, 25Hz square wave signal, and then observe the output voltage waveform. As shown in Fig. 6 and Fig. 7, it can be seen that the change of input voltage has no effect on the output voltage waveform, and the dynamic performance of system is very good. It shows that the OCC feedforward control improvement strategy has good input interference resistance ability.

Figure 6. Work waveform under input voltage superposition 10V, 100Hz sinusoidal signal

Figure 7. Work waveform under input voltage superposition 12V, 25Hz square signal

In order to verify input interference resistance ability of feedforward control strategy of CUK converter of OCC, let the load LED equivalent resistance jump, the load current changes from 1A to 0.8A suddenly. As shown in Fig. 8, the output voltage also has a large mutation, but after a short period, it restores smooth output. We can see OCC feedforward control improvement strategy has a good anti-load interference.

Figure 8. Workflow for load current changing from 1A to 0.8A

Conclusion

In this paper, CUK topology-related features are discussed in detail, and a new CUK efficient drive control principle and scheme is proposed, that is, a large-signal nonlinear dynamic control-OCC technique is used to construct the CUK topology semiconductor lighting drive system, SIMULINK and SIMPOWERSYSTEMS software is used to simulate, and the corresponding dynamic relationship expression of the system work is deduced, and the advanced nature of the system, such as fast response, strong anti-interference and good stability are demonstrated.

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