Design and simulation of DC regulated circuit for current source input type based on Tina-TI

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Abstract. In the multi-output high-voltage isolated power supply for solid-state switches, LCL resonant network is used to obtain the constant current source on the bus, and the bus current is independent of the load. Therefore, the secondary side of the toroidal transformer needs to use the current input voltage regulator circuit. When the input is a current source instead of a voltage source, the traditional voltage regulator circuit is no longer applicable. Therefore, this paper focuses on the study of dc voltage regulated circuit with current source input. Compared with the traditional linear regulated power supply, switching power supply has the advantages of high efficiency, large output power, small size, light weight and low cost. In this paper, pulse width modulation (PWM) technology is used to control the switching on and off, and UC3843 is used to design a switch type regulated power supply with small size, simple circuit, adjustable output and over voltage protection function. Tina-TI software was used for simulation analysis, and the main circuit and control circuit were built. The current source of 1.25A and 40kHz output by the secondary side of the toroidal transformer is converted into a stable 10V DC voltage source, which verified the correctness of the design. Tina-TI software can be used to analyze and design power supply with different requirements, improve power efficiency, reduce design complexity, and thus shorten development cycles.

1. Introduction
In HVDC transmission system, the solid-state switch part needs to use several solid-state switches in series, and several solid-state switch drivers in series need to be isolated for power supply. The LCL resonant network is used to obtain the high-frequency current source, and then the toroidal transformer is used to pick up the power from the current bus [1]. The switching power supply on the secondary side of the toroidal transformer needs to convert the voltage suitable for the solid-state switch drive circuit. At present, switching power supply is mainly used in some common electronic equipment in daily life. It is characterized by small size, good reliability and high efficiency, and has gradually developed into an indispensable power supply equipment in the contemporary electronic information industry [2-3].

The switching power supplies use different topologies to convert input voltages to output voltages required by various devices. In power electronics, there are many topologies of switching power
supply, common circuit topologies are forward converter, flyback converter, push-pull, full bridge and half bridge, etc [4-6]. In [7], a new design of multi-output flyback switching power supply is proposed, which uses pulse width modulation (PWM) technologies. The power supply has protection circuits such as voltage stabilization, short circuit protection, over-current protection and feedback compensation, etc. Which can enhance the safety and reliability of the power supply, but the circuit design process is relatively complex. In [8], the DC voltage regulated circuit was simulated by Multisim software, which was used to design and verify the switching power supply, so as to save costs and reduce workload. The expected effect could be achieved under certain conditions, but MCU level simulation could not be carried out.

In this paper, because the input is the current source, the traditional voltage regulator is no longer applicable, so a novel voltage regulator is proposed for the current source input. UC3843 is adopted as the control core, Tina-TI software is used to build the main circuit and control circuit, and a power supply is designed to convert current source (1.25A and 40kHz) into 10V dc voltage source. Tina-TI software is used to design and verify the switching power supply, so as to save costs and reduce workload.

2. Circuit structure and principle

The general structure of the circuit was introduced in section 2.1 and the circuit principle was analyzed in section 2.2. In Section 2.3, the self-starting circuit and protection circuit using UC3843 as control core was designed.

2.1. The whole structure of the circuit

The switching type stabilized voltage power supply designed in this paper for current source input is composed of a full-bridge rectifier module, a circuit topology similar to boost converter, an over-voltage protection circuit, and a filter circuit, as shown in Figure 1.

![Figure 1. Block diagram of the entire design.](image)

The main working principle is as follows, the current source becomes dc pulsating current after the full-bridge rectifier, and becomes dc voltage with constant amplitude after PWM control module and capacitor filtering. The topology of main circuit is similar to the boost circuit [9]. Output voltage is input to the UC3843 core through a simple feedback loop to control the turn-on and turn-off of the switch, so as to realize the function of voltage regulation by controlling the duty ratio of the switch gate signal. The output of the power supply has an over-voltage protection circuit. When the load needs a small power, if the switch cannot bypass all the input current, the output voltage will rise. At this time, the over-voltage protection circuit will play a role, so that the output will not produce over-voltage.

2.2. Circuit principle analysis

The structure diagram of the switching regulator circuit suitable for the current source input is shown in Figure 2. i is the high-frequency sinusoidal current source, D1-D4 constitutes the full-bridge rectifier module, M is the switching tube, D is the diode, C is the filter capacitor, Uo is the output voltage and RL is the output load.
Figure 2. The diagram of switching type voltage regulated circuit for current source input.

Figure 3 shows the simplified topology of voltage regulated circuit and its working state. Figure 4 shows the operation waveform of the main circuit when switch turn-on and turn-off, and the basic working principle can be divided into the following two modes.

![Figure 3](image_url)

Figure 3. The simplified topology of voltage regulated circuit and its working state.

![Figure 4](image_url)

Figure 4. Operation waveform of voltage regulated circuit.

1) Mode 1 [t0-t1]. When the output voltage is lower than the reference voltage, the switch M is in the off state. The current source charges capacitor C through diode D, and supplies the load at the same time. The current on the capacitor C and the current through the diode D are shown in the following formula respectively

\[ i_c(t) = C \frac{du_o(t)}{dt} = i_i(t) - \frac{u_o(t)}{R} \]  

(1)

\[ i_i(t) = i_1(t) \]  

(2)

2) Mode 1 [t0-t1]. When the output voltage is higher than the reference voltage, the control circuit sends a gate signal to switch M, the current source is in a short circuit state, and capacitor C provides
power for the load. When the switch M is turn-on, the current on the capacitor C and the current through the diode D are respectively

\[
i_c(t) = C \frac{du_c(t)}{dt} = - \frac{u_c(t)}{R_L}
\]

(3)

\[
i_i(t) = 0
\]

(4)

2.3. Design of self-start circuit and protection circuits for UC3843

UC3843 is a control chip of current-type pulse width modulation, with double-loop feedback control capability of voltage and current [10]. Its duty ratio up to 97%, starting threshold voltage of 8.4V, normal working voltage of 7.6-30V, maximum oscillation frequency of 500kHz. At the same time, UC3843 has the characteristics of simple connection and high reliability, so UC3843 is selected as the control core of the voltage regulator circuit.

The self-starting circuit of the control chip of the traditional voltage type DC-DC converter has been relatively mature [11]. For example, as shown in Figure 5, the start-up process of the chip is as follows. The input voltage is charged for C1 and C2, when the voltage rises to a certain value, zener diode Z1 is used to stabilize the voltage and the chip is started. When the circuit is in normal working state, the output voltage of the main circuit is used to supply power to the chip, and the voltage is higher than the voltage on capacitor C1. Because the diode D1 reverse blocking effect, effectively prevents current recoil.

![Figure 5. The self-starting circuit of the traditional voltage regulated circuit regulated circuit.](image)

This paper designs a voltage regulated circuit suitable for current source input. Since the input is a current source rather than a voltage source, the current source will charge the capacitor directly before the circuit is working properly. Especially when the load requires a small amount of power, if the control chip is not started in time, the switch M will not work normally, resulting in extremely high output voltage (open current source) and damage to the whole circuit.

Therefore, the zener diode Z, resistance R and triode Q are used to form the over-voltage protection circuit. When the output over-voltage is detected, the current source is directly short-circuited to make the voltage drop, so as to protect the whole circuit. The circuit structure is shown in Figure 6. The number of components in the starting circuit is few, which improves the efficiency of the circuit.
Figure 6. The structure diagram of self-starting circuit for voltage regulated circuit.

The protection circuit of traditional voltage type DC-DC converter is as follows, when over-voltage is detected, the switch is turned off and the converter is turned off. In converters where the input is a current source, this method is no longer applicable. If the switch is turned off, the input current will continue to charge the capacitor, resulting in more severe over-voltage. Therefore, the protection circuit in this paper is designed to short-circuit the input current source when over-voltage is detected, thus playing a protective role.

3. Simulation analysis
In this paper, Tina-TI software of Texas Instruments is used to design the voltage regulated circuit. In the simulation, the circuit model of UC3843 is adopted, the main circuit and control circuit are built, and the output voltage is controlled by setting the value of the feedback resistor. Table 1 shows the main parameters of the simulation circuit.

| Parameter                        | Value  |
|----------------------------------|--------|
| RMS value of input current $I_{in}/A$ | 1.25   |
| Frequency of input current $f$/kHz | 40     |
| Switch $M$                       | IRF520 |
| Control chip                     | UC3843 |
| Filter capacitor $C_0$/uF        | 1000   |
| Output voltage $U_o/V$           | 10     |
The main circuit is shown in Figure 7(a). The effective value of setting the current source is 1.25A and the frequency is 40kHz. The voltage regulated circuit based on UC3843 is used to obtain the DC output voltage of 10V. According to the UC3843 data tables set up CT=1nf, RT=8.6kΩ, to control the output frequency of the PWM waveform is 200kHz. The start up threshold voltage of the UC3843 is about 8.4V, which realizes the self-start and self-power supply of the chip, so the output dc voltage of the voltage regulated circuit should be greater than 8.4V. By setting the value of feedback resistors Rf1 and Rf2, the output dc voltage of the voltage regulated circuit is 10V, and the supply voltage of UC3843 obtains power from the output voltage of 10V. The simple PI compensation controller and the control circuit based on UC3843 are shown in Figure 7(b).

In Figure 8 and Figure 9, the simulation waveform is the input current source (Iin/A), the voltage at both of the current source (Vin/V), the drain source current of IRF520 (IDS/A), the gate voltage of IRF520 (VGS/V), the feedback voltage value of FB pin of UCC3843 (VFBIN/V), and the output voltage after voltage regulator (VOUT/V), respectively.

Combined with Figure 8 and Figure 9, the input current remains unchanged. With the reduction of the power required by the load, more input current will be bypassed by the switch M, and the input power will also be reduced, thus improving the circuit efficiency. It can be seen from the simulation waveform that the voltage regulated circuit based on UC3843 can output 10V dc voltage stably under different loads. When the load is 10Ω, the peak-peak value of the output dc voltage ripple is 30mV. When the load is open, the peak-peak value of the output dc voltage ripple is 50mV. The ripple coefficient of the output voltage is less than 1%, which meets the design requirements.
4. Conclusions
In this paper, Tina-TI software is used to design a switch type stabilized voltage power supply suitable for current source input. The power supply can convert the current source picked up from the current bus into a stable DC voltage. The main circuit topology and control circuit are given, and UC3843 is selected as the control core. Tina-TI was used for modeling and simulation, and the output voltage of the power supply could stabilize at 10V under different loads, which met the design requirements. It can be seen from the simulation that Tina-TI software has a powerful simulation function and is simple to use. It greatly improves the research efficiency and provides guidance for the actual production of stabilized voltage power supply. Thus the development cost is effectively saved.

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