S4–05

Analysis and Parameter Selection Method of New Boost DC–DC Converter with High Step–Up Ratio

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Summary

This paper proposes the operating principle and characteristic of the H–type boost DC–DC converter with high step–up ratio. It makes clear the relations between the current and voltage, and describes the selection method of elements for the H–type boost DC–DC converter. And also it provides the simulating results by using LT spice and experimental results of its device.

Keywords: Component; parameter selection; boost DC–DC converter; step–up ratio

1. Introduction

There are numerous converter structures to raise the output voltage by stepping–up an input voltage. But in these converters the step–up ratio may be ideally raised to infinity, whereas it is practically limited to 1.5 to 3.

In application it is often necessary to boost a relatively low input voltage (e.g. batteries, fuel cells or solar panels) to a higher output voltage (e.g. to supply the single–phase or 3–phase inverter) [3, 6]. Thus DC–DC converters with higher ratio are widely being studied now. The cascade boost DC–DC converter [2, 4] and the hybrid DC–DC converter are suggested to raise the step–up ratio [1, 5]. This paper suggests a new H–type boost DC–DC converter with high step–up ratio, and analyzes the operating principle and the relation between the voltages and the currents. It provides the simulating results by using LT_spice and experimental results of its device.

2. Basic analysis

The diagram of a new H–type boost DC–DC converter is shown in Fig.1. It consists of three active switches, one diode, two inductors and one capacitor. On the output of the converter there can be a voltage source or a capacitor in parallel to the load. To study the basic function of the converter assume that active switches are ideal devices and operate under continuous current mode (CICM), the circuit is in steady state, and the capacitors are large enough so that the voltage across it can be taken constant. In continuous current mode the converter has two modes. In stage 1, S_1 and S_3 are turned on and S_4 is turned off. The voltage across L_1 is the input voltage U_1 and the voltage across L_2 is U_C. The currents in both inductors are increased. When S_1 and S_3 are turned off, we must turn on S_4.

Now the voltage across L_1 is U_1–U_C and across L_2 it is UC–U_2. Both voltages are negative and therefore the currents in the inductors are decreased.

With the voltage–time–balance across the inductors we can express as follows.

$$U_1 \cdot d \cdot T = |U_1 - U_C|(1-d)\cdot T \qquad (1)$$

$$U_C \cdot d \cdot T = |U_C - U_2|(1-d)\cdot T \qquad (2)$$

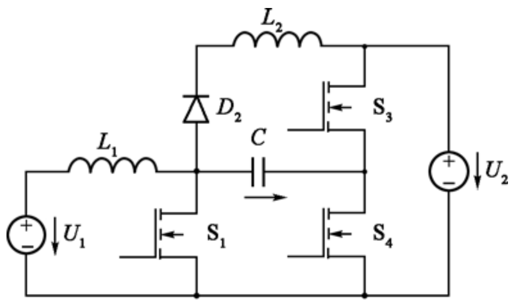

Figure1. Diagram of the H–type boost DC–DC converter

From Eq. (1) and (2) we can get the relation between the output voltage U_2 and the input voltage U_1 as follows.

$$U_2 = \frac{1}{(1-d)^2}U_1 \qquad (3)$$

The capacitor voltage of the converter is represented by

$$U_C = \frac{1}{(1-d)}U_1 \qquad (4)$$

The voltages across the semiconductor elements are given as

$$U_{S_1,\max} = U_C = \frac{1}{(1-d)}U_1 \qquad (5)$$

$$U_{S_3,\max} = U_2 = \frac{1}{(1-d)^2}U_1 \qquad (6)$$

$$U_{S_4,\max} = U_2 = \frac{1}{(1-d)^2}U_1 \qquad (7)$$

$$U_{D_2} = -(U_2 + U_C) = -\left[\frac{2-d}{(1-d)^2}\right]U_1 \qquad (8)$$

Eq. 5~7 show that voltages across both active switches S_3 and S_4 are higher than the voltages across the active switches S_1. And equation 6 also shows that the highest stress is for the diode D_2. For realizing the system we must choose elements with a voltage about 1, 3 till 2 higher than these values mentioned above in application.

To get a relation for the currents we use the current–time balance through capacitor C and output capacitor.

$$\left|-I_{L_2}\right|\cdot d\cdot T=(I_{L_1}-I_{L_2})\cdot(1-d)\cdot T \tag{9}$$

$$\left|-I_{Load}\right|\cdot d\cdot T=(I_{L_2}-I_{Load})\cdot(1-d)\cdot T \tag{10}$$

The mean values of the inductor currents can therefore be expressed according to the load current.

$$I_{L_1}=\frac{1}{(1-d)^2}I_{Load} \tag{11}$$

$$I_{L_2}=\frac{1}{(1-d)}I_{Load} \tag{12}$$

3. Parameter selection

When the active switch S_1 is turned on the input voltage is across the inductor. The current through L_1 increases as

$$\frac{di_{L_1}}{dt}=\frac{U_1}{L_1}$$

So for a chosen inductor current ripple the inductor L_1 can be taken as

$$L_1=\frac{U_1 d}{\Delta I_{L_1} f}=\frac{U_1}{\Delta I_{L_1} f}\cdot\left(1-\sqrt{\frac{U_1}{U_2}}\right) \tag{13}$$

During the on–time of the active switch S_1 the active switch S_3 is also turned on and the current through L_2 increases as

$$\frac{di_{L_2}}{dt}=\frac{U_C}{L_2}$$

So for a chosen inductor current ripple the inductor can be calculated as

$$L_2=\frac{U_C d}{\Delta I_{L_2} f}=\frac{U_1}{\Delta I_{L_2} f}\cdot\left(\sqrt{\frac{U_2}{U_1}}-1\right) \tag{14}$$

During the on–time of switch S_1 and S_3 the capacitor C is discharged by the current through the second inductor L_2. The voltage decreases as

$$\frac{du_C}{dt}=\frac{-I_{L2}}{C_1}$$

Here I_{L_2} is the mean value of the inductor current.

For a chosen voltage ripple the capacitor can be calculated as

$$C_1=\frac{I_{L_2} d}{\Delta U_{C_1} f}=\frac{I_{Load}}{\Delta U_{C_1} f}\cdot\left(\sqrt{\frac{U_2}{U_1}}-1\right) \tag{15}$$

The output capacitor C_2 is discharged by the load current when S_1 and S_3 are on. Therefore, one gets for the output capacitor

$$C_2=\frac{I_{Load}}{\Delta U_{C_2} f} \tag{16}$$

4. Simulation

A simulation model has been implemented by using LT–Spice. The input voltage is 50°V, the output is around 400°V and the power is 0.5°kW. A frequency of 50°kHz is chosen. Therefore the duty cycle may be about 0.65.

The waveforms of voltage and current of inductors are shown in Fig. 2 and Fig. 3. From the waveforms of simulation the output voltage is around 400V while input voltage is 50V.

The experimental result is shown in Fig. 4.

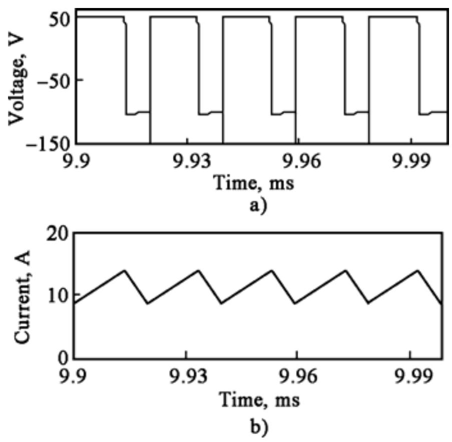

Figure 2. Waveforms of voltage(a) and current(b) of inductor L1

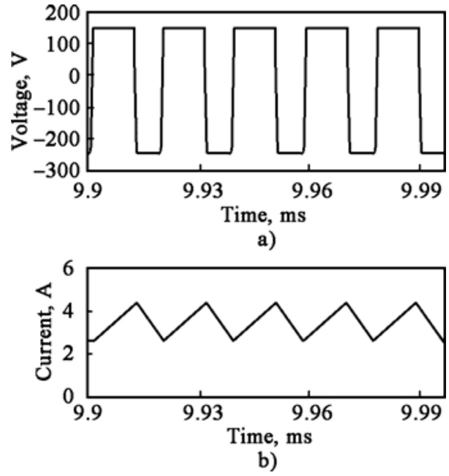

Figure 3. Waveforms of voltage(a) and current(b) of inductors L2

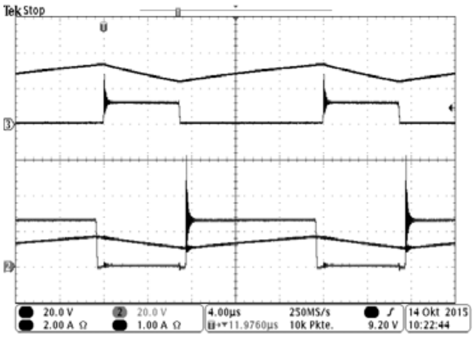

Figure 4. Experimental result

5. Conclusion

This paper suggests a new H−type boost DC−DC converter with high step−up ratio, and analyzes the operating principle and the relation between the voltages and the currents to get the parameter selection method of the elements. Finally it provides the simulating results using LT_spice and experimental results of this device.

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