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Modified Double-Boost DC/DC

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Abstract— In this paper anew boost topology is proposed. The circuit is similar with two parallel boost dc-to-dc converters, but the two inductors are charged in parallel and release energy in series, thus enhancing the voltage boost ratio. After a short analysis of the circuit, a comparative study with other classic boost converter (single boost and double boost converter) is presented. The simulation results show a net improvement of the boost ratio for the new proposed topology.

Keywords—High voltage gain;DC/DC converter;Topology; Efficiency.

I. Introduction

An increased boost factor suits the many emerging applications in the automotive industry,telecommunications industry, IT industry as well as power generation via fuel cells, photovoltaic arrays and wind turbines [1-8]. The basic boost topology does not provide a high boost factor. This has led to many proposed topologies such as the tapped-inductor boost, cascaded boost and interleaved boost converters [5-8]. This paper introduces another variation which provides a higher boost factor and also provides for the possibility to gear up or down thus extending the control range.Although control methods such as fuzzy logic [11], sliding mode control [14] and others [10, 12, and 14] are available, a simple IP controller is used to verify the proposed double -boost topology.

II. PROPOSED SYSTEM

A. BLOCK DIAGRAM

The following is block diagram of the proposed system consisting DC voltage source,Double Boost Converter,Load, Gating signal for MOSFET.

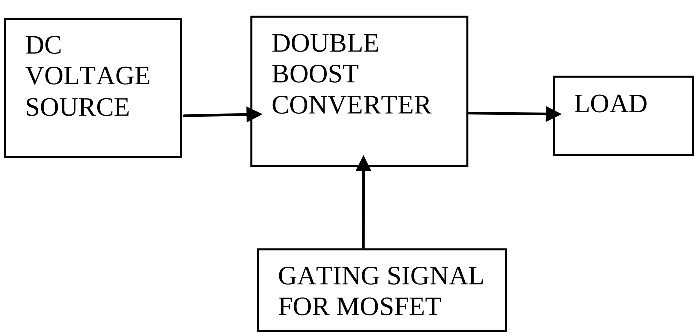

Figure 1. Double-boost converter Diagram..

The proposed double-boost converter is shown in Figure 2. The converter consists of two power switches Q1, Q2, two inductors L1, L2, three diodes D1, D2, D3 and an output filter capacitor C1.Assuming that the inductors L1, L2 are the same, the remaining diodes and metal-oxide-semiconductor field-transistor (MOSFET) switching also have the same parameters. The two switches in the converter are turned on or together, and the two operating modes are shown in Figure 2.

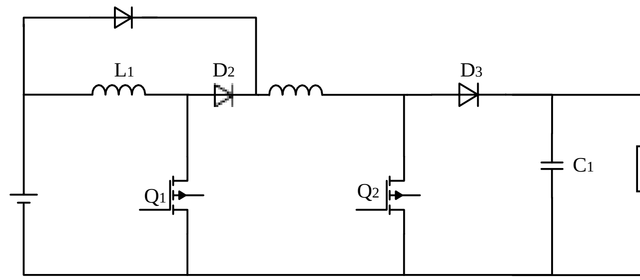

Figure 2. Double-boost converter topology.

B. MODE 1

When switches Q_1 and Q_2 are turned on, that is, the converter is in the ON operating mode, the inductors L_1 and L_2 are charged by the input power source, and the inductors absorb energy; the capacitor C_1 supplies energy to the load. The operating mode of the proposed converter is shownin Figure 2.

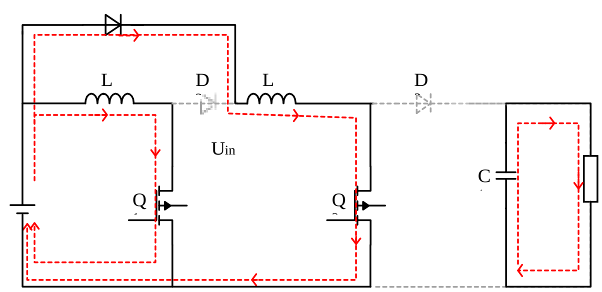

Figure 3. Converter operating mode in ON state.

In this mode, diode D_1 is turned on, and diodes D_2 and D_3 are turned off under reverse voltage. During this stage, there are three loops in the equivalent circuit. The input power U_{in} charges the inductor L_1 through the switch Q_1 to form the first loop. The input power U_{in} charges the inductor L_2 through the switch Q_2 to form the second loop. The output capacitor C_1 provides energy to the load to form the third loop.

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The voltages across the two inductors L_1 and L_2 are the voltages U_{in} of the input voltage power source.

then the turn-on time of switches Q_1 and Q_2 is $D \times T_S$ in one cycle. Suppose that the currents through the inductors L_1 and L_2 are I_{L1} and I_{L2}, respectively. In this stage, the currents of the two inductors are equal, and the energy absorbed by the two inductors in a PWM period is shown in Equation (1).

$$W_L = U_{in} \times I_L \times D \times T_S$$

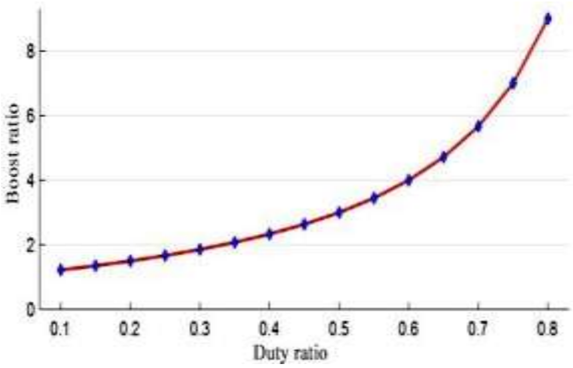

Figure 4. The relationship between voltage gain and duty cycle

where W_L represents the energy absorbed by the inductor during the turn-on period of the switch.

C. MODE 2

When the switches Q_1 and Q_2 are turned off, that is, the equivalent circuit is in the OFF mode, the inductors L_1 and L_2 are connected in series with the input power source to provide energy to the load and charge the capacitor C_1; the operating mode of the converter is shown in Figure 3.

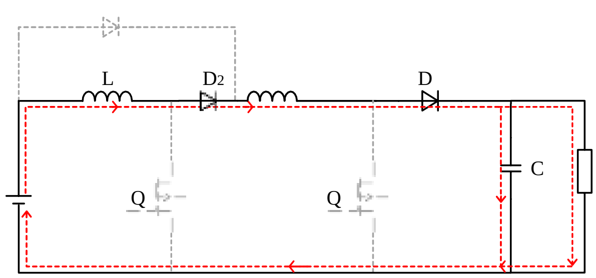

Figure 5. Converter operating mode in OFF state.

In this mode, diodes D_2 and D_3 are turned on, and diode D_1 is turned off under reverse voltage. During this stage, there is only one loop in the equivalent circuit. The input power source U_{in} and inductors L_1 and L_2 are connected in series to provide energy to the load and charge the output capacitor C_1. By ignoring the conduction voltage drop in the diode, the voltage across the two inductors L_1 and L_2 are the voltage U_{in} of the input voltage. The voltage and current reference directions on the inductor are uncorrelated, and the energy released by the two inductors in a PWM period is shown in Equation (2).

$$W_L' = (1/2)\,\underline{U_o - U_{in}} \times I_L \times (1 - D) \times T_S \quad (2)$$

where $1 - D$ represents the turn-off period of the switch, and W_L' represents the energy released by the inductor during the turn-off period of the switch. Based on the law of the conservation of energy, the following equation can be obtained as Equation (3).

$$W_L = W_L' \quad (3)$$

According to Equations (1)–(3), the voltage gain G_D of the proposed converter can be obtained as shown in Equation (4).

$$G_D = \frac{1 + D}{1 - D} \quad (4)$$

.

By calculating this, the relationship between the voltage gain and the duty cycle D of the proposed double-boost converter can be obtained, as shown in Figure 4

D. DESIGN ASPECTS OF THE PROPOSED SYSTEM

According to the two operating modes and Kirchhoff's Current Law (KCL), we can obtain the current stress of each device of the proposed converter. In the two operating modes, the capacitor current is represented by I_{Con} and I_{Coff}, and the equation is as follows.

$$I_{Con} = -I_o \quad (5)$$

$$I_{Coff} = I_{D3} - I_o \quad (6)$$

where I_o represents the output current and I_{D3} represents the current flowing through diode D_3. By applying ampere-second balance to the capacitor, the following equation can be obtained as

$$I_o \cdot D = (I_{D3} - I_o) \cdot (1 - D) \quad (7)$$

According to Equation (7), the current stress of diode D_3 can be expressed as:

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$$I_{D3} = \frac{I_o}{1-D} \tag{8}$$

Ignoring the loss of the converter, assuming that the input power and the output power are the same, the following equation can be obtained as:

$$U_{in} \cdot I_{in} = U_o \cdot I_o \tag{9}$$

From (4) and (9), the relationship between input current I_{in} and output current I_o can be expressedas follows:

$$I_{in} = \frac{1+D}{1-D} . I_0 \tag{10}$$

According to the operating principle of the ON mode, the current stress of the switches Q_1, Q_2 and the diode D_1 can be obtained as:

$$I_{Q1} = I_{Q2} = I_{D1} = \frac{I_{in}}{2} = \frac{1+D}{2(1-D)} \cdot I_o \tag{11}$$

where I_{Q1} and I_{Q2} represent the current flowing through switches Q_1 and Q_2, respectively, and I_{D1} represents the current flowing through the diode D_1.

According to the operating principle of the OFF mode, the current flowing through the diode D_2 is equal to that of diode D_3, and it can be described as follows:

$$I_{D2} = I_{D3} = \frac{I_o}{1-D} \tag{12}$$

Finally, according to Equations (5) and (6) and the root mean square principle of the capacitor current, the current stress I_{C_1} of capacitor C_1 can be obtained as:

$$I_{C_1} = \frac{D}{1-D} \cdot I_o \tag{13}$$

III. Design of the Double-Boost Converter Controller

1.1 Calculation of Inductor and Capacitor of Converter

The parameters of the experimental prototype are as follows: the input voltage is 20 V, the rated output voltage is 100 V, the rated load is 100 Ω, the output power rating is 100 W, the values of inductors L_1 and L_2 are both 0.35 mH, the value of the capacitor is 47 μF, the type of switch is IFR640N, the type of diode is DFE10I600PM and the switching frequency is 20 kHz.

According to Equation the inductance value can be calculated as:

$$L_1 = L_2 = \frac{U_{in} \times D}{2 \times \Delta I_L \times f} \tag{14}$$

where ΔI_L is the inductor current ripple; taking 20% of the average current as the inductor current ripple, the inductance value of the two inductors can be calculated to be 0.35 mH.

According to Equation, the capacitance (10) value can be calculated as:

$$C_1 = \frac{I_{out} \times D}{\Delta U \times f} = 35\ \mu F \tag{15}$$

where ΔU is the output voltage fluctuation (11), taking 1% of the average output voltage as the capacitor voltage fluctuation, and the capacitor value can be calculated as 47 μH.

Table 1. Comparison of the proposed converter and other converters.

Converter	Traditional Boost	Double-Boost
Number of inductors	1	2
Number of capacitors	1	1
Number of switch devices	1	2
Number of diodes	1	3
Total number of devices	4	8
Stress of switch devices	U_o	$(U_o + U_{in})/2$
Capacitance	$I_{out}D/(\Delta U \times f)$	$I_{out}D/(\Delta U \times f)$
Inductance	$U_{in}D/(\Delta I_L \times f)$	$U_{in}D/2(\Delta I_L \times f)$
Theoretical voltage gain	$1/(1-D)$	$(1+D)/(1-D)$

IV. SIMULATION RESULTS

A. Double-boost converter- simulation model

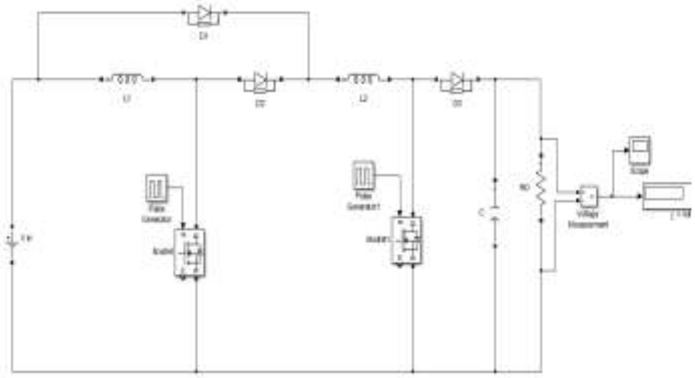

Figure.6 Double-boost converter- simulation model

To validate the above study, the MATLAB software platform has been used to simulate the proposed topology (Fig.5) but also the simple and the two cascade boost converters. For all the above circuits, the values of the element have been very conservative chosen as: V_b =20 V, L = 100 µH, r_L = 0.1 Ω, C = 10 µF, V_d = 0.8 V, R_L = 10 Ω, r_{dson} = 50 mΩ and the switching frequency of f_s = 50 kHz.Figures 7 & 8 show the simulation model for the proposed boost converter and the output voltage. The model has been tune to give the maximum output voltage of 122.1 V for a duty cycle of 85 percentages.

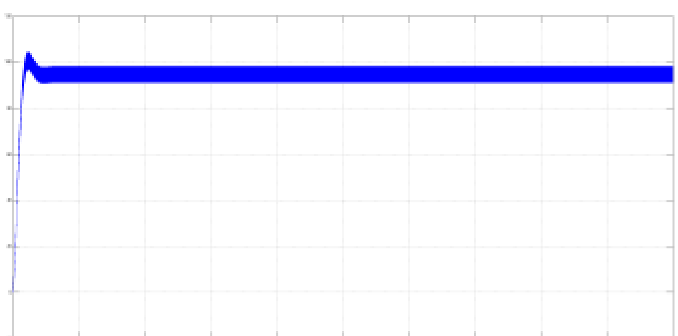

Figure.7 Double-boost converter- maximum output voltage

In figure 7 & 8, the simple boost simulation model and maximum output voltage are shown. The maximum output voltage achieved was 52.7 V for a duty cycle of 80 percentages. The boost factor is 4.4 compared with and estimated of 4.67.

B. Simple-boost converter

when the simple boost converter having the input of 12v,when the simulation circuit is shown.

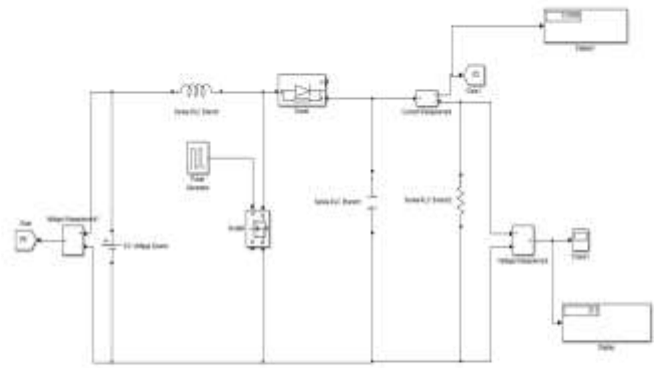

FIGURE.8 Simple-boost converter- simulation circuit

The results obtained from the simulation circuit is given in the form of maximum output voltage.

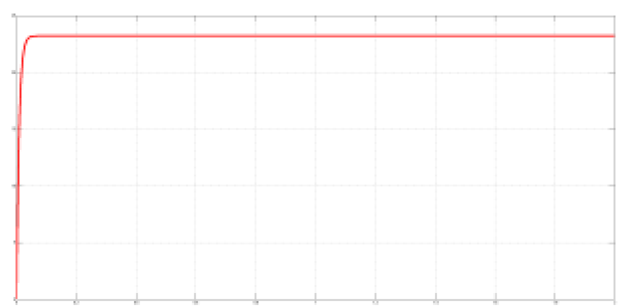

FIGURE.9 Simple-boost converter- maximum output voltage

V. Conclusion

The present paper has presented a new boost topology which ensures a significant improvement on boost factor. The new double-boost converter has been modeled and the simulation results are presented in comparison with classical known boost converters. The experimental results show an improved boost factor. For the double-boost converter, the proposed feedforward double closed-loop control is more robust than the feedforward double closed-loop control; when the load and input voltage change suddenly, it can make the output voltage return to stability faster.

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