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Design and Implementation of a Single Switch Z – Source DC-DC Converter

S.Aafrin

Assistant Professor, Dept. of EEE, Grace College of Engineering, Tuticorin, India

ABSTRACT: A single switch Z-source dc-dc converter is proposed in this paper. When compared to the conventional Z- source dc-dc converter, the proposed converter can provide high voltage gain and low voltage stress of switch and the impedance network capacitor and also operates with wide range of load. The proposed Z-source dc-dc converter not only has lower cost but also has lesser weight and size. The operating principle and parameter design is explained.

KEYWORDS: Converter circuit, Pulse Width Modulation, Renewable energy systems, Z-source converter.

I.INTRODUCTION

The single switch Z-source impedance network was firstly proposed by F. Z. Peng in 2002 [1]. Applying this impedance network into the circuit makes it obtain buck-boost conversion ability and high reliability [2-7]. Therefore, the Z-source inverter is very suitable for the renewable energy systems which are usually required to convert the low dc input voltage to the high dc output voltage, such as fuel-cell and photovoltaic. As mentioned in [10], both the improved Z - Source and Quasi Z - Source are derived from the traditional Z - Source . Considering the voltage-fed type as an example, Figure 1(a) shows the connection way between the original X-shape Z-source network and the voltage source. By shifting the position of the voltage source, the input part of the Quasi Z - Source and improved Z – Source are shown in Figure 1(b) and Figure 1(c) respectively. In Figure 1(a), the original X-shape Z-source network is actually a two-port impedance network. While in Figure 1(c), the combination of diode D with the X-shape Z- source network can be regarded as a one-port impedance network.

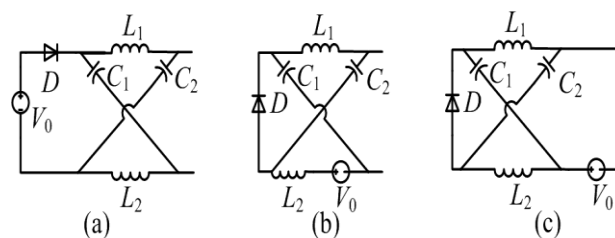


Figure 1. (a) traditional Z-source inverter; (b) quasi-Z-source inverter and (c) improved Z-source inverter.

II.PROPOSED WORK

The impedance network as in the inverter is applicable for other three types of power converters too, i.e. dc-dc, ac-ac and ac-dc converters. As this insertion makes the converter achieve high voltage gain, a series of Z-source and quasi-Z-source dc-dc converters have been proposed in [11], and a traditional Z-source dc-dc converter is shown in Figure 2 [12]. However, high capacitor voltage stress, poor load capacity or high switch voltage stress are the drawbacks of Z-source dc-dc converters. Therefore, as referred to the improved Z-source inverter in [8], a modified Z-source dc-dc converter based on one-port impedance network as seen in Figure 1(c) is proposed. As shown in Figure 3, the proposed converter has lower switch and capacitor voltage stress and wide load-range compared with the traditional Z- source dc-dc converter in [12]. The circuit analysis, voltage relationship and parameter design of the proposed converter are explained. Simulation and experimental results are provided to verify the validity of the proposed converter.

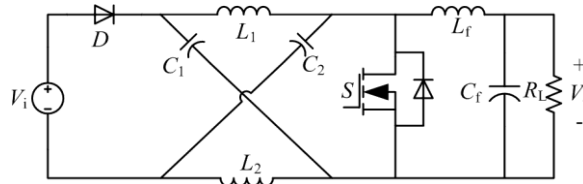


Figure 2. Traditional Z-source dc-dc converter

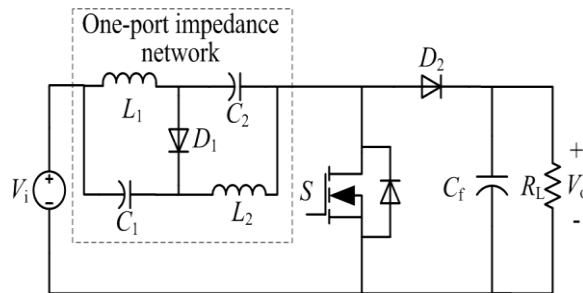


Figure 3. Proposed single switch Z-source dc-dc converter

It can be seen from Figure 3 that the proposed Z-source dc-dc converter consists of an input voltage source V_i , an one-port impedance network, a diode D_2 , a switch S , an output filter capacitor C_f and a load R_L . The network consists of two identical capacitors (C_1, C_2), one diode D_1 and two identical inductors (L_1, L_2). The network is in series with the input voltage source, thus the input voltage can share the common ground with the output.

Before the circuit analysis, the following assumptions are made.

1. All components are ideal;
2. The converter is operating in the continuous conduction mode (CCM);
3. The control strategy of switch S is Pulse-Width-Modulation (PWM).

The switching period is denoted by T_s and duty ratio of switch S by d . According to the on-off state of switch S and diodes D_1, D_2 , the proposed converter has three operating modes in a switching period, which are shown in Figure 4. v_s is the drain to source voltage of switch S ; V_o is the output voltage; i_i is the input source current; i_{D1} and i_{D2} are currents of diodes D_1 and D_2 , respectively.

Due to the symmetry of the network ($C_1=C_2, L_1=L_2$), the following equations can be established.

$$\begin{cases} i_{L1} = i_{L2} = i_L \\ i_{C1} = i_{C2} = i_C \end{cases} \quad (1)$$

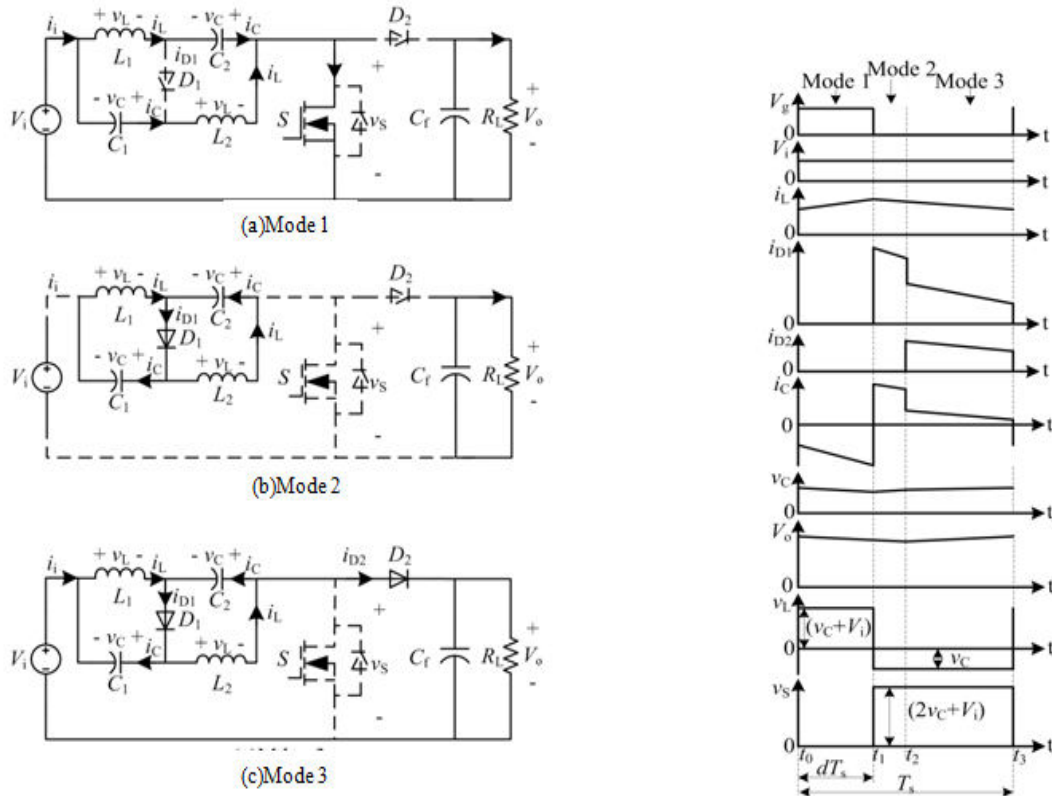


Figure 4. Three operating modes of proposed converter. Figure 5. Key waveforms of proposed converter

$$\begin{cases} v_{L1} = v_{L2} = v_L \\ v_{C1} = v_{C2} = v_C \end{cases} \quad (2)$$

where v_L and i_L are the voltage and current of the one-port impedance inductor; v_C and i_C are the voltage and current of the one-port impedance capacitor.

[Mode 1] Switch S is on and diodes D_1, D_2 are off. From Figure 4(a), there are two voltage loops in the converter, where inductor L_1 is charged by input voltage V_1 and capacitor C_2, L_2 is charged by input voltage V_1 and capacitor C_1 . Thus, the inductor current i_L is increasing linearly and the following equations can be derived.

$$\begin{cases} \dot{i}_L = -i_C \\ \dot{i}_i = 2i_L \end{cases} \quad (3)$$

$$v_L = V_1 + v_C \quad (4)$$

$$v_S = V_1 + 2v_C \quad (5)$$

In addition, the load R_L is supplied by capacitor C_f . The key waveforms of this mode are shown in the interval $[t_0, t_1]$ in Figure 5. This mode is end when switch S is turned off and the duration time is dT_s .

[Mode 2] As shown in Figure 4(b), switch S is turned off and diode D_1 is forward biased. The following equations are established.



$$\begin{cases} i_L = -i_C \\ i_{D1} = 2i_L \end{cases} \quad (6)$$

$$v_L = -v_C \quad (7)$$

$$v_s = V_i + 2v_C \quad (8)$$

The capacitors C_1 and C_2 are charged from inductors L_1 and L_2 , respectively. Then the inductor current i_L is decreasing linearly. The corresponding waveforms of this mode are shown in interval $[t_1, t_2]$ in Fig. 5. However, voltage v_S is smaller than the output voltage V_o , thus diode D_2 is off. Due to the input voltage source is in series with the one-port impedance network, the input current i_i equals to zero. It is equivalent that the one-port impedance network is isolated from both the voltage source and the load. Once the voltage v_S increases to be greater than V_o , diode D_2 will conduct and mode 2 will be end.

[Mode 3] Switch S is still in off state, but both diodes D_1 and D_2 are on, as shown in Figure 4(c). Thus, equation (7) is still established and the following equations are derived.

$$\begin{cases} i_i = i_L - i_C \\ i_{D1} = 2i_L - i_i \end{cases} \quad (9)$$

$$V_o = v_s = V_i + 2v_C \quad (10)$$

Therefore, the one-port impedance network inductors not only charge the capacitors (C_1, C_2), but also supply the output capacitor C_f and load R_L with the input voltage source V_i . The inductor current i_L is still decreasing linearly. The corresponding waveforms of this mode are shown in interval $[t_2, t_3]$ in Figure 5. Mode 3 is end when switch S is turned on again in the following switching period. Thus, the duration time of modes 2 and 3 is $(1-d)T_s$.

III. VOLTAGE RELATIONSHIP

Due to the large capacitance of capacitor and the high switching frequency, the capacitor voltage v_C can be assumed to be a constant value V_C . According to the operating principle of the proposed converter, the inductor voltage v_L equals to $V_i + V_C$ when switch S is on and equals to $-V_C$ when switch S is off. Applying the volt-second balance for the inductor, we have

$$(V_i + V_C)dT_s + (-V_C)(1 - d)T_s = 0 \quad (11)$$



Then,

$$V_c = \frac{d}{1-2d} V_i \tag{12}$$

Combining (12) with (10), the voltage gain G of the proposed converter can be derived as

$$G = \frac{V_o}{V_i} = \frac{1}{1-2d} \tag{13}$$

Denote V_s as the drain to source voltage of switch S when switch S is off. Then, the following equation can be obtained.

$$V_s = V_o = \frac{1}{1-2d} V_i \tag{14}$$

From (12), (13) and (14), it is found that the operating range of the duty cycle d is from 0 to 0.5.

A comparison between the proposed converter and the traditional Z-source dc-dc converter in [12] has been presented in Tab. I. It can be found that the proposed converter has higher voltage gain than the traditional one under the same duty ratio d , lower capacitor and switch voltage stress than the traditional one under the same output voltage V_o . Therefore, the cost and size of the proposed Z-source dc-dc converter has been largely reduced.

Tabulation I. Comparison between the proposed converter and the traditional Z-source dc-dc converter:

Voltage	Proposed Z-source dc-dc converter	Traditional Z-source dc-dc converter
V_o	$\frac{1}{1-2d} V_i$	$\frac{1-d}{1-2d} V_i$
V_c	$\frac{d}{1-2d} V_i = dV_o$	$\frac{1-d}{1-2d} V_i = V_o$
V_s	$\frac{1}{1-2d} V_i = V_o$	$\frac{1}{1-2d} V_i = \frac{1}{1-d} V_o$



V. SIMULATION RESULT

The proposed converter is verified by MATLAB/Simulink. The simulation parameters are: $V_i=20V$, $d=0.3$, $f_s=100kHz$, the rated output power $P_{out}=50W$ and $R_L=50\Omega$. The capacitor voltage $V_C=15V$ based on (12), the output voltage $V_o=50V$ based on (13). Set $x_L\%=15\%$, the minimum inductance $L_{min}=280\mu H$ is derived based on (19). Set $x_C\%=1\%$, the minimum capacitance $C_{min}=50\mu F$ is derived based on (25). Therefore, inductance $L=280\mu H$ and capacitance $C=100\mu F$ are selected in simulation. The output capacitance C_f is $100\mu F$ as well.

The simulation result is shown in Figure 7(a). As can be seen that the capacitor voltage V_C is about 15V, output voltage V_o is about 50V and switch voltage V_s is about 50V, which are accord with the theoretical value.

By changing the duty ratio d to 0.4 and load R_L to 300Ω while the other parameters are unchanged. Based on (22), the proposed converter will still operate in CCM. The corresponding simulation result is shown in Figure 7(b). It is obviously that the inductor current i_L is continuous; the voltage V_C is about 40V, voltage V_o is about 100V and voltage V_s is about 100V which are agree with the theoretical analysis as well.

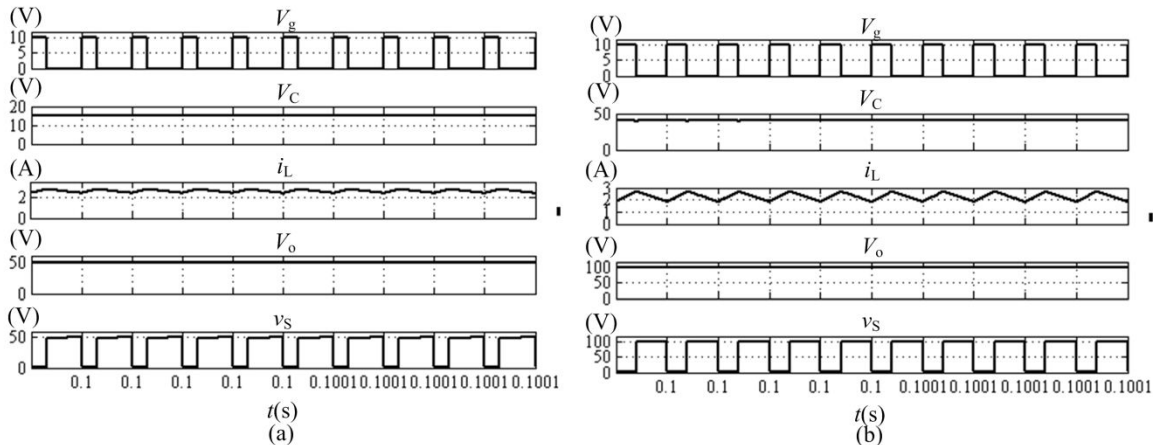


Figure 7. Simulation results of the proposed converter: (a) $d=0.3$, $R_L=50\Omega$, (b) $d=0.4$, $R_L=300\Omega$.

VI. CONCLUSION

A single switch Z-source dc-dc converter is proposed in this paper. The circuit analysis, parameter design and load capacity of the proposed converter have been illustrated in detail. The validity of the proposed converter has been verified by simulation. It can be concluded that the proposed single switch Z-source dc-dc converter can obtain high voltage gain with lower voltage stresses of switch and the impedance network capacitor. Moreover, it has the advantages of wide-range load, low cost and high power density. Therefore, the proposed Z-source dc-dc converter is suitable for the renewable energy systems which needs a high voltage gain converter to boost their low input dc voltage.

REFERENCES

1. F.Z. Peng, "Z-source inverter," IEEE Trans. Ind. Appl, vol. 39, no. 2, pp. 504-510, Mar./Apr.2003.
2. M. Shen and F.Z. Peng, "Operation Modes and Characteristics of the Z-source Inverter with Small Inductance or Low Power Factor," IEEE Trans. Ind. Electron, vol. 55, no. 1, pp. 89-96, Jan.2008.
3. M. Shen, J. Wang, A. Joseph, F. Z. Peng, L. M. Tolbert, and D. J. Adams, "Constant Boost Control of the Z-source Inverter to Minimize Current Ripple and Voltage Stress," IEEE Trans. Ind. Appl, vol. 42, no. 3, pp. 770-777,



May/Jun, 2006.

4. F. Z. Peng, M. Shen, and K. Holland, "Application of Z-source Inverter for Traction Drive of Fuel Cell- battery Hybrid Electric Vehicles," IEEE Trans. Power Electron, vol. 22, no. 3, pp. 1054-1061, May 2007.
5. J. B. Liu, J. G. Hu, and L. Y. Xu, "Dynamic Modeling and Analysis of Z-source Converter-derivation of AC Small Signal Model and Design-oriented Analysis," IEEE Trans. Power Electron, vol. 22, no.5, pp. 1786-1796, Sep. 2007.
6. F. Z Peng., M. Shen and Z. M. Qian, "Maximum Boost Control of the Z-source Inverter," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 833-838, Jul./Aug. 2005.
7. P. C. Loh, D. M. Vilathgamuwa, Y. S. Lai, G. T. Chua, and Y. W. Li, "Pulse-Width Modulation of Z-source Inverters," in Rec., 39th IAS Annual. Meeting, 2004, pp. 148-155.
8. Y. Tang, S. J. Xie, C. H. Zhang and Z. G. Xu, "Improved Z-Source Inverter with Reduced Z-Source Capacitor Voltage Stress and Soft-start Capability," IEEE Trans. Power Electron, vol. 24, no. 2, pp. 409-415, Feb. 2009.
9. Y. Li, S. Jiang, J. G. Cintron-Rivera and F. Z. Peng, "Modeling and Control of Quasi-Z-Source Inverter for Distributed Generation Applications," IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1532-1541, Apr. 2013.
10. D. Li, F. Gao, P. C. Loh, M. Zhu, and F. Blaabjerg, "Hybrid-source Impedance Networks: Layouts and Generalized Cascading Concepts," IEEE Trans. Power Electron., vol. 26, no. 7, pp. 2028-2040, Jul. 2011.
11. D. Cao and F. Z. Peng, "A family of Z-source and Quasi-Z-source dc-dc converter", in Proc. IEEE Applied Power Electronics Conf 2009, pp. 1097-1101, Feb. 2009.
12. V. P. Galigekere and Marian K. Kazimierczuk, "Analysis of PWM Z-source dc-dc converter in CCM for steady state", IEEE Trans. Circuits and Syst. Regul. Pap., vol. 59, no. 4, pp. 854-863, Apr., 2012.



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