SWITCHED INDUCTOR Z SOURCE HALF BRIDGE CONVERTER

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Abstract— Applying an Switched Impedance network into a half-bridge converter, a novel Switched Inductor Z-source half-bridge converter is presented. This Switched Inductor Z-source half-bridge converter can solve the problems of the shoot-through and limited voltage. Also the boost ability of the converter is also improved compared to conventional z source converter. Furthermore, it can generate a broader range of output voltage values and much more kinds of waveforms, such as the varied positive or negative output voltages and the varied time ratio between positive and negative voltages, which are particularly desirable for some special power supplies, like the electrochemical power supply. Finally, the proposed converter is simulated in MATLAB/SimulinkR2010a, and the simulation results can verify the effectiveness of the proposed converter

Keywords— Half-bridge converter, limited Voltage, shoot-through, Switced Inductor Z-source**,** electrochemical power supply, Switched Impedance, boost ability

INTRODUCTION

Conventional half-bridge converters have their switches in series, as shown in Fig. 1, with which the shoot-through can occur [1], which means that the strong current flowing through the switches makes them break down. Moreover, the ac output voltage is limited below the dc voltage, which is named the limited voltage problem, because, in practice, ac output voltage is sometimes desirable to be higher than the dc voltage. Furthermore, an unbalanced midpoint of input capacitors in conventional half-bridge converters leads to large ripples [2], [3], making the system unstable.

In half-bridge VSI, where two large capacitors are required to provide a neutral point N, such that each capacitor maintains a constant voltage $\frac{V_i}{2}$. Because the current harmonics injected by the operation of the inverter are low-order harmonics, a set of large capacitors (C+ and C-) is required. Figure 1.1 shows the power topology of a half-bridge VSI. It is clear that both switches S1 and S2 cannot be on simultaneously because a short circuit across the dc link voltage source V_i would be produced. In order to avoid the short circuit across the dc bus and the undefined ac output voltage condition, the modulating technique should always ensure that at any instant either the top or the bottom switch of the inverter leg is on.

Here, a switched inductor Z-source half-bridge converter is proposed, in which, instead of putting two LC Z-networks a switched inductor Z Source network is used to couple with the capacitors. It can generate a much broader range of output voltages and more abundant wave- forms than the conventional Z-source converter. It is also remarked that it has higher efficiency than conventional half-bridge converters, where an additional dc-dc boost converter is needed to obtain such desired outputs. The switched inductor Z-source converter can generate boost- buck voltage, minimize component count, increase efficiency, and reduce cost and For applications where over drive is desirable and the available dc voltage is limited, an additional dc-dc boost converter is needed to obtain a desired ac output. The additional power converter stage increases system cost and lowers efficiency.

A typical application of the switched inductor Z-source half-bridge converter is in the electrochemical power supply, whose output voltages are requested to be varied, including varied positive or negative output voltages and the varied time ratio between positive and negative voltages. These characteristics, desired in electrochemical power supply, are the very ones of the proposed converter.

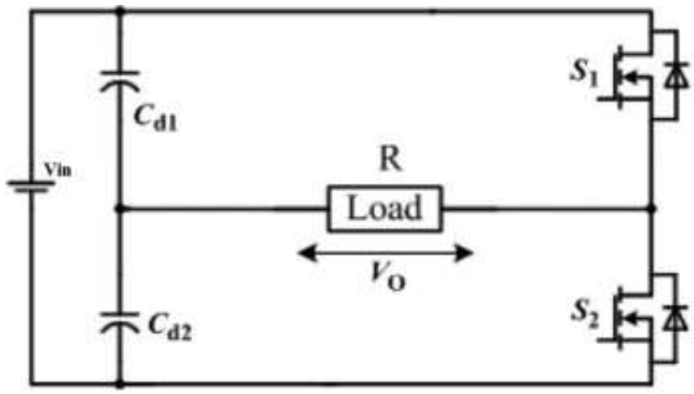


Figure.1 : Conventional half-bridge converter

SYSTEM DESIGN AND ANALYSIS

The proposed converter is depicted in Fig. 2, in which switched inductor Z source converter consisting of four inductors L_1, L_2, L_3, L_4 and capacitors C_1 and C_2 integrated to conventional half bridge converter, , consisting of capacitors C_{d1} and C_{d2}, switches S_1 and S_2, and diode D, which is used to prevent the current from flowing back to the source. There in, the use of the inductors in the Z-network is to avoid strong current in the circuit when the switches are in the shoot-through state.

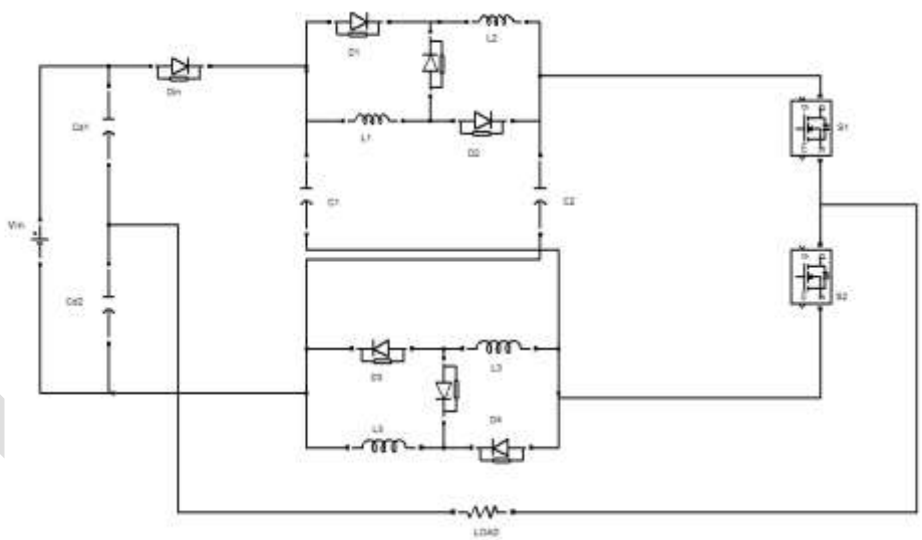


Figure. 2: Switched Inductor Z Source Converter

The proposed converter performs differently in two cases:D_1 +$D_2 \leq 1$ and D_1+D_2 > 1.

A. Case. 1: D_1 +$D_2 \leq 1$

In this case, S_1 and S_2 are not switched on at the same time; then, the circuit is in the non-shoot-through state. There are three modes corresponding to the states of the switches. In the first mode, Fig. 2.2(a) shows an equivalent circuit for the mode when the S_1 is on and S_2 is off, in which the current flows out of the source, through the diode, the Z-network, and S_1, and then back to the source. The arrows indicate the current directions. In the second mode, Fig. 2.2(b) shows an equivalent circuit of that when S_1 and S_2 are off, in which the current also flows out of the source, through the diode and the Z-network, and back to the source; there is no output here. In the third mode, Fig. 2.2(c) shows an equivalent circuit of that when S_2 is on and S_1 is off, in which the diode suffers a negative voltage and, thus, turns off. The current flows out of the source, through the load, S_2, and the Z-network, and then back to the source. Furthermore, the current direction is also indicated. The operation process for this case is similar to the traditional one for half-bridge converters, which is not detailed here.

B. Case 2: $D_1 + D_2 > 1$

In this case, the behaviour of the switches in the circuit leads to three modes within a switch period T, which correspond to three linear equivalent circuits: Mode 1, when S_1 and S_2 are on; Mode 2, when S_1 is on and S_2 is off; and Mode 3, when S_1 is off and S_2 is on.

Denote t_0 as the beginning of one period, t_1 as the mode transition instant from mode 1 to mode 2, i.e., $t_1 = t_0 + (D_2 + D_1 - 1)T$, t_2 as the mode transition instant from mode 2 to mode 3, i.e., $t_2 = t_1 + (1 - D_2)T$, and $t_3 = T$ as the end of the period. In the steady state of the converter, its operation process in a switch period is analysed in the following, and the output voltage v_0 will be deduced in each mode.

Mode 1: $t \in [t_0, t_1]$

As shown in Fig.3, in loops 1and 2, capacitors C_1 and C_2 discharge the energy to inductors L_1 and L_2, L_3 and L_4 thereafter, i_{L1}, i_{L2}, i_{L3} and i_{L4} increases. Thus, all inductors store the energy, and one has

$$V_{L1} = V_{L2} = V_{C1}$$
$$V_{L3} = V_{L4} = V_{C2} \qquad (1)$$

where i_{L1}, i_{L2} , i_{L3} and i_{L4}, V_{L1} , V_{L2} , V_{C1}, and V_{C2} are the currents of L_1, L_2, L_3 and L_4 and the voltages of L_1, L_2, L_3 and L_4, C_1 and C_2 respectively. The voltage of diode D is $-(V_{C1} + V_{C2} - V_d)$, so D undertakes negative voltage stress and, thus, turns off. The energy of C_2 is delivered to the load R_L and C_{d2} through the $C_2 - R_L - C_{d2}$ loop, so C_{d2} charges and C_{d1} discharges.

In terms of the $C_2 - R_L - C_{d2}$ loop, the output voltage of the converter read

$$V_o = V_{C2} - V_{Cd2} \qquad (2)$$

Where V_{Cd2} is the voltage of C_{d2}.

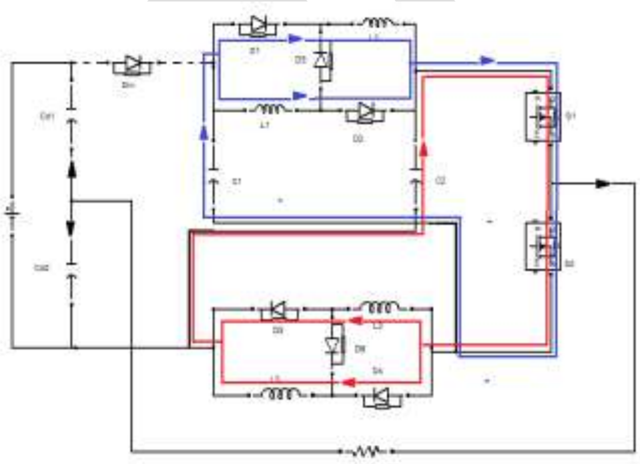


Figure3. Mode 1 Operation

Mode 2: $t \in [t_1, t_2]$

As shown in Fig.4, S_1 is on, and S_2 is off. In loop 1, the source V_d and L_1 and L_2 discharge the energy to C_2, so that V_{C2} increases. In loop 2, the source V_d and L_3 and L_4 discharge the energy to C_1; thereafter, V_{C1} increases. Then, the energy of C_2 is delivered to the load R_L and C_{d2} through the $C_2 - R_L - C_{d2}$ loop, so C_{d2} charges and C_{d1} discharges. From loop 1,

$$V_{L1} = V_d - V_{C2} \ . \qquad (3)$$

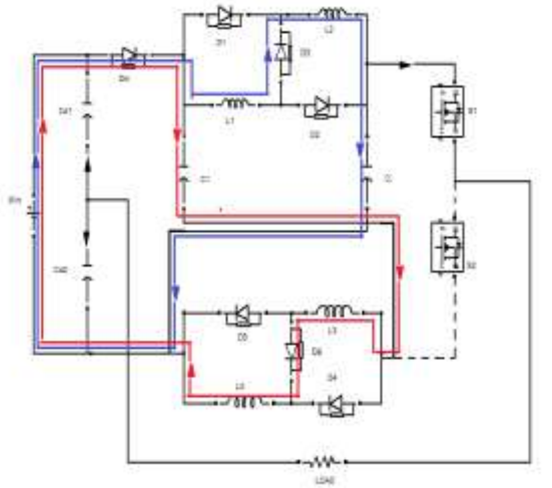


Figure. 4: Mode 2 Operation

Mode 3: $t \in [t_2, t_3]$

In Fig. 5, S_1 is off, and S_2 is on. In loop 1, the source V_d, L_1 and L_2 discharge the energy to C_2; thus, V_{C2} increases. Similarly, in loop 2, V_d, L_3 and L_4 discharge the energy to C_1; thus, V_{C1} increases. The energy of L_2 and C_{d2} is delivered to R_L through the $L_2{-}C_{d2}{-}R_L$ loop, so C_{d2} discharges and C_{d1} charges.
In terms of loop 1, one has the same equation as (3). In terms of the $V_d{-}D{-}C_1{-}R_L{-}C_{d2}$ loop, the output voltage is

$$v_0 = -(v_{Cd2} + v_{C1} - V_d) \qquad (4)$$

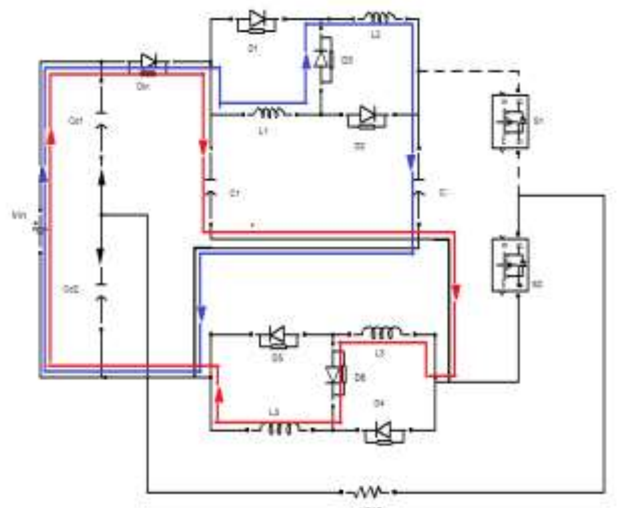


Figure. 5: Mode 3 Operation

SIMULATION RESULTS

To verify the feasibility and validity of the proposed converter was simulated using MATLAB/SimulinkR2010 software. The pre-assigned parameters are as follows: $x_C\% = 1\%$, $x_L\% = 3\%$, V_d= 12 V, V_o = 24 V, Io = 6 A, and T = 20 µs. According to the design,the parameters of the converter can be calculated: C1 = C2 = 6 µF and $L_1 = L_2 = L_3 = L_4$ = 80 µH. However, in practice, the parameters can be chosen as follows: C1 = C2 = 470 µF and the same inductor values. The Simulink model is shown in Fig.6.

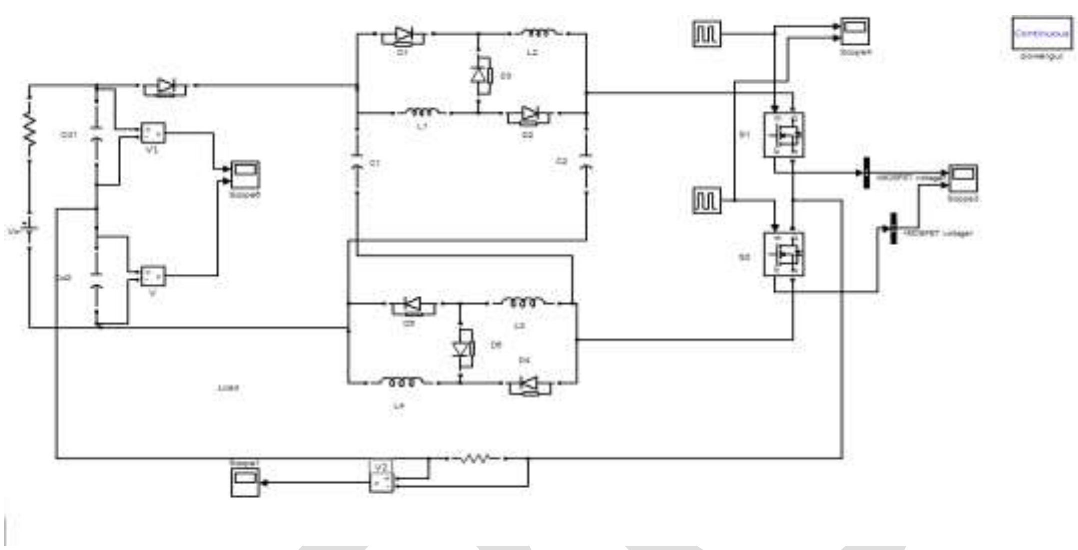
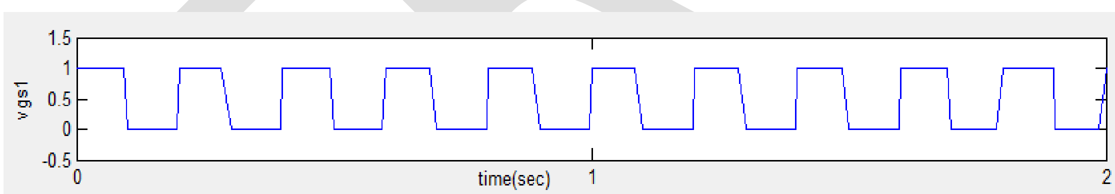
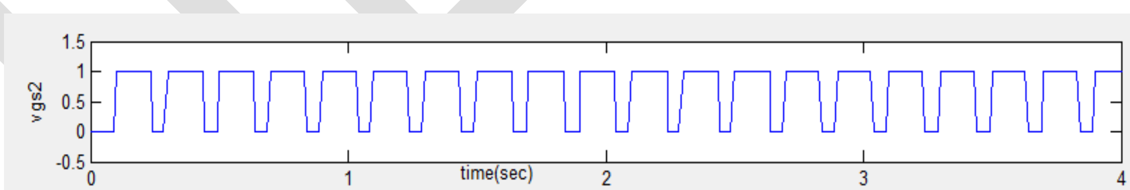


FIGURE. 6: SIMULINK MODEL

Fig. 7 shows the gate pulses to the switches with 50% and 70% duty cycles.



(a)



(b)

Fig. 8: Gate Pulses (a) S_1 (b) S_2

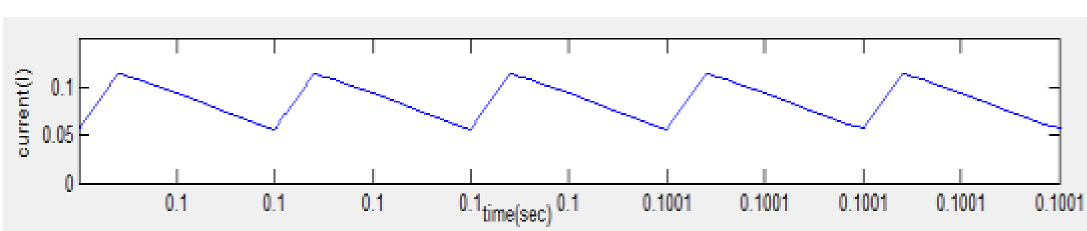


Fig. 9 : Inductor Current

Fig. 9 shows the inductor current. All the inductor have the same current waveforms. Voltage across the switches is shown in Fig. 10. Both the switches have the same voltage waveform.

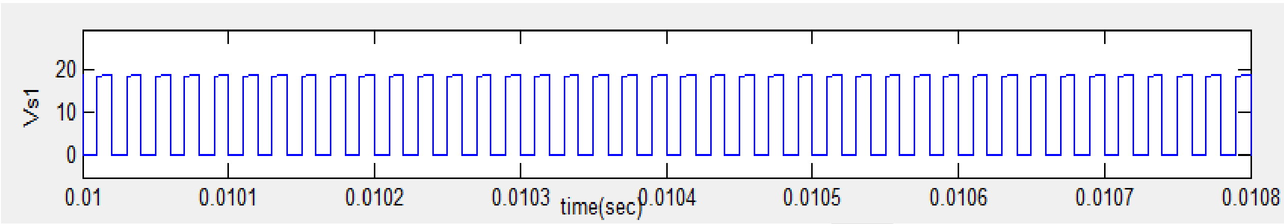
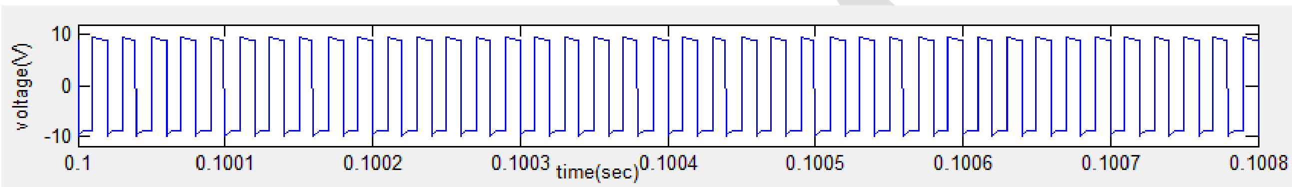
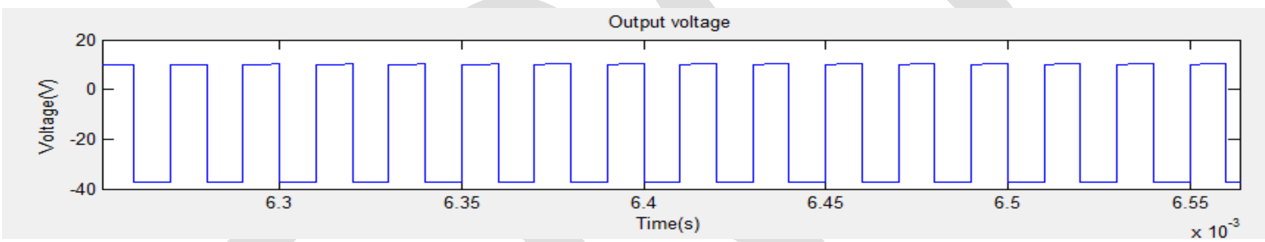


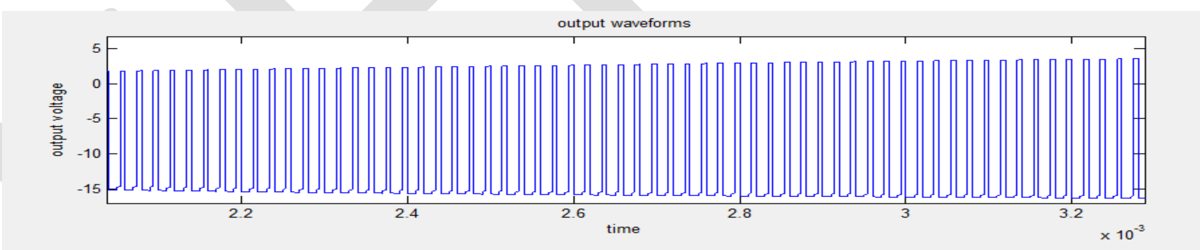
Fig. 10 : Voltage Across Switch



(a)



(b)



(c)

Fig. 11: (a) (b) (c)Output Volatge Waveforms For Various Duty Cycles

Fig. 11 shows the output voltage waveforms for different duty cycles. Thus, by varying the duty cycle, the positive and negative peak and also the time period can be varied

CONCLUSION

This paper propose a novel Z-source half-bridge converter that can output buck– boost voltages. Different from the Z-source converter, it needs only switched inductor Z-network between the input capacitors and the switches. From the simulation it is known that the proposed inverter can provide a strong boost ability to overcome the limitations of the classical Z-source converter.

The converter produces output voltage waveforms with varied positive and negative peaks and with varied time periods. Moreover, the converter has been analyzed in two different states, including the shoot-through and non-shoot-through states. Furthermore, the feature of the proposed converter owning abundant outputs under an appropriate control is very desirable for requirements of the electrochemical power supply.

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