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Design and simulation of the single phase Z-Source Inverter

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ABSTRACT

Z-source converter overcomes the conceptual and theoretical barriers and limitations of the traditional voltage-source converter (abbreviated as V-source converter) and current-source converter (abbreviated as I-source converter) and provides a novel power conversion concept. The Z-source concept can be applied to all DC-to-AC, AC-to-DC, AC-to-AC, and DC-to-DC power conversion. Z –source inverters have been recently proposed as an alternative power conversion concept as they have both voltage buck and boost capabilities. These inverters use a unique impedance network, coupled between the power source and converter circuit, to provide both voltage buck and boost properties, which cannot be achieved with conventional voltage source and current source inverters. To facilitate understanding of Z – source inverter, this paper presents a detailed analysis, showing the design of impedance network, implementation of simple Boost control PWM technique and simulation of Z – source inverter for different values of modulation indices.

Keywords— *Z-source, Converter, Inverter, Simple Boost control, Matlab Simulink*

1. INTRODUCTION

In a traditional voltage source inverter, the two switches of the same phase leg can never be gated on at the same time because doing so would cause a short circuit (shoot-through) to occur that would destroy the inverter [1]. In addition, the maximum output voltage obtainable can never exceed the dc bus voltage. These limitations can be overcome by the new Z-source inverter that uses an Impedance Network (Z-network) to replace the traditional dc link [2]. The Z-source inverter advantageously utilizes the shoot-through states to boost the dc bus voltage by gating on both the upper and lower switches of a phase leg. Therefore, the Z-source inverter can buck and boost voltage to the desired output voltage that is greater than the available dc bus voltage. In addition, the reliability of the inverter is greatly improved because the shoot-through can no longer destroy the circuit. Thus it provides a low-cost, reliable, and highly efficient single-stage structure for the buck and boosts power conversion [5].

2. Z SOURCE INVERTER

The basic circuit diagram of the single-phase Z-source inverter is as shown in figure 1 below. The network consists of a split-Capacitor and inductor connected in an X shape to provide an impedance source (Z-source) coupling the DC source to the inverter.

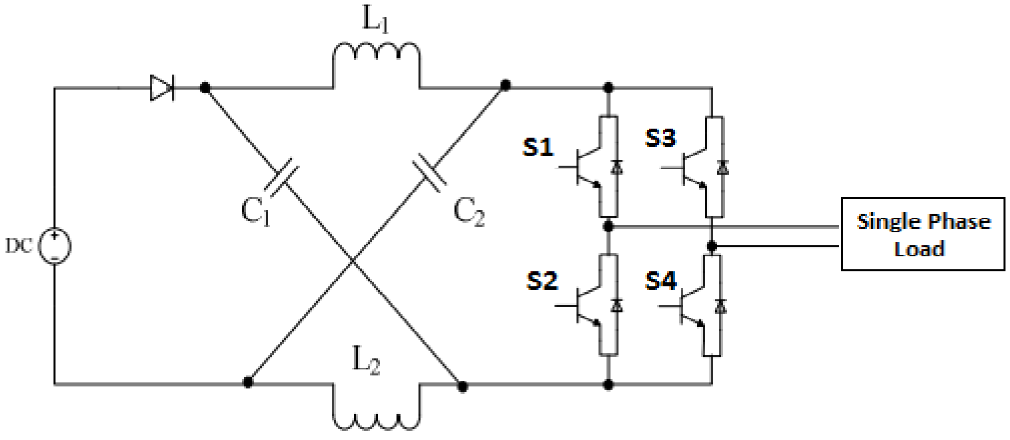

Fig. 1: Basic circuit diagram of the single-phase Z-source inverter

2.1 Pulse width modulation techniques

Various PWM techniques are used for the control of the switches in Z-source inverter [3]. Namely:

- Simple Boost Control
- Maximum Boost Control
- Constant Maximum Boost Control.

The simple Boost control technique has been used for the simulation of the Z-source inverter in this paper. The pulse generation for the switches in the circuit is shown figure 2.

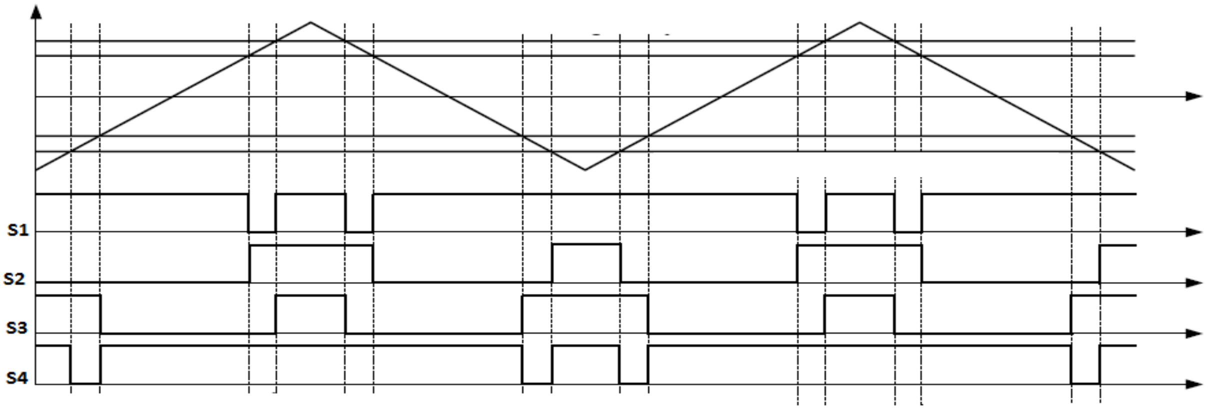

Fig. 2: The pulse generation for the switches in the circuit

3. DESIGN OF CIRCUIT PARAMETERS

Assuming

$$V_{C1}=V_{C2}=V_C$$
$$V_{L1}=V_{L2}=V_L$$
$$V_D=2Vc$$

Let the switching frequency be 5 KHz.
Therefore

$$T = 1/f$$
$$T = 2*10^{-4} \text{ sec}$$

Let Duty cycle be 30%.

The maximum current through the inductor when shoot through happens.

$$I_{Lmax} = I_L + I_L * 30\%$$
$$I_{Lmin} = I_L – I_L* 30$$
$$\Delta I_L= I_{Lmax} – I_{Lmin}$$
$$I_L= (P_{in}/V_{in})$$
$$= (60*8.3)/ (60)$$
$$= 8.3A$$

$$I_{Lmax} = 10.79 \text{ A}$$
$$I_{Lmin} = 5.81 \text{ A}$$
$$\Delta I_L= I_{Lmax} – I_{Lmin}$$
$$=10.79-5.81$$
$$=4.98 \text{ A}$$

Boost factor:

$$B = \frac{1}{1 – 2D}$$
$$= 3.8$$

Capacitance of Z –source network

$$C= (IL*T) (VL*3\%)$$
$$C= (8.3*2*10-4) (146.2*0.03)$$
$$C =7280.76*10-6 \text{ F}$$
$$C =7280\mu F$$

Shoot through duty cycle is

$$Ds = (B - 1) /2B= (3.8 -1) / (2*3.8) = 0.37$$
$$Vc = (Vin+Vin1) / 2$$
$$= (60+383.4) / 2 = 221.7V$$
$$L = T * (Vc/\Delta IL)*D$$
$$= 2*10-4 *(221.4 * 0.3) / 5.81$$
$$L=2.29mH$$

4. SIMULATION OF SINGLE PHASE Z-SOURCE INVERTER

The simulation of the proposed circuit is carried out using MATLAB Simulink Software. The logic block for generation of triggering pulses for Switch S1 is shown in figure 3. Similarly, the triggering pulse is generated for the remaining three switches.

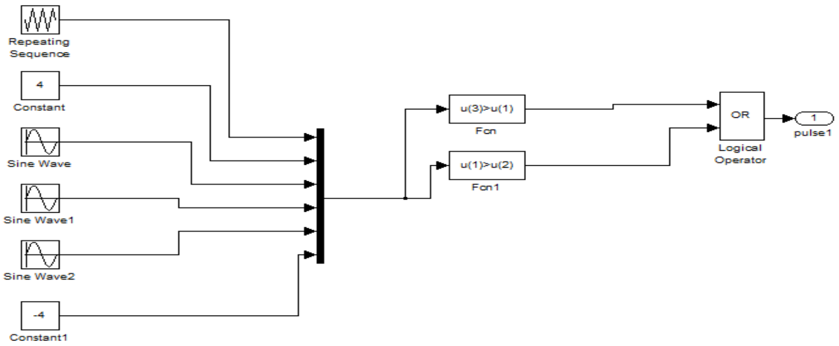

Fig. 3: The logic block for generation of triggering pulses for Switch S1

The simulated results of the triggering pulses for the switches is shown in figure 4.

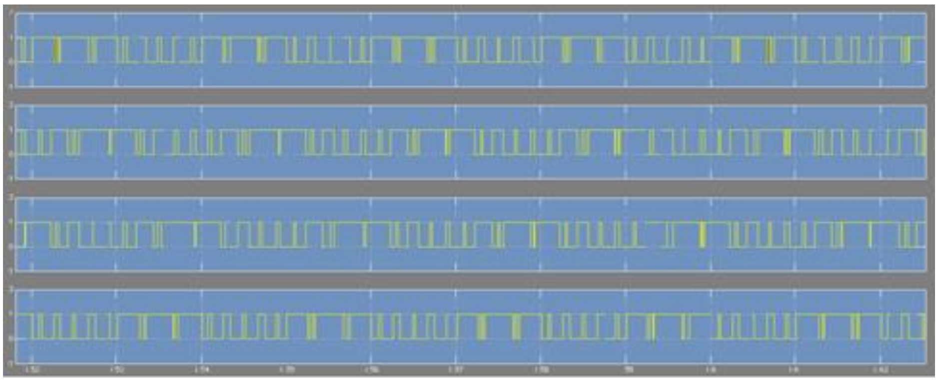

Fig. 4: Simulated results of the triggering pulses for the switches

The simulation of the Single phase Z-source inverter using Matlab Simulink is shown in figure5

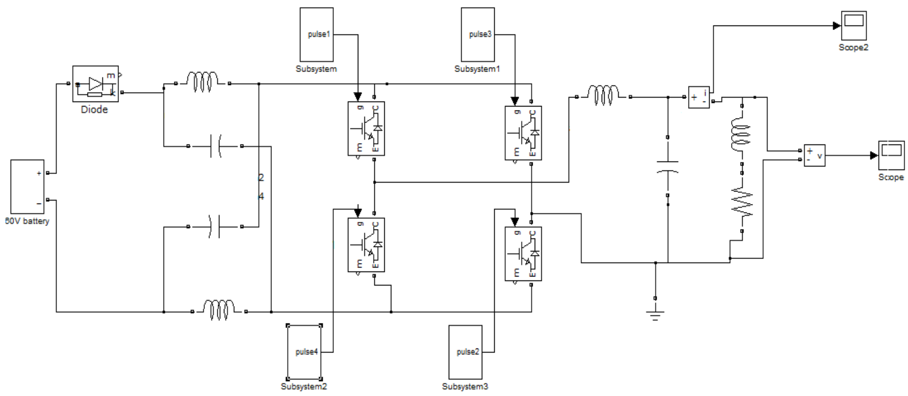

Fig. 5: Simulation of the Single phase Z-source inverter using Matlab Simulink

The output voltage and current waveforms of the circuit are shown in figure 6 below

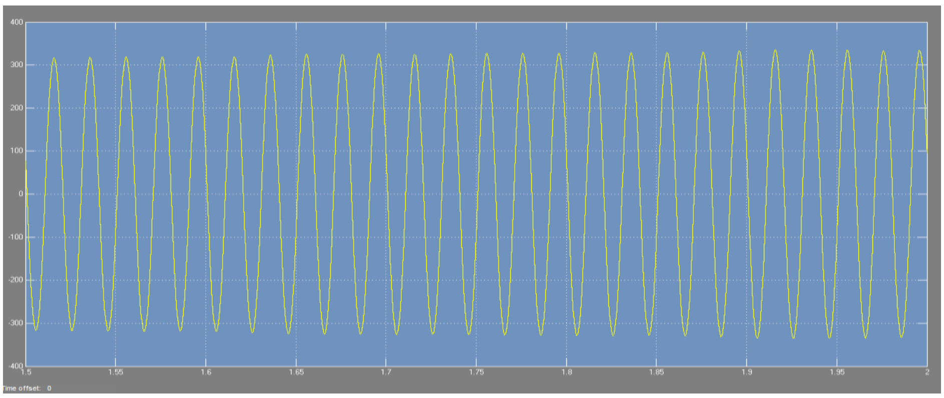

Fig. 6 (a): Output voltage and current waveforms of the circuit

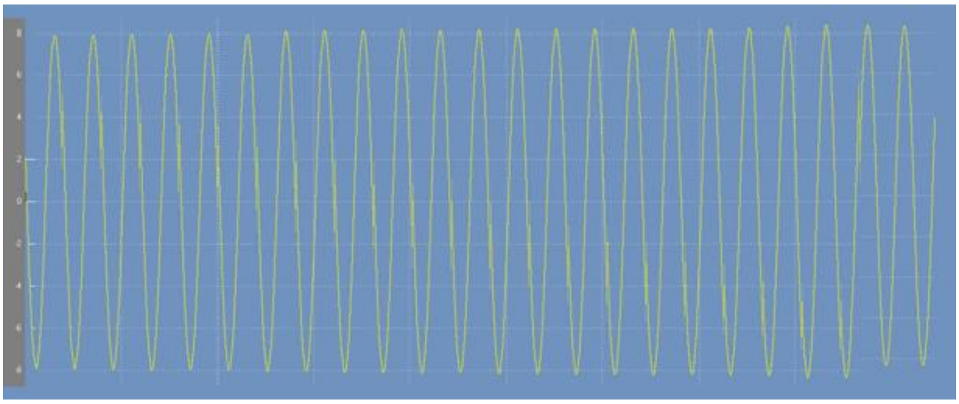

Fig. 6 (b): Output voltage and current waveforms of the circuit

5. CONCLUSION

In this paper, the generation of the triggering pulses for the four switches is generated using a simple boost control technique is proposed using the Matlab Simulink. The design and simulation of the Single phase Z-source inverter is carried out and the results are shown. Simulation results show that the sinusoidal load voltage and current can be achieved by the Z-source inverter using a filter which is compared to the traditional inverter.

6. FUTURE SCOPE

Only one method of ZSI namely simple boost control has been carried out in this paper. The main limitations of the simple boost control technique are the high voltage stress and high inductor current ripple. This problem is reduced by Maximum boost control and Maximum constant boost control techniques.

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