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DESIGN OF SINGLE PHASE Z-SOURCE BUCK BOOST MATRIX CONVERTER

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ABSTRACT

This project proposes a design of single phase Z-source buck boost matrix converter. The proposed matrix converter can buck and boost the input voltage to the desired output level. And also the proposed converter can step up or step down the frequency of the output voltage. This proposed converter employs a safe commutation to establish a continuous current path, which reduces voltage spikes on the switches without a snubber circuit. The traditional AC-AC converter which is a two stage converter with a large energy storage dc link capacitor. The proposed matrix converter is a single stage converter which provides a wide range of ac output voltage with buck and boost function and it offers inherent bidirectional power flow. The proposed model of Z-source buck boost matrix converter is simulated using MATLAB package and found to provide the source current THD less than 30% and improve the input power factor to more than 0.95.

Keywords— *Z-Source Bust Book, MATLAB etc*

I. INTRODUCTION

The impedance source power converter is designed by buck boost matrix converters. The Z-source converter provides both buck and boost functions by a single stage conversion. Z-source converter has the advantage of low inrush current and output voltage is free from voltage distortion, and the buck boost function is achieved by one stage conversion. The single stage matrix converter is implemented [1]. The proposed implementation of matrix converters [2] and its operations also analyzed under various input voltage disturbances. The design of three phase circuits [3] also used here. Bidirectional power flow is analyzed with this matrix converter [4]-[5].

The proposed single phase buck boost matrix converters designed by [6]-[7] and its switching process [8] is explained with the help of PWM techniques. Z-source inverter with soft switching capability [10]-[11] is analyzed. Here safe commutation scheme is employed, which establishes a continuous current path, in order to eliminate voltage spikes on switches without a snubber circuit. Z-source matrix converters with various loads [12]-[14] also simulated.

A. Z-Source Converter

It is also known as impedance-source power converter or impedance-fed power converter. It employs a unique impedance network to couple the converter main circuit to the power source and load. The possible conversions by the Z-source matrix converter are dc to ac conversion, ac to dc conversion, dc to dc conversion and ac to ac conversion. This converter provides the buck boost function by a single stage conversion. The z-source converter applies to a place where only voltage regulation is required. It is immune to the EMI noise. It allows the switches on the same phase leg to turn on simultaneously.

B. Matrix Converter

A matrix converter is an ac-ac converter that can directly convert an ac power supply voltage into an ac voltage of variable amplitude and frequency without a large energy storage element. It is an array of controlled semiconductor switches and it is a forced commutated converter. It has the capability to block the voltage and conduct current in both directions. Each output phase can be connected to any input phase at any time. Switching pattern and commutation control must avoid line to line short circuits at the input and must avoid open circuits at the output.

C. *Features Of Matrix Converter*

The matrix converter has the following features such as direct conversion, no dc link requirement and No restriction on input and output frequency within limits imposed by switching frequency and Potential for high power density if switching frequency is high enough.

Figure1. Block Diagram of Single Phase Z-source Buck Boost Matrix Converter.

D. Block Diagram of Proposed Converter

Figure 1.shows the block diagram of the proposed converter. The block diagram consists of ac input source, LC input filter, Z-source network, matrix converter and load.

The ac input voltage is given to the LC input filter. The LC input filter is required to reduce switching ripple included in input current. The Z-source network is used to provide a large range of output voltage with buck-boost function. The matrix converter is used to step up or step down the output frequency.

E. Circuit Diagram of Proposed Converter

Figure 2.shows the circuit diagram of the proposed Z-source buck boost matrix converter. L_{IN}, C_{IN} are the input filter which is used to reduce the ripple content in the input current. The inductor and capacitor values are small, which is enough to filter the switching ripples. The switches S_{SA}, S_{SB} form bidirectional switches which are used as a driver switch for the proposed converter. During the freewheeling period, the source should be short circuited, for that the driver switches are opened during that period.

The z-source network provides the shoot through state. This shoot through period controls the buck boost function of the proposed converter. Shoot through period is nothing but turning on the switches on the same leg of the matrix converter. This shoot through period only determines the duty cycle for the proposed converter. During the shoot through period the z-source network is short circuited and hence there is no output voltage across the load.

The matrix converter requires four bidirectional switches for its operation. The bidirectional switches are able to block voltage and conduct current in both directions. All the bidirectional switches are common emitter back to back switch cells. The diodes are included to provide the reverse blocking capability. The IGBT's are used because of their high switching capabilities of switching periods and their high current carrying capacities, which are desirable for high power switching applications.

Analyzing the single phase Z-source buck boost matrix converter requires different bidirectional switching arrangements depending on the desired amplitude and frequency of the output voltage.

The circuit uses two control parameters which are given below.

$$\text{Duty cycle, } d = \frac{T_o}{T} \qquad (1)$$

$$\text{Modulation Index, } M = \frac{T_{on}}{T} \qquad (2)$$

where,
To =Shoot through period
Ton= On period of matrix converter
T = Switching period.

The amplitude of the output voltage depends on the duty cycle and the modulation index. The frequency of the output voltage depends on the switching strategy.

F. Switching strategy

The entire operation is explained in four modes as given in figure 1. Each mode contains either two or three states. If the modulation index is greater than the duty cycle then it has three states. The three states are - on period of the matrix converter, shoot through period and the freewheeling period. If the modulation index is less than or equal to the duty cycle then it has two states. The two states are - on period and the shoot through period. But for the constant frequency only two modes of operation is possible (mode 1 and mode 4). For the step down frequency, the modes 2 and 3 of step up frequency is interchanged and the modes 1 and 4 remains same and the time interval is doubled.

In figure 2, state 1 refers to the on period of the matrix converter, state 2 refers to the shoot through period and state 3 refers to the freewheeling period. In these switching patterns, the current path is always continuous whatever the current direction. Thus the voltage spikes are eliminated during switching and commutation process.

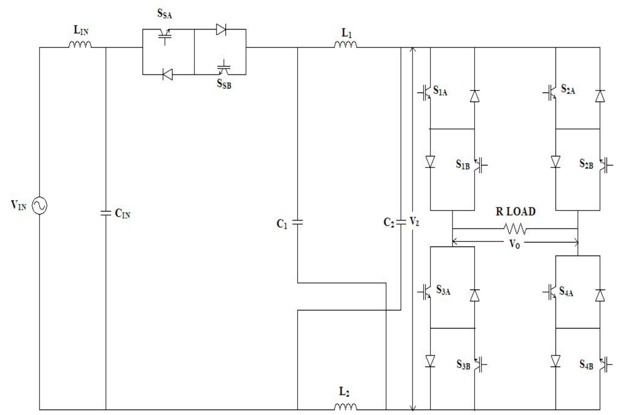

Figure2. Circuit Diagram of Single Phase Z-source Buck Boost Matrix Converter

States and Modes Of Operation Of Single Phase Z-Source Buck Boost Matrix Converter

State 1:

This stage refers to the on period of the matrix converter. During this stage the source is connected to the load through the Z – source network. During this stage the energy stored in the inductor and capacitor of the Z – source network is dissipated.

State 2:

This stage refers to the shoot through period. During the shoot through period switches on the same leg of the matrix converter is turned on and thus the inductors and capacitors in the z-source network are charged. During this period there is no load voltage.

State 3:

This stage refers to the freewheeling period. During the freewheeling period the source is short circuited. This is done by opening the driver switches.

Buck mode:

Figure 3 shows the pulse generation circuit for the Z-source buck boost matrix converter in buck mode for step down frequency operation. Figure4. shows the pulse generation waveform for the Z-source buck boost matrix converter in buck mode for step down frequency operation. Here the duty cycle was set as d=0.2.

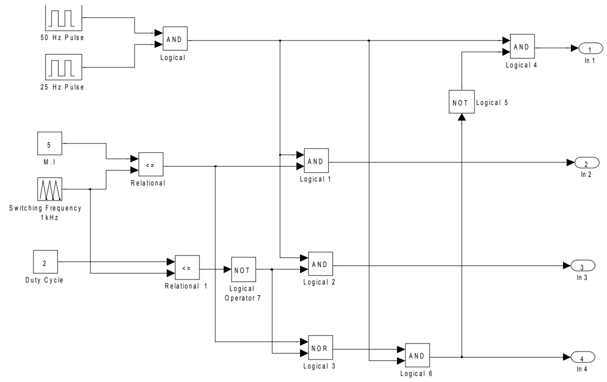

Figure 3.Pulse Generation Circuit for Z-source Buck Boost Matrix Converter with Step down Frequency Operation in Buck Mode.

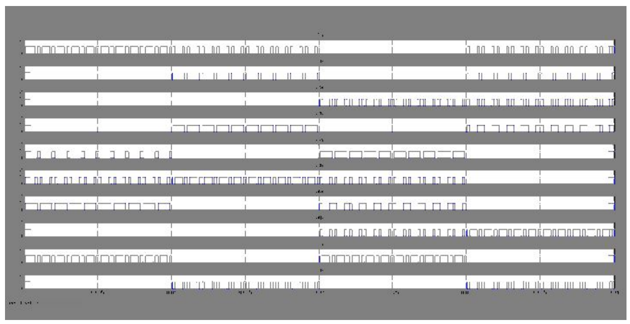

Figure 4.Pulse Generation waveform for Z-source Buck Boost Matrix Converter with Step down Frequency Operation in Buck Mode.

Figure 5 shows the input voltage and input current waveform for the Z-source buck boost matrix converter with step down frequency operation in buck mode. Input rms voltage V_{in}=40V: input rms current I_{in}=0.02369A.

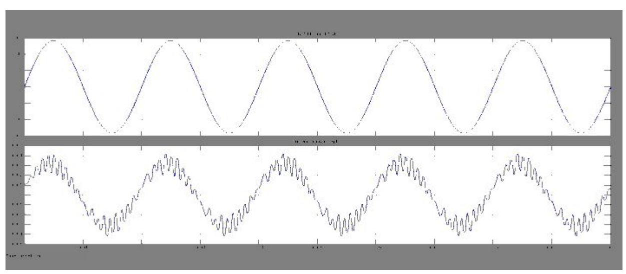

Figure 5.Input Voltage and Input Current Waveform for Z-source Buck Boost Matrix Converter with Step down Frequency Operation in Buck Mode.

Figure 6.shows the output voltage and output current waveform for the Z-source buck boost matrix converter with step down frequency operation in buck mode. Output RMS Voltage V_{out}=26.25V: Output RMS Current I_{out}=0.02625A

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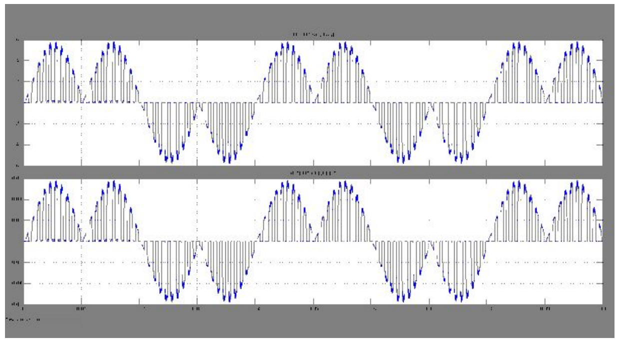

Figure 6.Output Voltage and Output Current Waveform for Z-source Buck Boost Matrix Converter with Step down Frequency Operation in Buck Mode.

Boost Mode:

Figure 7.shows the pulse generation circuit for the Z-source buck boost matrix converter in boost mode for step down frequency operation. Figure 7.shows the pulse generation waveform for the Z-source buck boost matrix converter in boost mode for step down frequency operation. Here the duty cycle was set as d=0.5.

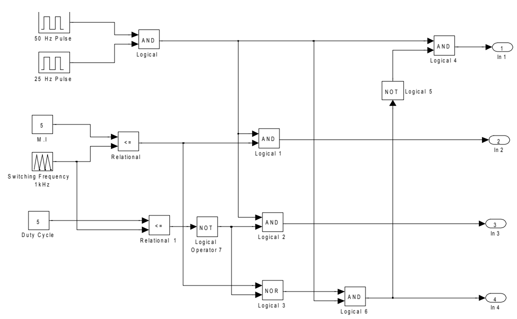

Figure 7.Pulse Generation Circuit for Z-source Buck Boost Matrix Converter with Step down Frequency Operation in Boost Mode.

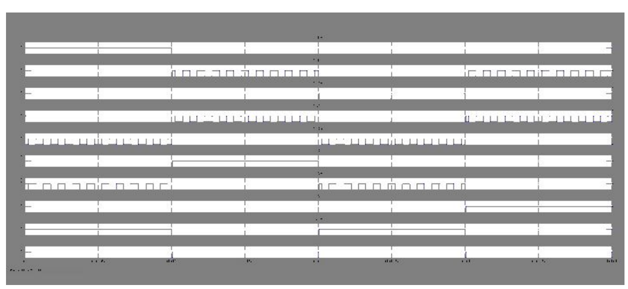

Figure 8.Pulse Generation Waveform for Z-source Buck Boost Matrix Converter with Step down Frequency Operation in Boost Mode.

Figure 9.shows the input voltage and input current waveform for the Z-source buck boost matrix converter with step down frequency operation in boost mode.Input RMS Voltage V_{IN}=40V: Input RMS Current I_{IN}=0.09088A.

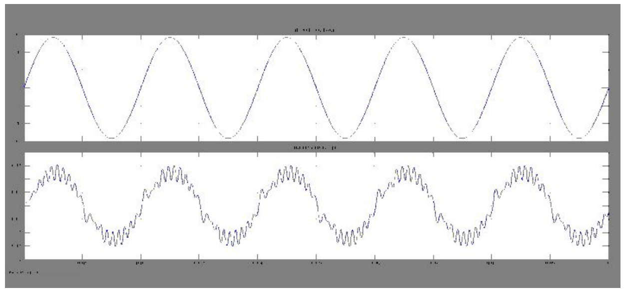

Figure 9. Input Voltage and Input Current Waveform for Z-source Buck Boost Matrix Converter with Step down Frequency Operation in Boost Mode.

Figure 10.shows the output voltage and output current waveform for the Z-source buck boost matrix converter with step down frequency operation in boost mode. Output RMS Voltage V_{out}=58.92V: Output RMS Current I_{out}=0.05892V.

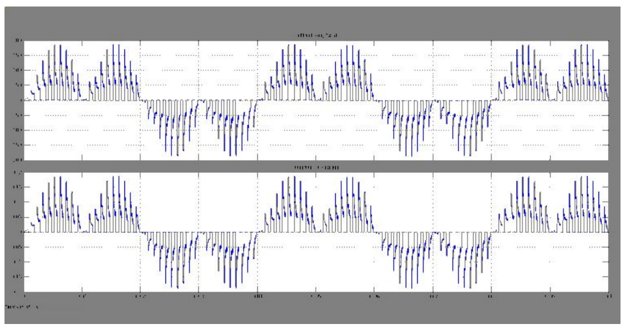

Figure 10.Output Voltage and Output Current Waveform for Z-source Buck Boost Matrix Converter with Step down Frequency Operation in Boost Mode.

Figure 10.shows the relationship between the output voltage and duty cycle for various modulation index. From this we observe that for the input voltage V_{in}=40V**,** the output voltages are buck-boost to the various values depending on the duty cycle and modulation index.

II. CONCLUSION

In this project the proposed single phase Z-source buck boost matrix converter can buck and boost to the desired output voltage with step changed frequency. The output of this proposed single phase Z-source matrix converter produces the voltage in buck boost mode with a step changed frequency, in which the output frequency will be an integer multiple or an integer fraction of the input frequency. It also provides a smooth and regular current path by using a several commutation strategy. The important application of this safe commutation strategy is always a significant improvement as it makes it possible to avoid voltage spikes on the switches without the use of a snubber circuit. And also the proposed converter has the main advantage that it provides the source current THD less than 30% and the input power factor more than 0.95 when compared to the traditional matrix converter which provides the source current THD greater than 50% and the input power factor less than 0.9. The proposed single phase Z-source buck boost matrix converter can be used in various industrial applications that require step changed frequencies and variable voltage amplitudes. It is particularly suitable for controlling the speed of a fan or a pump without the use of an inverter because for these applications, the supply voltage frequency must be changed to control their speed by stages.

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