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A SINGLE PHASE Z SOURCE FULL BRIDGE INVERTER AND MATRIX CONVERTER

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Abstract: The paper proposes two single phase Z source converter for two loads. The Z source converter can be used for both current source and voltage source converter. Z source overcomes both the limitation of both VSI & CSI. The Z source concept can be implemented to all type of power conversions. The input given to Z source is taken from a photo-voltaic array. The power conditioner circuit links the PV array to the load. The PV-PCU boosts the output voltage of the PV array and supplies the load with AC output voltage. Usually the PV-PCU consists of a two stage conversion, dc-dc boost converter and a voltage source inverter. But in this paper, the PCU consists of a single stage conversion, Z source full bridge inverter. The output voltage taken here can be bucked or boosted. The output is again fed to a Z source matrix converter. The converter can buck and boost with step changed frequency, and both the voltage and frequency can be stepped up or stepped down. In addition, the converter can employ a safe commutation strategy to conduct along a continuous current path which results in elimination of voltage spikes on switches without the need of a snubber circuit. The simulation result has been verified for the presented circuit. Any non-linear AC load can be used (induction motor, fan or pump) for industrial purpose.

***Index Terms*—Z Source Converter, Buck-Boost Voltage, Full Bridge Inverter, Matrix Converter**

I. INTRODUCTION

In recent years, photovoltaic grid connected systems become more popular. The power conditioner circuit links the PV array to the load. The PV-PCU boosts the output voltage of the PV array and supplies the load with AC output voltage. Usually the PV-PCU consists of a two stage conversion, dc-dc boost converter and a voltage source inverter. But in this paper, the PCU consists of a single stage conversion. Reduction of component cost, omission of isolation transformer is attained by this paper. The output voltage taken here can be bucked or boosted. The output is again fed to a Z source 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 [1]. Recent research on matrix converters has focused mainly on modulation schemes and on ac drive applications. Obviously, all published studies have dealt with three-phase circuit topologies. The first study of a single phase matrix converter was performed by Zuckerberger on a frequency step-up and fundamental voltage step-down converter. The research focused on step-up/step down frequency operation with a safe-commutation strategy. Applications of single-phase matrix converters have been described for induction motor drives, radio-frequency induction heating, audio power amplification, and compensation voltage sags and swells [1]. It has been reported that the use of safe-commutation switches with pulse width modulation (PWM) control can significantly improve the performance of ac/ac converters.

However, in the conventional single-phase matrix converter topology, the ac output voltage cannot exceed the ac input voltage. Furthermore, it is not possible to turn both bidirectional switches of a single phase leg on at the same time; otherwise, the current spikes generated by this action will destroy the switches. These limitations can be overcome by using Z-source topology[2],[3]. Research on Z-source converters has focused mainly on dc/ac inverters and ac/ac converters. The Z-source ac/ac converters focus on single-phase topologies and three-phase topologies. In applications where only voltage regulation is needed, the family of single-phase Z-source ac/ac converters proposed in has a number of merits, such as providing a larger range of output voltages with the buck–boost mode, reducing inrush, and harmonic current. However, no one has designed a converter based on a Z-source structure and a matrix converter topology that can provide ac/ac power conversion with both a variable output voltage and a step-changed frequency[2]. We show from operating principles, analyses, simulation, and experimental results that the proposed single-phase Z-source buck–boost matrix converter can buck and boost voltages in step-up/step-down frequency

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operation. We use a safe-commutation technique that is very simple to implement as a free-wheeling path to provide the required free-wheeling operation similar to what is available in other converter topologies. The safe-commutation scheme establishes a continuous current path in dead time to eliminate voltage spikes on switches without a snubber circuit[6]. The simulation results show that the output voltage can be obtained at three different frequencies—120, 60, and 30 Hz—and in the buck–boost amplitude mode. Thus, the proposed single-phase Z-source buck–boost matrix converter can be used for voltage applications that require step-changed frequency or amplitude. In particular, it can be applied to the starting of an asynchronous motor as well as to the speed control of an induction motor, which needs a step-changed speed.

II. PROPOSED TOPOLOGY

The DC supply is obtained from a PV panel; the output is given to a z source full bridge inverter through a LC filter. The full bridge inverter has MOSFET switches with a space vector modulation. The AC output is obtained here for a non-linear load. The output is again fed to a z source matrix converter through a LC filter. Here we use PWM technique to drive the gates. The matrix converter uses bidirectional mosfet switches[5]. The output of the matrix converter is given to an AC load (Induction motor). The Block Diagram is shown in Fig 1

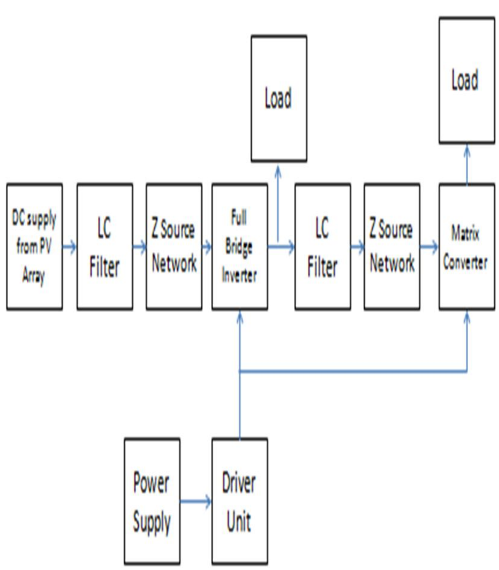

Fig 1 Block Diagram

The Z source converter employs a unique impedance network to couple the converter main circuit to the power source, thus providing features that cannot be obtained in the traditional voltage source and current source converters. The converters overcome the theoretical barriers and limitations of the traditional Voltage source and current source converters. The Z source concept can be applied to all types of power conversions, dc-dc, ac-ac, ac-dc, and dc-ac[3]. It consists of Symmetrical LC components, a combination of two inductor and capacitor, as energy storage /filtering element. The input of the Z source is given through a LC filter. The input LC filter is required to reduce the switching ripples in the input current[2].

It is a single stage conversion from PV array to AC load. The photovoltaic power conditioning circuit converts the DC power produced by the PV array to AC power which is compactable for non-linear loads. The Power conditioning Circuit here is a z source full bridge inverter. We don't use isolation transformer, therefore the cost is reduced.

The voltage can be bucked or boosted by the Z source full bridge inverter. The control switches used here is mosfet. Mosfet has high switching speed characteristics and low switching losses, little gate power and simple gate drive circuits. To control the mosfet switches we go in for Space vector modulation.

The Z-source network is a combination of two inductors and two capacitors. This combined circuit, the Z-source network is the energy storage/filtering element for the Z-source inverter. The Z-source network provides a second-order filter and is more effective to suppress voltage and current ripples than capacitor or inductor used alone in the traditional inverters[2],[4]. Therefore, the inductor and capacitor requirement should be smaller than the traditional inverters. The design parameters are given for a full bridge inverter.

It produces space vector pulse width modulation [11] Fig 2 for the inverter and pulse width modulation for converter. The space vector modulation [4] is the approximation of the reference voltage by averaging the inverter output voltage in the given period same as that of the reference voltage. This helps in producing synchronized and symmetrical output voltage which leads to self balancing of the dc bus voltage over every cycle. The output of the pulse generator is given to the driver circuit. The switches in the converter and the inverter are gated accordingly using the PWM pulses.

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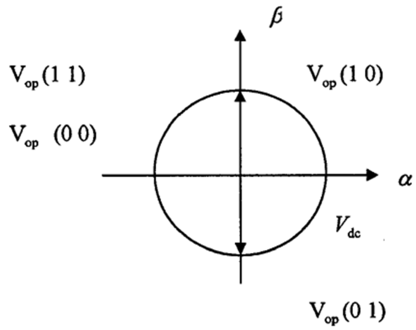

Fig 2 Space Vector Modulation

Matrix Converter is a single stage converter. It uses bi-directional fully controlled switches for direct conversion from ac to ac[1]. A matrix 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., earlier have a number of merits, such as providing a larger range of output voltages with the buck–boost mode, reducing inrush, and harmonic current.

Where a & b are the switching signals for the four MOSFETs with "1" representing the turn-on state and "0" representing the turn-off state[1]. Based on the four working modes of the full bridge inverter, the vector [a b] is:

Mode l: [a b] = [l 0] V op(l 0) = Vdc;
Mode 2: [a b] = [1 1] V op(1 l) = 0 ;
Mode 3: [a b] = [0 l] V op(0 1) =-Vdc;
Mode 4: [a b] = [0 0] V op(0 0)=0.

All inductors and capacitors are small and used to filter switching noise. Matrix converter removes the need for the large reactive energy storage components used in conventional inverter based converters. It can step up and step down the frequency with a safe commutation technique. It establishes a continuous current path in dead time to eliminate the voltage spikes on switches without a snubber circuit. It provides sinusoidal output waveform with minimal higher order harmonics and no sub harmonics. It has inherent bidirectional energy flow capability. Input power factor can be fully controlled. It can handle variable voltage and variable frequency drives.

III. CIRCUIT DESCRIPTION

The ac voltage across the single-phase matrix converter *va* is boosted by the ac/ac Z-source converter with ac input voltage *vi* . Then, the single-phase matrix converter modulates the frequency of *va*. The output voltage *vo* is obtained with a step-changed frequency and a variable amplitude[8]. Since the switching frequency is much higher than the ac source (or line) frequency, the requirements for the inductors and capacitors should be low.

Duty Cycle/Frequency	60 Hz	120 Hz
Boost D=0.3	66Vrms	65Vrms
Buck D=0.7	31Vrms	31Vrms

Table 1 Duty Cycle

This paper, the frequency of input voltage *fi* is assumed to be 60 Hz, and the desired output frequency *fo* is synthesized to be 120 Hz (step-up frequency), Table illustrates the converter's switching strategy over one cycle of input voltage for a 120-Hz output frequency in boost mode as shown in Table 1

To double output frequency of the input voltage, the operation of the converter is divided into four stages, as shown in the Fig 3

f_i	f_o	Stage	Switch "on" states				
			State 1		State 2		
			Active	Commutation	Shoot-through	Free-wheeling	Commutation
60 Hz	120 Hz	1	$S_{sa}, S_{1a}, S_{4b}, S_{sb}, S_{1b}$	S_{2b}, S_{4a}	S_{1a}, S_{3b}	(S_{1a}, S_{2b}) or (S_{3b}, S_{4a})	S_{sa}, S_{4a}
		2	$S_{sa}, S_{2a}, S_{3b}, S_{sb}, S_{2b}$	S_{1b}, S_{3a}	S_{2a}, S_{4b}	(S_{1b}, S_{2a}) or (S_{3a}, S_{4b})	S_{sa}, S_{3a}
		3	$S_{sb}, S_{2b}, S_{3a}, S_{sa}, S_{3b}$	S_{2a}, S_{4b}	S_{1b}, S_{3a}	(S_{3a}, S_{4b}) or (S_{1b}, S_{2a})	S_{sb}, S_{2a}
		4	$S_{sb}, S_{1b}, S_{4a}, S_{sa}, S_{4b}$	S_{1a}, S_{3b}	S_{2b}, S_{4a}	(S_{3b}, S_{4a}) or (S_{1a}, S_{2b})	S_{sb}, S_{1a}
	60 Hz	1	$S_{sa}, S_{1a}, S_{4b}, S_{sb}, S_{1b}$	S_{2b}, S_{4a}	S_{1a}, S_{3b}	(S_{1a}, S_{2b}) or (S_{3b}, S_{4a})	S_{sa}, S_{4a}
		2	$S_{sb}, S_{1b}, S_{4a}, S_{sa}, S_{4a}$	S_{1a}, S_{3b}	S_{2b}, S_{4a}	(S_{3b}, S_{4a}) or (S_{1a}, S_{2b})	S_{sb}, S_{1a}
	30 Hz	1	$S_{sa}, S_{1a}, S_{4b}, S_{sb}, S_{1b}$	S_{2b}, S_{4a}	S_{1a}, S_{3b}	(S_{1a}, S_{2b}) or (S_{3b}, S_{4a})	S_{sa}, S_{4a}
		2	$S_{sb}, S_{2b}, S_{3a}, S_{sa}, S_{3b}$	S_{2a}, S_{4b}	S_{1b}, S_{3a}	(S_{3a}, S_{4b}) or (S_{1b}, S_{2a})	S_{sb}, S_{2a}
		3	$S_{sa}, S_{2a}, S_{3b}, S_{sb}, S_{2b}$	S_{1b}, S_{3a}	S_{2a}, S_{4b}	(S_{1b}, S_{2a}) or (S_{3a}, S_{4b})	S_{sa}, S_{3a}
		4	$S_{sb}, S_{1b}, S_{4a}, S_{sa}, S_{4b}$	S_{1a}, S_{3b}	S_{2b}, S_{4a}	(S_{3b}, S_{4a}) or (S_{1a}, S_{2b})	S_{sb}, S_{1a}

Fig 3 Switching States

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The proposed single-phase Z-source buck–boost matrix converter requires four bidirectional switches to serve as a single-phase matrix converter and one source bidirectional switch All bidirectional switches are common emitter back-to-back switch cells.. The bidirectional switches are able to block voltage and conduct current in both directions. Because these bidirectional switches are not available at present, they can be substituted for by combinations of two diodes and two MOSFET connected in anti-parallel (common emitter back to back), as shown in Fig. The diodes are included to provide the reverse blocking capability.

The MOSFETs are used because of their high switching capabilities and their high current-carrying capacities, which are desirable for high-power applications. As indicated in the figure, *D* refers to the equivalent duty ratio and *T* is the switching period. Implementing the single-phase Z-source matrix converter requires different bidirectional switching arrangements depending on the desired amplitude and frequency of the output voltage. The amplitude of the output voltage is controlled by the duty ratio *D*, while the frequency of the output voltage depends on the switching strategy.

In stage 1 in the boost mode when both input voltage and output voltage are positive. The switches are fully turned on (S2b is turned on for commutation purposes, while Ssa and S4a are turned on for continuous current flow); S1b, S3b, and S4b are modulated complementary to the dead time. In state 1, S4b turns on and conducts current flow during the increasing positive cycle of input voltage; Ssb and S1b turn on and conduct negative current flow from the load to the source, if possible; S2b turns on for commutation purposes.

Then, Ssb and S4b turn off, and S3b has not yet turned on, and there are two commutation states that occur. If $i_{L1} + i_{L2} + i_o > 0$, the current flows along a path from Ssa ,; if $-i_{L1} - i_{L2} + i_o > 0$, the current flows along a path from S4*a* and S2b, as shown in Fig. 4(c, the path of the current flowing through S2b is $-i_{L1} - i_{L2} + i_o$. Because switch S2b must be conducting, the current condition for this state is $-i_{L1} - i_{L2} + i_o > 0$.

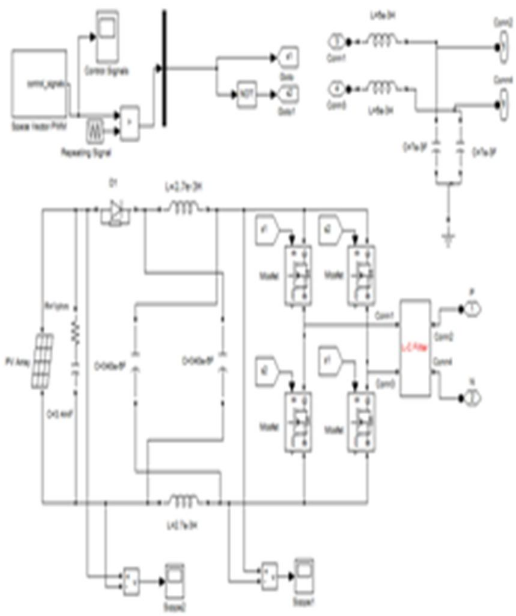

Fig. 4 Simulation of Full bridge inverter

In state 2, S3b turns on and conducts current flow in the Z-source network as a shoot-through path; the positive load current may be freewheeled through S2b and S1a; the negative load current may be freewheeled through S3band S4a. In these switching patterns, the current path is always continuous whatever the current direction.

Thus, the voltage spikes are eliminated during switching and commutation processes. The analysis for stages 2, 3, and 4 is similar to that for stage 1. The in Fig. 4 indicates the safe-commutation switch during each particular stage. The operations at the other output frequencies of 60 and 30 Hz are performed by changing the switching strategies. The operation for an output frequency of 60 Hz is implemented by omitting stage 2 and stage 3 and doubling the time intervals for stage 1 and stage 4.

Similarly, the operation for an output frequency of 30 Hz can be implemented by interchanging stage 2 and stage 3 and doubling the time intervals of all stages. In the operations for output frequencies of 60 and 30 Hz, the time interval of each stage is 8.33 ms. provides the switching sequences for the operations for output frequencies of 120, 60, and 30 Hz.

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IV. SIMULATION RESULT

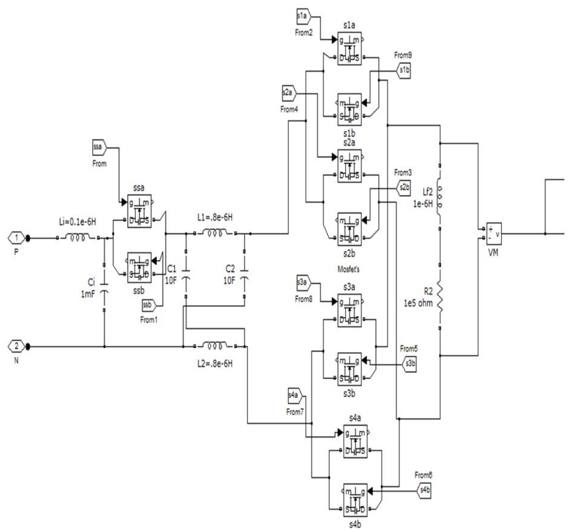

Fig 5 Simulation of Matrix Convereter

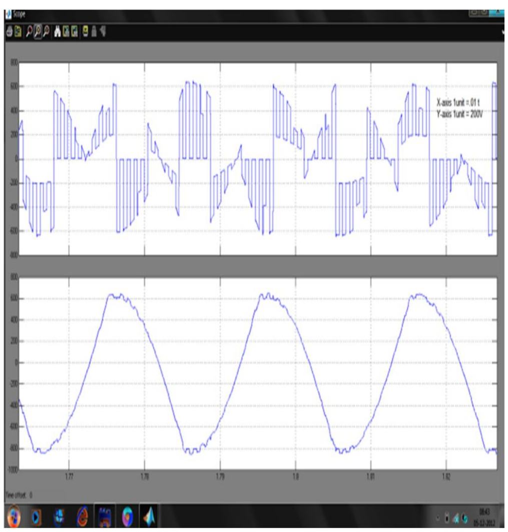

Fig 6 Output of matrix converter and full bridge inverter

V. CONCLUSION

In this paper, we have proposed a Full Bridge inverter & a single-phase Z-source buck–boost matrix converter that can buck and boost to the desired output voltage with step-changed frequency. The output of this single-phase Z-source buck–boost matrix converter produces the voltage in buck–boost mode with a step-changed frequency, in which the output frequency is either an integer multiple or an integer fraction of the input frequency. It also provides a continuous current path by using a commutation strategy. The use of this safe-commutation strategy is a significant improvement as it makes it possible to avoid voltage spikes on the switches without the use of a snubber circuit. We presented a steady-state circuit analysis and described the operational stages.

The proposed structure of single phase Z source full bridge inverter is discussed. An optimal switching pattern for the converters have been proposed, Which reduce the switching loss and common mode EMI. We expect that this proposed strategy can be used in various industrial applications that require step-changed frequencies and variable voltage amplitudes. The proposed converter is particularly suitable for controlling the speed of a fan or a pump without the use of an inverter because for these applications, the input voltage frequency must be changed to control their speed by stages.

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