A Novel Single-Phase Z-source Buck-Boost Matrix Converter

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Abstract---This paper presents a novel type of Z-source buck-boost matrix converter which has unique features that cannot be obtained in traditional matrix converter. The proposed converter employs Z-source network to buck or boost the input voltage. The converter employs safe commutation strategy which eliminates voltage spikes on the switches without need of a protection circuit.

Key words: Single phase matrix converter, Z-source converter, Buck-boost voltage, Step-up and Step-down frequency

I. INTRODUCTION

A single phase AC/AC converter is used to convert directly an AC voltage into an AC voltage of variable amplitude and frequency. The topology was first introduced by Gyugyi and Pelly[1] in 1976. It was analyses by various researchers and the Single-phase matrix converter was first introduced by Zuckerberger [2] based on direct AC-AC converter. Recent research on matrix converters has extended its operation to other converter The research mainly focused on step up / step down frequency operation with a safe-commutation strategy. But in all these topologies, the AC output voltage cannot exceed the AC input voltage due to there is no energy storage components are present between the input and output side. Furthermore, it is not possible to turn ON both the bidirectional switches of a single phase leg on at the same time; otherwise the current spikes generated by this action will destroy the switches. Both of these limitations can be overcome by using Z-source Buck-boost topology. Many researches have also focused on Z-source AC/AC converters which mainly find applications where only voltage regulation is needed.

A single phase impedance source buck-boost matrix converter based on a single phase matrix converter that connects directly the single-phase source to the single-phase load. The converter can buck and boost both voltage and frequency. This converter has several attractive features that have been investigated in the last few decades. This converter gives variable output frequency and variable output amplitude. In the last few years, an increase in research work has been observed, bringing this topology closer to the industrial application.

In this paper, presents a noval topology is to elimination of voltage spikes on switches without need for a snubber circuit by providing safe-commutation switching strategy to conduct along a continuous current path. The new modulation strategy keeps the number of switching at a minimum. Implementing this converter requires different switching arrangements based on the desired amplitude and frequency. The amplitude of the output voltage is controlled by the shoot-through period and the frequency of the output voltage depends on the switching strategy. The operating principles of proposed single phase impedance source buck-boost matrix converter are described. In particular, it can be applied to the speed control of an induction motor as well as to the starting of asynchronous motor,

I. PROPOSED TOPOLOGY

Impedance source buck-boost matrix converter is combination of two system names as a Z source buck boost converter and Matrix converter. First a Z source buck boost converter employs a unique LC impedance network for coupling the converter main circuit to the power source, which provides with a way of buck and boosting the input voltage, a condition that cannot be achieved in the traditional inverters and second The Matrix converter consist of four bi-directional switches arranged in a group. A bi-directional switch is capable to control the current flow and voltage blocking in both directions. The single phase Impedance source buck-boost Matrix converter Topology is shown in fig.1

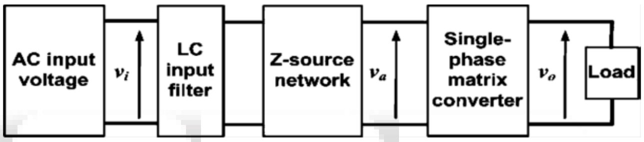

Fig. 1: General block diagram of proposed topology.

The ac voltage across the single-phase matrix converter *va* is bucked or 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.

Figure 2 shows the circuit of the Z-source Single-Phase Matrix Converter. It uses four bi-directional switches to serve as a SPMC. It employs a Z-network, bi-directional switches, R-L load. The symmetrical Z-network, a combination of two inductors and two capacitors, is the energy storage/filtering element for the proposed converter. Since the switching frequency is much higher than the AC input source frequency, the inductor and capacitor requirements should be low This arrangement has the advantage of independent control of the current in both directions.

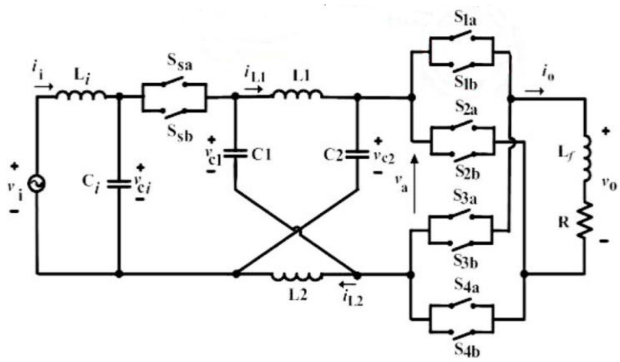

Fig. 2: Circuit of the Z-source SPMC

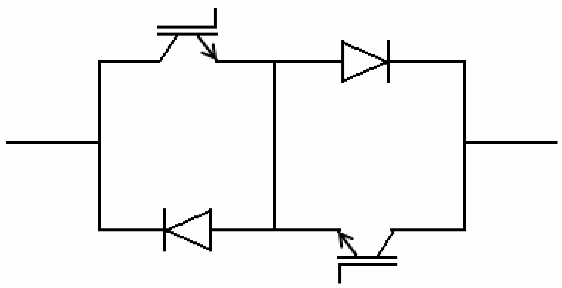

Fig. 3: Common emitter Bi-directional topology

In this configuration IGBTs are as controlling switch used because of its high switching capabilities and high current carrying capabilities for high power applications. Diodes are included to provide the reverse voltage blocking capability.

II. SWITCHING STRATEGIES WITH SAFE COMMUTATION

Operation of proposed topology can divide into four modes as shown in figure 4. Here we are adding extra state called shoot-through state so each mode has two states (i)shoot-through state and (ii)non-shoot-through state. By using proper switching sequencing of four modes desired output voltage frequency can obtained.

The proposed single-phase Z-source buck–boost matrix converter requires four bidirectional switches $S1j$, $S2j$, $S3j$, and $S4j$ (j = a, b) to serve as a single-phase matrix converter and one source bidirectional switch Ssj (j = a, b), where a and b refer to drivers 1 and 2, respectively. All bidirectional switches are common emitter back-to-back switch cells. The five switches Ssj, $S1j$, $S2j$, $S3j$, $S4j$ (j=a, b) used in the single-phase Z-source buck–boost matrix converter are bidirectional Switches, as shown in Fig. 2. As indicated in the figure, D refers to the equivalent duty ratio and T is the switching period. Implementing 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 amplitude of the output voltage is controlled by the duty ratio D, while the frequency of the output voltage depends on the switching strategy.

Fig. 4 illustrates stage 1 in the boost mode when both input voltage and output voltage are positive. The switches which turn on during stage 1 are Ssa, S1a, S2b, and S4a. (Here switch S2b is turned on for commutation process and Ssa and S4a are turned on for continuous current flow in the circuit); during the increasing positive cycle of input voltage,S4b turns on and conducts; 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 will two commutation states that occur in the circuit. If $iL1 + iL2 + io > 0$, the current flows along a path from Ssa , as shown in Fig. 4.2; if $-iL1 - iL2 + io > 0$, the current flows along a path from S4a and S2b, as shown in Fig. 4.3.the path of the current flowing through S2b is to be $(-iL1 - iL2 + io)$. Because switch S2b must be conducting, the current condition for this state will be $-iL1 - iL2 + io > 0$. In state 2, as shown in Fig. 4.4,switching occurs in shoot-through period. S3b turns on and conducts current flow in the Z-source network as a shoot-through path; Freewheeling of the positive load current and negative load current may be occurs through S2b,S1a and S3b,S4a;biggest advantage of these switching strategy that the current path is always continuous whatever the current direction. Thus, the voltage spikes are eliminated during switching and commutation processes which was occurs before. In Figure 4 the dotted line indicates the safe-commutation switch during each particular stage. Output frequency can be changed by proper switching operation in sequences .The operation for an output frequency of 60 Hz (i.e. same as input frequency) is implemented by eliminating stage 2 and stage 3 and doubling the time intervals for stage 1 and stage 4.Table I provides the switching sequences for the operations for output frequencies of 120, 60, and 30 Hz.

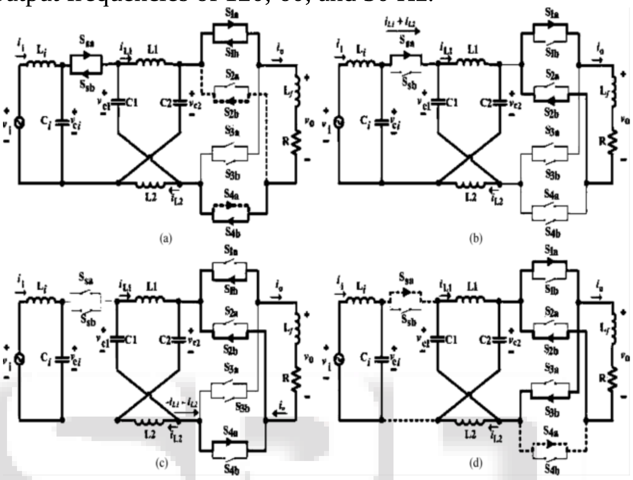

Fig. 4: Stage 1 for the boost mode for a frequency of 120 Hz. (a) State 1. (b) Commutation state when iL1 + iL2 + io >0 (c) Commutation state − iL1− iL2 + io > 0 (d) State 2.

In their early years electric power systems did not reach far from the generating station. Since then power systems have been inter-connected to cover first regions and later nations. Today they extend over entire continents and contain a huge number of components that together serve to supply electric energy to the customers. The aim is to maintain the voltage and the frequency at their nominal values. To improve reliability both design and operation of power systems involve safety margins to the cost of some profit. Much effort today is spent on control and supervision that can reduce these margins, which also has environmental aspects.

"Environmental and economic aspects make it difficult to build new power lines and to reinforce existing ones. The continued growth in demand for electric power must therefore to a great extent be met by increased loading of available lines. A consequence is that power system damping is reduced, leading to a risk of poorly damped power oscillations between the generators. This thesis proposes the use of controlled active loads to increase damping of such electro-mechanical oscillations. The focus is on structural aspects of controller power system damping by fact device Statcom."

Input freq	Output freq	mode	Switch on				
			State 1	State 2			
			Active	commutation	Shoot through	Free wheeling	commutation
60 Hz	30 Hz	1	Ssa,S1a,S4b, Ssb,S1b	S2b,S4a	S1a,S3b	(S1a,S2b) or (S3b,S4a)	Ssa,S4a
		2	Ssb,S2b,S3a, Ssa,S3b	S2a,S4b	S1b,S3a	(S3a,S4b) or (S1b,S2a)	Ssb,S2a
		3	Ssa,S2a, S3b,S2b	S1b,S3a	S2a,S4b	(S1b,S2a) or (S3a,S4b)	Ssa,S3a
		4	Ssb,S1b,S4a, Ssa,S4b	S1a,S3b	S2b,S4a	(S3b,S4a) or (S1a,S2b)	Ssb,S1a
	60 Hz	1	Ssa,S1a,S4b, Ssb,S1b	S2b,S4a	S1a,S3b	(S1a,S2b) or (S3b,S4a)	Ssa,S4a
		2	Ssb,S1b,S4a, Ssa,S4a	S1a,S3b	S2b,S4a	(S3b,S4a) or (S1a,S2b)	Ssb,S1a
	120 Hz	1	Ssa,S1a,S4b, Ssb,S1b	S2b,S4a	S1a,S3b	(S1a,S2b) or (S3b,S4a)	Ssa,S4a
		2	Ssa,S2a,S3b, Ssb,S2b	S1b,S3a	S2a,S4b	(S1b,S2a) or (S3a,S4b)	Ssa,S3a
		3	Ssa,S2a,S3b, Ssb,S2b	S2a,S4b	S1b,S3a	(S3a,S4b) or (S1b,S2a)	Ssb,S2a
		4	Ssb,S1b,S4a, Ssa,S4b	S1a,S3b	S2b,S4a	(S3b,S4a) or (S1a,S2b)	Ssb,S1a

Table 1: Switching control sequence for proposed converter
Boost mode

III. CIRCUIT EQUATIONS

The proposed Z-source buck-boost converter has inductor and capacitor of same rating inductance (L) and capacitance (C) respectively so Z-source network becomes symmetrical.

$vC1 = vC2 = vC$ (1)

$iL1 = iL2 = iL$ (2)

Single phase Z-source buck boost matrix converter has mainly two operating states which is shown in figure 4.in state 1 the time interval is (1-D)T, where D is the equivalent duty-ratio and T is the switching period. in this state the AC supply given to the load through Z-network and during this it charges the Z-network capacitors, while the inductor discharge.

$v_C = v_i - v_L$ and (3)

$v_0 = vi - 2v_L$ (4)

where vi is the input voltage, v_L is the voltage across the inductor and is the voltage across the capacitor.

In state 2, the time of interval is DT. Energy stored in capacitors during state 1 discharge, while inductors charge and store energy.

$v_C = v_L$ and (5)

$v_0 = 0$ (6)

Ignoring the effects of dead time and assuming that the inductor in the Z-source network is very small and no line frequency drop across the inductors

$v_L = \oint_0^{DT} vc\, dt + \oint_0^{(1-D)T} (vi - vc)dt$ and

Voltage across the load should

$vc = \frac{1-D}{1-2D} \cdot vi$ (7)

From equation number (7) it is proof that the output voltage of the single phase Z-source buck-boost matrix converter can be bucked and boosted by changing duty ratio D.

IV. MAIN MODEL & RESULTS

Basic schematic view of single phase Z-source buck-boost matrix converter configuration is shown in figure 5 which is implementing in Matlab software.

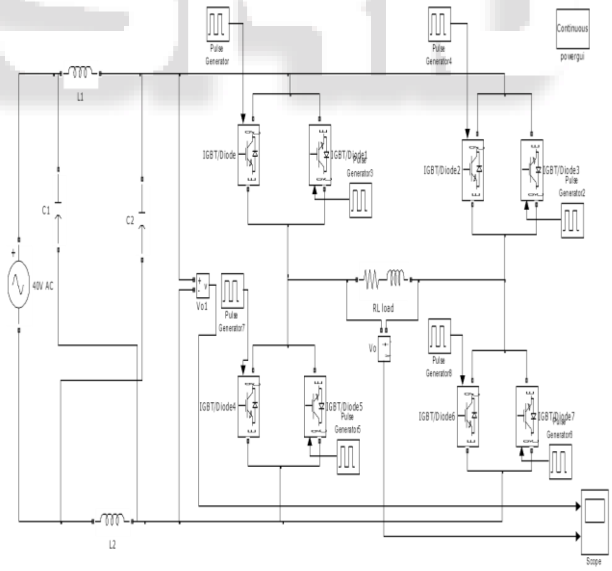

Fig. 5: Main model of Z-source SPMC

In this model the switches used are the bi-directional switches used to block the voltage and conduct current in both directions.

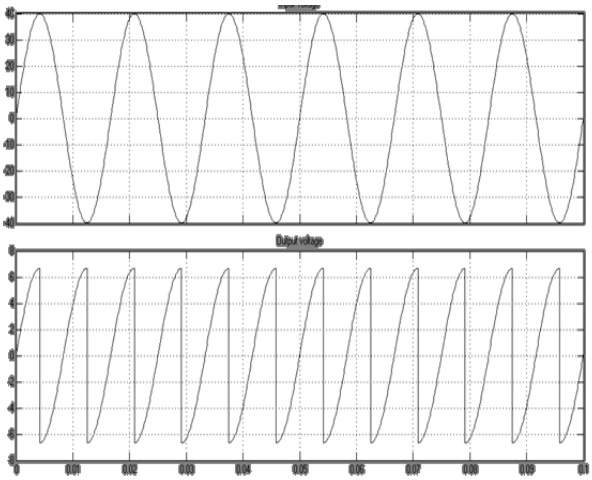

Fig. 6: Input and Output Voltage Waveform

Here input voltage 40v rms, 60Hz taken as input and we got double the frequency (120 Hz) with step down voltage up to 8v rms. Similarly we can step up the input voltage with frequency simultaneously.

V. CONCLUSION

A novel single phase Z-source buck-boost matrix converter is presented in this paper. by combining the features or properties of Z-source network and Matrix converter we can obtain output as step up/step down frequency with buck/boost the input voltage. Furthermore, proposed topology use safe-commutation strategy to provide a continuous current path. Simulation model and results waveforms are illustrated.

This proposed converter can apply to the step changed speed application like an induction motor. It can also be used as DVR (Dynamic Voltage Regulator) to compensate voltage sags and swells in AC line conditioning. This technology has potential benefits especially for applications where size, weight and long term reliability are important factors.

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