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Z-Source Based Multi Level Inverter

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Abstract

This paper presents a novel single Z-source based seven level multilevel inverter. In this topology single Z-source impedance network is used to boost up the output voltage using shoot through state control. A new PWM technique is implemented by using three reference signals and a triangular carrier signal which are used to generate the PWM signals for inverter switches, and the shoot through state for Z-network is achieved by inserting DC reference signal. The advantage of proposed topology makes reduction in number of switches, and this new configuration is suitable for applications working at lower and medium power levels. The performance of proposed topology is validated using MATLAB/SIMULINK software.

Index Terms — Z-source inverter, multilevel inverter, renewable energy resource.

I. Introduction

IN RECENT years, due to energy crisis, renewable energy resource, such as wind turbine, photovoltaic (PV) cell, and fuel cell are becoming more and more popular in industrial and residential applications [1]. Photo-Voltaic (PV) sources are used today in many applications as they have the advantages of being maintenance and pollution free. Solar-electric-energy demand has grown consistently by 20%–25% per annum over the past 20 years, which is mainly due to the decreasing costs and prices. This decline has been driven by the following factors: 1) an increasing efficiency of solar cells 2) manufacturing technology improvements and 3) economics of scale.

In the conventional PV array systems, the other converter as a DC-DC boost chopper is utilized to increase output DC voltage of the PV. In the suggested topology, Z-source inverter is employed instead of DC-DC boost chopper. The Z-source inverter utilizes Z impedance network between the DC source and inverter circuitry to achieve boost operation [2]. The voltage boost is achieved by providing a shoot-through state when both switches in the same phase leg are on which is not possible with traditional inverter topology. The Z-Source inverters in the comparing of traditional inverters are lower costs, reliable, lower complexity and higher efficiency [3-4].

Various topologies for multilevel inverters have been proposed over the years. Common ones are diode-clamped [5]–[8], cascaded H-bridge [9-10], and modified H-bridge multilevel [11]–[15].

TABLE I
COMPARITION OF MULTILEVEL INVERTER

Multilevel Inverter type	H bridge Auxiliary switch	Diode Clamped	Capacitor Clamped	Asymmetric Cascade
Main switch	4	36	36	36
Required blocking voltage	Vs/2	Vs/7	Vs/7	Vs/7
Anti parallel diodes	8	36	36	36
Auxiliary switches	2	36	-	-
Required blocking voltage	Vs/3	-	-	-
Auxiliary diodes	4	-	-	-
Switches total	6	36	36	36
Diodes total	12	72	36	36
Capacitors	3	7	17	9

Multilevel inverter, which used to convert dc power obtained from PV modules into ac power. Multilevel inverters are promising; they have nearly sinusoidal output-voltage waveforms, output current with better [16-17].

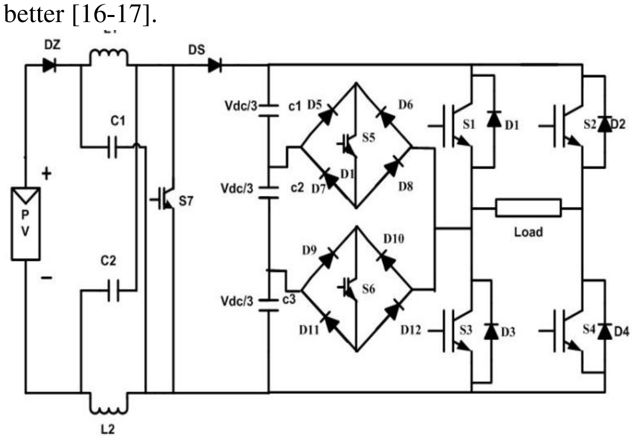

Fig.1. Proposed single Z-source based multilevel inverter

They offer improved output waveforms, smaller filter size, lower EMI and lower total harmonic distortion (THD). This paper recounts the development of a novel modified H-bridge single-phase multilevel inverter that

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has two diode embedded bidirectional switches and a novel pulse width modulated (PWM) technique.

II. Proposed topology

A) *Z-source network*

Fig. 2(a) shows the suggested basic unit for a proposed Z-source topology. This consists of a DC voltage source, Z impedance with one switch S7 and Diode DS. It can operate in two modes: non shoot-through and shoot-through state. In the shoot-through state, switch S7 is on and diode DS off output voltage of z-network is zero. The shoot-through pulse is generated by comparing a dc reference line with the triangular carrier wave.

i) Shoot-through state:

The equivalent circuit of shoot-trough state is shown in Fig. 2(b). With the analysis of circuits 2(b) it can be expressed as:

$$V_L = V_c \quad (1)$$

$$V_{in} = 0 \quad (2)$$

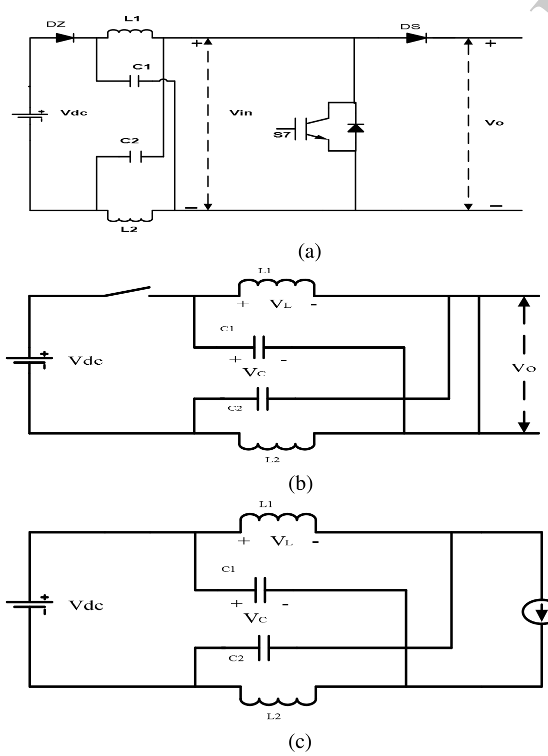
ii) Non Shoot-through state:

The equivalent circuit in non shoot-through state is shown in Fig. 2(c). Inductors voltage and output of LC network can be calculated as:

$$V_L = V_{dc} - V_c \quad (3)$$

$$V_{in} = V_c - V_L \quad (4)$$

$$V_{in} = 2V_c - V_{dc} \quad (5)$$



(a)

(b)

(c)

Fig.2 Circuit diagram of (a) single phase proposed basic unit, (b) basic unit in shoot through state, (c) basic unit in non shoot through state.

It is assumed that average voltage of inductor is zero so relation between capacitor and output voltage is found as:

$$\frac{V_c}{V_{in}} = \frac{T_{ns}}{T_{ns} - T_{sh}} \quad (7)$$

Where Tsh is the total shoot-through state period and Tns is the total non shoot-through state period during all period of switching. Substituting (8) in to (7) during non shoot through state Vin is obtained as

$$V_{in} = \frac{V_{dc}}{1 - 2\frac{T_{sh}}{T}} \quad (8)$$

$$B = \frac{1}{1 - 2\left(\frac{T_{sh}}{T}\right)} \quad (9)$$

Where T is period of switching and B is boost factor and it is clear that $B \geq 1$.

TABLE II
SWITCHES STATES AND Vo VALUE

State	Output Voltage(V_0)	Switches
1	V_{in}(Non Shoot-through)	S_7 OFF, D_S ON
2	0(Shoot-through)	S_7 ON, D_S OFF

B) Multilevel inverter topology

The proposed single-phase seven-level inverter was developed from the five-level inverter in [11]–[12]. It consist of a single-phase conventional H-bridge inverter, two bidirectional switches, and a capacitor voltage divider formed by *C*1, *C*2, and *C*3, as shown in (Fig. 1). The modified H-bridge topology is significantly advantageous over other topologies, i.e., less power switch, power diodes, and less capacitors or inverters of the same number of levels. Photovoltaic (PV) arrays were connected to the inverter via a single z-source converter. Proper switching of the inverter can produce seven output-voltage levels (*V*dc, 2*V*dc/3, *V*dc/3, 0, −*V*dc, −2*V*dc/3, −*V*dc/3) from the dc supply voltage.

TABLEIII
SWITCHING STATES OF PROPOSED INVERTER

V_0	S1	S2	S3	S4	S5	S6
V_{dc}	On	Off	Off	On	Off	Off
$2V_{dc}/3$	Off	Off	Off	On	On	Off
$V_{dc}/3$	Off	Off	Off	On	Off	On
0	Off	Off	On	On	Off	Off
0*	On	On	Off	Off	Off	Off
$-V_{dc}/3$	Off	On	Off	Off	On	Off
$-2V_{dc}/3$	Off	On	Off	Off	Off	On
$-V_{dc}$	Off	On	On	Off	Off	Off

III. Novel PWM Modulation

PWM switching signals are generated by a novel PWM modulation technique. Three reference signals (Vref1, Vref2, and Vref3) were compared with a carrier signal (Vcarrier).The reference signals had the same frequency and amplitude and were in phase with an offset value that was equivalent to the amplitude of the carrier

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signal. The reference signals were each compared with the carrier signal. If Vref1 had exceeded the peak amplitude of Vcarrier, Vref2 was compared with Vcarrier until it had exceeded the peak amplitude of Vcarrier. Then, onward, Vref3 would take charge and would be compared with Vcarrier until it reached zero. Once Vref3 had reached zero, Vref2 would be compared until it reached zero. Then, onward, Vref1 would be compared with Vcarrier. The shoot-through pulse for Z-source network is generated by comparing dc reference line with the carrier signal. Shoot-through time varies depending on the magnitude level of dc reference line as compared with Vcarrier.

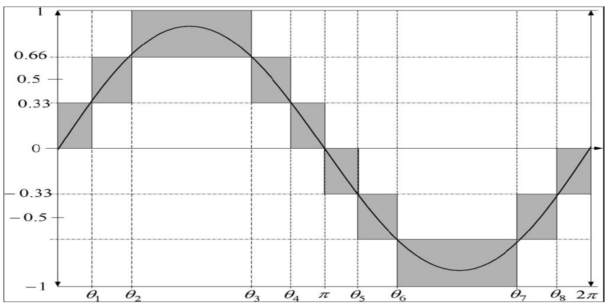

Fig.3 Proposed PWM Technique

IV. Simulation Results

The PWM switching patterns were generated by comparing three reference signals (*V*ref1, *V*ref2, and *V*ref3) against a triangular carrier signal (see Fig. 4). One leg of the inverter operated at a high switching rate that was equivalent to the frequency of the carrier signal, while the other leg operated at the rate of the fundamental frequency (i.e., 50 Hz). Switches *S*5 and *S*6 also operated at the rate of the carrier signal. The shoot-through pulse is shown in fig.5 (g).

TABLE IV
Z-Source Network

Parameters	Value
L1,L2	1mH
C1,C2	2600uH

Simulation result of 7- Level Multilevel Inverter at switching frequency 3 kHz, 230V, 4A, 720W were shown in fig (6 & 7). The seven-level inverter produces lowest THD value (0.42%) as compared with five and three-level inverter with filter shown in fig (9).

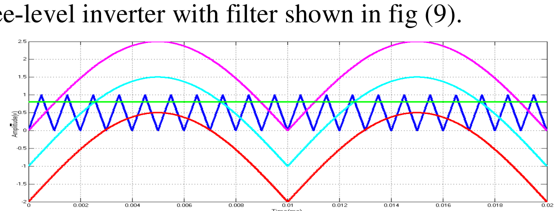

Fig .4 Proposed PWM switching pattern

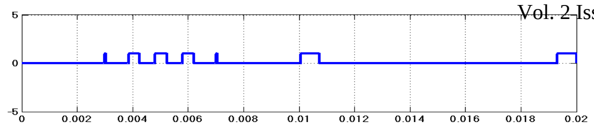

Fig.5 (a) PWM signal for S1

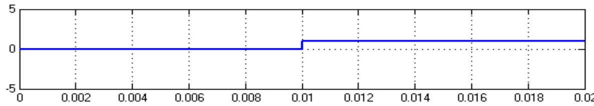

Fig.5 (b) PWM signal for S2

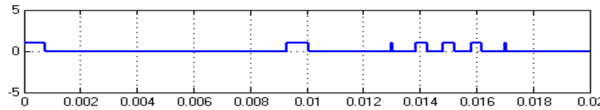

Fig.5 (c) PWM signal for S3

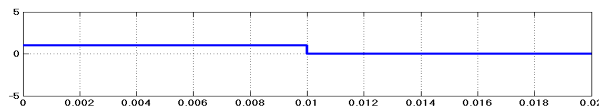

Fig.5 (d) PWM signal for S4

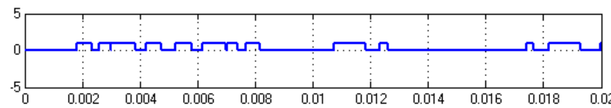

Fig.5 (e) PWM signal for S5

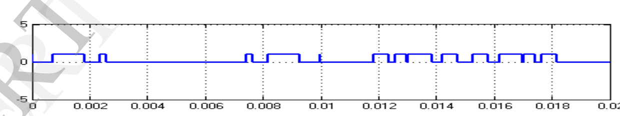

Fig.5 (f) PWM signal for S6

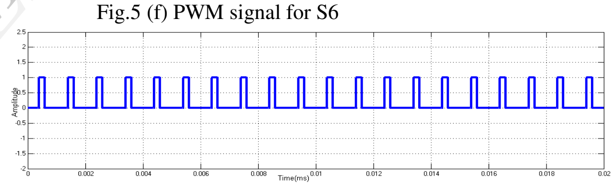

Fig.5 (g) Shoot-Through pulse for S7

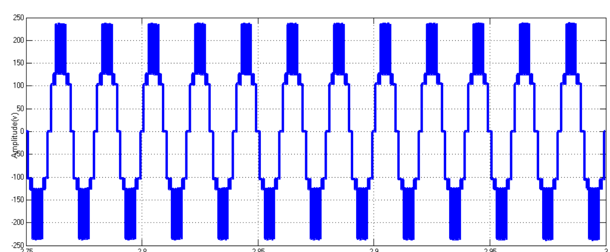

Fig.6 Inverter output voltage (Vout)

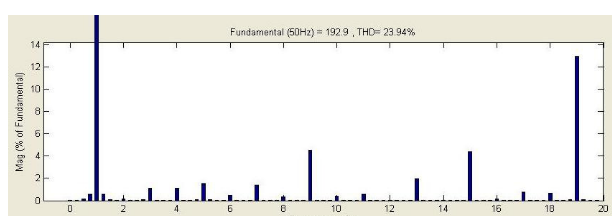

Fig.7 Harmonic analysis for output Voltage (without filter)

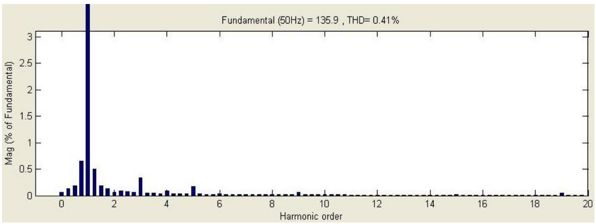

Fig.8 Harmonic analysis for output Voltage (with filter)

V. Conclusion

In this paper the modeling and simulation of novel single Z-source based multilevel inverter have been shown. The PWM switching signals are generated by comparing three reference signals against a triangular carrier signal. The voltage level of the PV panel is improved using Z-source network & multilevel inverter. The proposed multilevel inverter is to reduce both voltage & current THD of the inverter .The proposed topology has minimum number of switches compare than other configuration.

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