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Analysis of PV Based Energy Generation System Using Cascaded Multi-level Z-Source Inverter

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Abstract: Multilevel inverters have been newly recognized additional attention in the power engineering. A novel cascaded Z-source Multilevel Inverter (ZS-MI) is promising technique useful for photovoltaic power generation system is presented in this paper. It can defeat the difficulties of conventional photovoltaic power generation system, due to its stabilized DC-link voltage throughout by its boost capability, and also reduction in modules count. In addition, this work investigates all of the operating modes for a module and measures its efficiency. Simulation and experimental results are also given to express the novel features of the proposed scheme for level inverter.

Keywords: H-Bridge, Multilevel Inverter, Photovoltaic, Total Harmonic Distortion, Z-source inverter.

1. INTRODUCTION

A Z-source Inverter (ZI) is a kind of inverter, it transfers DC to AC. It ability as a buck inverter with no making exploitation of DC-DC converter expansion because of its one of a configuration. Impedance Z-source circuits offer a creative technique for power exchange in the heart of source and heap in a extensive collection of power conversion applications. The amount of modifications and new-fangled Z-source configurations has turn into exponentially. Developments to the impedance circuits by presenting attached striking have furthermore been of late projected for finish considerably advanced voltage boosting, while exploiting a small shoot-through time. They comprise the Γ-source, T-source, trans-Z source, TZ-source, LCCT-Z-source. Amongst, the Y-source is flexible and looked as the common network, from which all the other networks are obtained. It can support DC information voltage with no precondition of boost converter or step up transformer, as a result prevail over yield voltage imprisonment of expected voltage source inverter and also reduces its cost.

An assessment amongst usual Pulse Width Modulation (PWM) inverter, DC-DC boosted inverter, and ZI demonstrates that ZI requirements are lower in device count and control circuit price, which are the most important expenses of a power electronics conversion system. This consequence in rising concentration on Z-source inverter, particularly for the purpose wherever the input DC source has a broad voltage variant range, such as the Photovoltaic (PV) based power generation and fuel cell motor drives [9-10]. Furthermore, for Z-source inverters no need to agonize about EMI pressure since shoot through is greet and even subjugated. It improves the inverter consistency. The Z-source converter utilizes an exclusive impedance network to join the converter major circuit to the source, thus provide exclusive effects that cannot be attained in the usual voltage-source and current-source converters where commutating components are used. The Z-source converter defeats the intangible barriers and restrictions of the established voltage-source converter and current-source converter and offers a new power conversion model.

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The modulation ideas of three-level multiphase Z-source inverters with either two Z-source set-ups or one Z-source set-up connected between the DC sources and inverter. With the most excellent probable balance incorporated for complete sought four-leg operation and enhanced harmonic implementation, authors have the proposed balance tactics of four-leg three-level Z-source inverters can accomplish the standard buck-support under uneven modulation circumstances. Excluding of the modulation difficulty unseen in the four-leg inverters, five-phase three-level Z-source inverters demonstrates completely dissimilar modulation necessity and output presentation. For noticeably demarcates the point by modulation, time domain assessment rather than the expected multi-dimensional space vector display is acknowledged which discover the accurate scheme to embed shoot-through lengths of time in the swap succession with insignificant substitute check [1].

On the origin of the predictable Z-source inverter, an improved impedance-type power electronic inverter that is named as the switched inductor Z-source inverter. To expand voltage adjustability, inverter utilizes a exclusive network to combine the major circuit and the source. Compared with the typical Z-source inverter, this inverter amplifies the voltage boost inversion capability appreciably. Only a very short shoot-through zero state is necessary to attain high voltage boost up ratios, which is valuable for recovering the output power quality. In accumulation, the voltage buck inversion capacity is also supply in this inverter for those applications that require small ac voltages. Idea of switched inductor ZI can be apply to a variety of applications in power conversion [2].

Compared to earlier ZI configuration; it can decrease the *Z*-source capacitor voltage stress very much, and has an intrinsic restriction to inrush current. The control scheme is precisely the same as the earlier one, so all active control schemes can be utilized sprightly. Soft-start approach is presented to keep away from the inrush current and resonance in the *Z*-capacitors and the *Z*-inductors [3].

A required AC voltage is accomplished from numerous levels of DC voltages is completed by multi-level inverters. These inverters are used to high voltage and high power industrial applications due to enhanced harmonic and loyal output. In current years a single X-shaped LC network is significant enlargement in multi-level inverters. The power quality perfection is derived by dropping the voltage harmonics available at the output of the inverter [4].

Minh-Khai et. al., discussed with a novel group of high boost voltage inverters that recover upon the usual trans-Z-source and trans-quasi-Z-source inverters. The enhanced trans-ZI offers constant input current and boost voltage inversion ability. In accumulation, the enhanced inverter can restrain resonant current at start-up, which might obliterate the semiconductor device. In assessment to the usual trans-Z-source/-trans-quasi-Z source inverters, for the value of the transformer turn ratio, input and output voltages, the better inverter has a higher value modulation index with less voltage stress on the DC side, lower current strain on the windings and diode, and little input current ripple. Thus, the volume and mass of the power transformer in the enhanced inverter can be concentrated [5].

Three-phase locomotives utilize Voltage Source Inverter (VSI) for the speed control of drives used for traction. The VSI is feed by active front end converter linked in H Bridge with locomotives .Since the VSI operates in buck mode, a high DC-link voltage is necessary to offer the exact voltage of traction drives rising the size and cost. Vasanthi and Ashok suggested a good performance bi-directional ZI as an alternative of VSI. They analysed in all areas of function of locomotive acceleration, free running and regenerative braking of the motor. They showed from simulation results that the DC-link voltage gets concentrated by 39% which reduces the voltage stress and minimum transformer output voltage. Decrease in the harmonics present at the output by 16% minimizes the overheating of traction motor [6].

Z-source impedance network is designed to boost the voltage using shoot through state control. A innovative PWM procedure is executed by using three reference signals and a carrier signal which are utilized to produce the PWM signals for inverter power switches, and the shoot through state for Z-network is accomplished by introduced DC reference signal. The merit of this circuit gives less in number of switches, and this new construction is flexible for lower and medium power applications [7].

The ZI is a kind of converter that displays voltage buck and boost potential. This type of idea applied to all multilevel power electronic conversion. Multi-level converters present several reward for higher power applications. Usually in Z-source neutral point clamped inverter carrier based modulation method is utilized for controlling. Shid Pilehvar and M Mardaneh presents the space vector modulation for controlling Z-source neutral point clamped inverter. This provides more benefits, in terms of harmonics performance [8].

Chapter 2 discuss about the circuit operation of the proposed configuration. Chapter 3 presents the simulated and experimental results obtained from the proposed converter. Chapter 4 concludes this paper.

2. PROPOSED METHOD

PV based power generation system is upcoming new popular technology. Many applications and research investigations of multilevel-inverter-based PV systems are rising unceasingly due to the multilevel inverter gains and high power-scale and high-voltage demands [11-13]. Also cascaded multilevel inverter has exclusive benefits when used to the PV system, since it can accomplish the Maximum Power Point Tracking (MPPT) to maximize the whole efficiency and attain high-power grid power without a power transformer. Still, conventional power system unit comprises buck inverter, DC-link voltage changes with the PV voltage. So, while the MPPT is used in every unit, the unbalanced DC voltage will occur between all units. Unlike the other type of H-bridge inverters, H-bridge ZI can provide shoot-through states to increase the input DC voltage when both power switches in the similar leg are on, and because of this unique feature, the consistency of the inverter is significantly enhanced. In comparison with the traditional H-bridge inverters, H-bridge ZI is more reliable and has lower costs and higher efficiency.

By combining cascaded multilevel inverter and H-bridge ZI, features of both structures, such as shoot-through capability and ability of voltage increasing and harmonics decreasing can be achieved. Despite these useful features, a unified approach to voltage control of ZS-MI has not been proposed so far. Also, although in recent year's different strategies are proposed for the formulation and calculation of phase voltage and its Total Harmonic Distortion (THD) in traditional multilevel inverters, the phase voltage and its THD have not yet been calculated for ZS-MI. The block diagram of the proposed multi-level ZI is shown in Figure 1. This shows the structure of cascaded ZS-MI. This multilevel inverter produces the desired voltage from several separate dc sources. These resources can be supplies from batteries, fuel cells or solar cells.

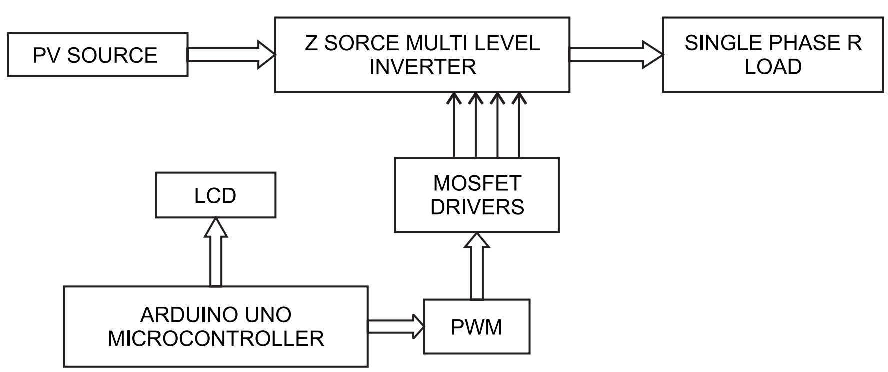

Figure 1: Block Diagram - Z-Source Multi-Level Inverter

A simple configuration of the proposed ZS-MI is shown in Figure 2, which contains of three units with outputs coupled in series. Each unit comprises a PV panel and a ZI H-bridge inverter. The unipolar PWM technique is utilized in every unit to activate the H-bridge inverter. Seeing the ZI's working principle, the shoot-through state is further in the conventional zero state in the modulation progression. Hence, every unit in the system still produces a three-level voltage of V_H. For the entire system's modulation process, the SPWM technique in [14-15] is used, and the carrier signal of three units are shifted by 60°to each other. As an outcome, the amount of energy stored in ZS-MI delivers a seven-level output voltage V_H to supply to the utility grid via the L-filter. The proposed configuration can accomplish the distributed MPPT of PV panels, balance out the power among different units, and offer the anticipated power to the utility grid. Each unit is designed as shown in Table 1.

Table 1
Circuit Design Parameters

Parameters	*Values*
L_1	500 μH
L_2	500 μH
C_1	4400 μF
C_2	4400 μF
Carrier Frequency	10 kHz
PV Voltage	45-90V

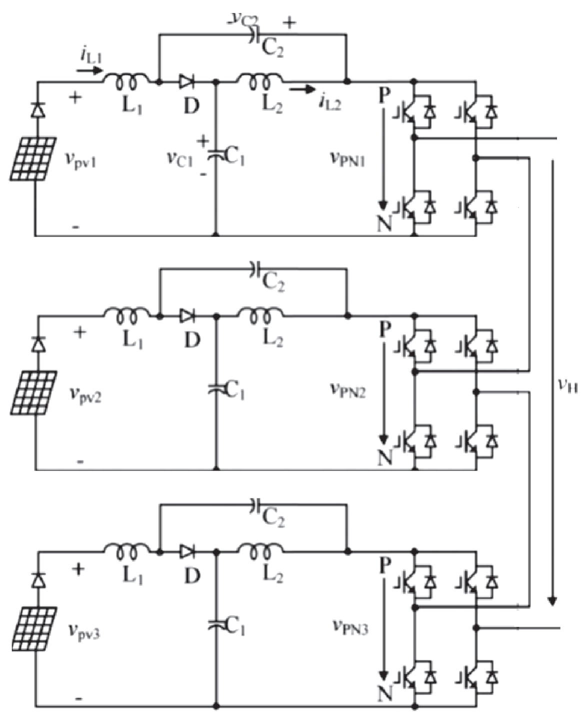

Figure 2: Proposed Converter Configuration

3. EXPERIMENTAL RESULT

The simulation is done MATLAB/Simulink software for the phase shifted PWM method and the carrier signal frequency is 5 kHz to 20 kHz and after evaluating the system parameters for the various frequencies the carrier signal is operated at 10 kHz where the output waveform depicts the best out comes in terms of THD. The simulation is completed with the normal supply frequency of 50Hz. The similar control method is used for various levels of cascaded ZS-ML circuit configurations.

The simulation is also completed for various levels to attain the best possible solution in terms of quality of the output. The equivalent control procedure is employed to the various levels with various carrier frequencies unrelated to the number of levels, 10 kHz outcomes improved system performance when matched to all the other carrier frequencies. Consequently the similar carrier frequency is used for this proposed system unrelated to the number of levels of the cascaded configuration. The offset output voltage for the proposed five level ZS-ML configurations is shown in Figure 3. Figure 4 shows the voltage waveforms attained from the proposed PS-PWM scheme carrier signal.

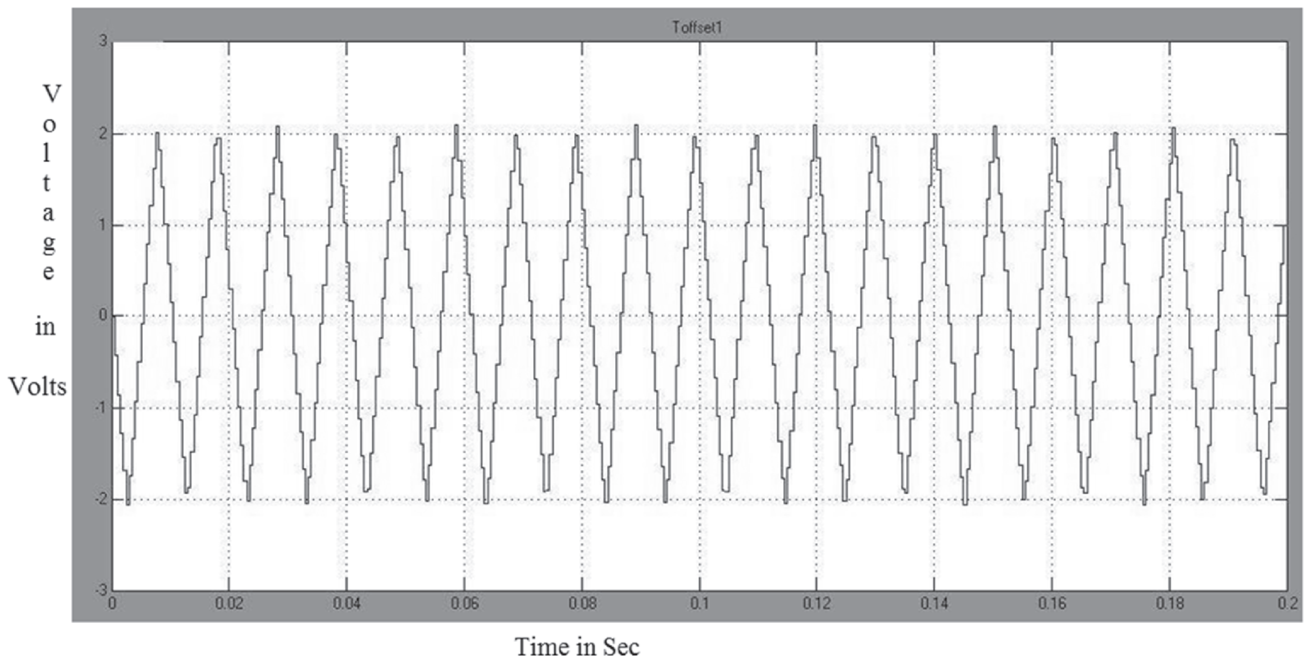

Figure 3: OFFSET voltage waveform

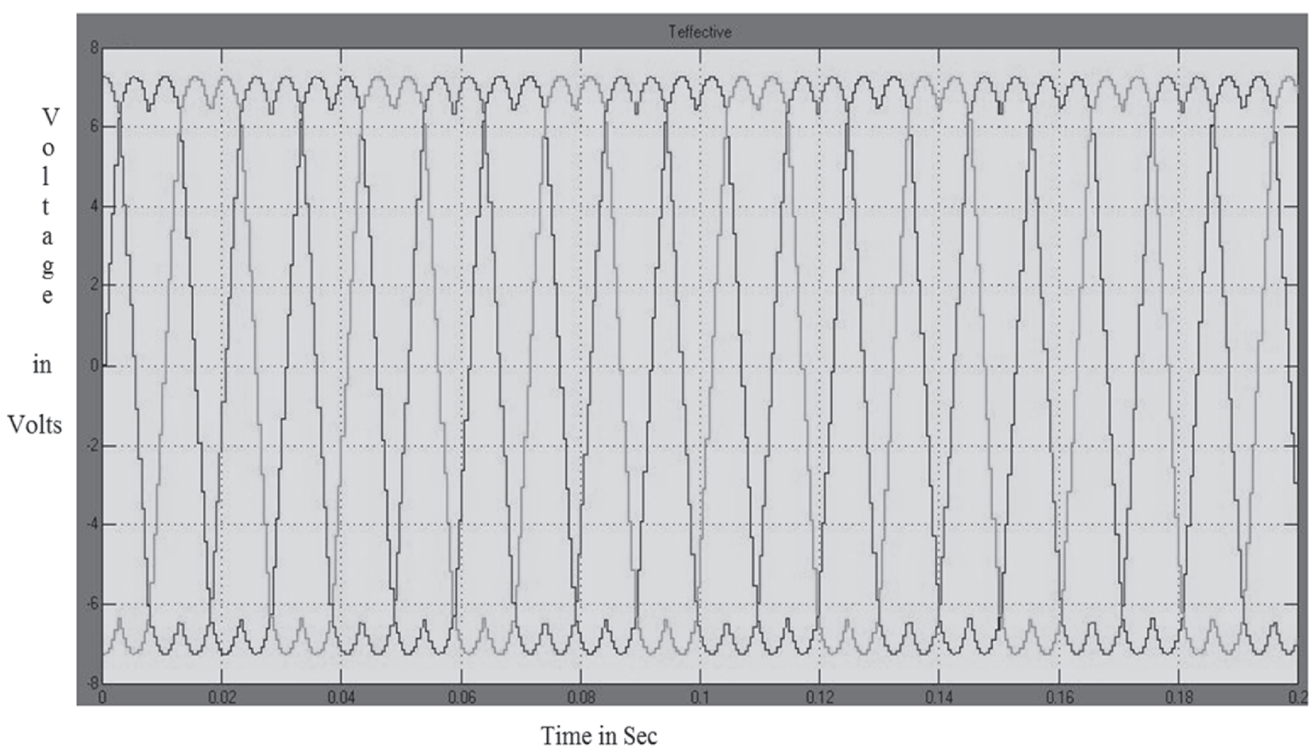

Figure 4: Effective Voltage Waveform of Carrier Signal

The simulated five level output phase voltages are as shown in Figure 5. The output waveform for single phases approves the constant magnitude over the extensive range of system operation and the phase angle displacements are 120° apart from each other's. The results obtained from experimental setup for the same five level ZS-MI is shown Figure 6.

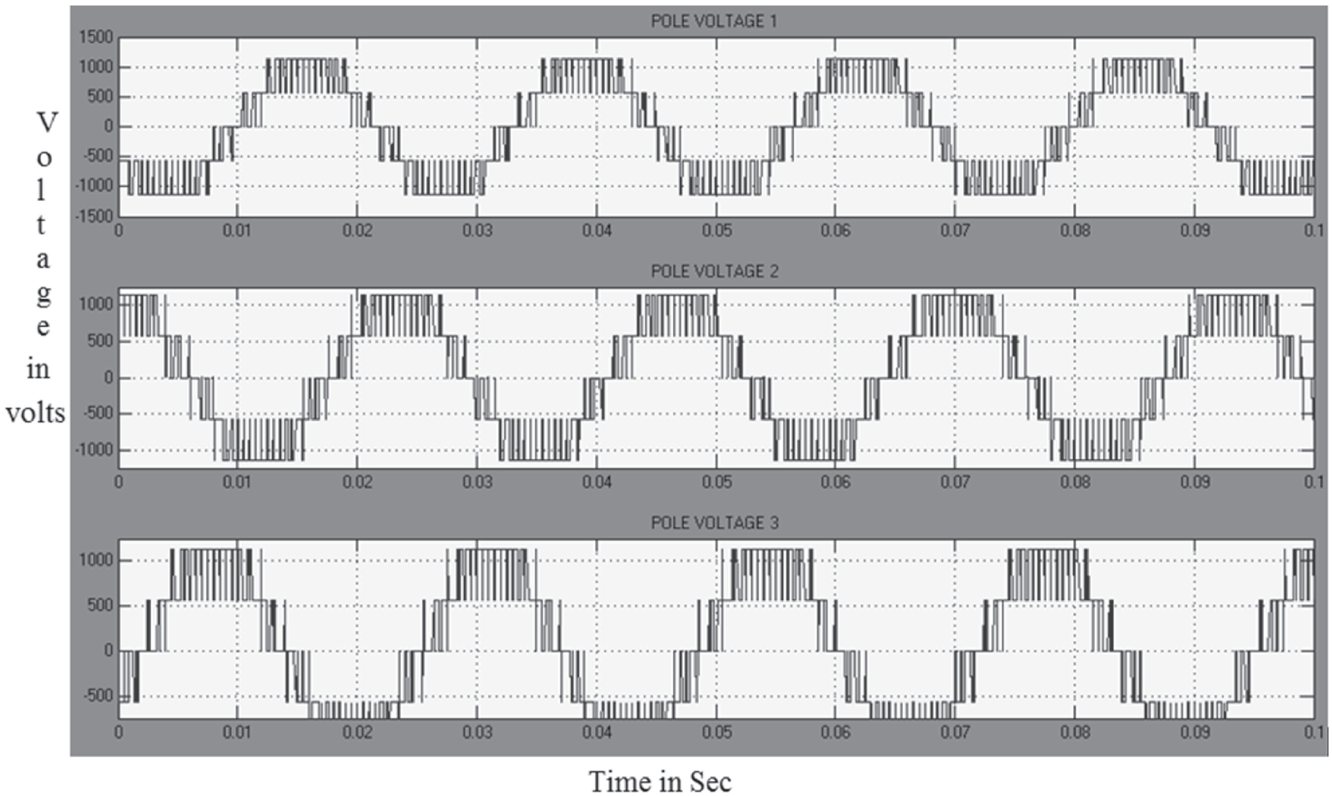

Figure 5: Output line voltage waveforms

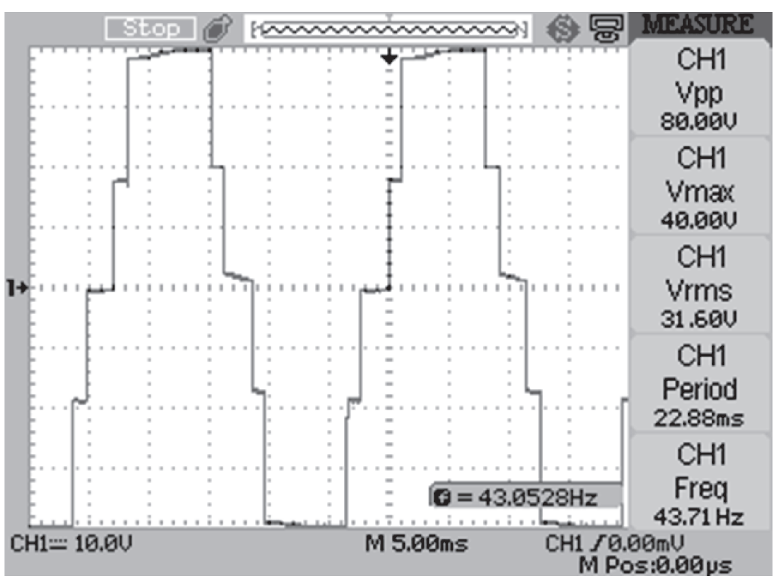

Figure 6: Output Voltage waveform of multi-level Z-source inverter

4. CONCLUSION

In this research study, the analysis and simulation of a new multilevel-based cascaded Z-source inverter have been discussed. The proposed inverter has fewer switches as compared to a traditional cascaded multilevel inverter. The projected control technique contains the distributed maximum power point tracking for every unit, DC-link peak output voltage balance of entire unit, furthermore, a novel multi-level space vector modulation technique is given for the proposed ZS-MI. Simulink results and results from experimental set up shows the capability of the proposed Z-source inverter. The simulated result shows that it offers exceptional voltage regulation.

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