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Simulation of Z-Source Inverter with Low Voltage Stress on Balancing Capacitor

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ABSTRACT: The Z-Source Inverter (ZSI) has been reported suitable for residential PV system because of the capability of voltage boost and inversion in a single stage. Recently, four new topologies, the quasi-Z-Source Inverters (qZSI), have been derived from the original ZSI. This project analyzes one voltage fed topology of these four in detail and applies it to PV power generation systems. By using the new quasi-Z-Source topology, the inverter draws a constant current from the PV array and is capable of handling a wide input voltage range. It also features lower component ratings and reduced source stress compared to the traditional ZSI. A prototype which provides three phase 50-Hz, 230Vrms ac has been built in laboratory. It is demonstrated from the theoretical analysis and MATLAB/SIMULATION results that the proposed qZSI can realize voltage buck or boost and dc-ac inversion in a single stage with high reliability and efficiency, which makes it well suited for PV power systems.

KEYWORDS: PV Array, Z-Source Inverter (ZSI), HB-ZSI.

I.INTRODUCTION

Yuan Li, Joel Anderson, Fang Z. Peng and DichenLiu[1] presents a Half bridge-Z-Source Inverter(HB-ZSI)that is a new topology derived from the traditional Z-Source Inverter(ZSI). The HB-ZSI inherits all the advantages of the ZSI, which can realize buck/boost, inversion and power conditioning in a single stage with improved reliability. In addition, the proposed HB-ZSI has the unique advantages of lower component ratings and constant dc current from the source. All of the boost control methods that have been developed for the ZSI can be used by the HB-ZSI. The HB-ZSI features a wide range of voltage gain which is suitable for applications in Power Generation (PV) systems due to the fact that the PV cell's output varies widely with temperature and solar irradiation. Theoretical analysis of voltage boost, control methods and a system design guide for the HB-ZSI in PV systems are investigated in this paper. A prototype has been built in the laboratory. Both simulations and experiments are presented to verify the proposed concept and theoretical analysis.

Fang ZhengPeng[2], Shows Z-Source Inverter for fuel-cell applications. Through the example, the paper described the operating principle, analyzed the circuit characteristics, and demonstrated its concept and superiority. Analytical, simulation, and experimental results have been presented. The Z-Source Inverter can boost–buck voltage, minimizes component count, increase efficiency, and reduce cost. It should be noted again that the Z-source concept can be applied to the entire spectrum of power conversion. Based on the concept, it is apparent that many Z-source conversion circuits can be derived.The Z-Source Inverter(ZSI) has been reported suitable for residential PV system because of the capability of voltage boost and inversion in a single stage. Recently, four new topologies, the Half bridge-Z-Source Inverters (HB-ZSI), have been derived from the original ZSI .This project analyzes one voltage fed topology of these four in detail and applies it to PV power generation systems. By using the new Half bridge-Z-Source topology, the inverter draws a constant current from the PV array and is capable of handling a wide input voltage range.It also features lower component ratings and reduced source stress compared to the traditional ZSI. It is demonstrated from the theoretical analysis and simulation results that the proposed HB-ZSI can realize voltage buck or boost and dc-ac inversion in a single stage with high reliability and efficiency, which makes it well suited for PV power systems.

Following are some electrical conditions that affect both side utility and customer.The new Z-Source Inverter(ZSI) advantageously utilizes the shoot through state to boost the dc bus voltage by gating on both upper and

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lower switches of a phase leg and produce a desired output voltage that is greater than the available dc bus voltage. In addition the reliability of the inverter is greatly improved because the shoot-through due to missgating can no longer destroy the circuit. Thus it provides a low-cost, reliable, and high efficiency single stage structure for buck and boost power conversion.

II.SYSTEM MODEL AND ASSUMPTIONS

The Half bridge-Z-Source inverter circuit differs from that of conventional Z Source Inverter in LC impedance network interface between the source and inverter. Half bridge-Z-source inverter acquires all the advantages of traditional Z-Source Inverter. Fig. 3.4 shows the basic topology of Half bridge Z-source inverter. The Half bridge Z-Source inverter extends several advantages over Z-Source inverter such as continuous input current, reduced component rating, and enhanced reliability. These advantages make the Half bridge Z-source inverter suitable for power conditioning in renewable energy system.

A PV cell's voltage varies widely with temperature and irradiation, but the traditional voltage Source Inverter (VSI) cannot deal with this wide range without over-rating of the inverter, because the VSI is a buck converter whose input dc voltage must be greater than the peak ac output voltage. Because of this, a transformer and/or a dc/dc converter is usually used in PV applications, in order to cope with the range of the PV voltage , reduce inverter ratings, and produce a desired voltage for the load or connection to the utility. This leads to a higher component count and low efficiency, which opposes the goal of cost reduction. The Z-Source Inverter (ZSI) has been reported suitable for residential PV system because of the capability of voltage boost and inversion in a single stage. Recently, four new topologies, the Half bridge-Z-Source Inverter (HB-ZSI), have been derived from the original ZSI.

By using the new Half bridge-Z-source topology, the inverter draws a constant current from the PV array and is capable of handling a wide input voltage range. It also features lower component ratings and reduced source stress compared to the traditional ZSI. It is demonstrated from the theoretical analysis and simulation results that the proposed HB-ZSI can realize voltage buck or boost and dc-ac inversion in a single stage with high reliability and efficiency, which makes it well suited for PV power systems

III.Z-SOURCE INVERTER VOLTAGE STRESS ON CAPACITOR

The lattice networks are used in filter sections and are also used as attenuators. Lattice networks are sometimes used in preference to ladder structure in some special applications. This lattice network, L1 and L2 areseries arms inductances, C1 and C2 are diagonal capacitances. This is a two port network that consists of split inductors L1 and L2 and capacitors C1 and C2 connected in X-shape (as shown in Figure 1.& 2.). This network is coupled with three phase inverter bridge and the DC power supply. Depending on the switching sequences, upper switches in the three phase legs of the bridge are named as S1, S3, S5 and the respective lower switches of the legs are named as S4, S6 and S2 (Rashid 2003). The three phase Z-source inverter bridge has nine permissible switching states unlike a traditional VSI that has eight switching states. When the load terminals are shorted through both upper and lower devices of any one phase leg/two phase legs or all three phase legs, the Z-source inverter bridge has one extra zero state called shoot-through state. This shoot-through zero state is forbidden in VSI/CSI, because it would cause a shoot-through and offer voltage distortion in the output AC voltage waveform. Sometimes if the current during shoot-through mode is high or greater than the rating of the power switches, the circuit would be damaged. In Z-source inverter, presence of the impedance network makes the shoot-through zero state operation possible and facilitates to improve the performance of the power conversion (Rajakaruna et al 2005). This state provides the unique buck-boost feature to the Z-source inverter. This network also acts as a second order filter and it should require less inductance and less capacitance (Huang et al 2006). Shoot-through state has no harmful effect on the inverter and is advantageously utilized to boost the DC link voltage of the inverter bridge. Several modulation schemes to control the Z-source inverter have been developed since the proposal by Peng (2003).

In carrier based modulation schemes, shoot-through states are generated by the separate comparator circuit with the same carrier signal and are inserted in the existing switching waveforms by logical gates. In the space vector modulation, the shoot-through zero state is diminished from the traditional zero states.

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IV.PROPOSED CONTROL SCHEME

Photovoltaic (PV) power generation is becoming more promising since the introduction of the thin film PV technology due to its lower cost, excellent high temperature performance, low weight, flexibility, and glass-free easy installation. However, there are still two primary factors limiting the widespread application of PV power systems. The first is the cost of the solar cell/module and the interface converter system; the second is the variability of the output (diurnal and seasonal) of the PV cells. A PV cell's voltage varies widely with temperature and irradiation, but the traditional Voltage Source Inverter (VSI) cannot deal with this wide range without over-rating of the inverter, because the VSI is a buck converter whose input dc voltage must be greater than the peak ac output voltage. Because of this, a will impact transformer and/or a dc/dc converter is usually used in PV applications, in order to cope with the range of the PV voltage , reduce inverter ratings, and produce a desired voltage for the load or connection to the utility. Output of PV Array-The PV Array generates the DC voltage at its output side. This DC voltage is used as input to the Half bridge-Z-Source network.

Half bridge-Z-Source Network-Half bridge-Z-Source network is derived from the traditional Z-Source network. The HB-ZSI inherits all the advantages of the ZSI, which can realize buck/boost, inversion and power conditioning in a single stage with improved reliability HB-ZSI has the unique advantages of lower component ratings and constant dc current from the source.

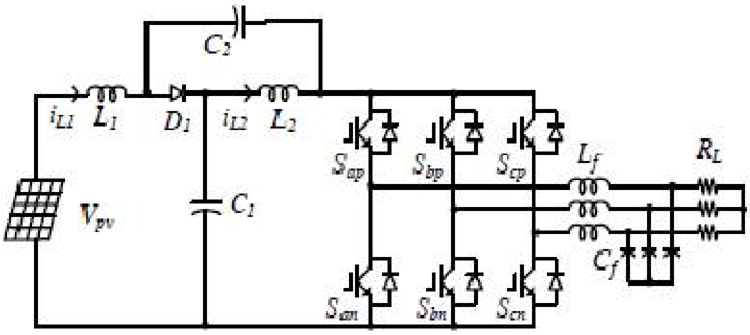

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Fig.1HB-ZSI in the PV Power Generation System.

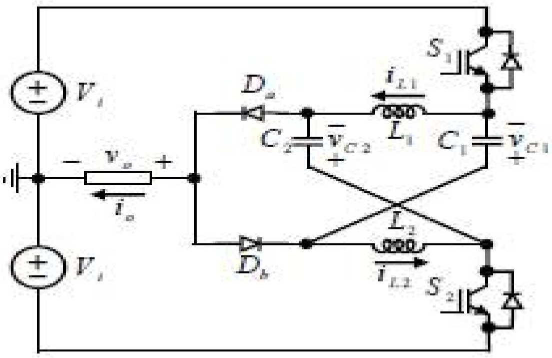

Fig.2.Model Diagram

HB-ZSI Design for Power Generation System- Fig. shows the proposed HB-ZSI in the PV power generation system. It connects the PV arrays and outputs three phase 50 Hz, 230 Vrms AC to resistive loads. A three-phase LC Filter connected in Y is set right after the inverter bridge to get 50-Hz sinusoidal AC outputs. The PV arrays have nonlinear I-V characteristics, whose output voltage varies widely with temperature and irradiation. If the PV voltage varies at a 1:2 range of 200 V to 400 V, in order to output 230 Vrms ac voltage, a transformer at line frequency or a dc/dc boost converter is commonly used in the traditional PV system.

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However, with the boost capability, the PV power generation system based on HB-ZSI is much simplified. According to the analysis presented earlier, if working in buck conversion mode, the minimum input voltage required by the HB-ZSI is Vin = 2 $\bar{V}_{in}$/ M = 324V (with M = 2/√3). Once the input voltage is below 324V, the HB-ZSI is designed to work in boost conversion mode.

V. RESULT

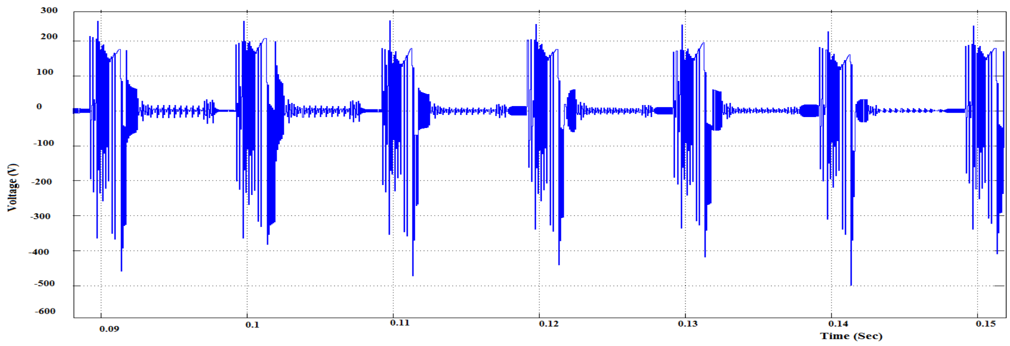

Fig: 3 Output Voltage without HBZ-S Inverter

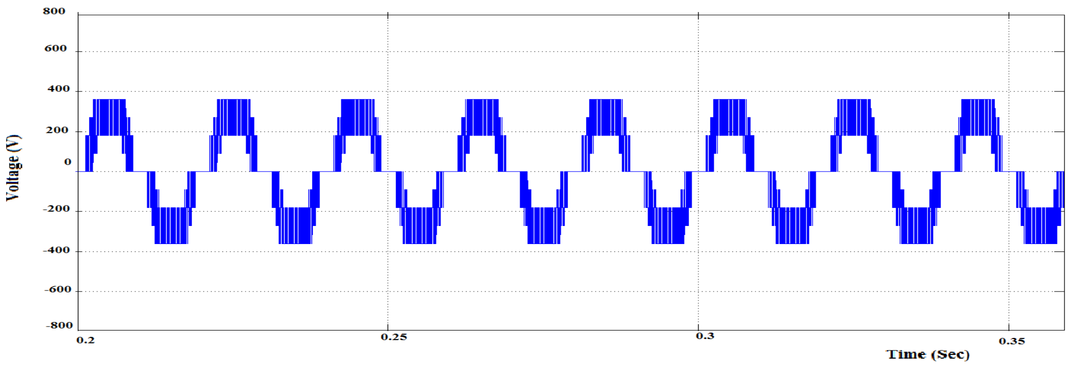

Fig: 4. Output Voltage with HBZ-S Inverter

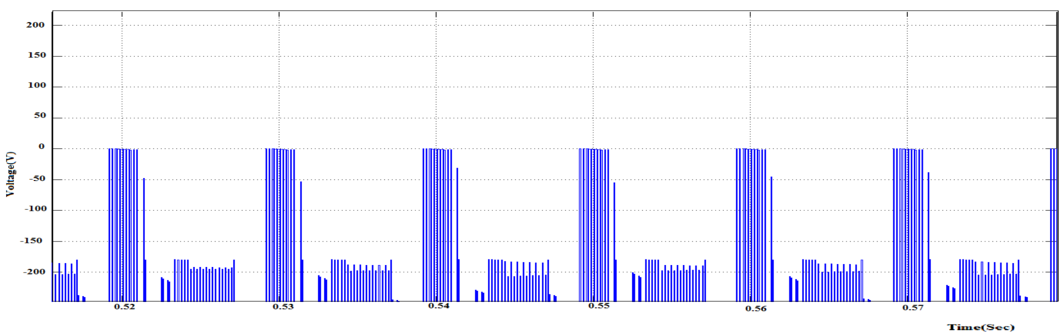

Fig: 5. Reduced Voltage stress on Capacitors

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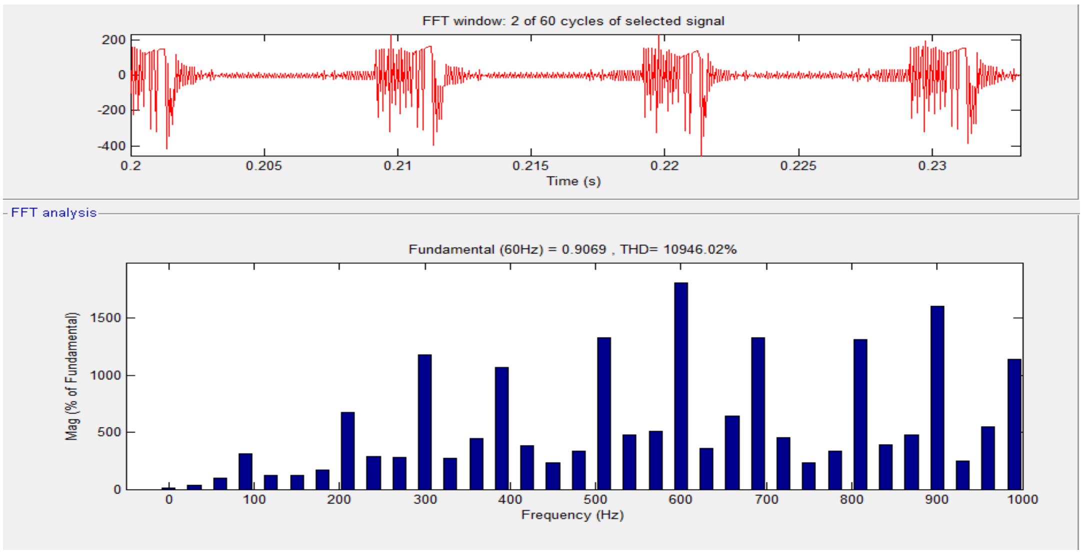

Fig 6. FFT Analysis without HBZ-SI

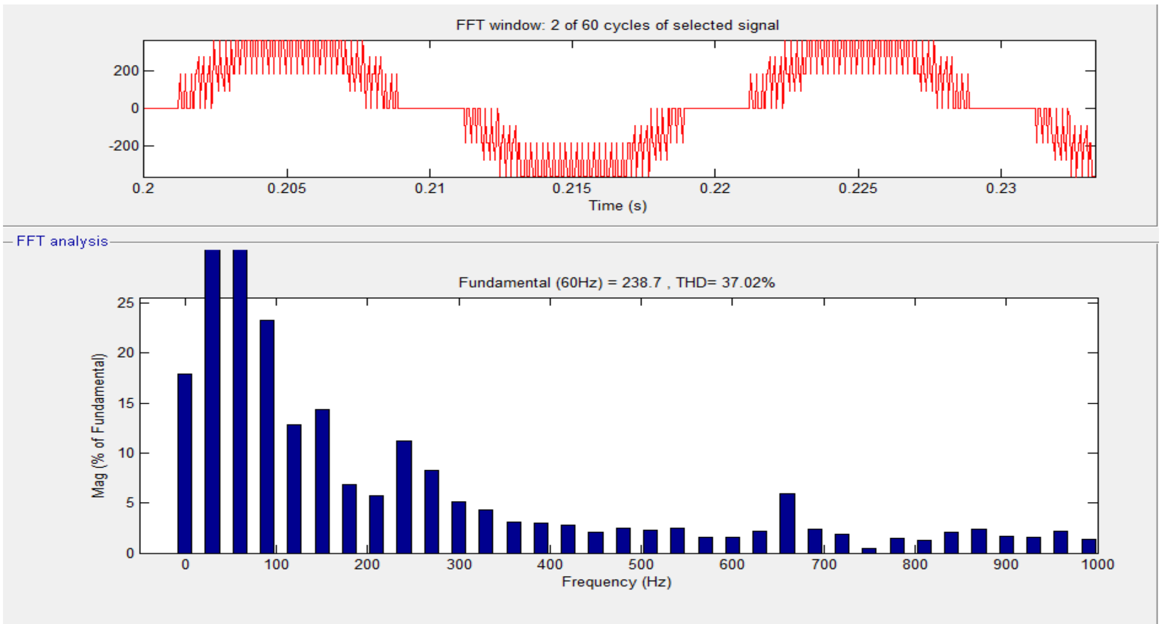

Fig 6. FFT Analysis with HBZ-SI

VI.CONCLUSION

Conclusion By referring to the project objectives, this project has been successful. This project mainly focuses on the study of Z source inverter and simple boost switching control method. The circuit has been designed based on the standard Z source inverter and simulated using MATLAB. The theoretical values has been calculated and the simulation results were gained through MATLAB simulations. The simulation results were almost similar to the calculated values both the output voltages and voltage stress. The output voltage also can be buck or boost depends on the requirement of the electronic or electrical power applications. However, for simple boost switching technique, the modulation index can only be in the range of zero and one. Thus, since the output voltage directly depending on the modulation index, the output voltage has been limited to a certain range for the Z source inverter instead of zero to infinity. From the results and progress throughout the project, Z source inverter has overcome the barrier of traditional inverters. The barrier is to produce AC output waveforms that are greater than the DC input sources. The project also can conclude that the simple boost switching control method still needs some improvement since the voltage stress is high. This makes the inverter demanding a very good switch for inverter operation. This project has presented quasi-Z-Source Inverter with a new topology, which is derived from the traditional ZSI. The proposed qZSI inherits all the advantages of the ZSI and features its unique merits. It can realize buck/boost power conversion in a single stage with a wide range of gain that is suited well for application in PV power generation systems. Furthermore, the proposed qZSI has advantages of continuous input current, reduced source stress, and lower component ratings when compared to the traditional ZSI. Theoretical analysis, control method, and system design guide are presented in this project. Simulation results show that with a voltage range of 1:2 at the PV input (from 200V to 400 V), the qZSI can provide three phase 50Hz, 230 V_{rms} ac voltage, which verifies the theoretical analysis.

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BIOGRAPHY

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