Power Quality Improvement using PV Coupled Non-Isolated Quasi Z Source Inverter

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Abstract: - Z source inverter is a DC to AC converter, but it can be operated as buck boost converter without employing separate bridge converter. The proposed work presents the new Quasi- Z Source Inverter to improve the effectiveness by drop in conduction loss of the system. High boost capability with smaller capacitance and inductance makes the system output stable, which is also suitable for Photovoltaic and Fuel cell based renewable energy systems. The existing DC link in the converter system has been replaced by X shape connected capacitors and inductors in Z source network with common ground connection. the new Quasi- Z Source Inverter increases the output voltage range with improved power factor, reduced harmonics and has good ride through capability. Photovoltaic fed quasi-Z source inverter is employed nowadays for its high potential to integrate with power systems. The proposed converter reduces the damping of the grid connected grid connected system to reduce the transient interactions. Unipolar PWM technique is employed to reduce the THD of the system. MATLAB simulink has been employed to simulate the proposed method and the prototype has been developed to verify the simulink.

Key-Words: - Quasi Z Source Inverter (QZSI), Photovoltaic (PV), Total Harmonic Distortion (THD).

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1 Introduction

Z Source Inverter is a single stage buck boost converter with good voltage gain. The wind and voltage control can be improved by injection of wind power using QZSI with battery assistance [1]-[2]. The THD and voltage gain are analysed and compared for different levels of QZSI [3]. The settling time and overshoot for frequency regulation and stabilization issues in power system can be reduced by Nonlinear Sliding Mode Controller [4] - [6]. The Proposed Resonance and Sliding Mode Controllers characteristics has been applied to UPS [7]. Model Predictive Control (MPC) scheme was employed in chemical industries in earlier days. The new and wide ranges of control schemes are described as MPC, do not imply any particular one controller. Nowadays, MPC application schemes plays a vital role in Power Electronics Drives System. Development of Pulse Width Modulation technique has replaced the existing controller techniques with demonstration of MPC system [8]-[11]. Auto Adaptive Discrete-time Model Predictive Control (ADMPC) compares the real speed with reference speed with acceleration of IM drive system [12]. In [13] Digital Predictive Current control design and implementation in Integrated Renewable Energy based system is discussed. Finite control Set MPC is a new alternative to constant switching.

Higher voltage boosting using shoot through state helps to improve the impedance networks using coupled magnetics. Many Industries employ traditional voltage source and current source inverters. Higher voltage boosting using shoot through state helps to improve the impedance networks using coupled magnetics. In [15] Existing DC link in the converter system are replaced by X shape connected capacitors and inductors in Z source network with common ground connection is depicted in Figure 1.

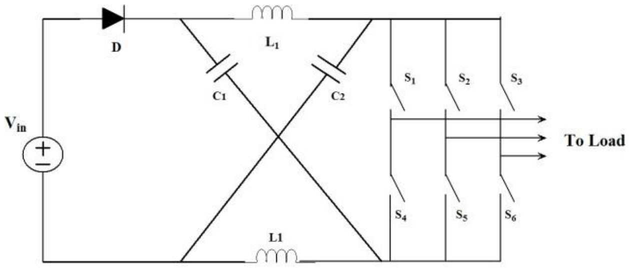

Fig. 1: ZSI circuit diagram

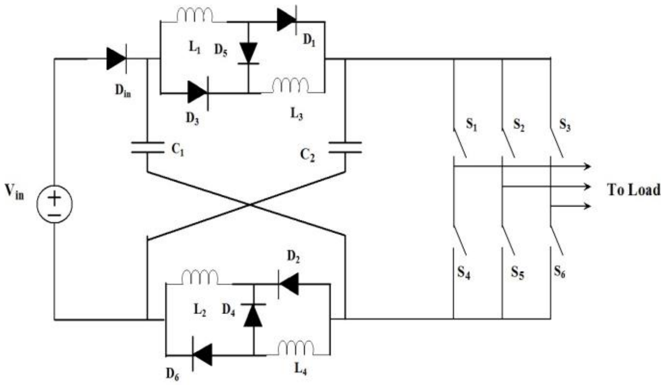

Fig. 2: ZSI with Switched Inductor

Shoot through duty cycle helps to achieve the desired AC voltage using singular LC Z source network. It has advantages as improved voltage range, improved power factor with reduced harmonics. Combining the continuous and discontinuous diode and capacitor assisted quasi-Z source Inverter to get the extended Z Source boost inverter [16]. ZSI with Switched Inductor cells are proposed in Figure 2. Quasi Z source with switched inverter is obtained by replacing network with two SL cells in QZSI and one SL cells. Enhanced Boost QZSI circuit diagram is depicted in Figure 3 and the Figure 4 depicts the Enhanced Boost Quasi Z Source Inverter to obtain the AC output [17]. Photovoltaic fed quasi-Z source inverter is employed nowadays for its high potential to integrate with power systems. To improve the voltage gain, L. Pan introduced a new Z-source inverter based on switched inductor network [18]-[20]. The above literature does not deal with the proposed quasi–Z Source inverter. Section II describes the proposed system and operating modes of the proposed system is explained in section III. Section IV describes the simulation results and concluded in section V.

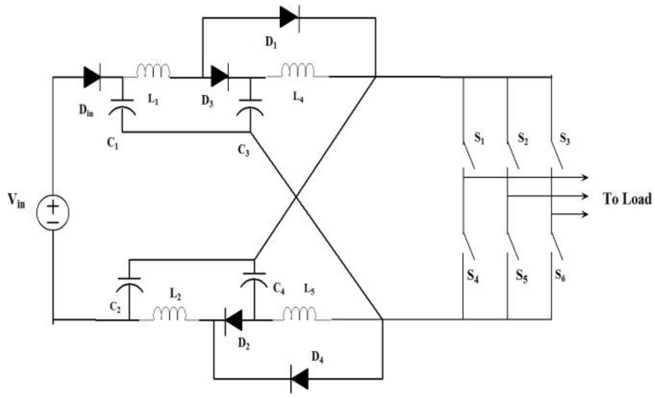

Fig. 3: Enhanced Boost Z Source Inverter

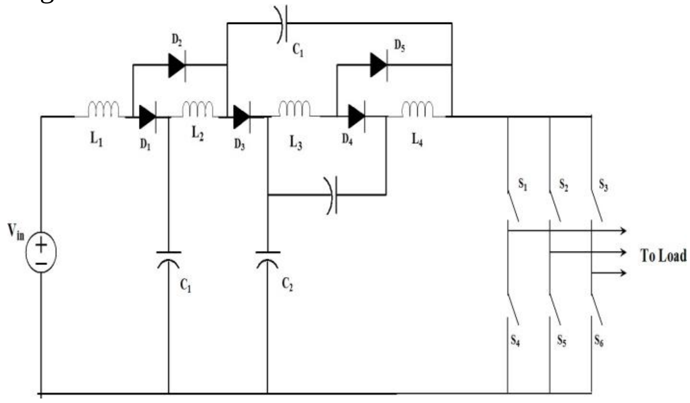

Fig. 4: Enhanced Boost Quasi Z Source Inverter

2 Proposed Method

The proposed system consists of two inductors, two capacitors with one diode to produce improved AC output voltage. Figure 5 depicts the QZSI circuit diagram.

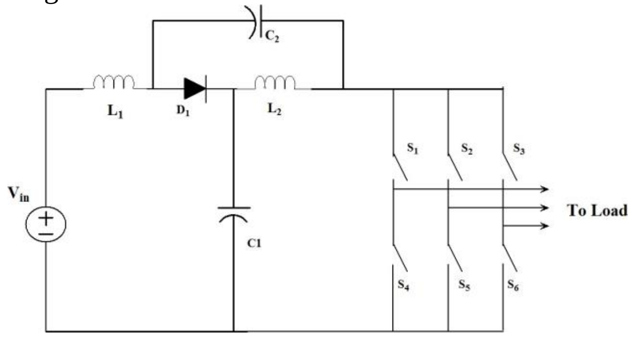

Fig. 5: Proposed QZSI circuit diagram

Block diagram of the QZSI is depicted in Figure 6. Renewable DC source has been generated by the PV system, processed through the proposed QZSI and applied to the inverter to get AC output waveform. An electronically commutated AC motor is employed and the AC power from the motor has been applied to it. The advantages such as less maintenance, high efficiency makes the system to employ BLDC motor.

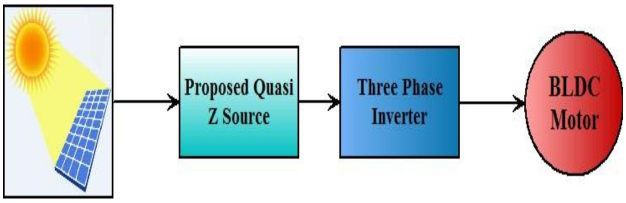

Fig. 6: Proposed QZSI block diagram

3 Operating Modes of Proposed QZSI

The boost capacity of the proposed QZSI is obtained by combining the two different quasi-Z source inverter using diodes D2 and D5. Each quasi-Z source network are with the combination of inductors and capacitors and each complement each other to produce the increased boosted output voltage.

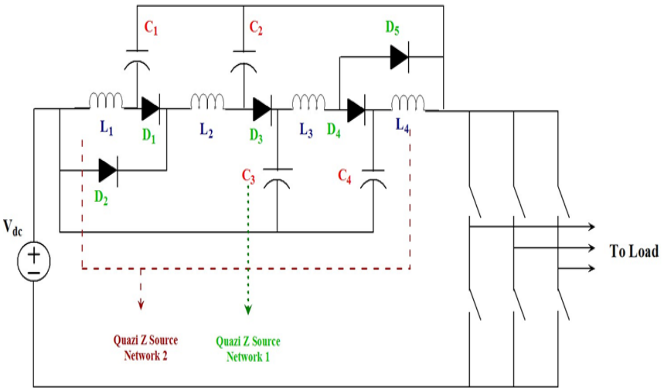

Fig. 7: Proposed Z Source Inverter with combined quasi network circuit diagram

Simplified analysis is done by considering the inverter bridge with Solid State Switch (SST). Each QZSI has two inductors, two capacitors with diode to have a boosted output voltage. SST is used to perform the active and shoot through modes of operations. During this mode, switches S1, S3 in first leg or switches S2, S4 in second leg will be turned, makes the inductors to store energy without short circuiting the DC capacitors is one of the added advantages of the network. The ramp up of inductor current takes place in this interval disconnect the output from input. The proposed method operation is similar to the classical QZSIs with two zero states, six active states and one additional shoot through zero state. Figure 8a depicts the QZSI shoot through mode.

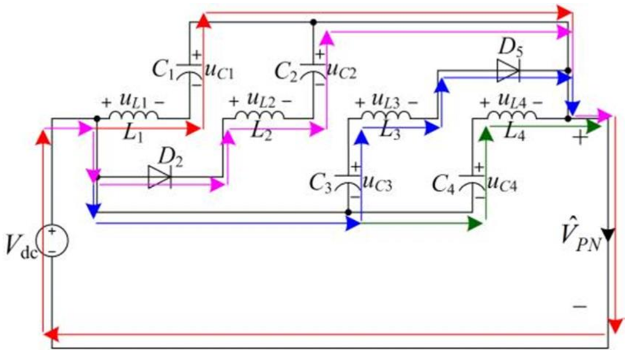

Fig. 8a: Shoot through mode of proposed QZSI.

Figure 8b represents the Proposed QZSI Non shoot mode with reverse biasing of diodes D1, D3 & D4 and forward biasing of diodes D2 & D5. There are four loops during this state: loop 1 consists of input voltage source Vdc, inductor L1, and capacitor C1. The input voltage source Vdc is in series with capacitor C1 to charge inductor L1; loop 2 consists of input voltage Vdc, diode D2, inductor L2, and capacitor C2. The supply voltage Vdc and capacitor C2 discharge the energy to inductor L2; loop 3 consists of supply voltage Vdc, capacitor C3, inductor L3 and diode D5. The supply voltage Vdc and capacitor C3 charge inductor L3 in series; loop 4 consists of the supply voltage Vdc, capacitor C4, inductor L4. The supply voltage Vdc and capacitor C4 discharge the energy to inductor L4. To have a linear increase of current in inductors, Capacitor voltages are kept constant. Inductors are connected to the DC source with each capacitor is in series with it.

In Figure 7, Open switch represents the equivalent circuit of working state with two zero states and six active states. Diodes D1, D3 and D4 will be activated during this state with diodes D2 and D5 are turned off to the reverse voltage of the inductors L1 and L4.

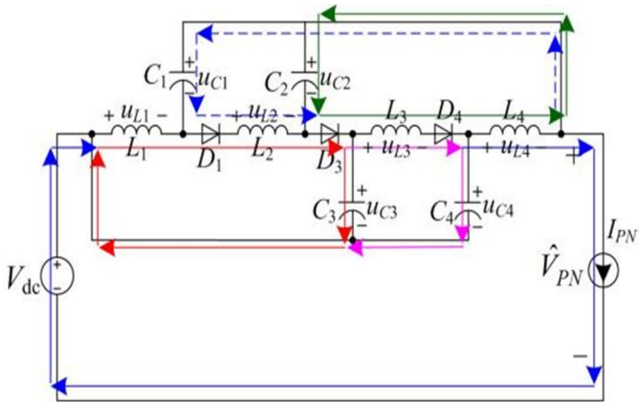

Fig. 8b: Proposed Quasi Z Source Inverter Non shoot mode

Operating state consists of five loops: loop 1 consists of inductor L1, L2, diodes D1, D3 and capacitor C3, Inductors L1 and L2 discharge the energy to capacitor C3; loop 2 consists of inductors L1, L2, L3, diodes D1, D3, D4 and capacitor C4. Inductors L1, L2 and L3 discharge the energy to capacitor C4; loop 3 consists of diodes D3, D4, inductors L3, L4 and capacitor C2. Inductors L3 and L4 charge capacitor C2 in series; loop 4 consists of diodes D1, D3, D4, inductors L2, L3, L4 and capacitor C1. Inductors L2, L3 and L4 discharge the energy to capacitorC1; loop 5 consists of supply voltage Vdc, inductors L1, L2, L3, L4, diodes D1, D3, D4, and therefore the inverter bridge.

Table 1. Switching states of Synchronous Rectifier

SWITCH	S1	S2	S3	S4	SYNCHRONOUS
SIDE	TOP SIDE		BOTTOM SIDE		SWITCH
Active state	ON	OFF	OFF	ON	ON
Shoot through	ON	ON	ON	ON	OFF
Active state	OFF	ON	ON	OFF	ON
Shoot through	ON	ON	ON	ON	OFF

4 Simulation Results

The proposed system simulation results are described in this section. L filter is employed in line with frequency to reduce the THD. The requirement of high inductance value results in increased cost in order of several Kilowatts. Low pass filter is employed to replace the small values of inductors and capacitors. Weight, height, size, costs are different, depending upon the type of the filter. Figures 9 and 10 depict the output voltage of QZSI without and with filter respectively. After employing the filter, the harmonics present in the filter has been reduced.

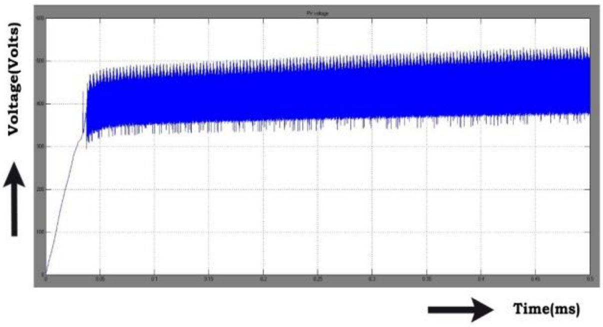

Fig. 9: Output voltage of QZSI without filter.

Simulations are done using the MATLAB simulink to boost the quasi-Z source inverter with the below parameters. All the components are assumed to be ideal in the simulation part. The simulation parameters of the proposed system are given in Table 2.

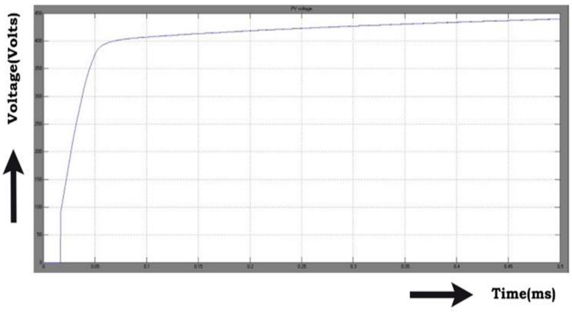

Fig. 10: Output voltage of QZSI with filter.

Table 2. Simulation parameters of proposed system.

S.NO	COMPONENTS	SPECIFICATIONS
1	DC input voltage	60V
2	Inductors (L1=L2=L3=L4)	1mH
3	Capacitors (C1=C2=C3=C4)	470uF
4	Fundamental frequency	50 Hz
5	Switching Frequency	10kHz
6	Output Inductor filter	2 mH
7	Output Capacitor filter	50uF
8	Resistive load (R_L)	50 Ω
9	Inductive load (L_L)	5MH

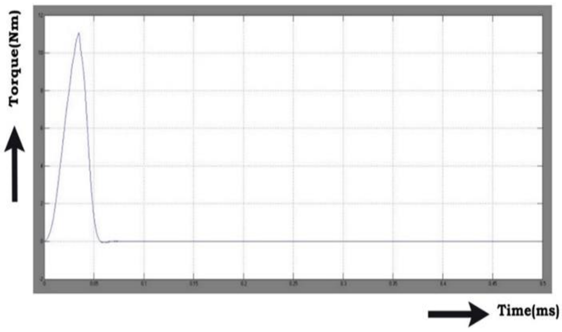

Fig. 11: Z Source Inverter output torque.

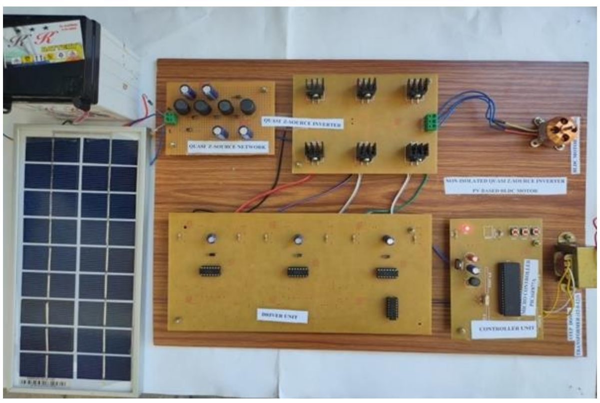

Fig. 12: Hardware prototype of Proposed QZSI

Figure 11 depicts the QZSI output torque. Hardware prototype has been developed for the proposed Quasi Z Source Inverter. The proposed hardware prototype has been developed with the same specification of the simulation parameters is shown in Figure 12.

5 Conclusion

A new Quasi Z source boost inverter, which combines the different Z Source networks has been presented in the proposed work. It also increases the output voltage range with improved power factor, reduced harmonics and has good ride through capability. The block diagram of the proposed system with its operating principles has been discussed. PV system has been employed as DC source to the proposed quasi-Z source inverter. An electronically commutated AC motor has been employed and the AC power from the motor has been applied to it. The advantages for the proposed work can be notified as less maintenance, high efficiency that makes the system to employ BLDC motor. Simulated output shows that the proposed system has better output voltage and torque. The proposed system has been simulated using MATLAB simulink and the hardware prototype has been developed to verify the simulation results of the proposed system.

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