Performance characteristics of a Solar operated Quasi Z Source Inverter under different load conditions

B. Kavya Santhoshi[1*], A. Sudharsan[2], M.Sai Viveka[3], Dr. M. Sasi Kumar[4]

[1,2,3]P.G Scholar,[4]Professor, Department of Electrical and Electronics Engineering, Jeppiaar Engineering College, Chennai, Tamil Nadu, India.

***Corresponding author:E.Mail:kavyabe2010@gmail.com**

Abstract

This paper deals with the comparison of THD levels for a solar operated Quasi Impedance Source Inverter (q-ZSI) under different load conditions. Electricity generation using Photovoltaic cells is a promising form of sustainable energy. A quasi-Z source inverter (q-ZSI) reduces the fluctuations in power that is produced by the solar panels. The harmonics are reduced by applying selective harmonic elimination and then the THD levels of the inverter for R and RL and loads are measured and tabulated. The simulation results prove the reduction of harmonics and a study can be made based on the comparative results.

Keywords: Harmonics, Selective Harmonic Elimination (SHE), Total harmonic distortion (THD), Renewable energy

INTRODUCTION

Power generation using photovoltaic cells has gained its importance over the years due to green energy. Traditional single stage topology must be more to handle the wide variation in PV voltage. Two-stage structure has the drawback of increased cost and reduced efficiency. Hence, as an alternate to these topologies, Z-source inverter (ZSI) is used. It has a single-stage structure that can achieve a two-stage inverter's performance. Wide range of variation in PV voltage can be handled by the ZSI thus leading to reduced capacity of inverter and lesser components thereby reducing the system cost. The quasi z-source inverter (QZSI) is a single stage power converter derived from the Z-source inverter topology, employing a unique impedance structure. The proposed Quasi Impedance source inverters are highly suitable to be applied in PV systems. They have the following benefits 1) lower capacitor rating 2) Reduced ripples while switching losses 3) Constant current drawn from the PV panel (There is no need for extra capacitors).

In general, solar power has problems like fluctuations and intermittency. In order to overcome these problems Energy storage is done. Any alternating form of load or grid can be supplied continuously with stable and smooth power from an Energy stored PV system. Usually, bidirectional dc-dc converters are used in order to manage the storage batteries. Thus, the proposed converter system becomes less cost and complex with lower efficiency.

Block diagram of existing Q-ZSI system: Fig. 1 shows the block diagram of a system using Q-ZSI. The Q-ZSI circuit differs from that of a conventional ZSI in the LC impedance network interface between the source and inverter. LC and diode network connected to the inverter bridge modify the operation of the circuit, allowing the shoot-through state which is forbidden in traditional VSI. This network will provide effective protection to the circuit from damage when the shoot through occurs and through the shoot-though state, the quasi-Z-source network increases the dc-link voltage.

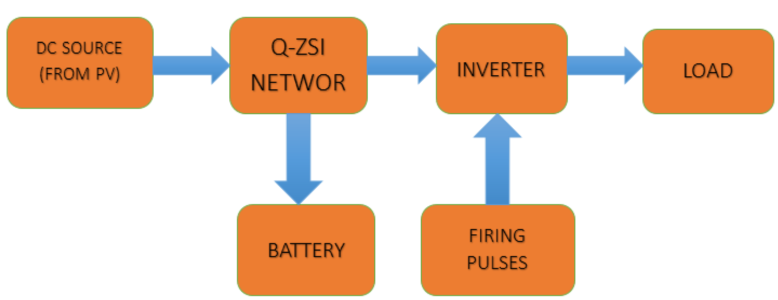

Fig.1.Block diagram of the existing Q-ZSI without SHE technique

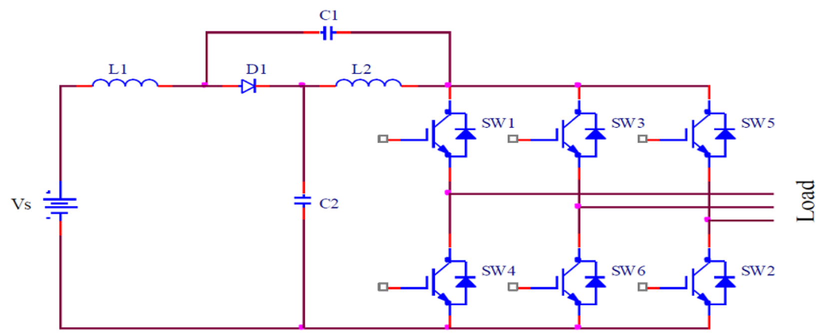

Fig.2.Conventional q-ZSI used for PV power generation

Block diagram of proposed q-ZSI system: A new topology that overcomes these drawbacks has been proposed. Fig 3 shows the block diagram of a system using Q-ZSI with energy storage and selective harmonic elimination. The components in the conventional circuit remain the same.

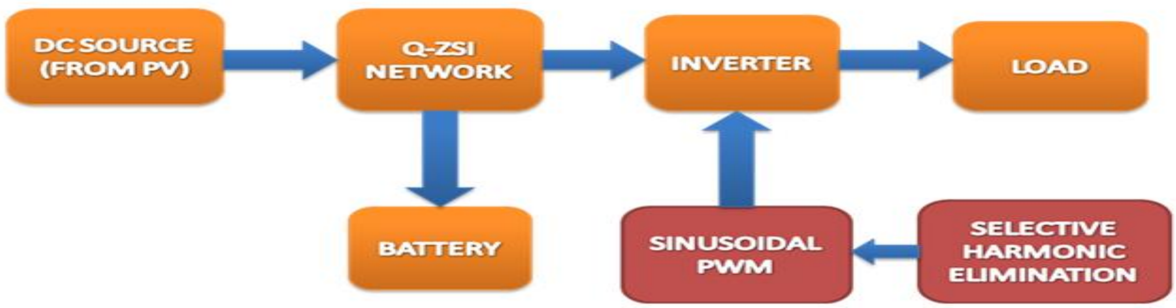

Fig.3.Block diagram of the proposed Q-ZSI with SHE technique

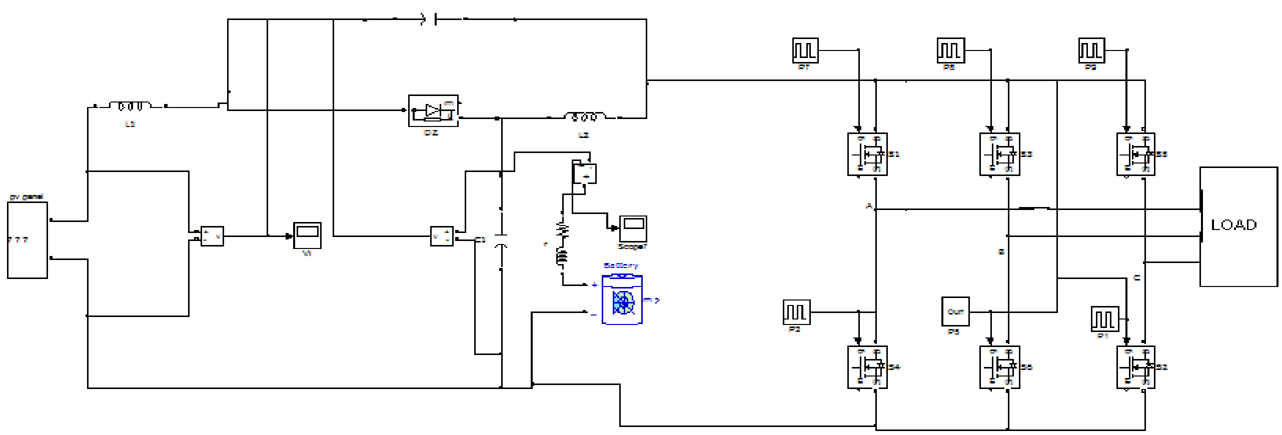

Fig.4.Proposed q-ZSI used for PV power generation

In Fig 4, there are three power sources. They are 1. PV panels 2. Battery and 3. Grid/Load. By controlling the flow of electrical power in two given sources, there will be a equal in the power of third source by the equation:

$$Pin - Pout + Pbat = 0 \qquad (1)$$

where Pin denotes the Input power from PV; $Pout$ denotes the Output from inverter and $Pbat$ denotes the power from battery. Pin is unidirectional. $Pbat$ is bidirectional (positive during discharging interval and negativewhile the power is delivered to the grid by quasi impedance source inverter).

Modes of operation of the proposed system:

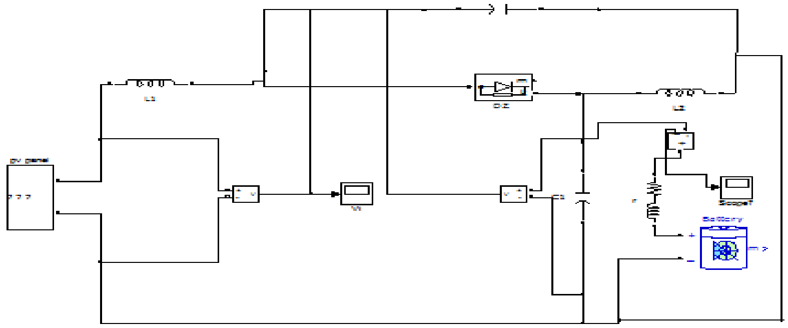

Fig.5.(a)Equivalent circuit of proposed system in Shoot-through state

Like the q-ZSI in the existing system, it has two states, namely, Shoot-through and Non-shoot through states. Shoot-through state is produced due to one phase leg or combinations of any two phase legs or by all three legs. During this state, the reverse-bias voltage across the diode Dz makes it to get turned OFF. Equivalent circuit of this mode is shown in fig 5.a). The circuit equations for this mode are:

$$CdVC1/dt = iB - iL2 \qquad (2)$$
$$CdVC2/dt = -iL1 \qquad (3)$$
$$L\,diL1/dt = Vin + VC2 \qquad (4)$$
$$LdiL2/dt = VC1 \qquad (5)$$

where $iL1$ and $iL2$ are the currents of inductors $L1$ and $L2$ respectively;
$VC1, VC2$ *and* Vin are the voltages of capacitors $C1, C2$ and PV panel respectively;
C is the capacitance of capacitors $C1$ *and* $C2$;
L is the inductance of inductors $L1$ *and* $L2$.

Non-shoot through state corresponds to one of the six active states and two traditional zero states [3]. The equivalent circuit of this mode, when continuous current flows through the diode Dz is shown in fig 5.b.

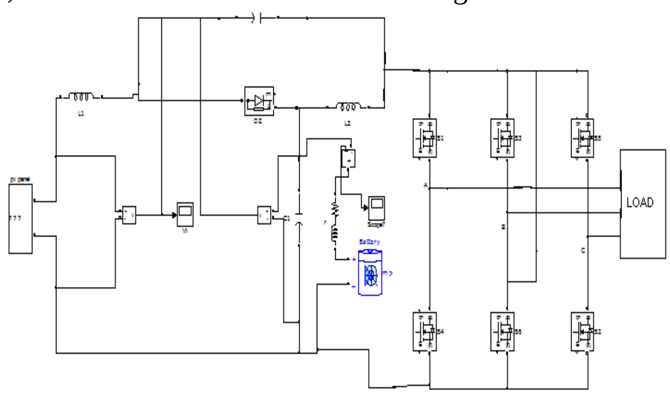

Fig.5. (b) Improved energy stored q-ZSI in non-shoot through state

The circuit equations are

$$CdVC1/dt = iB + iL1 - id \qquad (6)$$
$$CdVC2/dt = iL2 - id \qquad (7)$$
$$L\,diL1/dt = Vin - VC1 \qquad (8)$$
$$L\,diL2/dt = -VC2 \qquad (9)$$

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SIMULATION RESULTS AND DISCUSSION

The proposed system is simulated for an input voltage of 52 V. The simulated results of the Q-ZSI converter system are shown in Fig. It can be measured that the predominant harmonics have reduced significantly for the proposed system. The simulation is done using MATLAB.

Table.1. Specification and rating of the converter Components

Parameter	Value
Input voltage	52 Volts
Input current	18 Amperes
L1	1milli Henry
L2	1milli Henry
C1	100 micro Farad
C2	100 micro Farad
R	25 Ohms
L	100 milli Henry

R LOAD

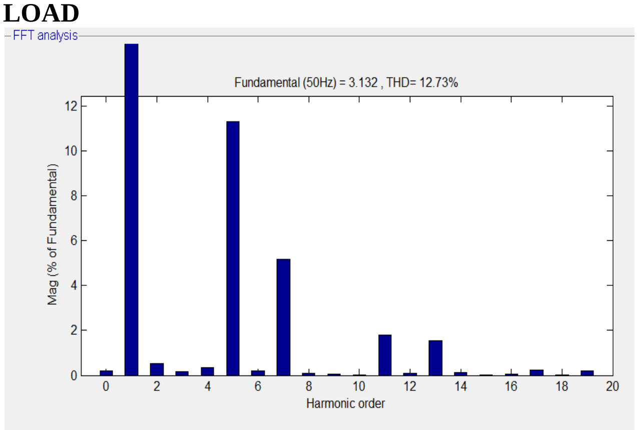

Fig.6. (a) THD level for R load with conventional circuit

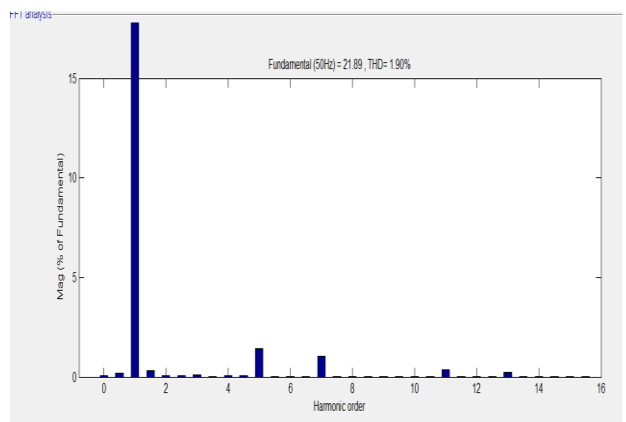

Fig.6. (b) THD level for R load with proposed circuit

RL LOAD

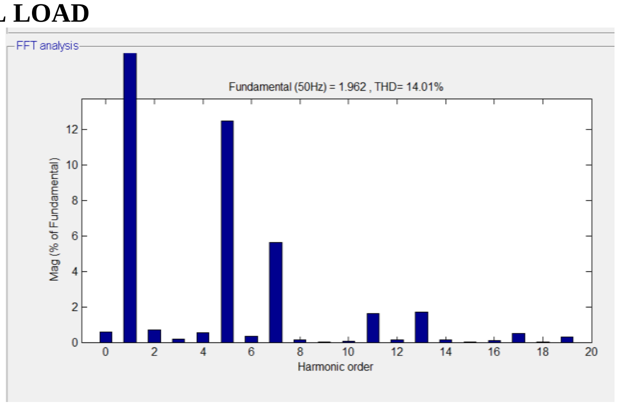

Fig.6.(c)THD level for RL load with conventional circuit

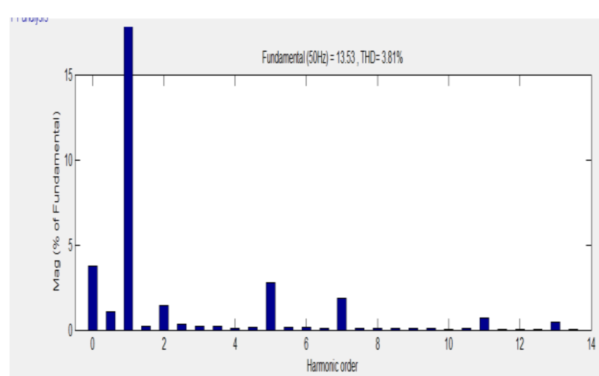

Fig.6. (d) THD level for RL load with proposed circuit

Table.2.Comparison of THD levels with existing and proposed circuits under different load conditions

Type of Load	Total Harmonic Distortion (THD) for Conventional Method	Total Harmonic Distortion (THD) for Proposed Method
R	12.73	1.9
RL	14.01	3.81

CONCLUSION

An improved q-ZSI based power generation system for PV applications with constant dc-link peak voltage was proposed. The shortcoming of narrow range of CCM was overcome. The third level of harmonics was reduced significantly. The new topology enables an improved ability to compensate power while maintaining a constant dc-link peak voltage with minimum harmonics. The new topology that is proposed draws a constant current from the PV panel thus eliminating the need for extra filtering capacitors. It features a lower capacitor rating and reduces switching ripples seen by the PV panels. It can handle the PV voltage variation over a wide range, which leads to minimum inverter capacity with the reduced component count and system cost. The harmonics in the ac output voltage of the inverter have reduced significantly.

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