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Comparative study of quasi Z-source and Trans Z-source inverter for PV applications

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Abstract
The quasi-Z-source inverter (qZSI) with battery operation can balance the stochastic fluctuations of photovoltaic (PV) power injected to the induction motor. Due to increase in the power demand, generation demand also has been rapidly increased. Hence the Photo Voltaic systems acts as major role in the renewable energy resources, in order to use these energy in the domestic appliances inverter has to be used. In the conventional Inverter the harmonic content is high and losses are more due to the switches. In order to reduce these problems, a new photovoltaic system based on trans-Z-source inverter (Trans-ZSI) is proposed. This inverter has been derived from quasi Z- source inverter recently. Trans Z-source network consists of one transformer and one capacitor. While maintaining all prominent features of pervious Z-source inverters, Trans-z-source inverter has several unique advantages such as increased voltage gain, reduced voltage stress and reduced components of impedance network. Due to these features, using trans Z-source inverter as a single stage converter in photovoltaic systems gives satisfactory results. In this concept the application of trans-ZSI in photovoltaic systems in both stand alone mode and grid connected mode has been investigated. Electronic loads are a family of power converters which can be used as a variable impedance load in different applications. It can achieve a high efficiency which reduces the system cost. The validity of this proposed method has been studied by the Matlabz/simulink software.

Keywords: Energy storage, photovoltaic (PV) power generation, power conversion, quasi-Z-source inverter (QZSI)

1. Introduction
Quasi-Z-source inverter (qZSI) is a new promising Power conversion technology perfectly suitable for interfacing of renewable (i.e., photovoltaic, wind turbines) and alternative (i.e., fuel cells) energy sources [1-3]. The qZSI has the following advantages: Excellent reliability due to the shoot-through withstanding capability; Low or no in-rush current during start up; Low common-mode noise. However, the efficiency and voltage gain of the qZSI are limited and comparable with the conventional system of a voltage source inverter with the auxiliary step-up

DC/DC converter in the input stage [4]. The concept of extending the qZSI gain without increasing the number of active switches was recently proposed by several authors [5-8]. Electronic loads are a family of power converters which can be used as a variable impedance load in different applications. With the continuous development of new dc power supply configurations and the accelerated production of electronic devices In order to test these new power supplies with high efficiency, the power recycling concept has been developed to reduce the cost and conserve energy [9, 12].

benefits that can significantly improve women's health and enhance their quality of life. Any sport can be beneficial if you participate regularly.

The Z-source converter was introduced an

impedance network to overcome the limitation of traditional voltage-source converters and current- source converters. It has been shown that it can be used in virtually all the power conversion range with a novel conversion concept, which can be extended too many applications. The Z-source converter can achieve an efficiency of more than 90% in most of the power operating range. Recently a new structure of Z-source inverters which is named Trans Z-source inverter has been introduced. This inverter has been derived from quasi Z-source inverter. Trans ZSI has all prominent features of pervious Z-source inverters.

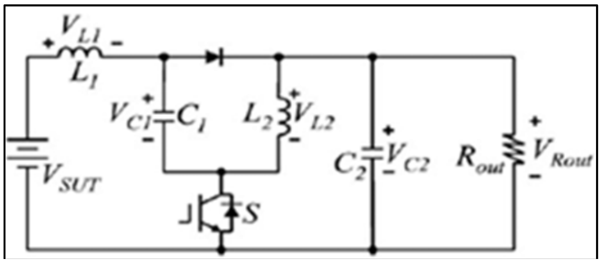

Fig 1: qZ-source-converter

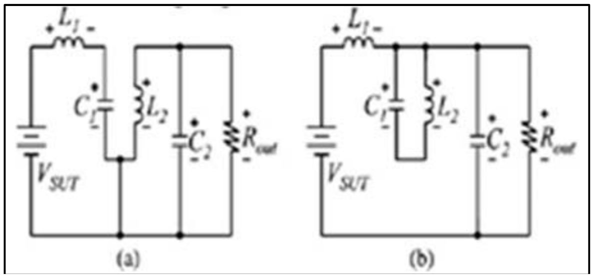

Fig 2: Equivalent circuits for the qZ-source converter. (a) Switch is on.(b) Switch is off.

Moreover this inverter has some unique privileges such as increased voltage gain, reduced voltage stress on switching devices and reduced components of impedance network. In this paper a PV system based on trans ZSI which is connected to a local load and a three phase grid, is proposed. The proper controller for both grid connected mode and stand alone mode is designed. In both modes the control of dc side and ac side is executed separately. In standalone mode, the controller parameter of dc side is determined by using the dynamic model of trans ZSI.

2. Proposed Topology

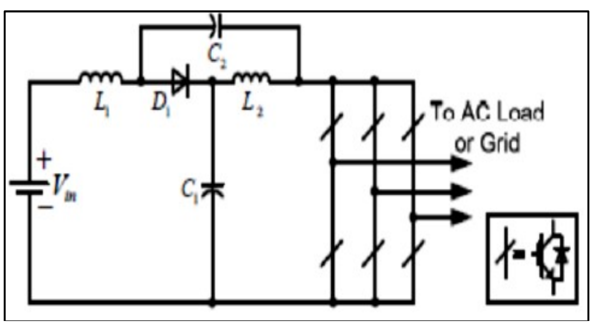

Fig 3: Existing qZSI with battery for PV power generation

Fig. 3 shows just one of the qZSI topologies, if the battery is connected in parallel with the capacitor *C*2 there is discontinuous mode will occur during battery discharge. As a counterpart, we connect the battery in parallel to the capacitor *C*1, leading to a new topology in Fig. 4. They have common points: 1) there are three power sources/consumers, i.e., PV panels, battery, and the grid/load, and 2) as long as controlling two power flows, the third one automatically matches the power difference, according to the power equation.

Without requirements of any additional dc/dc converters or components, the qZSI was first proposed for PV power generation system. But the solar irradiation and the PV panel's temperature change randomly, the dc-link peak voltage will fluctuate accordingly. So, the additional backup is needed like battery to supply the continuous power to the load. This paper aims to resolve the aforementioned problems, analyze all possible schemes of the energy-stored qZSI, compare their benefits and limitations, and find a new topology more preferable to application in the PV power system.

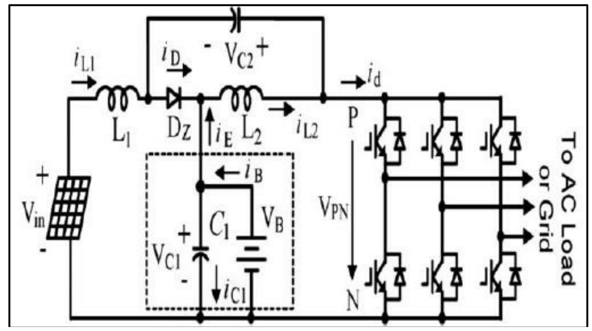

Fig 4: Energy-stored qZSI with battery

$$P_{in} - P_{out} + P_B = 0 \quad (1)$$

Where *P*in, *P*out and *PB* are the PV panel power, output power of the inverter and the battery power respectively. The power *P*in is always positive because the PV panel is single directional power supply, *PB* is positive when the battery delivers energy and negative when absorbing energy, and *P*out is positive when the inverter injects power to the grid.

3. Trans Z-source Inverter

The structure of the quasi ZSI and the trans ZSI are shown in figures 5 and 6 respectively. In structure of the trans ZSI, two inductors L1 and L2 are replaced with one transformer. Hence either C1 or C2 can be removed.

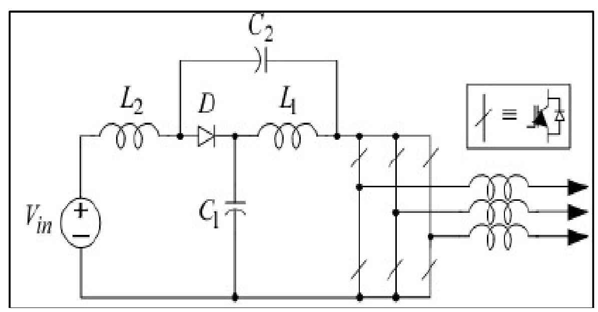

Fig 5: Quasi Z-source inverter

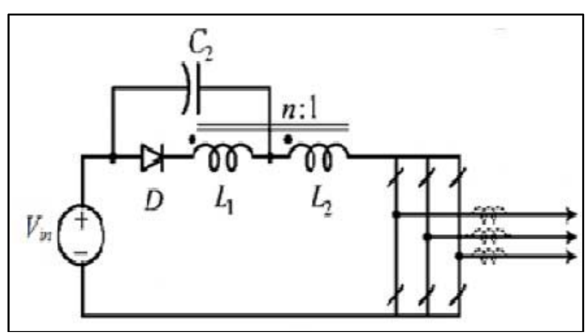

Fig 6: Trans Z-source inverter with C1 removed

With assuming T, T1 and T0 are switching period, non-shoot through interval and shoot through interval in a switching period, respectively and D0 is shoot through duty cycle, the trans Z-source network capacitor voltage can be calculated as follows

$$V_C = \frac{1-D_0}{1-(1+n)D_0} V_{in} \qquad (2)$$

$$v_{i-peak} = \frac{1}{1-(1+n)D_0} V_{in} \qquad (3)$$

It can been seen for n = 1, the trans ZSI equations are same with those of the traditional Z-source/quasi Z- source inverters. But for turns ratio (n) more than 1, the inverter dc link voltage boost can be higher given the same modulation index. In other words, it needs a smaller shoot through duty ratio (accordingly, a larger modulation index) to produce the same ac output than the traditional Z-source/quasi Z-source inverters do [7].In PV generation which may has a low dc output voltage, this feature of trans ZSI can be very efficient.

4. Photovoltaic System

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices

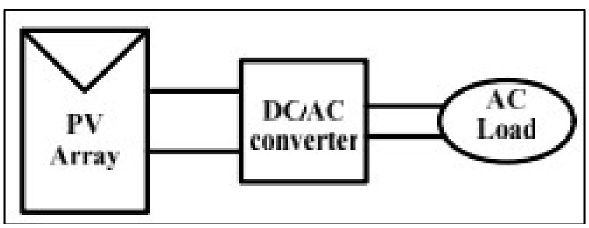

Fig 7: Block diagram representation of Photovoltaic system

This photovoltaic system consists of three main parts which are PV module, balance of system and load. The major balance of system components in this systems are charger, battery and inverter. The Block diagram of the PV system is shown in Fig.7.

A. Photovoltaic cell

A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited1

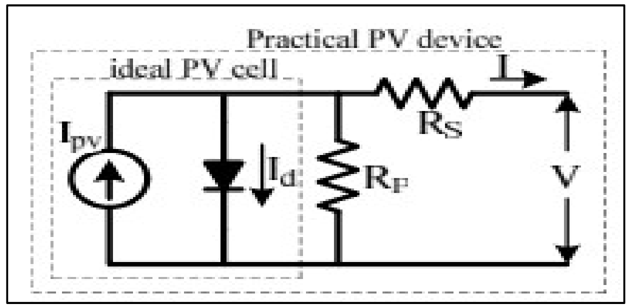

Fig 8: Practical PV device

The equivalent circuit of PV cell is shown in the fig.8. In the above figure the PV cell is represented by a current source in parallel with diode. Rs and Rp

Represent series and parallel resistance respectively.

The output current and voltage form PV cell are represented by I and V. The I-V characteristics of PV cell are shown in fig.9. The net cell current I is composed of the light generated current IPV and the diode current ID.

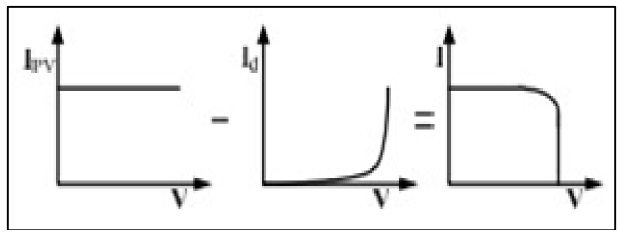

Fig 9: Characteristics I-V curve of the PV cell

5. Control Scheme

The main purposes of controller design in both grid connected mode and standalone mode are expressed respectively as follows:

1. Output voltage control with a valid magnitude and frequency.
2. Maximum power delivering with a desired power factor and low THD content.

A. Controller design for grid connected mode

As the same of standalone mode, the dc side control and the ac side control are executed separately. The main objectives of the dc side controller and the ac side controller are maximum power point tracking and controlling the injection power to the grid with desired power factor, respectively. In the dc side controller, maximum power point tracking (MPPT) is performed by adjusting the shoot through duty ratio. The output voltage of PV arrays is fed back and controlled through a PI controller which assisted with a feed forward d0.The feed forward d0 can be calculated from VMPP follows.

$$d_0 = \frac{V_C - V_{MPP}}{(1+n)V_C - V_{MPP}} \qquad (4)$$

The input voltage of trans Z source network (or output voltage of PV arrays) can be obtained as follows:

$$V_{in} = V_{PV} = \frac{T_1 - nT_0}{T_1} V_C \qquad (5)$$

B. Controller design for standalone mode

Overall configuration of the PV system based on the trans ZSI and the control system in the stand alone mode. L, r, Lm, C and R are stray inductance of transformer, stray resistance of transformer, magnetic inductance of transformer, trans Z-source network capacitor and equivalent series resistance of capacitor, respectively. Cf, Lf and Rf are filter capacitor, filter inductance and stray resistance of filter inductor, respectively. The present system is a multi-input and multi output system. Both the control parameters are dependent each other as change in one parameter imposes a limitation on the freedom of the other. This limitation imposes some problems and complexities in system control. By executing the control of the dc side and ac side of trans ZSI separately, the system complexity is reduced [8].

6. Matlab/Simulink Results

Here simulation results carried out by three cases 1) grid connected mode 2) standalone mode 3) Proposed converter applying to Induction motor

Case-1 grid connected mode

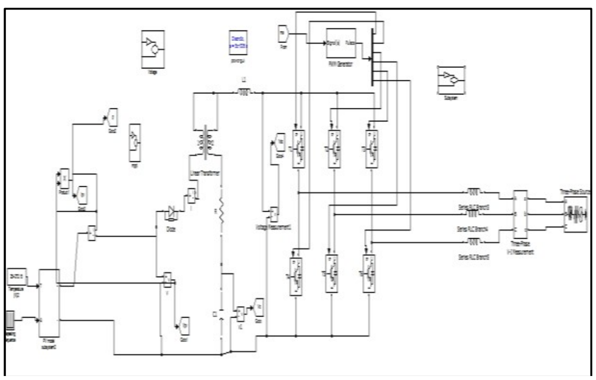

Fig 10: shows the simulink model of grid connected mode operation

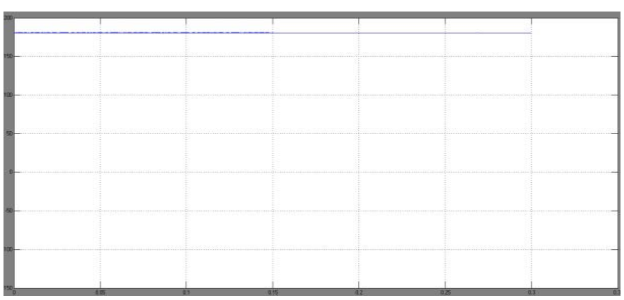

Fig 11: The MPP voltage and the PV arrays output voltage

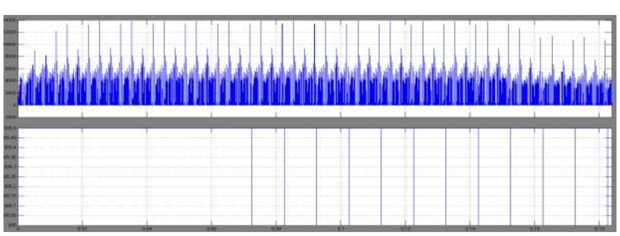

Fig 12: The output voltage of the impedance network and the capacitor voltage when the irradiance is changed

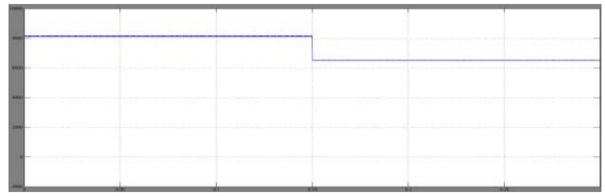

Fig 13: The output power of the PV arrays when the irradiance is changed from 1000 W/m2 to 800 W/m2

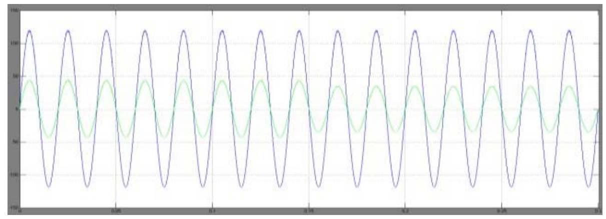

Fig 14: The grid voltage (phase a) and injected current to the grid (phase a)

Case-2 standalone mode

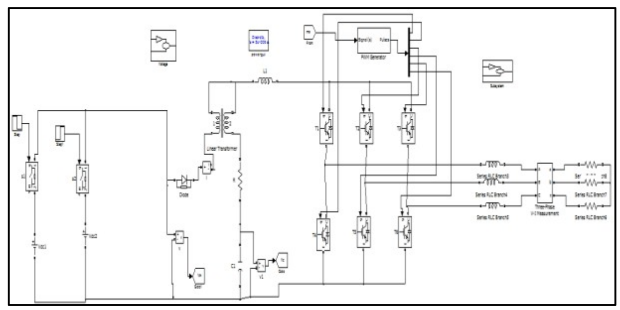

Fig 15: shows the simulink model of standalone mode operation

Fig 16: simulation wave forms of input voltage and capacitor voltage

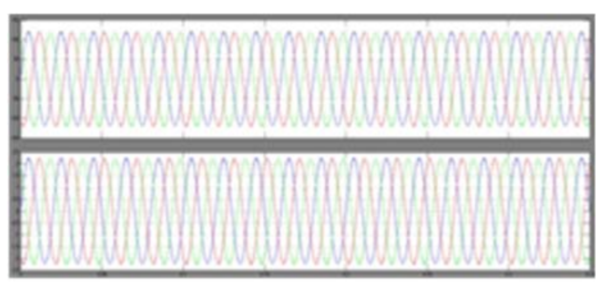

Fig 17: simulation wave forms of load voltage and the load current

The waveforms of input voltage, capacitor voltage, load voltage and current are shown in figures 16 and 17. When the input voltage is reduced, dc side controller increases shoot through duty ratio to maintain a constant output voltage of trans Z-source network.

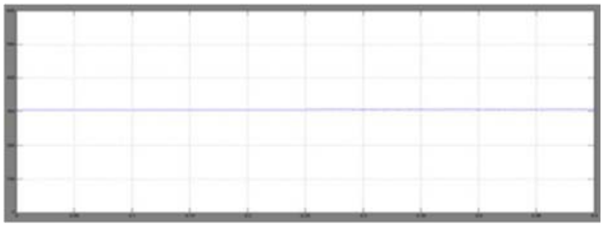

Fig 18: The capacitor voltage when the output load is changed

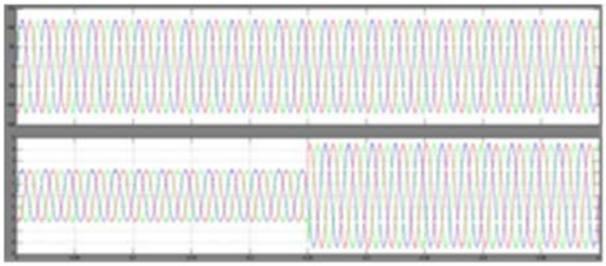

Fig 19: The load voltage and the load current when the output load is changed

Case-3 proposed converter applying to Induction motor

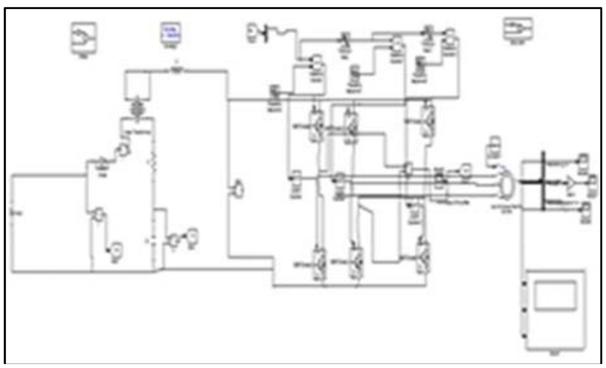

Fig 20: shows the simulink model of proposed converter applying to Induction motor

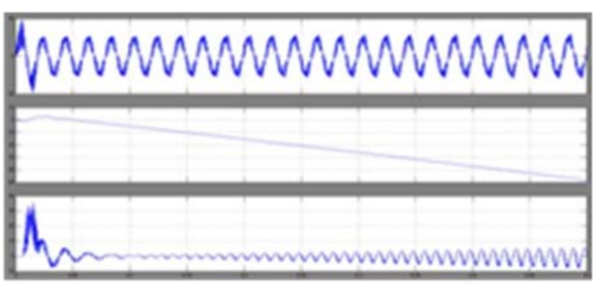

Fig 21: simulation wave forms of armature current, speed and torque characteristics of induction motor

7. Conclusion

The proposed topology operates as an ideal current source which enables the operation of the zero input voltage. It can achieve high efficiency and also reduces the system cost when compared to the traditional Z-source converter. In this research work, a novel topology for an energy stored qZSI has been proposed to overcome the shortcoming of the existing solutions in PV power system. A new photovoltaic system based on trans Z-source inverter which has been introduced recently. This inverter has a higher voltage gain compared to traditional Z-source/quasi Z-source inverters which is suitable for PV generation. The proposed concept is applying to induction motor and verifies the speed torque characteristics. The theoretical analysis, simulations results presented in this work clearly demonstrate the proposed energy-stored Qzsi. PV panels, battery, and the grid/load. As long as controlling two power flows, the third one automatically matches the power difference. So, recently proposed energy stored quasi-Z-source inverters (qZSI) have some new attractive advantages more suitable for application in PV systems. This will make the PV system simpler and will lower cost. These results verified using Matlab/simulink software.

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