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Feasibility Study of Modified Quasi Z Source Inverter for Solar PV Technology

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ABSTRACT

In recent years, Photovoltaic (PV) power generation systems have always been considered as an alternative energy source that can lighten the rapid consumption of fossil fuels. The current developments in the photovoltaic materials and power converters has emerged this as promising technology. A PV inverter is widely used to convert the photovoltaic energy into electrical energy as most of the demands are in AC voltage, either for local loads or supplied into the grid. Power converter topologies employed in the PV power generation systems are mainly characterized by single or multi stage inverters. The Z-source inverter (ZSI) has a single stage structure to achieve the voltage buck/boost character in a single power conversion stage. The energy storage device integrated to Quasi Z-source inverter (QZSI) topology eliminates need for an extra charging circuit. This upgraded topology acquires the operating characteristics from the traditional ZSI, along with the capability of operating under very low PV power conditions. Its main operating points are classified into two modes, the low PV power mode, where the battery is discharged and the high power mode, where the battery is charge up. An extended input power operating range is achieved since the lack of Photovoltaic power can be compensated by the battery. Hence we can conclude that QZSI realize boost/buck function in a single-stage with improved reliability, lower component rating, constant DC current from source and good power quality showing an efficient method for the energy-stored PV power generation

Keyword: *Solar PV, Z Source inverter, Quasi Z source inverter, PWM techniques.*

I. INTRODUCTION

India is a tropical country with sunshine in plenty and long days. About 301 clear sunny days are available in a year. Theoretically, India receives solar power of about 5000 trillion kWh/yr (600TW approx.) on its land area. On an average, daily solar energy incident over India ranges from 4 to 7 kWh/m2. Depending on the location sunshine hours varies from 2,300–3,200 hours in a year. This is far more than current total energy consumption. For instance, assuming conversion efficiency of 10% for PV modules, it will still be thousand times greater than the likely electricity demand in India by the year 2015.

The energy from the sun is used to operate various solar power applications, which includes Heating, Drying, Cooking, seasoning of timber, water treatment (Distillation and disinfection), Cooling (Refrigeration and Cold storage), etc.

The advantages of solar power are as follows,

- Solar Energy is renewable, clean, and sustainable form of energy which helps in protecting our environment.
- It does not create pollution by releasing gases like nitrogen oxide, carbon dioxide, mercury and sulphur dioxide into the atmosphere as many conventional forms of energy do.
- Solar Energy, does not contribute to global warming, acid rain or smog.
- It actively contributes to the decrease of harmful greenhouse gas emissions.
- Since solar energy does not use any fuel, it neither increases the cost nor does it add to the problems of the transportation and recovery of fuel or the storage and disposal of radioactive waste.

- Solar Energy systems once installed will last for decades and are almost maintenance free.
- Addition of solar panels is easy in case your family's needs grow in future.

PV modules are usually made from strings of crystalline silicon solar cells. These cells are made of extremely thin silicon wafers (about 300 um) and hence are extremely fragile. To protect the cells from damage, a string of cells is hermetically sealed between a layer of toughened glass and layers of ethyl vinyl acetate (EVA). An insulating tedlarsheet is placed beneath the EVA layers to give further protection to the cell string. An outer frame is attached to give strength to the module and to enable easy mounting on structures. A terminal box is attached to the back of a module; here, the two ends (positive and negative) of the solar string are welded or soldered to the terminals. This entire assembly constitutes a PV module. When the PV module is in use, the terminals are connected either directly to a load, or to another module to form an array. Single PV modules of capacities ranging from 10 Wp to 120 Wp can provide power for different loads. For large power applications, a PV array consisting of a number of modules connected in parallel and/or series is used.

The Quasi Z-source inverter is one of quite new ideas designated to renewable energy system, mainly fuel cell and photovoltaic. In the QuasiZ-source inverter, a special Z-network is introduced and shoot-through states may be used in similar manner as in Current Source Inverter. ZSI employs a unique impedance network to couple the converter main circuit to the power source, load, or another converter, for providing unique features that cannot be observed in the traditional voltage and current source inverters where a capacitor and inductor are used respectively. The QuasiZ-source converter overcomes the conceptual and theoretical barriers and limitations of the traditional voltage source and current source inverters and provides a novel power conversion concept. The following is the comparison of Quasi Z-source inverter and traditional inverters.

Table 1 Comparison of VSI, CSI, and ZSI

SI. No	Current source inverter	Voltage source inverter	Quasi Z-source inverter
1	As inductor is used in the DC link, the source impedance is high. It acts as a Constant current source.	As capacitor is used in the DC link, it acts as a low impedance voltage source.	As capacitor and inductor is used in the DC link, it acts as a constant high impedance voltage source.
2	This is used in only buck or boost operation of inverter.	This is also used in only a buck or boost operation of inverter.	This is used in both buck and boost operation of inverter.
3	Power loss is high	Power loss is high	Power loss is low
4	Lower efficiency because of high power loss .	Efficiency is low because of power loss high.	Higher efficiency because of less power loss.

Hence, from above comparison of Z-source inverter and traditional converters, it can be concluded that Quasi Z-source inverter have better performance than compared to conventional inverters.

II. BASIC TOPOLOGY OF QUASI Z SOURCE INVERTER

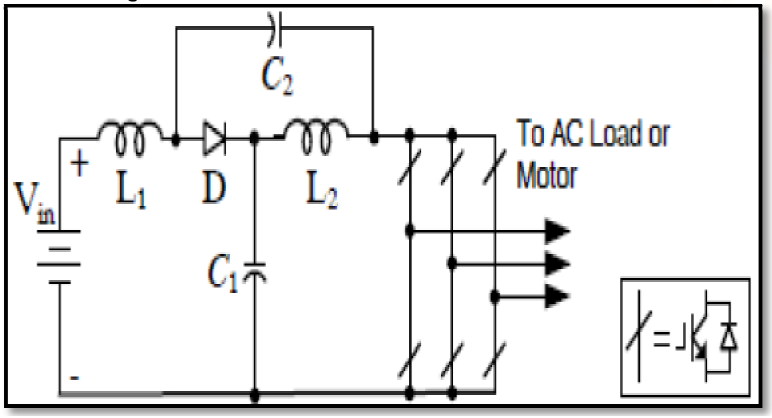

Fig .1 Basic topology of quasi-Z-Source Inverter without energy storage

The Quasi-Z-Source inverter circuit differs from that of conventional Z Source Inverter in LC impedance network interface between the source and inverter. Quasi-Z-source inverter acquires all the advantages of traditional Z-Source Inverter. Fig. 1 shows the basic topology of Quasi Z-source inverter. The Quasi ZSource inverter extends several advantages over Z-Source inverter such as continuous input current, reduced component rating, and enhanced reliability. These advantages make the Quasi 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 overrating 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 quasi-Z-Source Inverter (qZSI), have been derived from the original ZSI.

Fig.1 shows the Existing QZSI without battery for PV power generation. 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. The existing quasi z-source inverter has the following properties:

- It is a single stage buck (or) boost (DC/AC) converter.
- It consists of two split inductors and capacitors equal in magnitude.
- This impedance network itself acts as a filter so the additional filter is not required.
- The inductors are connected in series arms and capacitors are coupled in diagonal arms.
- The impedance network used to buck or boost the input voltage depends upon the buck or boost factor.
- It has one extra zero state when the load terminals shorted. This shoot through state is provided with buck-boost functions by single stage conversion.

III. MODIFIED TOPOLOGY OF QUASI Z SOURCE INVERTER

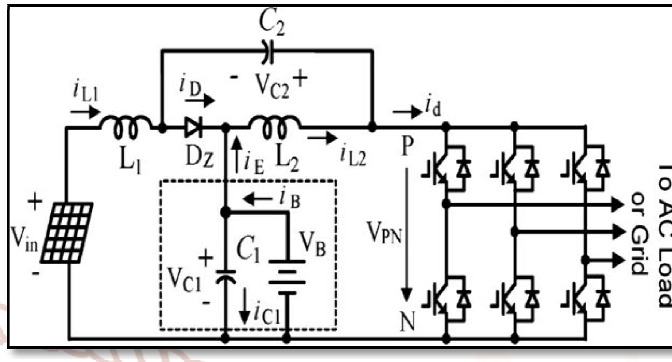

Fig.3 Energy stored QZSI with battery

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. It is demonstrated from the theoretical analysis and 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.

Modes of operation:

Similar to the existing QZSI operating principle, the system in Fig 3 also has two operating modes in the continuous conduction mode (CCM).

1. Active mode
2. Shoot through mode

Active mode:

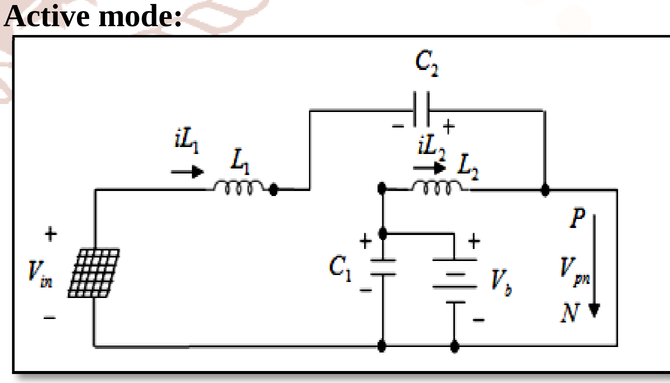

Fig.3 Equivalent circuit of QZSI in Active mode

Fig. 3 shows the equivalent circuit diagram of QZSI in active mode. In the non-shoot through mode or active mode, the switching pattern for the QZSI is similar to that of Voltage Source Inverter (VSI). This mode will make the inverter short circuit via any one phase leg, combinations of any two phase legs, and all three phase legs, which is referred to as the shoot through state. As a result, the diode Dz is turned off due to the reverse bias voltage. The input dc voltage is available as DC link voltage input to the inverter, which makes the QZSI behave similar to a VSI in this mode. During this time interval, the circuit equations are presented as follows:

Shoot through mode:

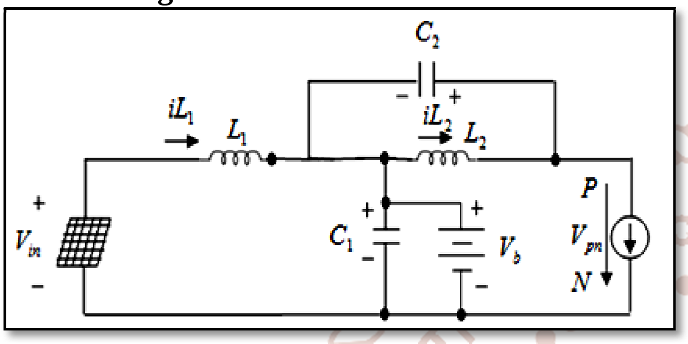

Fig. 4 Equivalent circuit of QZSI in shoot through mode

Fig. 4 shows the circuit diagram of QZSI in shoot through mode. In this mode, switches of the same phase in the inverter bridge are switched on simultaneously for a very short duration. The source however isn't short circuited when attempted to do so because of the presence of LC network (quasi), that boosts the output voltage. The DC link voltage during the shoot through states, is boosted by a boost factor, whose value depends on the shoot through duty ratio for a given modulation index. This mode will make the inverter short circuit via any one phase leg, combinations of any two phase legs, and all three phase legs, which is referred to as the shoot through state. As a result, the diode Dz is turned off due to the reverse bias voltage.

IV. Simulation& Results

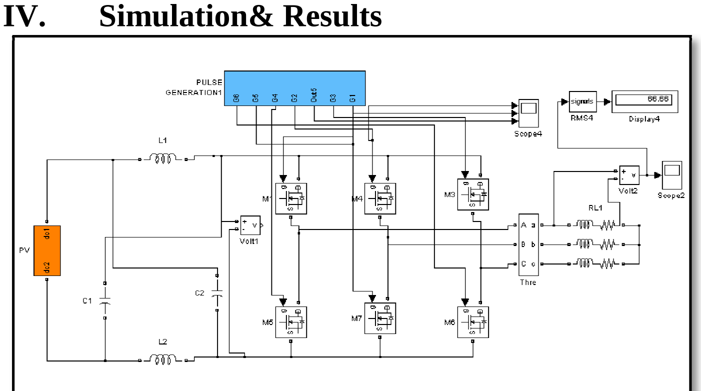

Fig. 5 Simulation model of Quasi Z Source Inverter

Fig. 5 shows the proposed quasi z-source inverter circuit diagram. It consists PV cell, impedance network, three phase inverter and load. The impedance network is used to boost the voltage as well as to protect the circuit during short circuit condition. Fig. 7 shows the inverter output voltage. Fig. 8 shows the inverter output current. Fig. 9 shows the FFT analysis for current waveform. From this result the current has THD 5.66%.

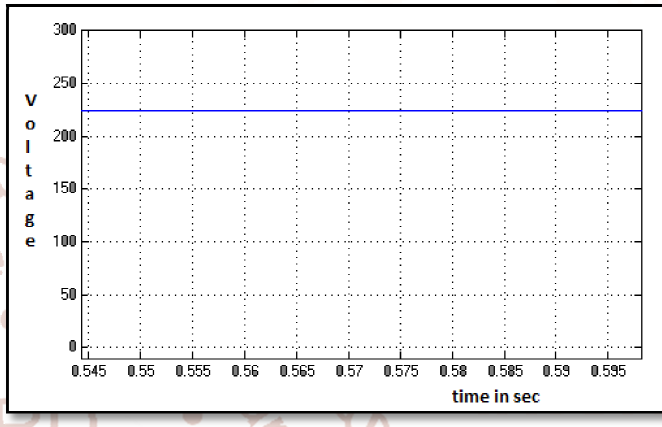

Fig. 6PV cell output voltage

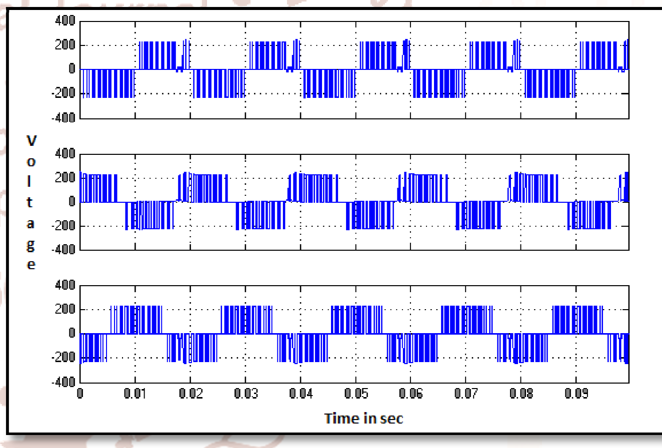

Fig. 7 Inverter Phase to phase voltage

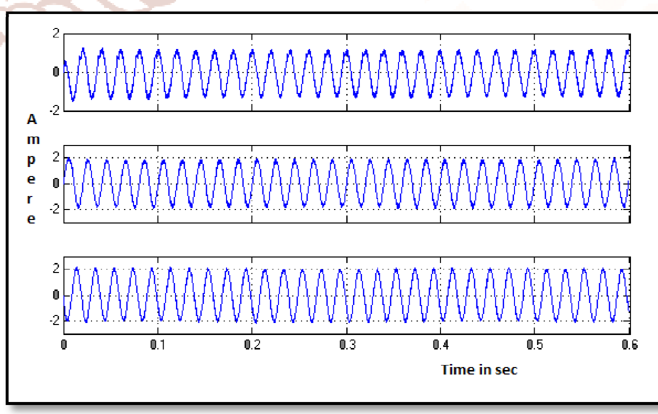

Fig. 8 Inverter output current

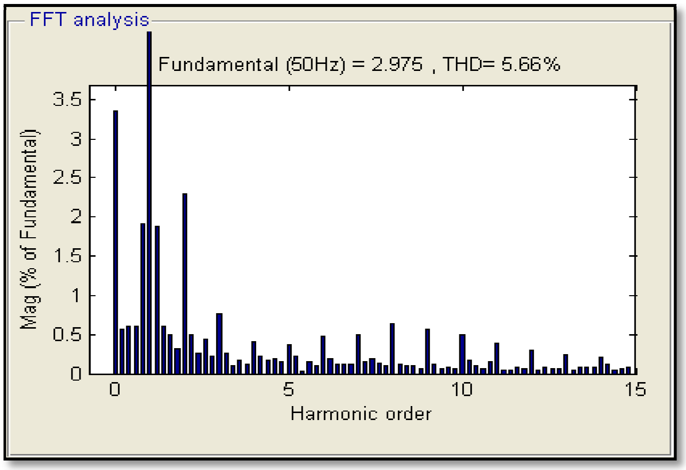

Fig. 9 FFT ANALYSIS for output current

The conventional circuit and proposed circuit simulation results are compared the proposed circuit has better performance compare than conventional circuit it is shown from the following table.

Table 2 Results of simulated model

SI.No.	Parameter	QZSI
1	Input Voltage (V)	225
2	Boost Output Volatge (V)	343
3	Rms Phase Voltage (V)	191
4	Rms Line Voltage (V)	103
5	Rms Current (A)	1.28
6	Thd (%)	5.66

V. Conclusion

The Quasi Z Source inverter has the following properties,

- It employs a unique impedance network including passive components to connect the three-phase inverter bridge to the power source. By designing the inductor properly and adjusting the previously forbidden shoot-through zero state, the magnitude of the bus voltage can be greatly stepped up.
- Shoot-through states, which are forbidden in conventional VSIs, are utilized to store and transfer energy within the impedance network to boost the amplitude of the bus voltage. Waveform distortion of the ac output voltage caused by dead time is essentially avoided.

Thus the proposed topology has more voltage gain, less capacitor rating and less harmonics.

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