



Modeling and Control of Quasi Z-Source Inverter for Advanced Power Conditioning Of Renewable Energy Systems

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ABSTRACT: Alternate Energy Sources such as Solar, Fuel Cell and Wind have a wide voltage change range due to the nature of sources. Photovoltaic cells voltage varies with temperature and irradiation. The voltage fed Quasi Z-Source inverter has been found suitable for photo voltaic (PV) applications mainly because of its single stage buck and boost capability and improved reliability. Fuel cells stack voltage drops greatly with current and this paper details modeling and control issues of Quasi Z-Source used for Distributed Generation (DG) such as photovoltaic (PV) or fuel cell power conditioning. A Robust and reliable grid power interface system for wind turbines using Permanent Magnet Synchronous Generator (PMSG) is proposed in this paper. The dynamic characteristics of the Quasi Z-Source inverter network are first investigated by small signal analysis based on the dynamic model, the stand-alone operation and grid connected operation with closed loop control methods are carried out which are the two necessary operation modes of distributed generation system.

KEYWORDS: Quasi Z-Source Inverter, DC-AC Converter, PMSG, Fuel cell Stack, Renewable Energy Sources, MPPT, Wind Turbine.

I. INTRODUCTION

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 [1]. 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 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 [2]-[3]. A transformer and 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.

In Recent Years, wind energy has been regarded as one of the significant renewable energy sources [4]. Among the existing wind power generation systems, their generators can be categorized into four main types: 1) fixed-speed squirrel-cage induction generator, 2) variable-speed wound rotor induction generator that employs variable rotor resistance, 3) variable-speed doubly fed induction generator that employs a frequency converter between the grid and its rotor windings and 4) variable-speed synchronous generator, which is either a wound rotor synchronous generator or a permanent-magnet synchronous generator (PMSG). Due to the fact that a multiple pole design can be easily realized in the synchronous generator, it is the only type that provides a realistic opportunity to implement gearless operation and hence, the features of lightweight and low maintenance can be obtained in wind generation system [5]-[6].

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II. QUASI Z-SOURCE INVERTER FOR PV SYSTEMS

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 paper 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.

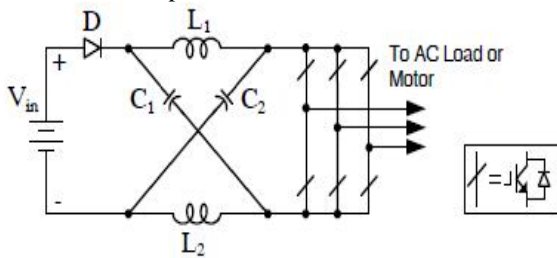


Fig.1. Voltage fed Z-source inverter

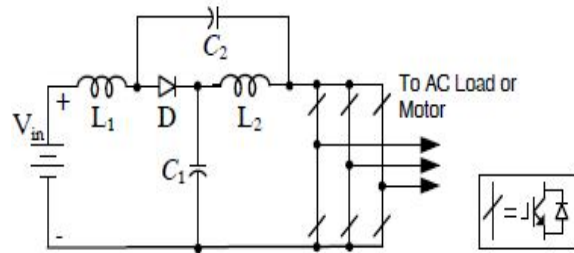


Fig.2. Voltage fed quasi-Z-source inverter

Figs. 1 and 2 shows the traditional voltage fed ZSI and the proposed voltage fed qZSI respectively. In the same manner as the traditional ZSI, the qZSI has two types of operational states at the dc side, the nonshoot-through states (i.e. the six active states and two conventional zero states of the traditional VSI) and the shoot-through state (i.e. both switches in at least one phase conduct simultaneously).

Fig. 3 shows the proposed qZSI in the PV power generation system. It connects the PV arrays and outputs three phase 50 Hz, 330 V ac to resistive loads, which is the standard utility level. A three-phase LC Filter connected in right after the inverter bridge to get 50Hz sinusoidal ac outputs.

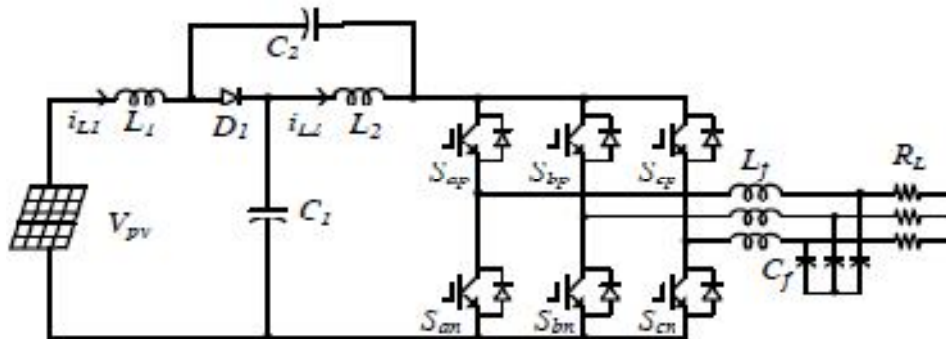


Fig.3. QZSI in the PV power generation system

III. QUASI Z-SOURCE INVERTER FOR FUEL CELL STACK SYSTEMS

Utility interactive inverters converting dc power sources such as fuel cells to ac grid systems are increasingly becoming popular as the energy crisis and environmental concern become the driving force for alternative energy.

In general, the inverters employed in the small distributed generation are required to have the following characteristics:

- Allowable for wide output voltage variation of distributed energy sources;
- Assured output power quality with low THD and voltage/current flickering as well as frequency deviation and
- Available for isolated operation and line parallel operation.

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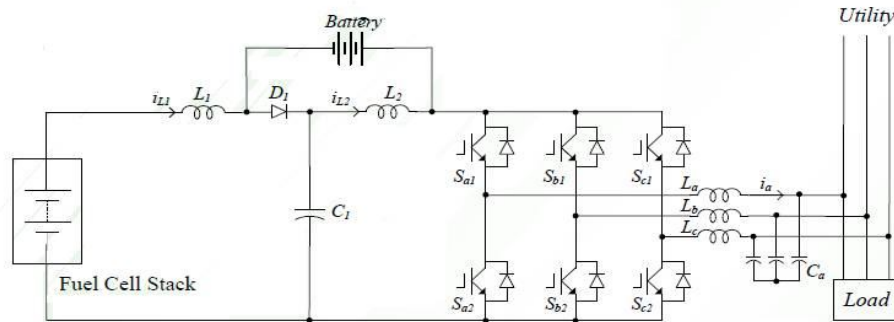


Fig.4. QZSI in the Fuel Cell Battery Based power generation system

Fig. 4 shows the proposed qZSI in the Fuel Cell Battery Based power generation system. It connects the Fuel Cell Stack and outputs three phase 50 Hz, 330 V ac to resistive loads, which is the standard utility level. A three-phase LC Filter connected in right after the inverter bridge to get 50Hz sinusoidal ac outputs.

IV. QUASI Z-SOURCE INVERTER FOR WIND POWER GENERATION SYSTEMS

The configuration of the proposed system is shown in Fig.5. The wind power captured by the turbine is converted by the PMSG and transferred to the grid via a three-phase three-switch PWM buck-type rectifier in series with a Z-source inverter. The detailed power circuit is shown in Fig.6.

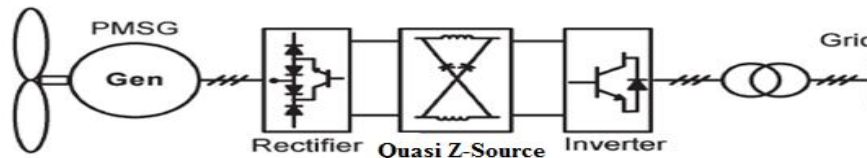


Fig.5. Proposed PMSG-based wind generation system

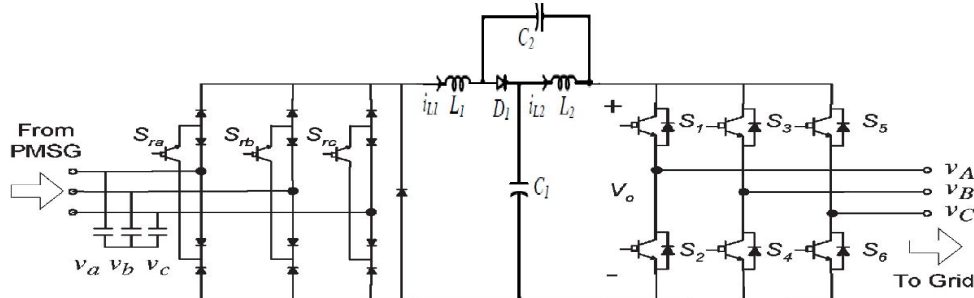


Fig.6. Proposed grid interface circuit for the PMSG

The main function of the generator side PWM rectifier is to regulate the power factor of the PMSG and to ensure sinusoidal generator currents. A small LC input filter can be designed to absorb the high frequency harmonics injected into the generator by the rectifier switching action.

The grid side Z-source inverter is chosen to be an alternative to conventional inverter topologies due to its many merits. For example, it has inherent voltage buck and boost capability using the shoot-through states in each phase leg of the inverter. This function realizes on a unique impedance network is implemented using split inductors (L_1 and L_2) and capacitors (C_1 and C_2) connected in X-shape. This enables the proposed wind generation system to achieve variable speed operation. The proposed configuration has eliminated the dc-dc chopper and thereby simplified the system structure. The system operation reliability is also improved since there is no shoot-through risk in both generator and grid-side converters.

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V. CONSTANT BOOST CONTROL FOR QUASI Z-SOURCE INVERTER

In the proposed PV power generation system, in order to lower the voltage stress on the inverter bridge and keep a high voltage gain, the maximum constant boost control with third harmonic injection was chosen as the control method. Fig. 7 shows the sketch map. At $(1/6)$ third harmonic injection, the maximum modulation index $M = (2/\sqrt{3})$ can be achieved.

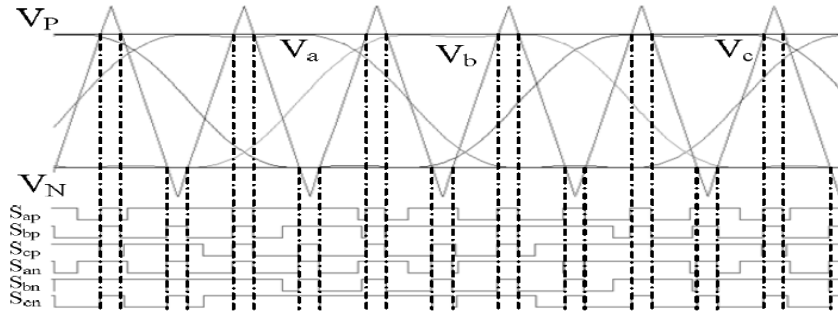


Fig.7. Sketch map of constant boost control for qZSI

This maximum constant boost control can be implemented using third harmonic injection. A sketch map of the third harmonic injection, with $1/6$ of the third harmonic, is shown in Fig. 8. As can be seen from Fig. 8, V_a reaches its peak value $(\sqrt{3}/2)M$ while V_b is at its minimum value $(-\sqrt{3}/2)M$. Therefore, a unique feature can be obtained only two straight lines, V_p and V_n are needed to control the shoot-through time with $1/6$ (16%) of the third harmonic injected.

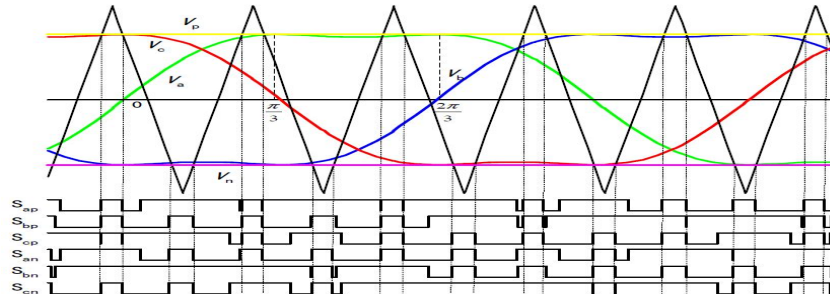


Fig.8. Sketch map of constant boost control with third harmonic injection

VI. SIMULATION RESULTS & DISCUSSION

A. SIMULATION CIRCUIT FOR QUASI Z-SOURCE INVERTER USING PHOTO VOLTAIIC SYSTEM

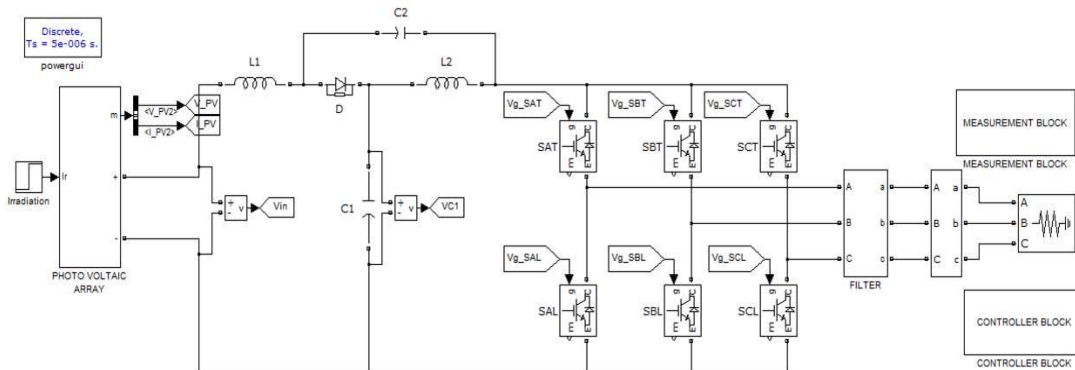


Fig.9. Quasi Z-Source Inverter using PV Module

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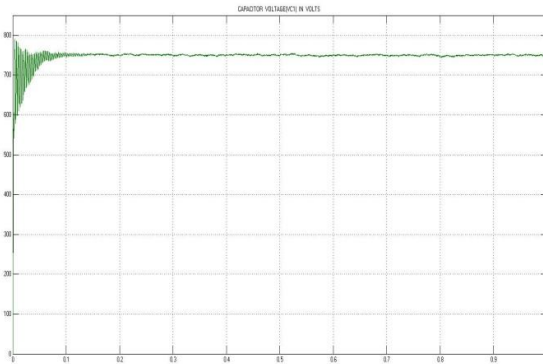


Fig.10. Capacitor Voltage Output

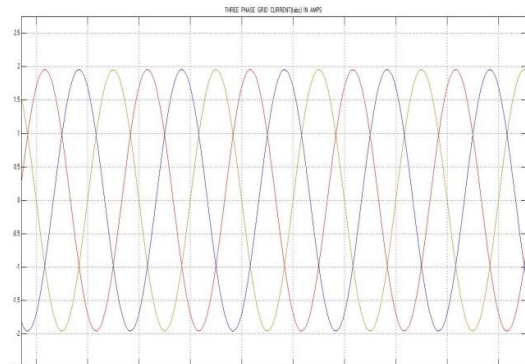


Fig.12. Three Phase Grid Current

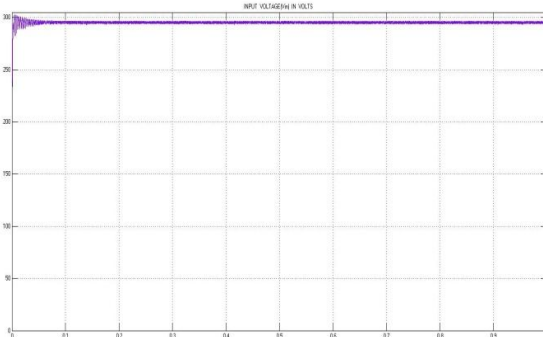


Fig.11. Input Voltage

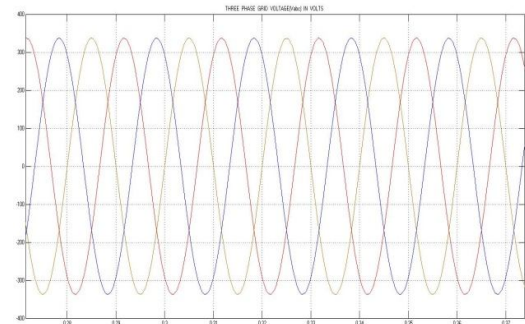


Fig.13. Three Phase Grid Voltage

B. SIMULATION CIRCUIT FOR QUASI Z-SOURCE INVERTER USING FUEL CELL STACK

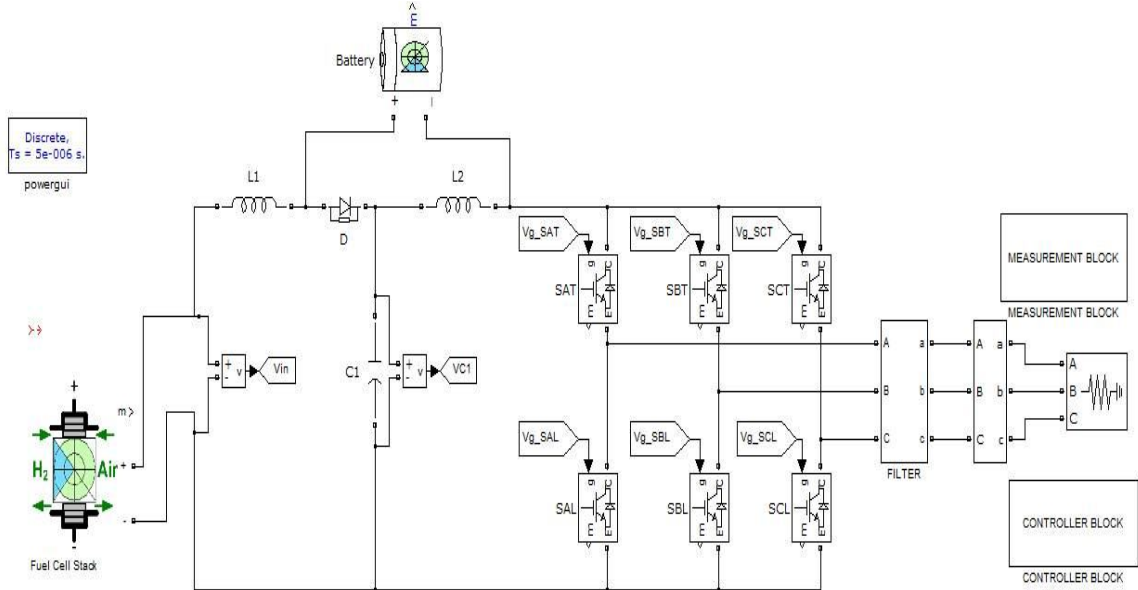


Fig.14. Quasi Z-Source Inverter using Fuel Cell Battery Based Distributed Power Generation

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C. SIMULATION CIRCUIT FOR QUASI-Z-SOURCE INVERTER USING WIND POWER GENERATION

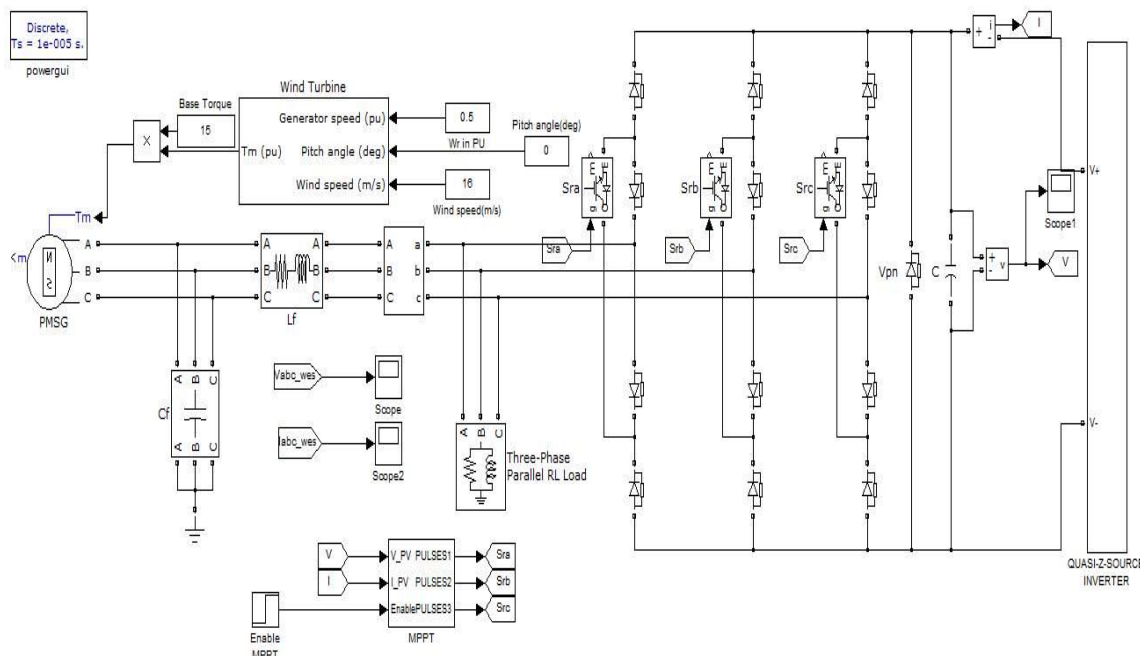


Fig.15. Quasi Z-Source Inverter using PMSG Based Wind Power Generation System

VII. CONCLUSION

This paper is emphasized the use of Quasi Z-Source inverter for advanced power conditioning of various renewable energy sources using distributed generator. The dynamic character has been analyzed experimentally using small signal analysis and MATLAB SIMULINK environment. The proposed system is able to withstand the fluctuation in voltage and does not require any additional converter. This system can provide a better operation with lower cost, higher reliability and higher efficiency. Along with this, the proposed system is highly immune to EMI Noise.

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