

Using modified modulation and double frequency ripple suppression control reduce the capacitance in a single phase PV quasi-z-source inverter

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Abstract- Mismatched double-frequency power is existed between the dc input and ac output in single-phase photo voltaic (PV) system. In a passive network the double-frequency ripple (DFR) energy needs to be buffered. Otherwise, the ripple energy will flow into the input side and adversely affect the PV energy gather. In existed PV system, electrolytic capacitors are usually used for high capacitance. However, electrolytic capacitors are considered to be one of the most failure prone components in a PV inverter. In proposed system, a capacitance reduction control strategy is proposed to buffer the DFR energy in single-phase Z-source/quasi-Z-source inverter applications. The capacitance requirement can be reduced and achieve low input voltage DFR in a proposed control method. Consequently, highly good in quality film capacitors can be used. The increased without using any extra hardware components. Switching device voltage stress and power loss due to the proposed control strategy will also be discussed. Simulation and experimental results are also shown to verify the proposed circuit and analysis.

Index Terms- Capacitance reduction, double-frequency ripple (DFR), Z-source (ZS)/quasi-Z-source (qZS).

I. INTRODUCTION

Today's world putting more efforts into distributed power generation (DG) of renewable energy sources (RES), such as photovoltaic (PV), wind power and fuel cells, which are sustainable and environmental friendly. Practically, several DGs consists distributed power grid and further they can be constructed through micro-grid with local loads and managements. To ensure proper performance of the micro-grid, DG is usually required to work in stand-alone or grid-connected.

Interface between RES and distributed power grid, the performance of power electronic converters

becomes critical. The voltage-fed z-source inverter (ZSI) and quasi-Z-source inverter (qZSI) considered for photovoltaic (PV) application in recent years. Due to the shoot-through capability these inverters feature single-stage buck-boost and improved reliability. Z-source inverter (ZSI) is known as a single-stage buck/boost inverter. With an impedance network coupling. In three-phase and single-phase the proposed scheme enables PV string voltage boost to a higher level, and solves the imbalance of DC-link voltage in traditional CHB inverters. A multilevel voltage waveform of applications ZSI and qZSI are both utilized. For higher voltage application and higher performance, single-phase ZSI/qZSI can also be connected in cascaded structure. Because of its single-stage voltage buck/boost properties, the ZSI can deal with variation in input voltage in a wide range, which is conventionally achieved by a two-stage DC-DC cascaded by DC-AC structure. Advantages and improved reliability due to the allowance of shoot-through state, ZSI gains increasing attention and was presented for use in several applications, such as DG, UPS, fuel cell vehicles, PV or wind power conversion, electronic loads, etc.

Photovoltaic (PV) Module Integrated Converter (MIC), which connects PV panels to single-phase ac grid in a modular structure, has become an important trend in PV market. The research and development of MICs have resulted in inverters ranging from 100 to 300 W. The MIC features several advantages such as low cost of mass production, easier installation and expansion, and improved energy harvesting due to the individual MPPT. However, compared with the string inverters, MICs have lower efficiencies. Three-

phase applications, the Z-source (ZS)/quasi-Z-source (qZS) network needs to be designed to handle the high-frequency ripples. High and low frequency ripples are handled by the single phase pv system. In a single-phase qZSI system the low-frequency ripple issue studied.

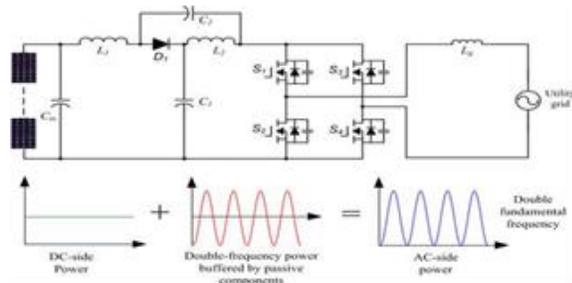
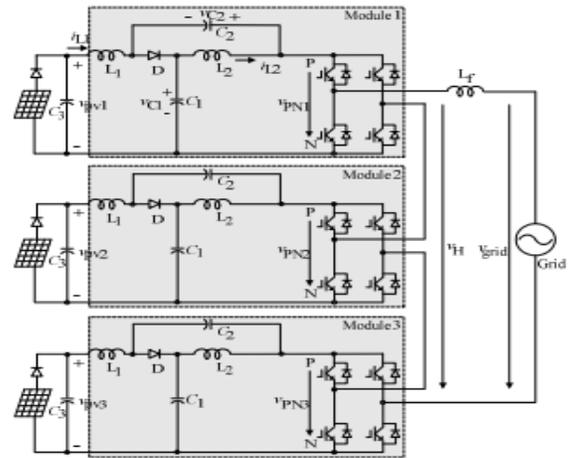


Fig.1.Diagram of a single phase qzsi-based pv system

inverter output is generated by an improved phase shifted sinusoidal pulse width modulation (PS-SPWM) algorithm, which introduces shoot-through states into the conventional zero states to control qZS-CHB module. The effective controls schemes are proposed to regulate the maximum power point tracking (MPPT) of each string, and control the DC-link voltage of each H-bridge, respectively. Ideally, the DC-side output power is pure dc and the ac-side power contains a dc component plus ac ripple component whose frequency is two times the grid voltage frequency. The mismatched ac ripple is called as double-frequency ripple (DFR). DFR power needs to vary by the passive components, to balance the power mismatch between the dc side and ac side. Mainly the qZS capacitor C_1 which has higher voltage rating than C_2 . The DFR peak power is the same as the dc input power, so large capacitance is needed to buffer this ripple energy. To achieve high inverter power density with reasonable cost, electrolytic capacitors are usually selected. Electrolytic capacitors contain a complex liquid chemical called electrolyte to achieve high capacitance and low series resistance. As the electrolytic capacitors age, the volume of liquid present decreases due to evaporation and diffusion. This process is accelerated with higher temperature, eventually leading to performance degradation over time. Therefore, electrolytic capacitors are considered to be the weak component regarding to lifetime, especially under outdoor operation conditions.

A.Quasi-Z Source Inverter:

The qZSI can be operated in two states, i.e., the non-shoot-through state and the shoot-through state. Fig. shows the qZSI equivalent circuits operating in the two states and defines the polarities of all voltages and currents.



To calculate the DFR for qZSI accurate analytical model and for selecting the capacitances design guidelines have been developed to limit the DFR .Nevertheless, the required capacitance is still large. To reduce the DFR of dc-link voltage in ZSI two additional smoothing-power circuits are employed. However, the added circuits increase the system cost and complexity. To minimize the DFR on Z-source capacitors In a low-frequency harmonic elimination PWM technique is presented. However, the method is used for application with constant voltage input source and DFR current is induced in the inductor and the input side. The ripple current will decrease the energy harvest from the PV panels so this is not used in PV application.

In some reported single-phase two-stage system which is composed of a dc–dc converter and H-bridge inverter, the dc-link capacitance can be significantly reduced by using dedicated control.

In this paper, mitigate the input DFR without using large capacitance, a new control strategy is proposed for ZSI/ qZSI to which enables us to use the highly reliable film capacitors. There is no extra hardware needed to implement the capacitance reduction. The proposed control system incorporates a modified

modulation strategy and a DFR suppression controller. In order to apply the capacitance reduction method, it is necessary to study the impact of decreasing the capacitance on system design and performance. The gallium nitride (GaN) devices are applied in the inverter to increase the system efficiency at high switching frequency. Finally, experimental results are provided to verify the effectiveness of the proposed control system. Several control strategies been proposed for the cascaded PV system with direct connection between individual inverter module and segmented PV arrays. But they were not consider the fact that PV arrays cannot be directly connected to the individual inverter module in high voltage large-scale PV system application due to PV insulation and leakage current issues. Even if there are low frequencies medium voltage transformers between the PV converters and grid, there are still complicated ground leakage current loops among the PV converter modules. Therefore, those methods not qualified for a practical large-scale grid-connected cascaded PV system. Moreover, reactive power compensation was not achieved are largely limits the functions of the cascaded PV system to provide ancillary services. Proper reactive power compensation can significantly improve the system reliability, and in the meantime help the MPPT implementation for the cascaded module under unsymmetrical condition as well as comply with the system voltage requirement simultaneously. A reactive and active power control strategy has been applied in cascaded PV system with isolated dc-dc converters.

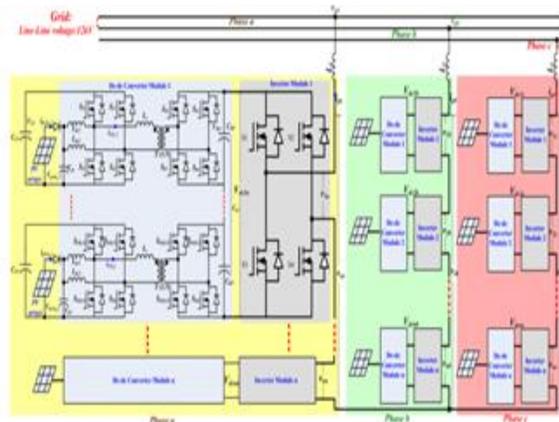


Fig.1 Diagram of the proposed control system

II. PROPOSED CONTROL SYSTEM FOR CAPACITANCE REDUCTION

The basic principle of the proposed capacitance reduction method can be explained by

$$\Delta E = \frac{1}{2} C (V_{C_max}^2 - V_{C_min}^2) \quad (1)$$

Where C is the capacitance, E is the ripple energy that is stored in the capacitor, and V_{C_max} and V_{C_min} are the maximum and minimum voltages across the capacitor. According to (1), there are two ways to increase E . One is to increase the capacitance C , and the other way is to increase the voltage fluctuation across the capacitor. Instead of increasing the capacitance, the proposed control system will increase the voltage fluctuation across the qZS capacitors to buffer more double frequency power strategy is needed to impose the DFR on qZS capacitors while preventing the ripple energy from flowing into the input. In order to achieve this, a modified modulation strategy and an input DFR suppression controller represented.

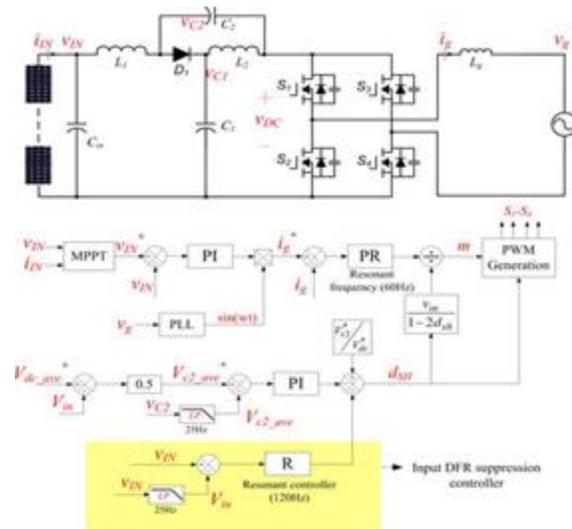


Fig.2 Diagram of the proposed control system

III. IMPACT OF CAPACITANCE REDUCTION

A. System Stability

In order to apply the proposed control system, it is necessary to study impact of decreasing C_1 on system stability. The possible operation states of voltage fed qZSI have been summarized with equivalent circuits, and the averaged model of qZSI can be obtained.

IV. EXPERIMENTAL RESULTS

A. Schematic Diagram

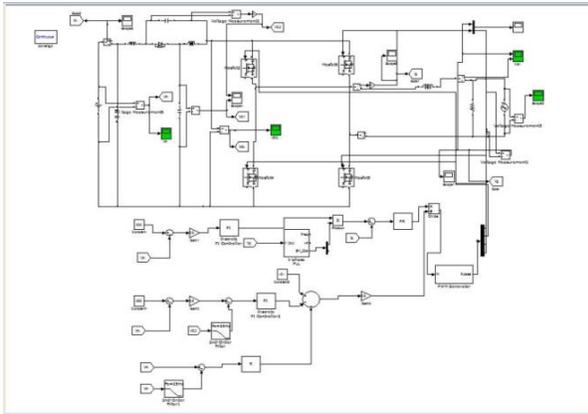


Fig: Schematic diagram of proposed control system

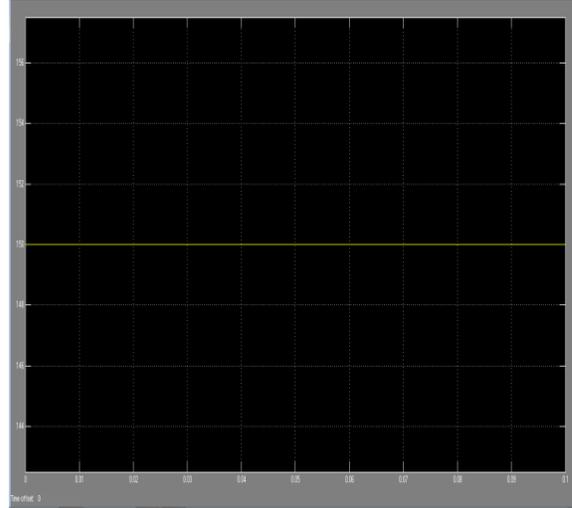


Fig: Vin Waveforms of the qZSI with proposed control diagram of proposed control

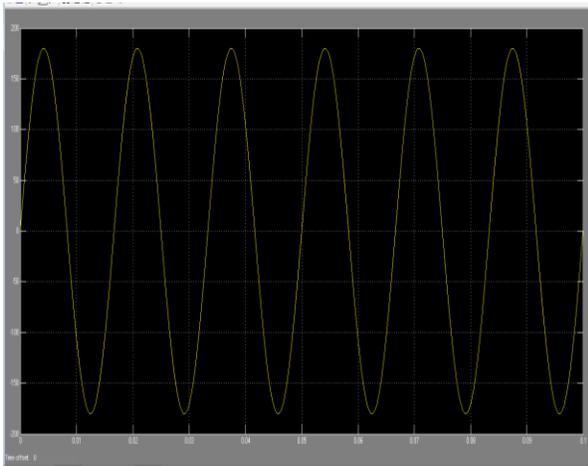


Fig: Vc2 Waveforms of the qZSI with proposed control diagram of proposed control

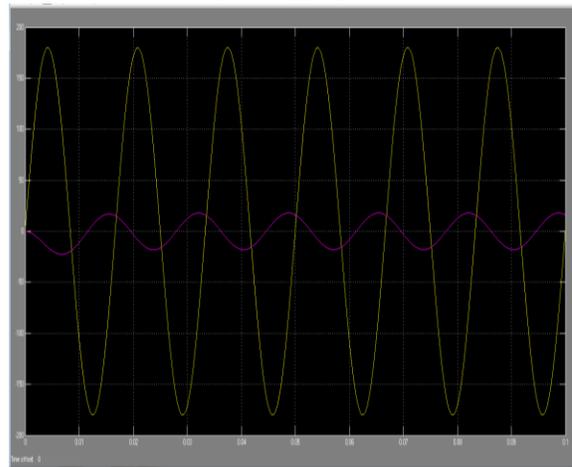


Fig: Output current waveform of the qZSI with the proposed control

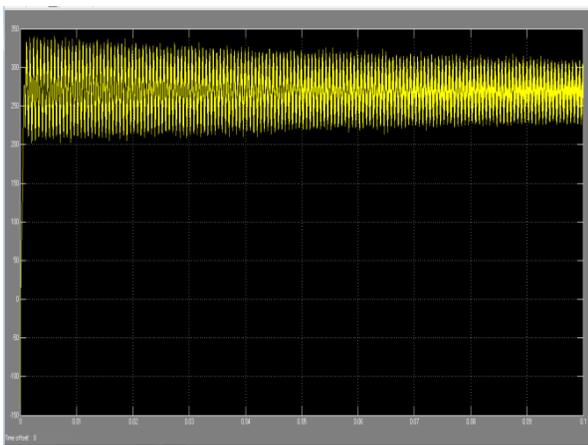


Fig: Vdc Waveforms of the qZSI with proposed control diagram of proposed control

V. CONCLUSION

In this paper, Instead of using large capacitance, to minimize the capacitance requirement in single-phase qZSI PV system a new control strategy is proposed. The qZS capacitors are imposed with higher double-frequency voltages to store the DFR energy. To decouple the input voltage ripple from the qZS capacitor DFR, a modified modulation and an input DFR suppression controller are used, to prevent the ripple energy flowing into the input PV side. The small signal model is developed and shows that the capacitance reduction does not impact the system stability much. For the developed 1-kW quasi-Z-source PV system, 2mF capacitor can be replaced with a 200μF capacitor by using the proposed

method. However, the voltage stress across the switching devices was increased by 53% compared with the conventional design. The efficiency was decreased by 0.12%-0.69% at several selected operation points. It is also shown that there is more benefit if the method is applied for 240 Vrms output qZSI. The increase of the switching device voltage stress is only 15% when compared with conventional design. In single phase ZSI application this control strategy can be used.

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