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IJIEMR Transactions, online available on 27th Oct 2017. Link :http://www.ijiemr.org/downloads.php?vol=Volume-6&issue=ISSUE-9

Title: **AN PASSIVE ENERGY STORED QUASI-Z-SOURCE CASCADE MULTILEVEL INVERTER-BASED SOLAR PHOTOVOLTAIC POWER GENERATION**

Volume 06, Issue 09, Pages: 318 – 321.

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AN PASSIVE ENERGY STORED QUASI-Z-SOURCE CASCADE MULTILEVEL INVERTER-BASED SOLAR PHOTOVOLTAIC POWER GENERATION

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ABSTRACT—The quasi-Z-source cascade multilevel inverter (qZS-CMI) presents many advantages over conventional CMI when applied in photovoltaic (PV) power systems. For example, the qZS-CMI provides the balanced dc-link voltage and voltage boost ability, saves one-third modules, etc. However, the qZS-CMI still cannot overcome the intermittent and stochastic fluctuation of solar power injected to the grid. This paper proposes an energy stored qZS-CMI-based PV power generation system. The system combines the qZS-CMI and energy storage by adding an energy stored battery in each module to balance the stochastic fluctuations of PV power. This paper also proposes a control scheme for the energy stored qZS-CMI-based PV system. The proposed system can achieve the distributed maximum power point track for PV panels, balance the power between different modules, and provide the desired power to the grid. A detailed design method of controller parameters is disclosed. Simulation and experimental results verify the proposed system and the control scheme.

Index Terms—Cascade multilevel inverter (CMI), energy storage, photovoltaic (PV) power generation, quasi-Zsource inverter (qZSI).

I.INTRODUCTION

NOWADAYS, applying multilevel inverters to photovoltaic (PV) power systems is gaining more and more attention Among the typical multilevel inverter topologies, the cascade multilevel inverter (CMI) is more widely used due to its attractive features, such as achieving the distributed maximum power point tracking (MPPT) and high voltage/high power grid tie without a transformer. However, each module is a buck inverter in the conventional CMI-based PV power system,and each module's PV voltage variation will cause the whole system's dc-link voltages to be imbalanced. Considering the unique features of the Z-source inverter (ZSI) and quasi-Zsource inverter (qZSI), i.e., implementing voltage boost/buck and inversion in a single stage the Z-source/quasiZ-source cascade multilevel inverter (ZS/qZS-CMI)-based PV

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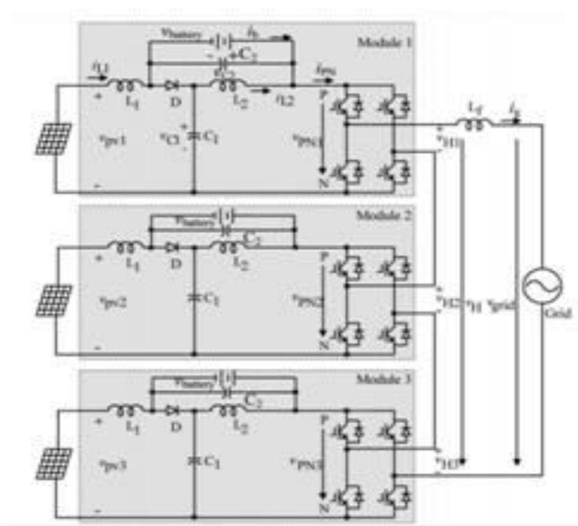
power systems have been proposed to overcome the aforementioned disadvantages of the conventional CMI-based PV system. In particular, GaN devices were used in ZS/qZSCMI-based PV systems to achieve high efficiency; three modulation methods, i.e., phase-shifted sinusoidal pulsewidth modulation (PS-SPWM), phase-shifted pulsewidthamplitude modulation (PS-PWAM), and modular multilevel space vector modulation (MMSVM), were proposed for the quasi-Z-source CMI (qZS-CMI)-based PV respectively, where PS-SPWM was a basic method derived from the conventional CMI, PS-PWAM was proposed to reduce the switching number and loss, and MMSVM was for the three-phase qZS-CMI to simplify modulation implementation and enhance the voltage utilization ratio. the qZSCMI-based PV system was compared with the traditional CMI system, and the conclusion was that the qZS-CMI PV system saved one-third of the modules than the traditional CMI-based PV system



II.PROPOSED ENERGY STORED QZS-CMI-PV POWER SYSTEM

A.Topology of Proposed System A sample topology of the proposed system which consists of three modules with outputs connected in series. Each module includes a PV panel, a battery, and a qZS H-bridge inverter. The unipolar PWM method is used in each module to operate the H-bridge inverter. Considering the qZSI's operating principle, the shoot-through state is added in the conventional zero state in the modulation process. Therefore, each module in the system still outputs a three-level voltage vHn. For the whole system's modulation, the PS-SPWM method in [9] is employed, and the carriers of three modules are shifted by 60◦ to each other. As a result, the energy stored qZS-CMI provides a seven-level output voltage vH to feed the 50-Hz grid through the L-filter.

B. Modeling of Proposed System In this paper, the two capacitors of each module have the same capacitance, and the two inductors of each module have the same inductance, i.e., C=C1 = C2 and L=L1 = L2. The reasons are as follows. 1) Different capacitances will cause different current behaviors of the two inductors. In particular, there will be larger inductor current second harmonic (2ω) ripple (at least for the inductor L2) when compared to the case with the same capacitance. Large inductor current 2ω ripple will result in large loss and high current stress of inductors. 2) Our design also aims to obtain constant inductor current without 2ω ripple. For this case, two capacitors will have the same 2ω current ripple. Two capacitors with equal

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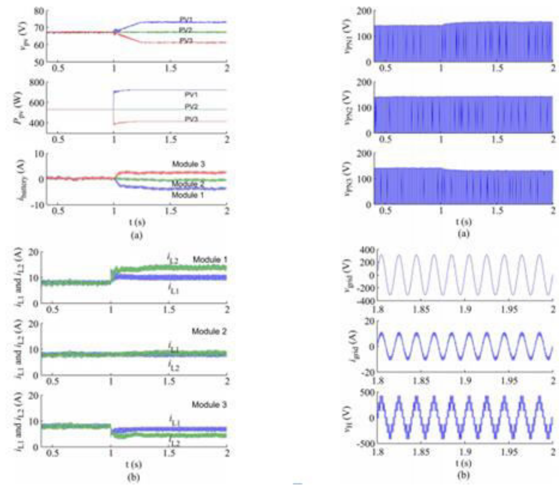
capacitance will result in the same 2ω voltage ripple, so the 2ω ripple of dc-link voltage is divided into two equal parts—half on the capacitor C1 and half on the capacitor C2. Otherwise, if the capacitor C2 has smaller capacitance than the capacitor C1, the capacitor C2 will have higher 2ω voltage ripple, which will result in higher 2ω ripple of the battery current.

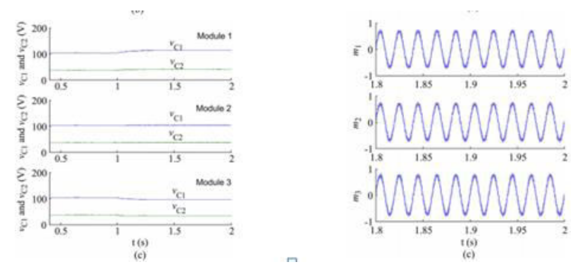
III.SIMULATION RESULTS

Before doing experiments, simulations are carried out to verify the proposed energy stored qZS-CMI-based PV system and control scheme. Simulation parameters are as follows: the rated PV panel power is 496.4 W, PV voltage range is 45–90 V, carrier frequency is fc = 10 kHz, L1 = L2 = 500 μH, C1 = C2 = 4400 μF, Lf = 500 μH, rf = 0.01Ω, vbattery = 36 V, P∗ grid = 1500 W, and each module's power reference is 500 W. The grid voltage is vg = 220 V, and the grid frequency is fg = 50 Hz. The operational conditions of three PV panels are as follows: During 0–1 s, all three PV panels are kept at 35 ◦C and 1050 W/m2, while at t = 1 s, the conditions of PV panels 1 and 3 change (i.e., PV1: 8 ◦C and 1300 W/m2 and PV3: 60 ◦C and 900 W/m2). This change is only for testing the system; in practical systems, the temperature change cannot be so large and so sudden.

IV.EXPERIMENTAL RESULTS

A set of experiments is carried out to verify the proposed energy stored qZS-CMI-based PV system and control scheme.





V.CONCLUSION

This paper has proposed an energy stored qZS-CMI-based PV power generation system. Its operating principle was presented in detail, and its control scheme was proposed. The controller parameters were well designed by employing the built small-signal model and Bode plots. A seven-level energy stored qZS-CMI-based PV system prototype was built. The simulation and experimental results verified the proposed energy stored qZS-CMI-based PV system and the proposed control method. Leakage current suppression is an important topic that will be researched next for the proposed system.

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