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Hybrid Pulse Width Modulated Three-Phase Quasi-Z-Source Grid-Tie Photovoltaic Power System

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ABSTRACT

A hybrid pulse width modulated three-phase quasi-Z-source inverter (qZSI) based grid-tie Photovoltaic (PV) power system is proposed. The hybrid pulse width modulation (HPWM) conducts PWM when the required ac output voltage is lesser than the dc source voltage, otherwise it performs pulse-amplitude modulation (PAM) for the three-phase qZSI. The low-frequency ripple voltage of dc link is utilized, resulting in reductions of quasi-Z-source inductance and capacitance, as well as power devices' switching actions. Control strategy of the proposed system is further presented to track the maximum power points of the PV panel and to inject the extracted PV power into grid. A grid-tie current controller, combining with the plug-in repetitive control and proportional-resonant regulator, is employed to achieve strong harmonic suppression, fast convergence, and zero tacking error.

I.INTRODUCTION

Fast increase of energy demands is motivating the development of grid-connected photovoltaic (PV) power systems. The quasi-Z-source inverter (qZSI) has attracted interests in PV applications because of single-stage power conversion, no dead time between switches of one bridge leg, and ability of handling wide dc voltage variations. Moreover, the single-phase qZSI can operate as a module to form cascaded inverter systems or as independent inverter systems. However, the second-order harmonic (2ω) pulsating power appears in the single-phase qZSI power module's dc link and transfers to qZS capacitors and qZS inductors, no exception to PV panels, which introduces low-order harmonics into the ac output and may shorten the lifetime of PV panels.

To limit the 2ω voltages and currents within tolerant ranges, large qZS capacitance and inductance are required when using the traditional carrier pulsewidth modulation (PWM) of the single-phase qZSI. Bulky qZS capacitors and inductors willnot only increase volume and cost, but also degrade system efficiency and reliability.

A hybrid pulsewidth modulation (HPWM) for three phase qZSI combines the PWM and pulse-amplitude modulation (PAM). The former works in the same way to the traditional voltage source inverter without shoot through states, when the qZSI's output ac voltage is lower than the input dc voltage; the latter produces 2ω dc-link voltage by changing shoot-through duty cycle so that only one switch of each bridge leg conducts switching.

Thus, the PWM switches at low dc-link voltage and the switching action is greatly reduced in PAM, so that low loss. Moreover, it results in low qZS impendence, so that high power density. It comes out with (M) modulation index & shoot through duty cycle D are independent in the hybrid modulated single phase qZSI, without the limitation of $M+D<1$ as seen in PWM controlled qZSI; whereas, the 2ω dc-link peak voltage, MPPT of PV panels, and power injection into grid should be taken care only through the modulation index. How to achieve these? Up to date, no literature has discussed such control of the qZS-based PV power system.

This paper will answer the question. For the conventional single-phase grid-tie PWM converter, several methods have been investigated to improve controller's harmonic suppressing capability.

The proportional-resonant (PR) control achieves zero tracking error for sinusoidal signals but presents infinite gain at only the fundamental frequency. The multi-PR control was proposed to eliminate harmonic components on multiples of the fundamental frequency, with the cost of high computation burden.

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The internal model principle (IMP) based repetitive controller (RC) presents ability to suppress harmonics on multiple frequencies, and the combination of proportional-integral (PI) or PR control is performed to improve its convergence response. This paper is to propose a hybrid pulsewidth modulated single-phase qZS-PV power system, including an effective grid-tie control strategy.

CONVENTIONAL METHOD

The fig 1shows that circuit diagram for conventional method. This conventional structure must be oversized to cope with the wide PV voltage variation derived from changes of irradiation and temperature

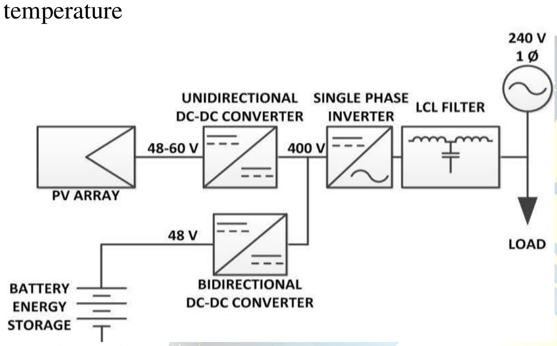

Fig 1 Circuit diagram for conventional method

The dual-stage inverter topology applies a boost DC-DC converter to minimize the required KVA rating of the inverter and boost the wide-range input voltage to a constant desired output value. Yet, the cost is increased and the efficienc y is decreased by the switch in the DC-DC converter. Many number of ESS system which will act as bidirectional dc / dc device to manage the batteries that makes the system intricate increase its price, and decreases its trustworthiness

PROPOSED METHOD

The fig 2 shows that circuit diagram for proposed method. This proposed system, as QZS network instead of DC-DC converter. It will be drawn a dc constant current and voltage

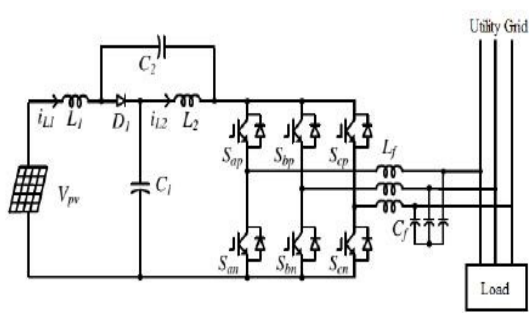

Fig. 2 Circuit diagram for proposed method

Normally the Z-source inverter (ZSI) had been used to achieve the voltage boost/buck character in a single power conversion stage, this type of converter can handle the PV dc voltage variations over a wide range without overrating the inverter. The part count and system price are decreased, with improved trustworthiness owing to the allowed shoot-through state. Recently anticipated quasi-Z-source inverters

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(qZSI) have some new appealing merits which is appropriate for application in PV systems follows

- The qZSI draws a constant current from the PV panel, and thus, there is no need for extra filtering capacitors
- The qZSI features lower component (capacitor) ratings
- The qZSI reduces switching ripples

II. OPERATION OF CONVERTER

BLOCK DIAGRAM

Fig 3 illustrates the fundamental diagram for PV power injected to the grid. The PV power is ascertained by MPPT, and it's calculated for the conversion by qZSI. By applying the HPWM to the qZSI to boost the voltage.The boosted voltage is tied with grid for distribution

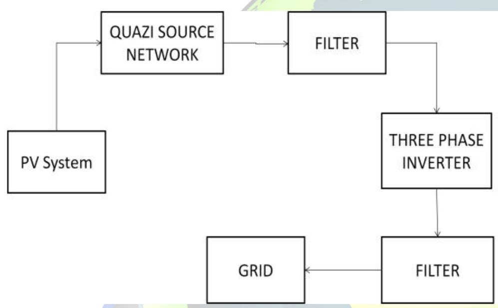

Fig 3 Block diagram of HPWM Three-Phase QZS Grid-Tie PV Power System

ENERGY CONVERSION EFFICIENCY

$$\eta = P_m/E*A \quad \text{----(1)}$$

The eqn (1) expressed as, Energy conversion efficiency η is the percentage of power transformed from absorbed light to electrical energy. while the solar cell is linked to an electrical circuit. This term is calculated using the ratio of maximum power P_m divided by input light irradiance E in W/m^2 under standard test conditions (STC) and A is area of the solar cell.

MAXIMUM POWER

The load that the cell will deliver most power at the extent of irradiation. The equation (2) states P_m is highest power, V_m is highest voltage, and I_m is the highest current

$$\mathbf{P_m = V_m * I_m} \quad \text{--(2)}$$

SOLAR MODULE AND ARRAY MODEL

Since a typical PV cell produces less than 2W at 0.5V approximately, the cells must be connected in series-parallel configuration on a module to produce enough high power. A PV array is a group of several PV modules which are electrically connected in series and parallel circuits to generate the uired current and voltage. The equivalent circuit for the solar module arranged in N_p parallel and N_s series. The terminal equation for the current and voltage

The mathematical eqn (3) of generalized model can be described as, we get

$$I=N_pI_{ph}- N_pI_s[\{(q(V/N_s)+(IR_s/N_p))/kT_cA\}-1] \text{----(3)}$$

The equivalent circuit is described on the following eqn (4) is

$$I = N_pI_{ph} - N_pI_s\ [\{(q(V/N_SkT_cA)\}-1] \quad \text{----(4)}$$

Where, N_s - is series number of cells for a PV array.
N_p- is parallel number of cells for a PV array.

III. MODES OF OPERATION

Pulse width modulation (PWM) strategies are necessary to correctly control the qZSI. The Hybrid PWM (HPWM)-based techniques of qZSI will be alienated into uncomplicated boost control, max and max constant boost control.They are simple to implement, but have defects of high switching frequency and additional switching operations, resulting in the incremental losses

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 are referred to as the shoot-through state. During this time interval, the circuit eqns are presented as shown in fig 4

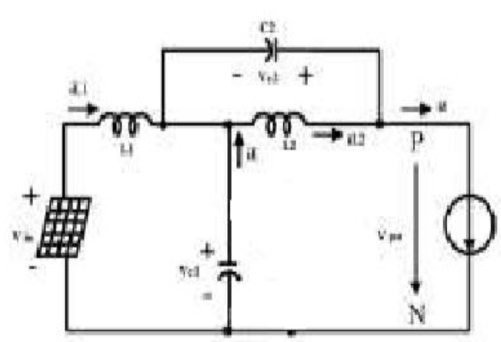

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Fig 5 Mode of operation

- Charging the inductor i_{L1}
- Voltage drop is in capacitor V_{C2}The proposed qzs converter performance is studied in MATLAB/SIMULINK platform. The fig 6 shows the simulated circuit proposed converter. The Double Deck Buck Boost converter is implemented in wind power generation system. Wind power generation system produced electrical power with maximum voltage of 320V. The ac is rectified into dc using diode bridge rectifier, the dc voltage is 300V. This is given as input for the double deck buck boost converter and it is boosted to average value of 750V. The HPWM controlled three phase Voltage Source Inverter is used to convert dc into ac; the output rms voltage is 400V.

Table 1, Simulation Parameters.

Circuit parameters	Value
Inductors L1 & L2	600 Uh
Capacitors	2200 uF
Dc link capacitor	2200 uF
Filter inductor	3.3 uH
Filter capacitor	1000 uF

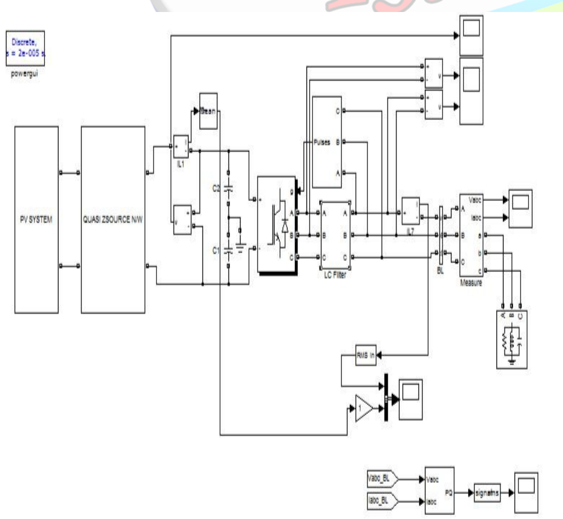
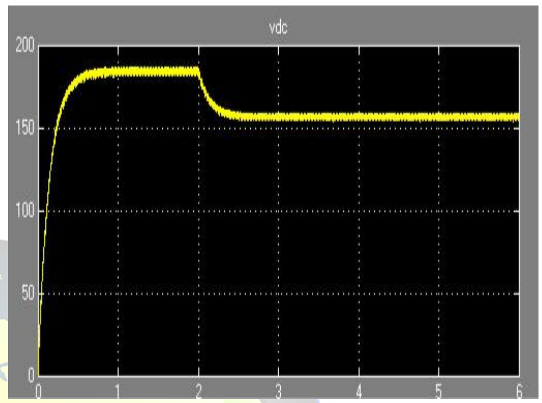


Fig 6 Simulation diagram of Three phase QZSI

The qZSI output is compared with the Hybrid PWM and energy balance is to be maintained during continuous conduction. In the qZSI output is possibly connected to the grid for distribution as shown in fig6.**WAVEFORM FOR DC LINK VOLTAGE**



WAVEFORM FOR QZSI OUTPUT

The output from qZSI is as shown in fig 7. The output is measured and the 3 phase supply is not directly coupled through the grid, due to the energy disparity is carried from the PV power. This may be optimized throughout the shoot-through state. Now the PV power may be controlled by the duty cycle. The inverter output is controlled by modulation index for stable, even and to augment the massive power.

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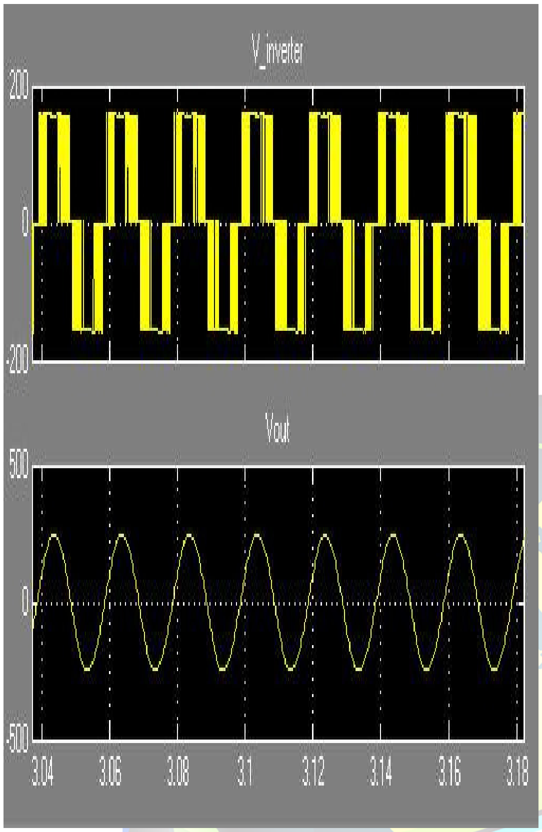
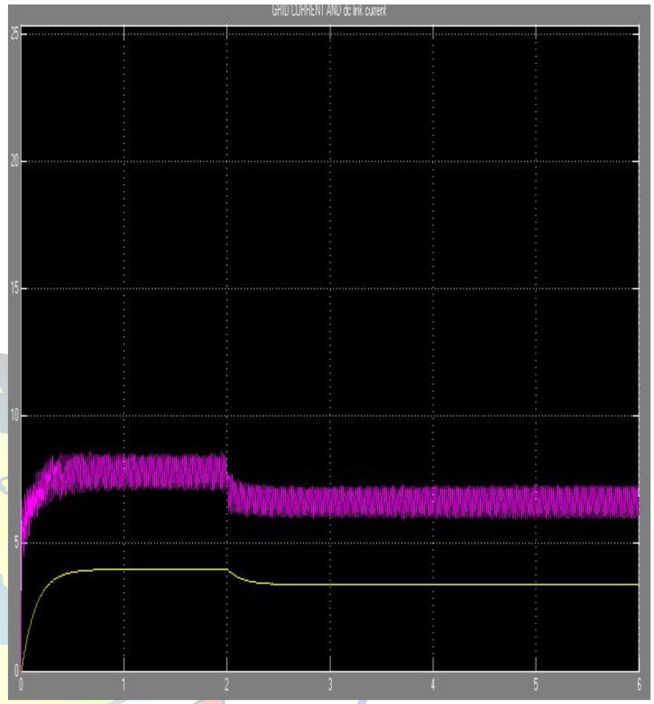
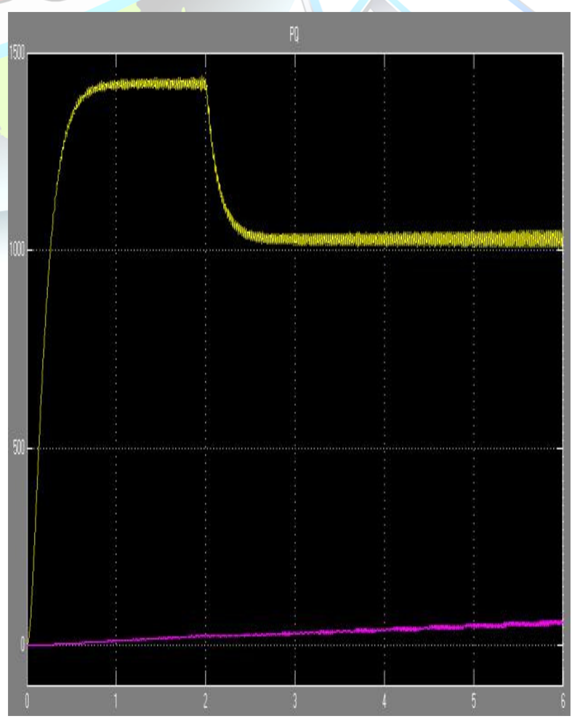


Fig 7 Inverter voltage & Output voltage

WAVEFORM FOR DC CURRENT AND INVERTER CURRENT



WAVEFORM FOR REAL AND REACTIVE POWER



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WAVEFORM FOR LOAD CURRENT AND VOLTAGE ACROSS LOAD

The load current waveform is shown in fig 8

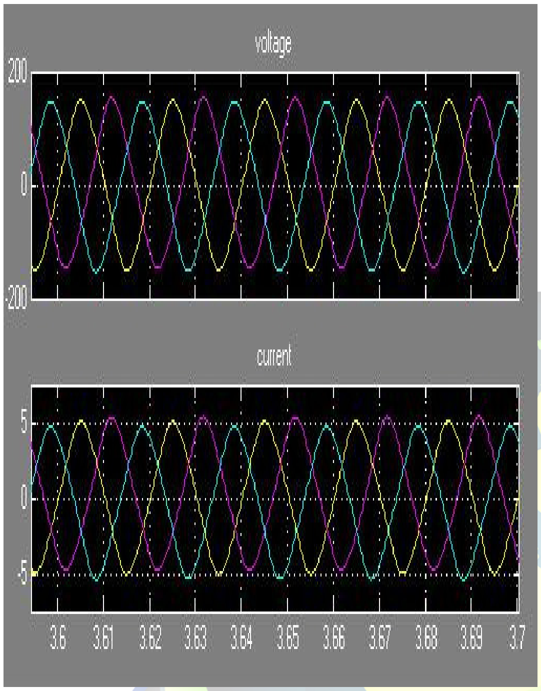

Fig 8 Grid voltage and current

V.CONCLUSION

In this paper, a hybrid modulated three-phase Qzsi based PV system with its grid-connected control strategy was proposed. The hybrid pulsewidth modulated qZSI resulted in low loss and reduced qZS impedance so that high power density. The MPPT of PV panel, grid-tie power injection, and 2ω dc-link peak voltage were fulfilled simultaneously by single control variable of the proposed qZSI. The grid-tie current control, combining plug-in repetitive controller and proportional resonant regulator, was discussed in detail to improve the harmonic suppression in multiple frequencies.

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