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AN EFFICIENT QUASI Z SOURCE INVERTER FOR PHOTOVOLTAIC POWER GENERATION

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ABSTRACT: This paper depicts a new topology of the energy stored quasi Z Source Inverter (qZSI) to overcome the stochastic fluctuations of photovoltaic (PV) power injected to the grid/load. In this qZSI voltage boost, inversion, and energy storage are integrated in a single stage inverter. Maximum Power Point Tracking (MPPT) is used to track the maximum power from PV when it is available and it can track the first local maximum point and stop progressing to the next maximum power point. Here, particle swarm optimization has been proposed to track the global maximum point and quasi Z- source inverter (qZSI) employed to improve the power compensation ability. Main benefit of this proposed system ensures the search space for PSO is reduced, time required for convergence can be greatly improved, and voltage ripple also reduced .The proposed qZSI are verified both in theoretical and experimental results.
Keywords: quasi Z Source Inverter (qZSI), Photovoltaic (PV), Maximum Power Point Tracking (MPPT), Particle Swarm Optimization (PSO)

I. INTRODUCTION

Photovoltaic (PV) cells, or solar cells, take advantage of the photoelectric effect to produce electricity. PV cells are the building blocks of all PV systems because that devices converts the sunlight to electricity. When light spray through a PV cell, it may be reflected, absorbed, or pass right through. But only the absorbed light generates electricity. The energy of the absorbed light is transferred as electrons in the atoms of the PV cell semiconductor material. When enough photons are absorbed by the negative layer of the photovoltaic cell then electrons are free from the negative semiconductor material. Due to the manufacturing process of the positive layer, these freed electrons naturally migrate to the positive layer creating a voltage differential, similar to a household battery[12]. When the 2 layers are connected to an external load, the electrons flow through the circuit creating electricity . Each individual solar energy cell produces only 1-2 watts. To increase power output, cells are combined in a weather-tight package called a solar module. These modules (from one to several thousand) are then wired up in serial and/or parallel with one another, into what's called a solar array, to create the desired voltage and amperage output required by the given project. With their newfound energy, these electrons escape from their normal positions in the atoms and become part of the electrical flow, or current, in an electrical circuit. A special electrical property of the PV cell provides the force, or voltage\e, needed to drive the current through an external load, such as a light bulb [13]-[15]. The quasi z-source inverter (QZSI) is a single stage power converter derived from the Z-source inverter topology, employing a unique impedance network. The conventional VSI and CSI suffer from the limitation that triggering two switches in the same leg or phase leads to a source short and in addition, the maximum obtainable output voltage cannot exceed the dc input, since they are buck converters and can produce a voltage lower than the dc input voltage. Both Z-source inverters and quasi-Z-source inverters overcome these drawbacks; by utilizing several shoot-through zero states. A zero state is produced when the upper three or lower three switches are fired simultaneously to boost the output voltage. Sustaining the six permissible active switching states of a VSI, the zero states can be partially or completely replaced by the shoot through states depending upon the voltage boost requirement [1]. Quasi-Z-source inverters (QZSI) acquire all the advantages of traditional Z source inverter.

The impedance network couples the source and the inverter to achieve voltage boost and inversion in a single stage. By using this new 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, reduces switching ripples to the PV panels, causes less EMI problems and reduced source stress compared to the traditional ZSI. The QZSI circuit differs from that of a conventional ZSI in the LC impedance network interface between the source and inverter. The unique LC and diode network connected to the inverter bridge modify the operation of the circuit, allowing the shoot-through state which is forbidden in traditional VSI[4]. This network will effectively protect the circuit from damage when the shoot through occurs and by using the shoot-though state, the (quasi-) Z-source network boosts the dc-link voltage. The impedance network of QZSI is a two port network .It consists of inductors and capacitors connected as shown in fig. This network is employed to provide an impedance source, coupling the converter to the load. The dc source can be a battery, diode rectifier, thyristor converter or PV array The QZSI topology is shown in the figure 1.

II. PRINCIPLE OF OPERATION

The two modes of operation of a quasi z-source inverter are:
1. Non-shoot through mode (active mode).
2. Shoot through mode.

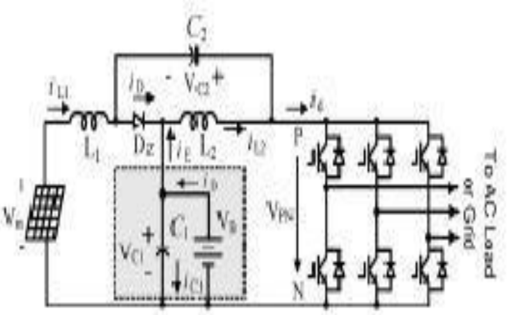

Fig.1.Qzsi for power generation

A. Active Mode

In the non-shoot through mode, the switching pattern for the QZSI is similar to that of a VSI. The inverter bridge, viewed from the DC side is equivalent to a current source. , the input dc voltage is available as DC link voltage input to the inverter, which makes the QZSI behave similar to a VSI [5].

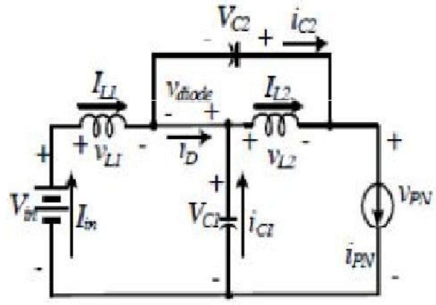

Fig.2 Equivalent circuit of QZSI in Active mode

B .Shoot through Mode

In the shoot through mode, switches of the same phase in the inverter bridge are switched on simultaneously for a very short duration. The source however does not get short circuited when attempted to do so because of the presence LC network, while boosting 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.

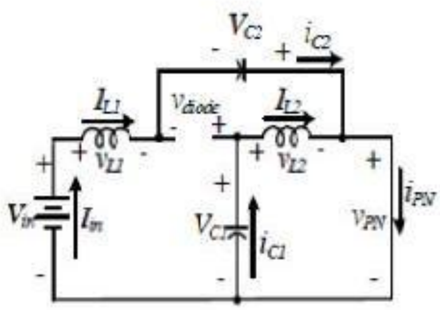

Fig.3 Equivalent circuit of QZSI in Shoot through mode

QZSI inherits all the advantages of the ZSI. It can buck or boost a voltage with a given boost factor. It is able to handle a shoot through state and therefore it is more reliable than the traditional VSI. It is unnecessary to add a dead band into control schemes, which reduces the output distortion. In addition, there are some unique merits of the QZSI when compared to the ZSI[3]-[4]. When the inverter is in the shoot-through state for an interval T0 during a switching cycle T, the capacitors discharge, the inductors charge, and the diode is the deadline under back pressure. The output power is zero. The following voltage can be described from Fig.2

$$VL1=VC2+VPV$$
$$VC1= VL2 \quad (1)$$
$$Vdc=0$$

When the inverter is in the active state for the intervalT1 during the switching cycle T, the inductors release energy, which can maintain the capacitor voltage and increase the DC bus voltage, meanwhile, the QZSI conduct DC/AC transformation like the traditional inverters and it can be described as follows from Fig1 Capacitor C1 of QZSI is equal to the capacitor voltages of ZSI, and the capacitor C2 is reduced. Because of the QZSI input voltage is easy to be sure, you can boost DC bus voltage by adjusting D. VC1 is a constant value through closed-loop feedback control, so the input voltage of QZSI reduces and the output voltage increases as the increasing of shoot-through duty radio, as shown in Fig.4.

III. CONTROL METHOD FOR PROPOSED SYSTEM

In a single-stage quasi Z source inverter-based PV system the inverter output power is adjusted to track the maximum power point (MPP) of the PV panel through changing the modulation index. Power difference between PV power and inverter output power charges/discharges the battery. As a result, the output power fulfills MPPT of the PV panel, and the duty ratio controls the dc-link peak voltage constant. There are several control methods for proposed system are, 1) Constant DC link voltage Control 2)MPPT Control 3)Battery current closed loop control 4)PSO based control

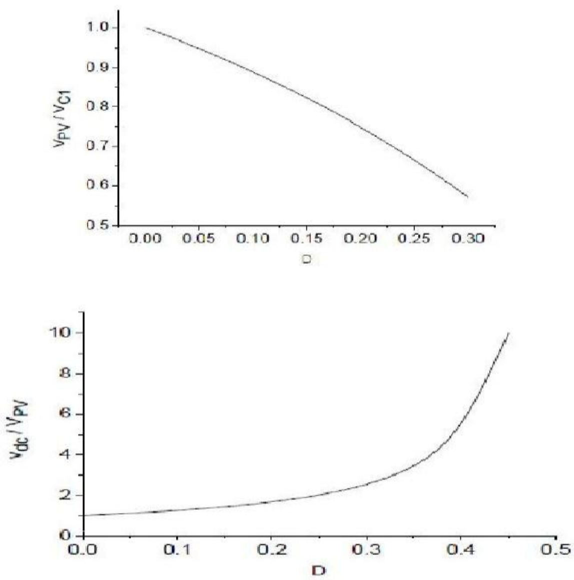

Fig 4. The relation between shoot-through time ratio and input voltage or output voltage of QZSI

A. Constant DC link voltage Control

Generally Solar PV system should have complex relationship with change in temperature and irradiation. At the standard condition solar irradiation of 1000W/m , temperature of 25 C, the PV panel has a input voltage, current and power at the MPP.

$V_{PN}^* = 2V_{C2}^* + V_{In,N}$ (2)

where V_{PN}^* is the desired dc-link peak voltage, and is the V_{C2}^* desired capacitor C2 voltage related to V_{PN}^*. Assume the variations of solar irradiation and temperature cause the PV panel to have a new MPP, i.e., voltage $V_{In,N} + \Delta V_{PN}$, current $I_{In,N} + \Delta I_{PN}$, and power $P_{In,N} + \Delta P_{PN}$, then the dc-link peak voltage will be

$V_{PN} = 2V_{C2} + V_{In,N} + \Delta V_{PN}$ (3)

Constant dc-link peak voltage requires $V_{PN} = V_{PN}^*$, from (1) and (2), there is

$V_{C2} = V_{C2}^* - 0.5\Delta V_{PN}$ (4)

$V_{C1} = V_{C1}^* + 0.5\Delta V_{PN}$ (5)

where V_{C1}^* is the desired capacitor C1voltage related V_{C2}^* to C2,

$V_{C1}^* = V_{C2}^* + V_{In,N}$ (6)

We choose a battery with open-circuit voltage $V_{B,OP} = V_{C1}^*$, then from (5) there is

$V_{C1} - V_{B,OP} = 0.5\Delta V_{PV}$ (7)

there is $V_{B,OP} = V_{C1} + i_B R_b$. Battery current is

$i_B = -0.5\Delta V_{PV} / R_b$ (8)

where Rb is the battery internal resistance. Using (5), (6) is written as

$i_B = -(V_{C2}^* - V_{C2} / R_b)$ (9)

Constant dc-link peak voltage can be achieved as soon as (8) is met

B.MPPT

MPPT technique mainly used in grid connected inverter, solar battery charger .To get maximum power from the PV .Solar cells have complex relationship between radiation and temperature & total resistance[15]. Due to this reason MPPT use to sample the output of cells and apply proper resistance to get maximum power for given environmental conditions.There are several MPPT techniques are available namely

1)Perturb &Observe
2)Incremental Conductance
3)Fractional short-circuit current
4)Fractional open circuit voltage
5)neural networks
6)Fuzzy logic.

Here hill climbing method is employed. Three sample curves of PV panel's – characteristic are from three conditions of irradiation and temperature: 1) condition A: 1200 W/m and 10 C; 2) condition B (standard test condition): 1000 W/m and 25 C; 3) condition C: 600 W/m and 40 C. Battery power from (8), is deduced as

$P_B = V_{B,OP}(V_{In} - V_{In,N}) / 2R_b$ (10)

Three output power curves I, II, and III are corresponding to three PV power curves 3, 2, and 1, respectively. For the aforementioned conditions A, B, and C, the PV panel has MPPs A1, B1, and C1, and the battery works on points A2, B2, C2, as a result of inverter output power points A3, B3, C3, respectively condition B (standard test condition), the total PV power is outputted to the grid

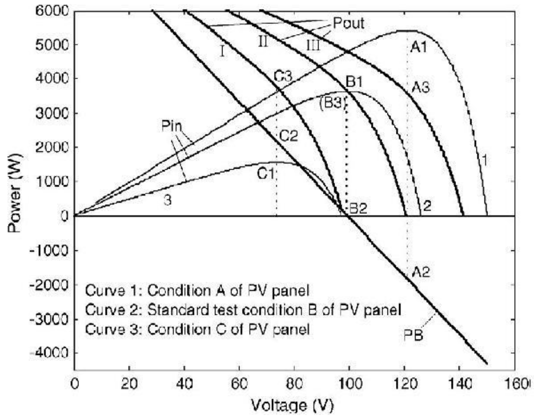

Fig.5.Power relationship curve

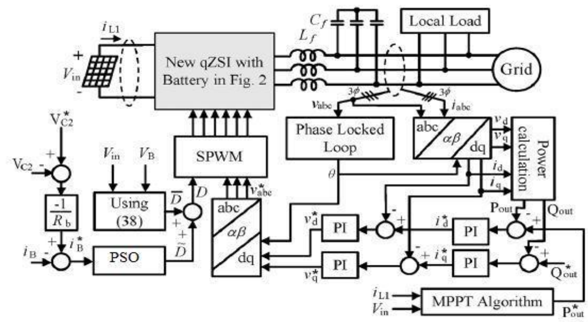

Fig.6.Proposed Qzsi inverter for power generation

at the MPP C1 of condition C, the PV panel and battery supply power to the grid (C3), and battery discharges in point C2. As shown in Fig. 5, the proposed PV power system has a smooth grid-injected power, such as A3, B3, and C3, even though PV power (A1, B1, and C1) changes significantly at conditions A, B, and C. From (9) and Fig. 6, battery power is determined by PV panel voltage, which is controlled by the PV panel operating state during MPPT. As shown in Fig. 6, PV panel voltage monotonously decreases when the inverter output power increases. The proposed PV power system's MPPT can be achieved through controlling inverter output power. When the hill climbing method is employed, Fig. 7 presents the MPPT algorithm, where is a small perturbing power. The PSO algorithm works by simultaneously maintaining several candidate solutions in the search space. During each iteration of the algorithm, each candidate solution is evaluated by the objective function being optimized, determining the fitness of that solution. The PSO algorithm consists of three steps, which are repeated until some stopping condition is met,

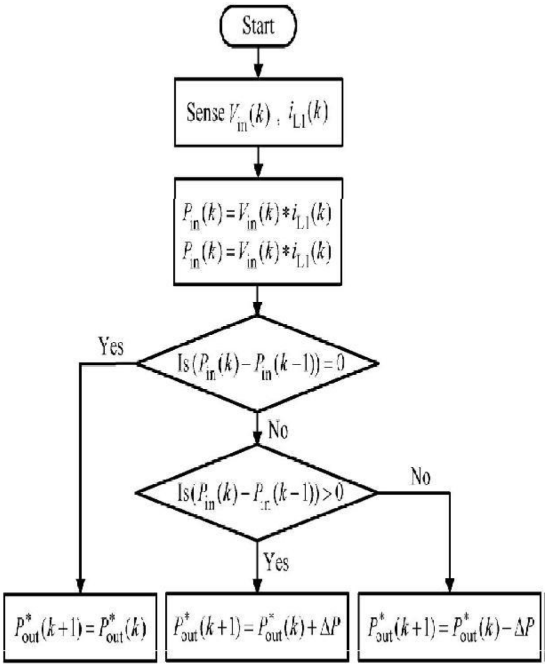

Fig.7 MPPT Algorithm

1. Evaluate the fitness of each particle
2. Update individual and global best fitness and positions
3. Update velocity and position of each particle

After every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. The fitness value is also stored. This value is called “pbest”. Another "best" value that is tracked by the particle swarm optimizer is the best value obtained so far by any particle in the population. This best value is a global best and called “gbest”. After finding the two best values, the particle updates its velocity and positions.

1. Initialize the swarm by assigning a random position in the problem hyperspace to each particle.
2. Evaluate the fitness function for each particle.
3. For each individual particle, compare the particle’s fitness value with its. If the current value is better than the value, then set this value as the and the current particle’s position as
4. Identify the particle that has the best fitness value. The value of its fitness function is identified as and its position as.
5. Update the velocities and positions of all the particles using (1) and (2).
6. Repeat steps 2–5 until a stopping criterion is met (e.g., maximum number of iterations or a sufficiently good fitness value).

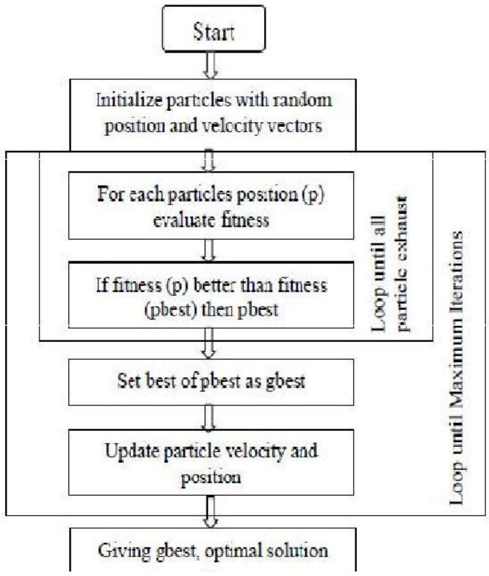

Fig.8 PSO Algorithm

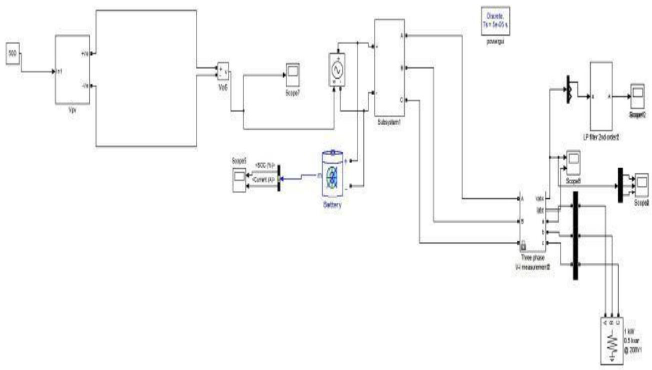

Fig.9 Simulation diagram using PSO

A. PSO Parameters

In the simulations, both the population size and archive size are set to 100, and the maximum number of iterations is varied from 100 to 500 to obtain various design criteria’s. The acceleration constants c1 and c2 are chosen as 1. Convergence factor is designed to be in the range of

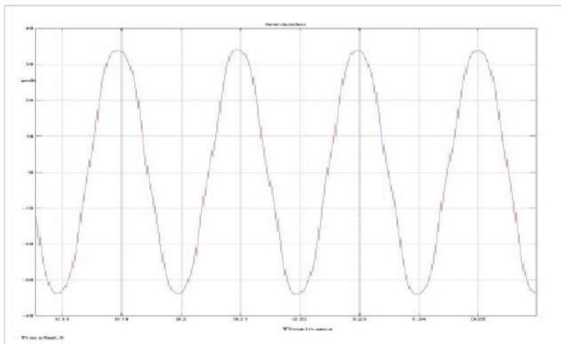

Fig.10 Simulation result for proposed system

IV. CONCLUSION

In this paper, the novel energy stored qZSI-based PV power system with constant dc-link peak voltage was proposed.. A constant dc-link peak voltage control and load related MPPT were proposed to fulfill a new PV power system, which ensured a constant dc-link peak voltage no matter what PV panel voltage varied. At the same time, the maximum PV power was harvested and the smooth power was injected to the grid/load even though PV power presented stochastic fluctuations and particle swarm optimization technique is used to reduce the voltage ripple of the inverter.

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