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A NOVEL CONTROL STRATEGY FOR QUASI-Z SOURCE CASCADE MULTILEVEL INVERTER-BASED GRID-CONNECTED SINGLE-PHASE PV POWER SYSTEM

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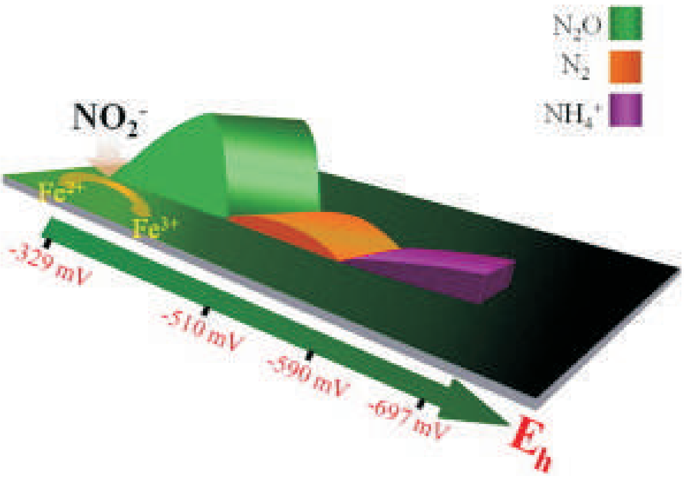

ABSTRACT:

A compelling control technique, including framework level control and heartbeat width tweak for semi Z-source course multilevel inverter (qZS-CMI) based network tie photovoltaic (PV) control system is proposed. The system level control accomplishes the network tie current infusion, autonomous most extreme power point following (MPPT) for partitioned PV boards, and dc-connect voltage adjust for all semi Z-source H-connect inverter (qZS-HBI) modules. The total plan process is unveiled. A multilevel space vector balance (SVM) for the single-stage qZS-CMI is proposed to satisfy the synthetization of the progression like voltage waveforms. Reproduction and analysis in view of a seven-level model are done to approve the proposed techniques.

KEYWORDS: Cascade Multilevel Inverter (CMI), Photovoltaic (PV) Power system, Quasi-Z-Source Inverter, Space Vector Modulation (SVM).

I.INTRODUCTION

A current upsurge in the investigation of photovoltaic (PV) control era develops, since they straightforwardly change over the sun powered radiation into electric power without hampering the earth. In any case, the stochastic vacillation of sunlight based power is conflicting with the coveted stable power infused to the network, attributable to varieties of sun oriented light and temperature. To completely abuse the sunlight based vitality, removing the PV boards' greatest power and nourishing them into networks at solidarity control consider turn into the most essential. The commitments have been made by the course multilevel inverter (CMI) [1], [2]. By and by, the H-connect inverter (HBI) module needs help work so that the inverter KVA rating prerequisite must be expanded twice with a PV voltage scope of 1:2; and the distinctive PV board yield voltages result in imbalanced dc-interface voltages. The additional dc–dc lift converters were coupled to PV board and HBI of the CMI to actualize isolate greatest power point following (MPPT) and dc-interface voltage adjust [3], [4]. Be that as it may, each HBI module is a two-arrange inverter, and numerous additional dc–dc converters not just build the unpredictability of the power circuit and control and the framework cost, additionally diminish the proficiency. As of late, the Z-source/semi Z-source course multilevel inverter (ZS/qZS-CMI)- based PV frameworks were proposed in [5]–[8]. They have the benefits of both conventional CMI and Z-source topologies. For instance, the ZS/qZS-CMI: 1) has brilliant staircase yield voltage waveforms with lower consonant bends, and diminishes/wipes out yield channel necessities for the consistence of framework symphonious gauges; 2) requires control semiconductors with a lower rating, and extraordinarily spares the costs; 3) indicates particular topology that every inverter has a similar circuit topology, control structure and tweak [1], [2]; 4) most essential of all, has free dc-connect voltage pay with the unique voltage venture up/down capacity in a solitary stage control transformation of Z-source/semi Z-source arrange, which permits an autonomous control of the power conveyance with high unwavering quality [9]–[11]; and 5) can satisfy the circulated MPPT [6], [8]. Keeping in mind the end goal to legitimately work the ZS/qZS-CMI, the power infusion, autonomous control of dc-connection voltages, and the beat width tweak (PWM) are vital. The work in[5] and [7] concentrated on the parameter outline of the ZS/qZS systems and the investigation of proficiency. The work in [8] introduced the entire control calculation, i.e., the MPPT control of isolated semi Z-source H-connect inverter (qZS-HBI) module, and the framework infused control, while the stage moved sine wave PWM (PS-SPWM) is the main existing PWM procedure for the single-stage ZS/qZS-CMI. The PS-SPWM devours more assets to accomplish the shoot-through states since two more references are contrasted and the bearer waveform. Also, the ZS/qZS-CMI based network tie PV framework has never been demonstrated in detail to outline the controllers.

The principle commitments of this paper include: 1) a novel multilevel space vector adjustment (SVM) method for the singlephase qZS-CMI is proposed, which is actualized without extra assets; 2) a network associated control for the qZS-CMI based PV framework is proposed, where the all PV board voltage references from their free MPPTs are utilized to control the lattice tie current; the double circle dc-interface top voltage control is utilized in each qZS-HBI module to adjust the dc-connect voltages; 3) the outline procedure of controllers is totally displayed to accomplish quick reaction and great strength; and 4) reproduction and trial comes about confirm the proposed PWM calculation and control conspire.

II.DESCRIPTION OF QZS-CMI-BASED GRID-TIE PV POWER SYSTEM

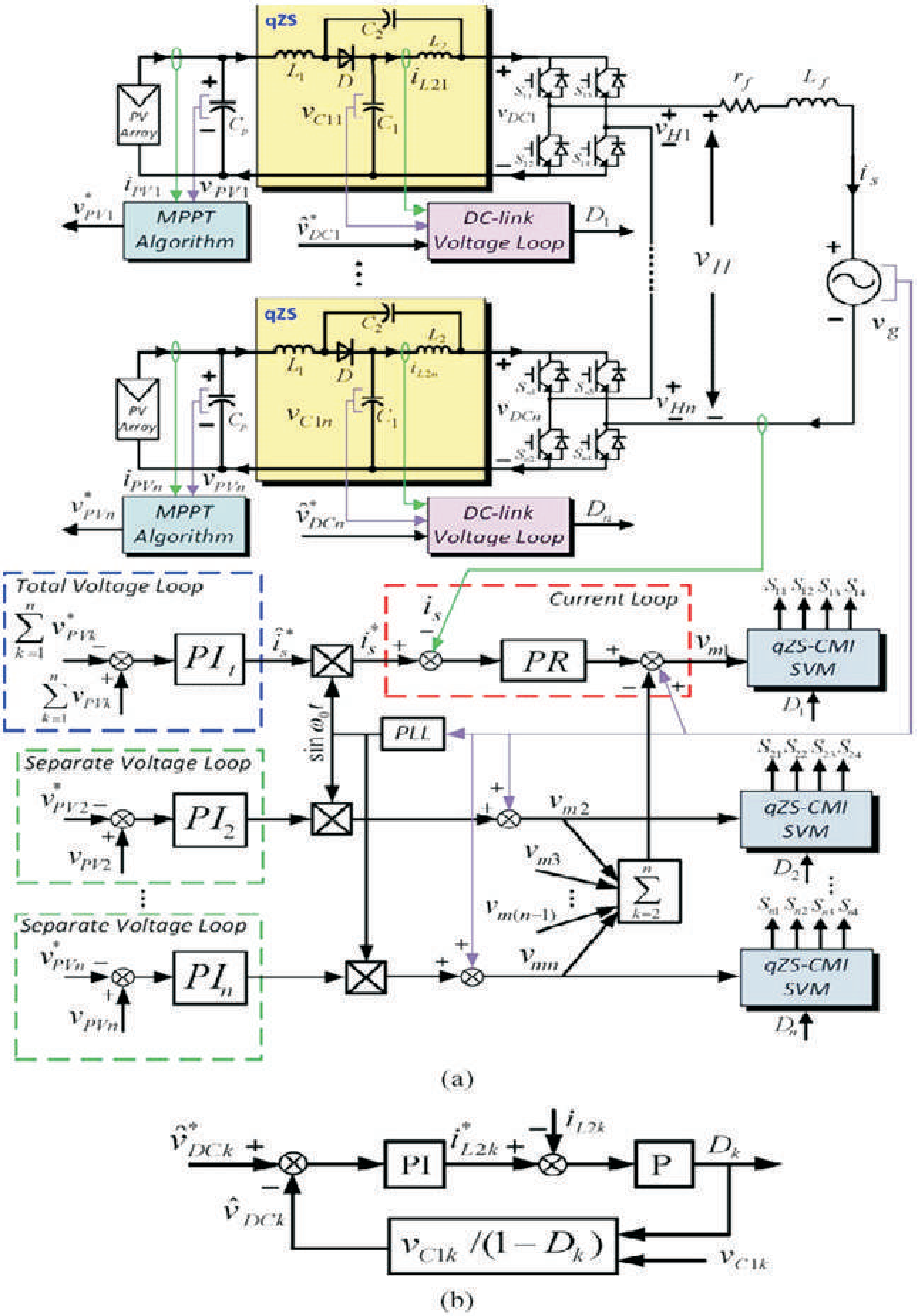

Fig. 1. (a) qZS-CMI based grid-tie PV power system. (b) DC-link peak voltage control.

Fig. 1 shows the discussed qZS-CMI-based grid-tie PV power system. The total output voltage of the inverter is a series summation of qZS-HBI cell voltages. Each cell is fed by an independent PV panel. The individual PV power source is an array composed of identical PV panels in parallel and series. A typical PV model in [12] is performed by considering both the solar irradiation and the PV panel temperature. The control objectives of the qZS-CMI based grid-tie PV system are:

1) the distributed MPPT to ensure the maximum power extraction from each PV array;

2) the power injection to the grid at unity power factor with low harmonic distortion;

3) the same dc-link peak voltage for all qZS-HBI modules. The overall control scheme of Fig. 1 is proposed to fulfill these purposes. For achieving the first two goals, the n+1 closed loop are employed, as Fig. 1(a) shows.

1.Total PV array voltage loop adjusts the sum of PV array voltages tracking the sum of PV array voltage references by using a proportional and integral (PI) regulator. Each PV array voltage reference is from its MPPT control independently.

2.Grid-tie current loop ensures a sinusoidal grid-injected current in phase with the grid voltage. The total PV array voltage loop outputs the desired amplitude of grid-injected current. A Proportional + Resonant (PR) regulator enforces the actual grid current to track the desired grid-injected reference. The current loop output's total modulation signal subtracts the modulation signal sum of the second, third, …, and the qZS-HBI modules to get the first qZS-HBI module's modulation signal.

3.The n-1 separate PV array voltage loops regulate the other n-1 PV array voltages to achieve their own MPPTs n-1 through the PI regulators, such as PI2 to PIn, respectively. With the total PV array voltage loop control, the PV arrays fulfill the distributed MPPT. In addition, the voltage feed forward control is used to generate each qZS-HBI module's modulation signal, which will reduce the n regulators' burden, achieve the fast dynamic response, and minimize the grid voltage's impact on the grid-tie current.

For the third goal, the dc-link peak voltage is adjusted in terms of its shoot-through duty ratio for each qZS-HBI module, as Fig. 1(b) shows. A proportional (P) regulator is employed in the inductor L2 current loop to improve the dynamic response, and a PI regulator of the dc-link voltage loop ensures the dc-link peak voltage tracking the reference.

Finally, the independent modulation signals vmk and shoot through duty ratios Dk of the qZS-CMI. k belongs to {1,2,…,n} are combined into the proposed multilevel SVM to achieve the desired purposes.

CONTROL STRATEGY:

The control objectives of the qZS-CMI based grid-tie PV system are:

1) the distributed MPPT to ensure the maximum power extraction from each PV array;

2) the power injection to the grid at unity power factor with low harmonic distortion;

3) the same dc-link peak voltage for all qZS-HBI modules. The overall control scheme of Fig. 1 is proposed to fulfill these purposes. For achieving the first two goals, the closed loops are employed.

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III. SYSTEM MODELING AND CONTROL

Fig. 2 shows block diagram of the proposed grid-tie control with the system model for the qZS-CMI based PV power system. The details will be explained as follows.

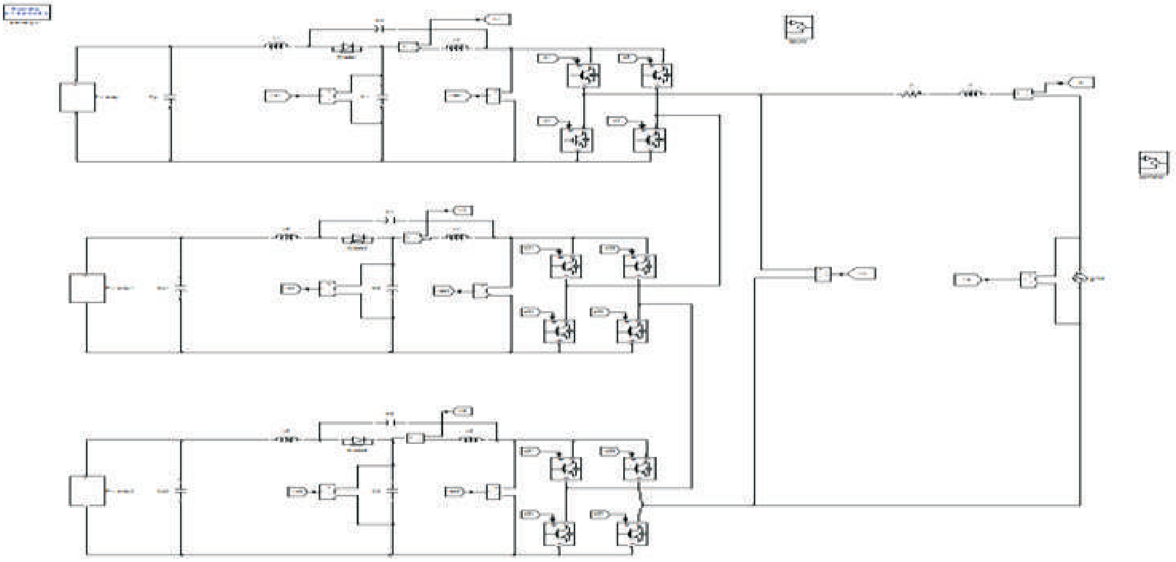


Fig.2: Simulink model of schematic diagram.

where is the current of qZS inductor , is the th PV array's current, and is the capacitance of PV array terminal capacitor. The qZS-CMI based grid-tie PV system has

$$v_H = v_g + L_f \frac{di_s}{dt} + r_f i_s$$

Where is the grid voltage, is the grid-injected current, is the filter inductance, and is its parasitic resistance. The transfer function of the grid-injected current can be

$$G_f(s) = \frac{I_s(s)}{V_H(s) - V_g(s)} = \frac{1}{L_f s + r_f}.$$

With the compensation of the PR regulator, the transfer function becomes

$$G_{\text{icom}}(s) = G_{\text{PRi}}(s) G_{io}(s)$$

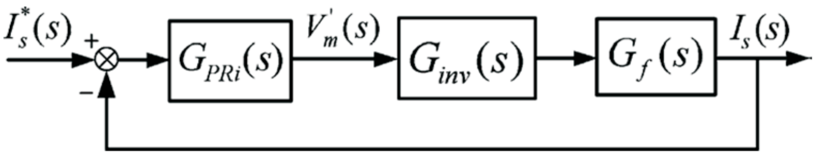


Fig.3: Simplified block diagram of the grid-current closed loop.

Consequently, the closed-loop transfer function of grid-tie current control can be obtained.

IV. PROPOSED MULTILEVEL SVM FOR QZS-CMI

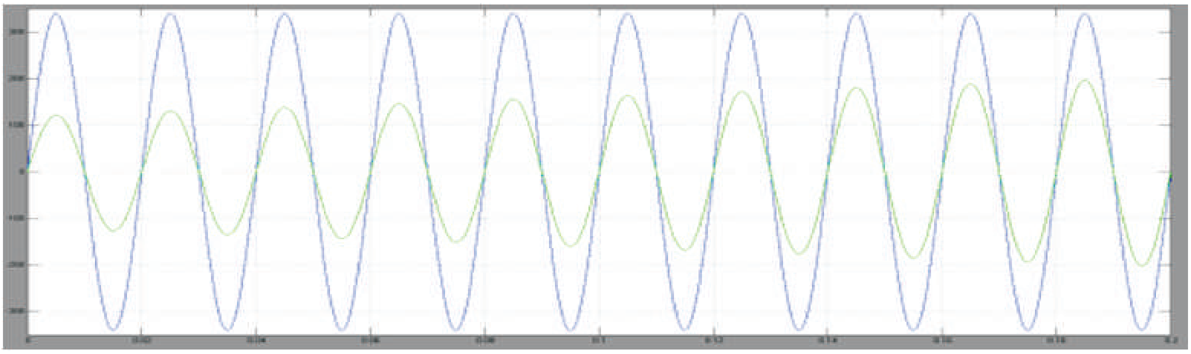
As the qZS network is embedded to the HBI module, the SVM for each qZS-HBI can be achieved by modifying the SVM technique for the traditional single-phase inverter [15]. Using the first qZS-HBI module of Fig. 1 as an example, the voltage vector reference is created through the two vectors. The switching times for the left and right bridge legs in traditional HBI. However, the shoot-through states are required for the independent qZS-HBI module. For this purpose, a delay of the switching times for upper switches or leads of the switching times for lower switches are employed at the transition moments. During each control cycle, the total time of shoot-through zero state is equally divided into four parts. The time intervals of and remain unchanged; and are the modified times to generate the shoot-through states; and are the switching control signals for the upper switches, and are that for the lower switches, . In this way, the shoot-through states are distributed into the qZS-HBI module without additional switching actions, losses, and resources. To generate the step-like ac output voltage waveform from the qZS-CMI, a phase difference, in which is the number of reference voltage vectors in each cycle, is employed between any two adjacent voltage vectors. The total voltage vector is composed of reference vectors from the qZS-HBI modules.

V. SIMULATION

A seven-level qZS-CMI for grid-connected PV power system is prototyped. Two Agilent E4360A Solar Array Simulators (SAS) are used to emulate the electrical behavior of PV arrays. Each SAS has two channel outputs, and each channel is with maximum 120-V maximum power point (MPP) voltage and 5-A MPP current. Simulation results are shown in Figs. 4.

a) DC-Link Voltage Balance Test:

The different PV array voltages are performed for the three qZS-HBI modules. The second module's PV voltage is set to 70 V and the others are at 90 V. A 50- resistor is used as ac load in this test. All of the voltages in experimental results are 100 V/div. From (1), the 136-V dc-link voltage of qZS-HBI module is required to support the 230-V grid. Fig. 4 shows the simulation results, where the second module's dc-link peak voltage is boosted to the same voltage value when compared with other modules, but with a longer shoot-through time interval. Also, the qZS-CMI outputs the seven-level voltage with equal voltage step from one level to another level. We can find that the same qZS-CMI output voltages and currents are achieved, which is derived from the designed dc-link peak voltage control.



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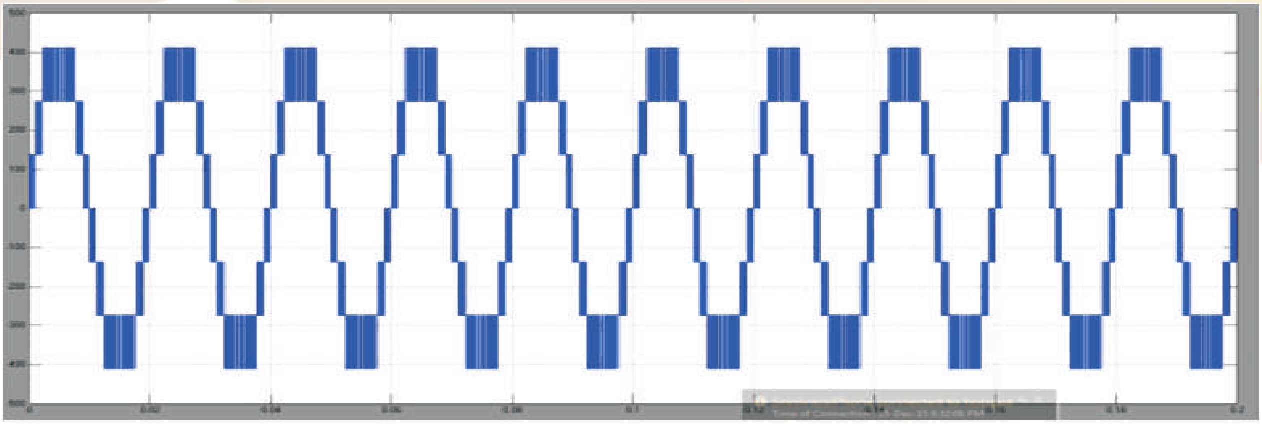
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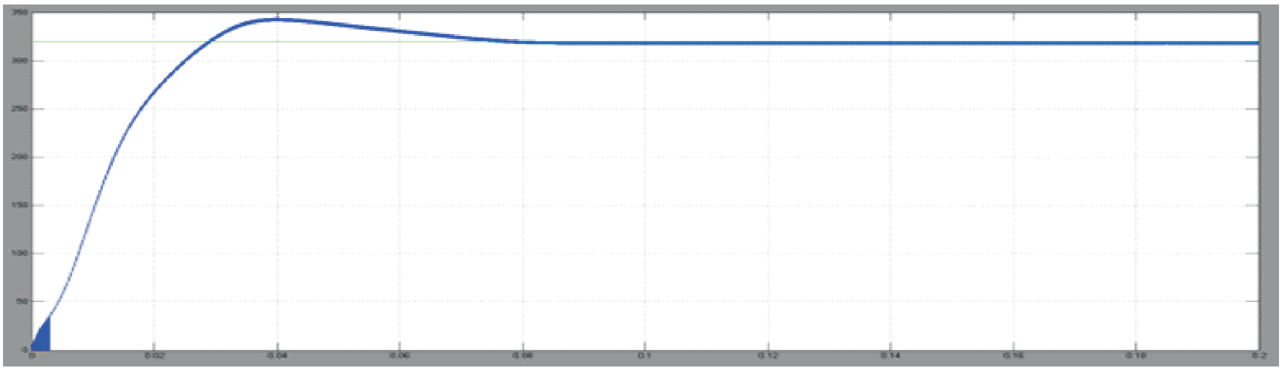
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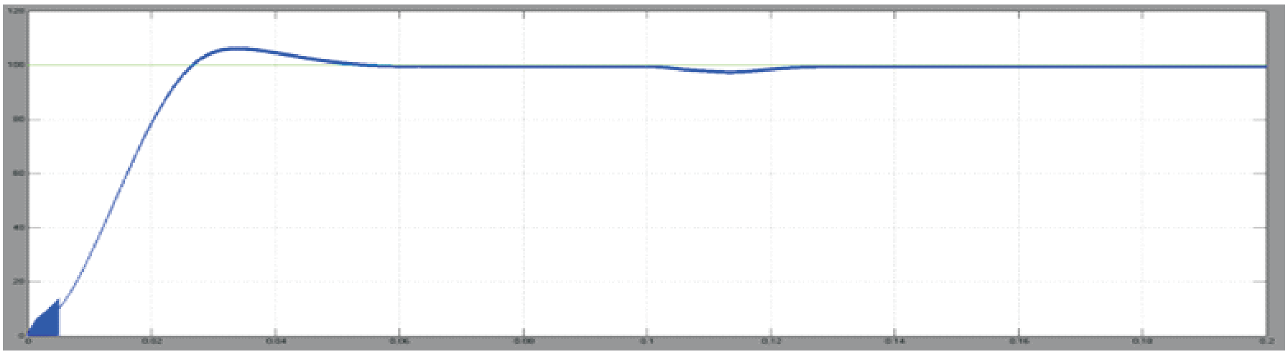
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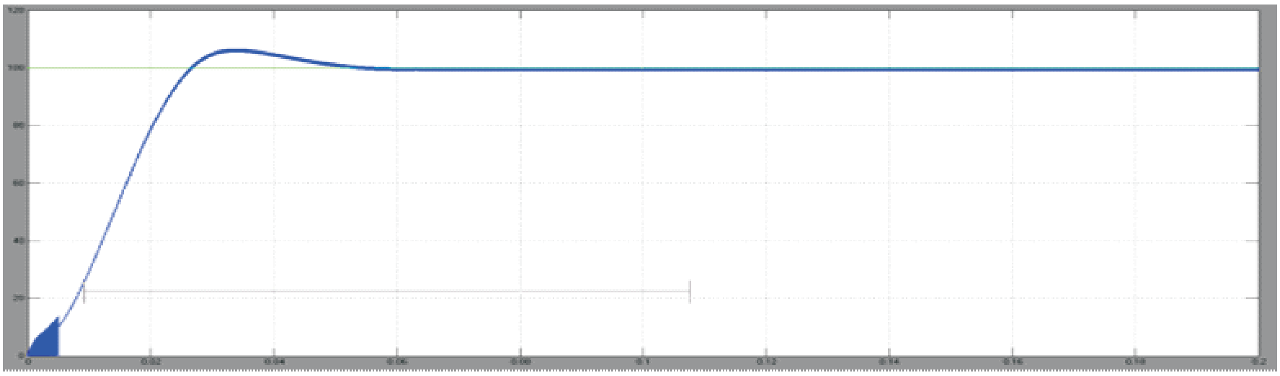
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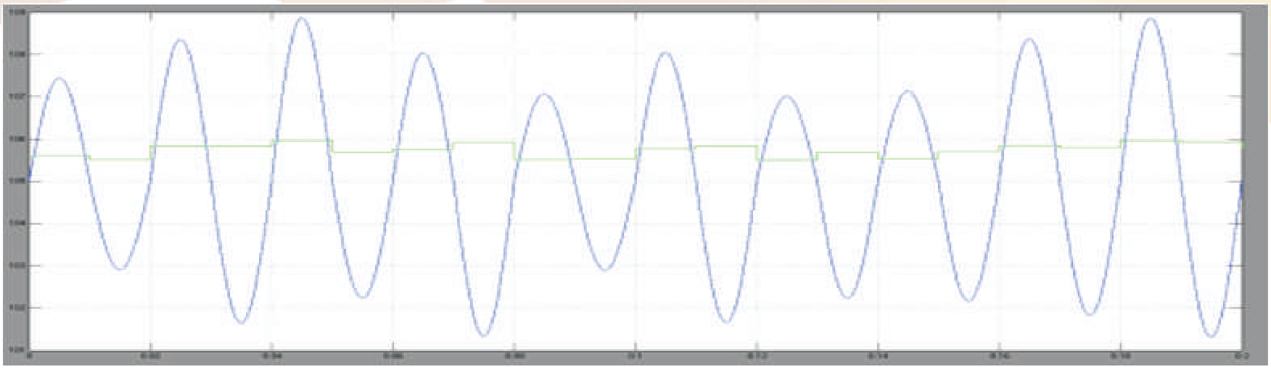

(f)

Fig.4: Output results for proposed converter (a) Grid voltage and current (b) Converter voltage (c), (d), (e) and (f) PV voltages and references.

B) GRID-TIE INVESTIGATION:

The qZS-CMI is connected to the grid in order to test the proposed grid-tie control. The measured PV array voltage and current of each module are used to calculate the actual PV power and the MPPT algorithm searches for the PV voltage reference at the MPP, which is refreshed every 0.05 s. Here, the perturbation and observation (P&O) MPPT strategy is applied in considering the excellent tracking efficiency and easy implementation.

At first, the three modules are all working at 900 W/m , and all of the initial voltage references of MPPT algorithms are given at 105 V. The second module's irradiation decreases to 700W/m from1 to 2 s in simulation. Fig. 14 shows the simulation results. In the experiments, the same test conditions of irradiation and temperature can be implemented by setting the curves of Agilent SAS. Fig. 5(a) shows the total PV voltage (sum of three PV panel voltages) and reference, PV panel voltages and references of modules 2 and 3, respectively. It can be seen that the excellent tracking performance is achieved during 0–1 s; even though the second module's PV irradiation changes after 1 s, the still tracks the reference very well after a very short transient.

VI.CONCLUSION

This paper proposed a control strategy for qZS-CMI based single-stage framework tie PV framework. The framework infused power was satisfied at solidarity control figure, all qZS-HBI modules independently accomplished their own particular greatest power focuses following regardless of the possibility that a few modules' PV boards had diverse conditions. Besides, the free dc-connect voltage shut circle control guaranteed all qZS-HBI modules have the adjusted voltage, which gave the fantastic yield voltage waveform to the matrix. The control parameters were all around intended to guarantee framework strength and quick reaction. A multilevel SVM incorporating with shoot through states was proposed to combine the staircase voltage waveform of the single-stage qZS-CMI. The reenactment and analysis were completed on the seven-level qZS-CMI model. The qZS-CMI based lattice tie PV framework was tried. The reenactment and test comes about confirmed the proposed qZS-CMI based lattice tie PV control framework and the proposed control strategy. On a basic level, the proposed framework can work with the frail matrix, despite the fact that this paper did not address this theme. In future work, we will concentrate on the application to the feeble lattice, and the point by point investigation and trial results will be unveiled in the following paper.

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