Simulation of Space Vector Modulated Quasi-Z-Source Cascade Multilevel Inverter For Grid-Tie based Single Phase PV System

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***Abstract*—This paper is concerned with the designing of quasi-Z-Source Cascaded Multilevel Inverter (qZS-CMI) based grid-tie photovoltaic (PV) power system which provides an attracting improvement over inverter efficiency by combing the quasi-Z-source network into the traditional cascaded multilevel inverter and improving the performance of the power plant by reducing the total harmonic distortion. It is perfectly suitable for interfacing of renewable energy sources. It is a conventional type single stage power converter derived from the Z-source inverter topology, employing a unique impedance network. The qZSI inherits all the advantages of the Z-Source Inverter(ZSI), which can realize buck/boost, inversion and power conditioning in a single stage with improved reliability. A novel space vector modulation(SVM) technique for the single phase qZS CMI, is implemented without additional resources. It is proposed to fulfill the synthetization of the step-like voltage waveforms**

Keywords—* *Cascade multilevel inverter (CMI), photovoltaic(PV) power system, quasi-Z source inverter ,space vector modulation (SVM).

I. INTRODUCTION

In recent years, power generation from the renewable energy sources are becoming more and more popular as there is an increasing power demand and scarcity of conventional non renewable energy sources. Solar energy is the most promising and abundantly available renewable energy which could be absorbed easily with PV systems. Focus has been placed on innovative and cheap inverter solutions and system configurations. Among them, the more preferable to reach utility-scale power ratings is Cascaded Multi-level Inverter (CMI) due to transformer-less, small size, high efficiency, and low cost[1].

The proposed quasi-Z-source CMI (qZS-CMI) is a new topology derived from the traditional Z-source inverter (ZSI), employing an impedance network which couples the source and the inverter to achieve voltage boost and inversion[1]. The qZSI inherits all the advantages of the ZSI, which realizes buck/boost, and inversion in a single stage with improved reliability.

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[3]. Both Z-source inverters and quasi-Zsource inverters overcome these drawbacks, by utilizing several shoot-through zero states.

The H-bridge inverter(HBI) module lacks boost function so that the inverter KVA rating requirement has to be increased twice with PV voltage range of 1:2; and the different PV panel output voltages result in imbalanced dc-link voltages [5].The extra dc–dc boost converters were coupled to PV panel and HBI of the CMI to implement separate maximum power point tracking(MPPT) and dc-link voltage balance. However, each HBI module is a two-stage inverter, and extra dc–dc converters not only increase the complexity of the power circuit and control and the system cost, but also decrease the efficiency. The Z-source/quasi-Z-source cascade multilevel inverter (ZS/qZS-CMI)-based PV system is proposed which possess the advantages of both traditional CMI and Z-source topologies.

The ZS/qZS-CMI: (1)has high-quality staircase output voltage waveforms with lower harmonic distortions ,and reduces/eliminates output filter requirements for the compliance of grid harmonic standards; (2) requires power semiconductors with a lower rating, and greatly saves the costs; (3) shows modular topology that each inverter has the same circuit topology, control structure and modulation; (4) most important of all, has independent dc-link voltage compensation with the special voltage step-up/down function in a single-stage power conversion of Z-source/quasi-Z-source network ,which allows an independent control of the power delivery with high reliability and (5) can fulfill the distributed MPPT.

In order to properly operate the ZS/qZS-CMI, independent control of dc-link voltages, and the pulse width modulation (PWM) are necessary. The work is focused on the parameter design of the ZS/qZS networks and the analysis of efficiency. The work also presents the algorithm, i.e., the MPPT control of separate quasi-Z-source inverter (qZS) module, and the grid-injected power control.

II. BLOCK DIAGRAM

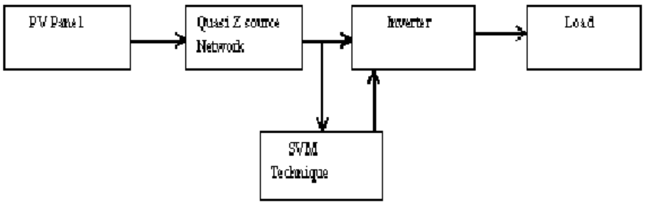

Fig. 1.Block Diagram

Fig.1 gives the block diagram of the paper.A photovoltaic (PV) cell is basically a PN junction and acts as a current source. Energy from sunlight is directly converted in to electrical energy,where the photons are absorbed by the semiconductor and free electrons are released. The generated voltage of PV is low and typically lies around 0.5V and 0.8V which depends on the semiconductor used. Since a single cell cannot be directly utilized to drive an application, it is necessary to connect a number of cells in series and parallel combination to form a PV module. A mathematical model of PV array is developed to obtain I-V and P-V curve.

The PV panel output varies with variation in the received solar energy and hence it is necessary to track the maximum available power. This function can be initiated by a dc/dc converter which transfers the maximum power when switched at an appropriate duty cycle. The switching signal can be derived by a maximum power point tracking algorithm. Perturb and Observe (P & O) algorithm is used for maximum power point tracking[4]. In this algorithm a slight perturbation is introduced in the system. If this perturbation results in an increase in power, perturbation is continued in that direction. If it results in decrease in power, the perturbation is preceded in the opposite direction. This procedure is continued till the steady state is reached. A PI controller then acts moving the operating point of the PV module to the voltage corresponding to the maximum power.

The voltage from the sources can be fed into the cascaded quasi Z source network, then the dc voltage from the network is converted into an ac voltage by using an inverter. Here, two different modes of operations can be done because of varying input voltage. The two different operating modes are, shoot-through and non-shoot-through mode. In the non-shoot-through mode, the cascaded quasi Z source inverter(qZSI) performs the voltage buck function. This kind of mode is used at light load condition, usually when the input voltage is more than the nominal input.

If necessary, the QZSI can be operated at shoot through mode, which is the conduction of two switches in same phase leg or all the switches in the inverter. This shoot through mode is not applicable in VSI because it causes short circuit and makes damage in the circuit.

III. CIRCUIT DIAGRAM

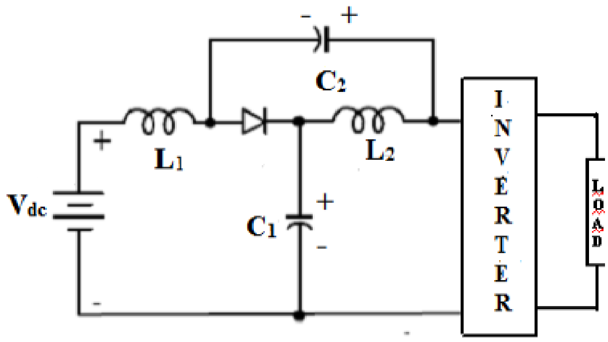

Fig. 2.Circuit Diagram of qZSI

Fig.2 shows the voltage fed qZSI. With the qZSI and ZSI, the unique LC and diode network connected to the inverter bridge modify the operation of the circuit, allowing the shoot-through state. 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. In QZSI, shoot through mode is used to boost the magnetic energy storage in dc side inductors like L1 and L2 without making the short circuit in the capacitors C1 and C2. This kind of magnetic storage provides the boost voltages at the inverter output during operating states. If the input voltage is more than the enough means, the shoot through modes are terminated, and it could be operates as a nominal VSI and it gives a constant output at the inverter output.

The major differences between the ZSI and qZSI are the qZSI draws a continuous constant dc current from the source while the ZSI draws a discontinuous current and the voltage on capacitor C2 is greatly reduced. The dependence of control variables voltage on C2 is much less than that on C1 during operating and this feature leads to lower manufacture cost The continuous and constant dc current drawn from the source with this qZSI make this system especially well suited for PV power conditioning systems.

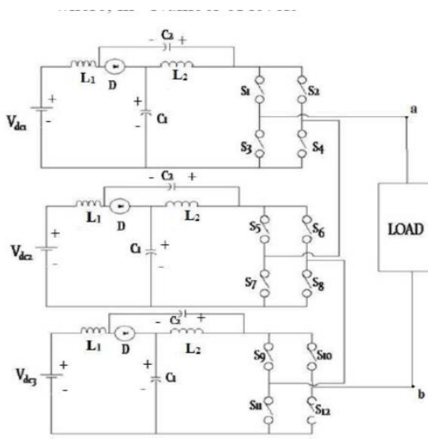

Fig. 3.Circuit Diagram of Single Phase 7 Level qZSI Cascaded Inverter

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Fig.3 shows the topology of the proposed single phase Quasi-Z-source seven level cascaded Inverter, consisting of a split inductors (L1 and L2) and two capacitors (C1 and C2) are connected with the input DC sources and switches. The diode D 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. Comparing with the normal Z-source inverter, the impedance are arranged so as to form the represented structure of qZSI. The proposed Quasi- Z-source based seven level cascaded inverter is controlled with their AC outputs transiting between the seven distinct voltages. They are: +3Vdc, +2Vdc, +Vdc, 0, -Vdc, 2Vdc and -3Vdc. To obtain the seven levels, the required switching scheme is given in table 1 below.

Table.1.Switching scheme

S_1	S_2	S_3	S_4	S_5	S_6	S_1'	S_2'	S_3'	S_4'	S_5'	S_6'	V_{ab}
1	0	0	1	1	0	0	1	1	0	0	1	+3 V_{dc}
1	0	0	1	1	0	0	1	1	0	1	0	+2 V_{dc}
1	0	0	1	0	1	0	1	1	0	1	0	+1 V_{dc}
1	0	1	0	0	1	0	1	1	0	1	0	0
0	1	1	0	0	1	1	0	1	0	0	1	-1V_{dc}
0	1	1	0	0	1	1	0	0	1	0	1	-2V_{dc}
0	1	1	0	0	1	1	0	0	1	1	0	-3V_{dc}

IV. MODULATION TECHNIQUE

To synthesize multilevel output AC voltage using different levels of DC inputs, semiconductor devices must be switched ON and OFF in such a way that desired fundamental is obtained with minimum harmonic distortion. There are different types of approaches for the selection of switching techniques for the multilevel inverters. Among all the PWM methods for cascaded qZSI, carrier based PWM methods and space vector methods are often used[2].

However, the space vector modulation (SVM) approach offers better harmonic performance (compared with carrier-based pulse width modulation (PWM) strategy without zero-sequence voltage injection) and can more conveniently handle overall switching patterns and constraints[4] . The contribution of this paper is, therefore, the development of a SVM algorithm for controlling the inverter. Simulations as well as experimental results are used to verify the operation of the circuit and proposed SVM-based modulation.

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. Using the first qZS-HBI module, the voltage vector reference is created through the two vectors and , by where and is the carrier frequency; the time interval is the duration of active vectors, and is the duration of traditional zero voltage space vectors. 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 a lead of the switching times for lower switches are employed at the transition moments.

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 qZSI HBI modules.

V. CONCLUSION

In this paper, SVM for a quasi Z-source cascaded multilevel inverter is presented. Switching signals for quasi Z-source multilevel inverter are developed using SVM technique. The simulation for the space vector modulated seven level inverter with Quasi z-source inverter can be been done by using the MATLAB/SIMULINK.

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