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CONTROL OF Z-SOURCE PHOTOVOLTAIC INVERTER CONSTANT-FREQUENCY HYSTERESIS CURRENT CONTROL

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ABSTRACT: **The main objective of this project is to control Z-source photovoltaic inverter for grid-connected application based on constant-frequency hysteresis current control. Due to the particularity of the shoot-through operating state in z-source inverter, the boosting characteristic of shoot-through vector and performance of voltage control are analyzed. The shoot-through vector control is inserted to the hysteresis grid-connected control.This control technology not only preserves the advantages of quick dynamic response, high tracking precision and stability quality but also overcomes the shortcomings of switching loss and difficulties in filter design caused by non-constant switching frequency. The correctness of theory analysis is validated by simulation results.**

1. INTRODUCTION

Because of the presence of energy crisis, the renewable energy such as solar energy, wind energy and biomass energy have received tremendous attention from people. The distributed generation which consists of kinds of renewable energy and load united to form micro-grid, which connected to main network by PCC (point of common coupling) during the parallel operation. In order to ensure the electric power quality index comply with national standards during grid-connected process[1], therefore do take effective control technology in the process of grid- connected, in that way grid-connected inverter control technology becomes the hotspot in this field[2][3]. The output of photovoltaic generation shows serious fluctuations caused by variation in circumstance, which leads to increasing problem of system stability [4]. In addition, the voltage level of inverter DC side is generally low, in order to meet the requirements of grid-connected, the two-stage converter which is composed of a DC/DC stage and a DC/AC stage is designed according to the traditional method.

To overcome the drawbacks, the z-source converter is adopted as the micro grid power converter topology. It is a single stage topology that can operate in both buck and boost modes, that has some merits [5-8].

The traditional photovoltaic grid-connected technology is the current control method based on pulse width modulation, containing two kinds: hysteresis current control and triangular wave comparing control [9][10], the former has highly accuracy and quickly dynamic response but non-constant switching frequency, the latter has constant switching frequency and highly security, but slow response and lower accuracy. In this project, the constant-frequency hysteresis current control is used in grid-connected operation of Z-source PV system; which can satisfy the requirement of quickly response and highly accuracy. To fix the frequency of hysteresis control by letting inductive current rise time is equivalent to fall time, this helps gain the high quality output performance. For the sake of meeting the requirement of DC side boosting, the shoot-through vector is inserted into the hysteresis control. According to the logical analysis, we adopt voltage close- loop to achieve voltage stabilization control.

2. CONSTANT FREQUENCY PRINCIPLE OF HYSTERISIS CONTROL

The control structure of full bridge inverter based on z-source as shown in Fig.1, the most special of it lies in that the diode *D* and X-shaped z-source network coupled boosting DC side and AC side together. The special X-shaped z-source structure allows the inverter to operate in shoot-through state, namely the upper and lower devices of each phase leg can be gated on

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simultaneously. When the system operated in shoot-through state, the energy transfer from capacitance to inductance, as a result, generates the boosting ability of z-source inverter. The diode *D* is used in system for fear that the current reverse because the capacitor voltage is higher than PV array.

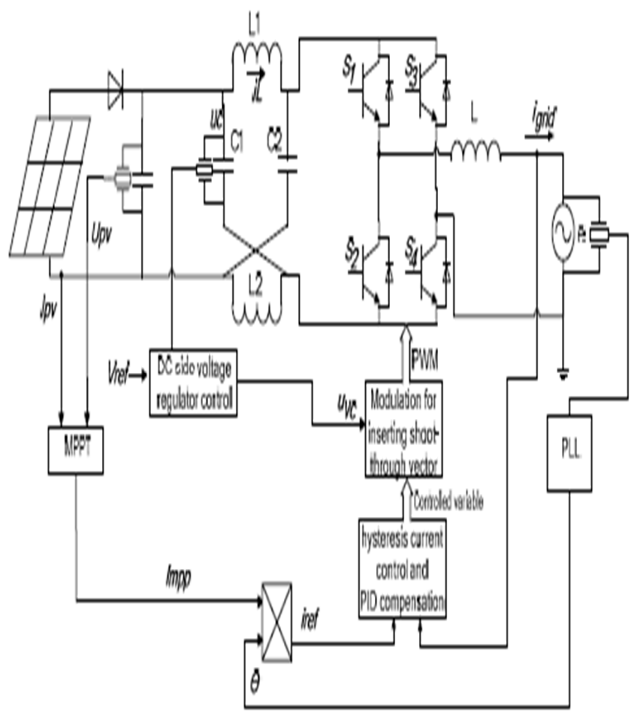

Fig.1 Control Structure of PV grid connected inverter based on Z-source

The whole system mainly consists of two control part. The DC side control of voltage close-loop realize boost by adding shoot-through vector; the AC side control of current close-loop can make the grid-connected current phase is in synchronism with the grid, and the current value is close to the current value coming from MPPT (maximum power point tracking) .Fig.2 shows the inductive current waveform of AC side when inverter operated in one switching cycle. i_{ref} is the reference value of grid-connected current, i_L is the inverting current, the hysteresis band is represented by *H*. The equivalent circuit as shown in fig.3, the inverter output connected to grid by output filter inductance L.

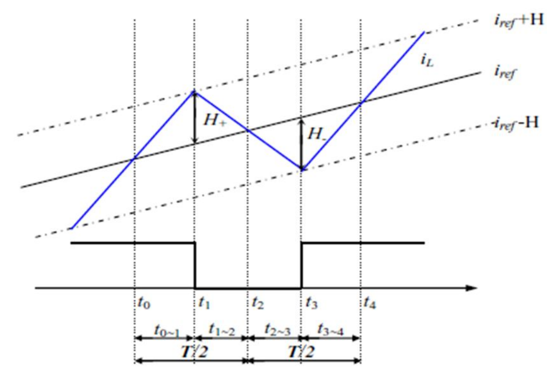

Fig.2 Inductive current operating waveform of AC side during one switching cycle

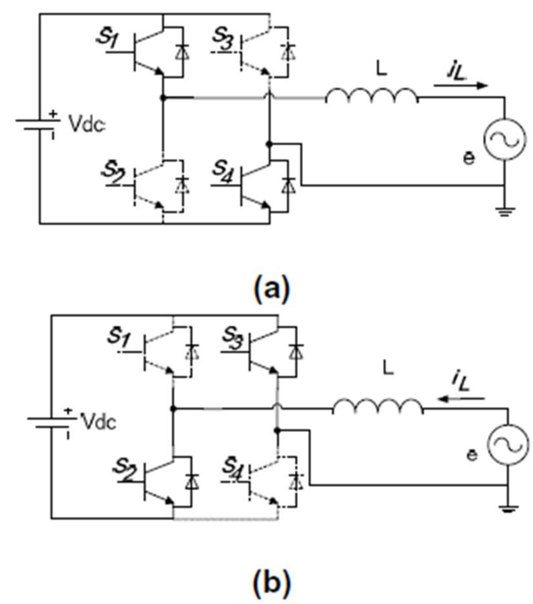

Fig.3 Equivalent circuit of AC side (a) S1, S4 on and S2, S3 off; (b) S2, S3 on and S1, S4 off

According to figure 3, we have the state equation of AC side inductive current in on/off mode as following:

At first,

, ON and ,

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L (—) 1, 4 = - e (1)

, ON and ,

L (—) 2, 3 = – - e (2)

From the figure 2, the inductive current rising section (~) as , and ≥ .

At the time instance , the load current

( ) = (—)1,4 * + ( ) (3)

At the time instance , the reference current

( ) = (——) * + ( ) (4)

In the figure 2, at the point of , the ( ) = ( ), so

(—) 1, 4 * + ( ) =

(——) * + ( )

( ) = ( ) ∗ −(— .) (5)

( ) = ( ) ∗ −(—— .) (6)

( ) ∗ − — . =

( ) ∗ −(—— .)

= ( ) ( ) / — , (——) (7)

After reaching the maximum (or) peak value of inductor current and at the time ~ , the inductor current will fall and the load current ≥

At the time instance , the load current is given by,

( ) = (—)2,3 * + ( ) (8)

At the time instance , the reference current is given by,

( ) = (——) * + ( ) (9)

At the point of , we have ( ) = ( ), then

= ( ) ( ) / — , (——) (10)

The inductive current falling section(~) as and ≤ , in this section (or) point, the state equation is given by,

( ) = (—) 2, 3 * + ( ) (11)

( ) = (——) * + ( ) (12)

Because of ( ) = ( ), that

= ( ) ( ) / — , (——) (13)

The inductive current rising section (~) as , and ≤ , due to ( ) = ( ) , we obtain,

( ) = (—) 1, 4 * + ( ) (14)

( ) = (——) * + ( ) (15)

= ( ) ( ) / — , (——) (16)

If possible to meet the constant- frequency control, then + = –

and + = – , here T is the expected period, and = ( ) – ( ) , to integrate equation (1), (2), (7), and (10), the is predicted by

= {—— – ——}⁻ (17)

By using (1) , (2) , (13) , (16) , we obtain

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$$_{\sim} = \{ \text{—} - \text{—} \}^{-} \quad (18)$$

Based on (1) and (7),

$$_{\sim} = \frac{\cdot}{(\frac{(\ )}{})} \quad (19)$$

Take (17) and (19) together, we have

$$(\ ) = - \cdot \frac{\frac{(\ )}{}}{} \quad (20)$$

Then,

$$(t) = \quad (t) \quad (21)$$

Let hysteresis band is H(t), namely H(t) = (t) = (t), the inductive current peak and valley are and respectively, then ( ) = (t) + H(t) and ( ) = (t) - H(t).

3.INSERTION METHOD OF BOOSTING SHOOT-THROUGH VECTOR

The conventional modulation can realize insertion of shoot-through vector for z- source inverter, according to PWM control, we choose two constant value of positive and negative to compare with triangular carrier, and then through boost ratio is limited by inverter modulation factor. In the hysteresis control, we insert the shoot-through vector by logical analysis, in this case the shoot- through vector can be inserted into any operation state (include effective state and traditional zero state) and never be influenced by modulation factor.

When the input voltage level does not reach the standard of inverter to grid-connected, z-source inverter boost DC side voltage by adjusting the duty cycle of shoot-through zero vector until meet the desired level. The DC side voltage close-loop control can make the PV system operated under the condition that input fluctuate widely. However, the DC side voltage is the form of pulsating (the voltage value is zero in shoot through mode), therefore we can maintain the DC voltage by detecting the capacitor voltage of z-source network.

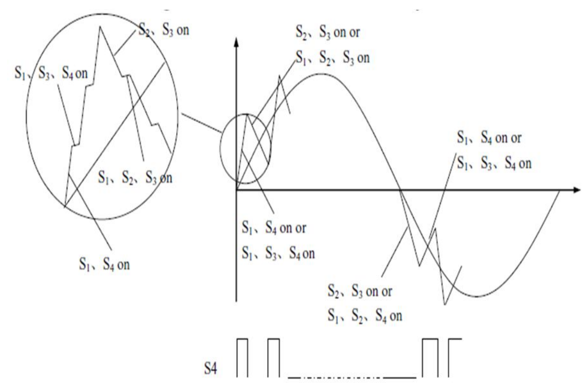

Figure 4 Schematic diagram of logical analysis for hysteresis control of Z-Source

According to control logical analysis, the truth table can be listed as table 1. Take switch S4, grid-connected current reference value and shoot-through vector m as the input, where S4 is 1 indicates switch on, and 0 indicates switch off; is the current value, 1 means positive and 0 means negative; m is 1 indicates shoot-through state and 0 means non-shoot-through state, and view the table 1 below for details.

Input			Output		
	M	S4	S3	S2	S1
1	1	1	1	0	1
1	0	1	0	0	1
1	1	0	1	1	1
1	0	0	1	1	0
0	1	1	1	0	1
0	0	1	0	0	1
0	1	0	1	1	1
0	0	0	1	1	0

Table I Truth value table of logical control

4. SIMULATION ANALYSIS

In order to validate the theoretical analysis, build system simulation platform based on MATLAB/Simulink, simulated the whole system with parameter of table 1. The system control mainly consists of the DC side control using voltage close-loop and the AC output control using hysteresis control.

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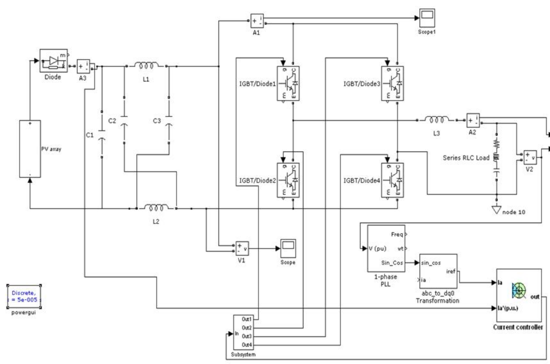

Fig.5 Simulation Diagram

Fig.6 is the grid-connected output waveforms using hysteresis control.

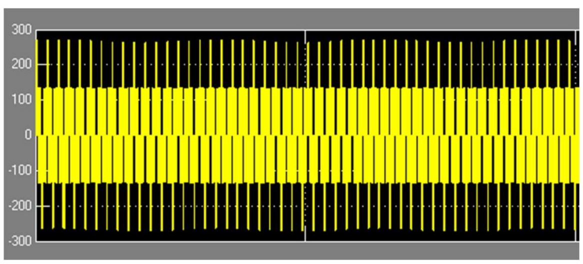

Fig.6 Output Diagram

The constant-frequency hysteresis control has the advantage of real-time dynamic response, when the condition changes, the PV system can track the maximum power point quickly. The whole system can realize real-time simulation and test the external circuit.

5. CONCLUSION

In order to realize the efficient grid-connected of PV system, the hysteresis control has been introduced into z-source inverter control, and the control frequency is fixed by computing the hysteresis band. In this project, firstly the shoot-through boosting characteristic and voltage control performance of DC side have been analyzed, and then we can obtain the shoot-through control signal, which is inserted into the hysteresis inverting control by logical analysis. Finally the control signals for devices of each phase leg can be received. In the PV system, it is better efficient to combine constant-frequency control with shoot-through vector control. The proposed control method was verified by simulation.

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