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Based on Single Very Type Current Type Sun Energy and the Analysis Research of Net inverter

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Abstract. Article have summarized application sun energy in regenerative energy generate electricity the related content of systematic importance. On this foundation, have led into single very type three-phase current type sun energy and net inverter systematic model. With the sampling sequence theoretical and fast Fourier of frequency domain, it is the regular method that describes control strategy specificly to alternate technology with I interval (0 ～ 1/3 π), for in I interval 7 alternate mould form in, analyse single very type current type sun energy specificly and net inverter system the realization of control method have gone on analyse comparatively in detail. The analog result of computer has shown the consistency of emulation and theory.

1. Foreword

Apply sun energy in regenerative energy to generate electricity system, again at the same time have environmental protection in view of the importance that regenerative energy develops with environmental protection for future world economy with is easy the advantages such as installation, add the mature and national plannedness of commercialization technology again assist to promote, have become the advanced national major option that develops the system of distribution type power source, Solar grid-connected inverter can directly feed the electricity generated by solar photovoltaic cells into the market power[1-3]. Now world developed countries have developed commercialize and net inverter, commercialize and net inverter is voltage source type , it is that step-down pattern carries out inversion because of voltage source type, So, ask the bus voltage of direct current of DC/AC to worth the export voltage effective value of electrical network that will be higher than 1.414[4-7], Its advantages are simple control mode, easy to expand, etc., the disadvantage is the use of two-stage transformation mode (dc-dc,DC/AC), so the conversion efficiency is not high. For this this paper have put forward a kind of based on single very type current type sun energy and net inverter circuit topology structure, it is fair only level power transformation , power density is high , converter efficiency high, cost low etc. advantage in one body.

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2. System Model

Systematic main circuit makes rubbing to rush at structure, show as Fig.1, this circuit is single very type three-phase current type sun energy and net inverter construction of system seeks. Circuit major from three-phase electrical network, last bridge arm and next bridge arm , store up can circuit etc. form.

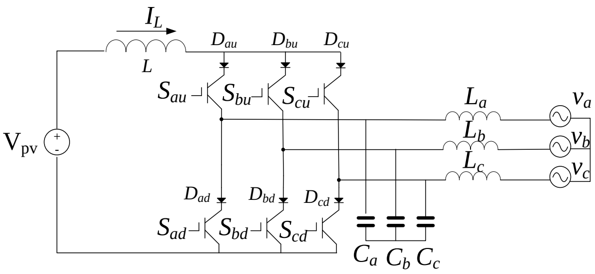

Fig.1 The system circuit diagram

3. Ystematic Analysis

3.1. System control method describe specificly

One power frequency cycle is divided into 6 sectors. As shown in Fig.2. The three-phase voltage of each interval has two identical numbers.The other phase is opposite in polarity to the first two phases.such as 0 to 1/3π interval Va>0, Vc>0 and Vb<0. 1/3π to 2/3π interval Va>0 and Vb<0, Vc<0.

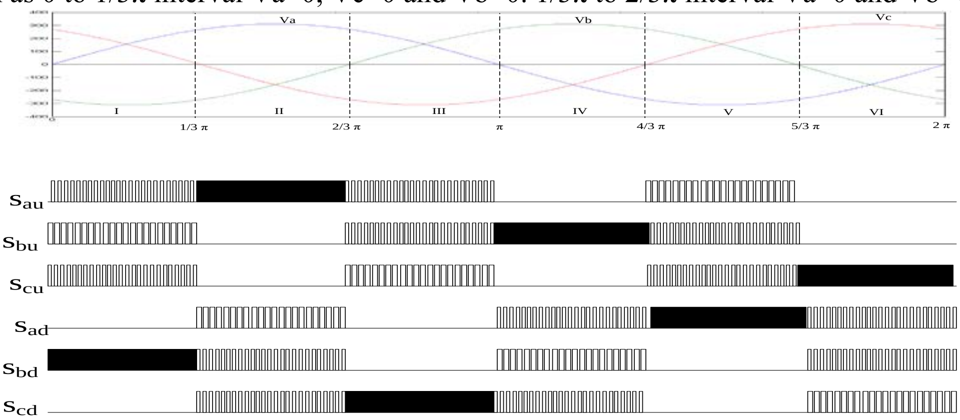

Fig.2 Figure 6 sectors of the power supply power frequency cycle

The control strategy is described in detail by taking the interval 0 to 1/3π as an example. As shown in Fig.3. In the interval of 0 to 1/3π, the upper bridge arm Sbd always keeps normal closed state, while Sad and Scd always keep normal open state. The lower bridge arms Sau, Sbu, and Scu are controlled at a high frequency switching frequency (SPWM mode).

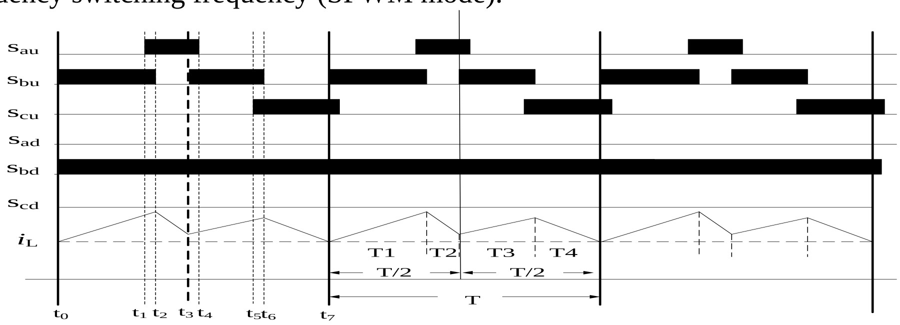

Fig.3 Controlling policy in the range 0～1/3 π

As shown in Fig.3, the seven modal transformation processes of a switching cycle T are now analyzed:

Mode 1: During the period from t0 to t1, Sbu and Sbd are closed, and other switches are in the off state. The energy storage inductance is in the energy storage state, the inductance current IL rises linearly, and the output grid current is provided by Ca, Cb and Cc. Modal 2: At time t1, Sau zero current is closed. During the period from t1 to t2, the reverse bias voltage (Vab>0) is applied to the Dau diode. The energy storage inductance is still in the energy storage state, the inductance current IL rises linearly, and the three-phase current of the output grid is still provided by Ca, Cb and Cc. Modal 3: At time t2, Sbu is disconnected. During the period from t2 to t3, the energy storage inductance releases energy through the Dau, La, Va, Vb, Lb, and Dbd loops, and the storage inductance current IL decreases linearly. The grid current of the Vc phase is provided by the Cc capacitor. Modal 4: At time t3, Sau is closed. During the period from t3 to t4, the energy storage inductance is in the energy storage state, the inductance current IL rises linearly, Dau is in the off state due to the reverse bias voltage (Vba<0) applied at both ends, and the output grid current is provided by Ca, Cb and Cc. Mode 5: At time t4, Sau zero current is disconnected. During the period from t4 to t5, the energy storage inductance is in the energy storage state, the inductance current IL rises linearly, and the output grid current is still supplied by Ca, Cb, Cc. Mode 6: At time t5, Scu zero current is closed. During the period from t5 to t6, the reverse bias voltage (Vbc<0) is applied to the off state at both ends of the Dcu. The energy storage inductance is still in the energy storage state, the inductance current IL rises linearly, and the three-phase current of the output grid is still provided by Ca, Cb and Cc. Modal 7: At time t6, Sbu is disconnected. During the period from t6 to t7, the energy storage inductance releases energy through the Dcu, Lc, Vc, Vb, Lb, and Dbd loops, and the storage inductance current IL decreases linearly. The grid current of the Va phase is provided by the Ca capacitor.

The next period T repeats the above seven modes. Similarly, the other five intervals 1/3π to 2/3 π, 2/3π to π, π to 4/3π, 4/3π to 5/3π, 5/3π to 2 π interval and 0 to 1/3π interval the control strategy is similar.

3.2. *System is specific as control method realizes to analyse*

The seven transformation modes of the first interval (0 to 1/3π) are taken as an example to analyze the implementation of the control method.

From the above analysis, it can be seen that the seven transformation modes of the first interval (0 to 1/3π) are as shown in Fig.4.

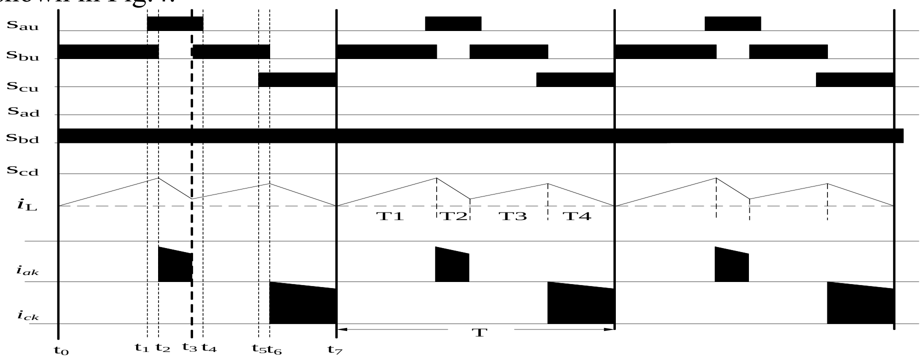

Fig.4 Seven swtching modes in region I(0～1/3π)

The seven modes of the first interval can be divided into two time sub-intervals t0 to t3 and t3 to t7, which are equivalent to two circuit modes of Fig.5 (a) and Fig.5 (b), respectively.

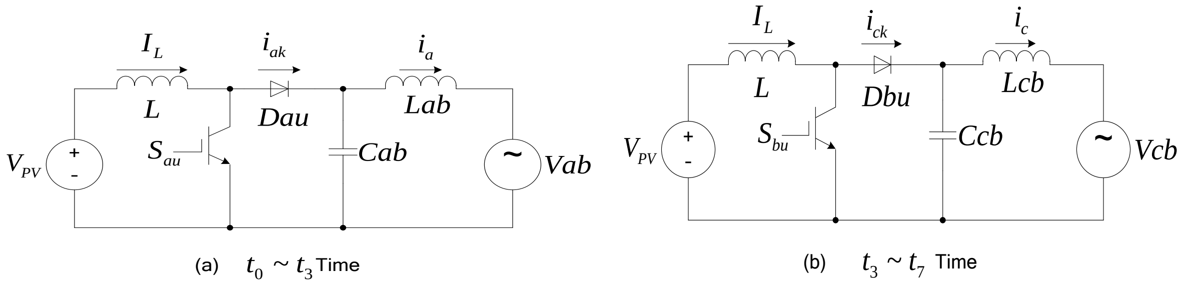

Fig.5 t_0～t_3 and t_3～t_7 has two subinterval circuit model of equivalent figure

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Assume that the closing time of Sbu between t0 and t3 is T1, the breaking time is T2, the closing time of Sbu between t3 and t7 is T3, the breaking time is T4, and T1+ T2 = T3 + T4= 1/T. Assume:

$$\overline{D}_{11} = \frac{(t_3 - t_2)}{T} \tag{1}$$

$$\overline{D}_{12} = \frac{(t_7 - t_6)}{T} \tag{2}$$

In the formula (1), $\overline{D}_{11}$ is the duty cycle of the time period from t0 to t3, and $\overline{D}_{12}$ is the duty cycle of the time period from t3 to t7 in the formula (2).

Assuming that the average current of IL is $\bar{I}_L$ (ie, DC component, when the switching frequency is high frequency, the current IL of the energy storage inductor is approximately DC), the average current of i_{ak} is within a switching period T.

$$\bar{I}_{ak} = \bar{D}_{11} \bullet \bar{I}_L \tag{3}$$

Since LC is low clear wave filter, have so under the switch frequency of high frequency

$$\bar{I}_{ak} = i_a \tag{4}$$

In addition, to transmit the maximum active power to the grid, it is necessary to transmit the current and voltage of the grid at the same frequency and phase, namely

$$i_a = \mathrm{k} \bullet \mathrm{V_a} \quad \text{(K is the proportionality constant)} \tag{5}$$

It can be obtained from equations (3), (4) and (5)

$$\bar{D}_{11} = \frac{k}{\bar{I}_L} \bullet V_a \tag{6}$$

Same reason can get

$$\bar{D}_{12} = \frac{k}{\bar{I}_L} \bullet V_c \tag{7}$$

Make three-phase voltage(U is worthed efficiently)

$$\mathrm{V}_a(t) = \sqrt{2} \bullet U \bullet \sin(\omega t) \tag{8}$$

$$\mathrm{V}_b(t) = \sqrt{2} \bullet U \bullet \sin(\omega t - 2/3\pi) \tag{9}$$

$$\mathrm{V_c}(t) = \sqrt{2} \bullet U \bullet \sin(\omega t + 2/3\pi) \tag{10}$$

Subtract equation (8) from equation (9) to get

$$\mathrm{V}_{ab} = \sqrt{2} \bullet U \bullet [\sin(\omega t) - \sin(\omega t - 2/3\pi)] = \sqrt{3} \bullet U \bullet \cos(\omega t - \frac{1}{3}\pi) \tag{11}$$

For the same reason, equation (9) and equation (10) can be obtained

$$\mathrm{V}_{cb} = \sqrt{2} \bullet U \bullet [\sin(\omega t + 2/3\pi) - \sin(\omega t - 2/3\pi)] = \sqrt{3} \bullet U \bullet \cos(\omega t) \tag{12}$$

FIG. 4 and FIG. 5 can be obtained according to the variation relation of energy storage inductance current

$$i_L(t_7) - i_L(t_0) = \frac{1}{L}\left[(t_7 - t_0) \bullet V_{pv} - (t_3 - t_2) \bullet V_{ab} - (t_7 - t_6) \bullet V_{cb}\right] \tag{13}$$

Substitute equation (1), (2), (6) and (7) into equation (13) and you can get

$$i_L(t_7) - i_L(t_0) = \frac{1}{L}\left[T \bullet V_{pv} - \frac{k}{\bar{I}_L} \bullet T \bullet (V_a \bullet V_{ab} + V_c \bullet V_{cb})\right] \tag{14}$$

Substitute equations (8), (10), (11) and (12) into equation (14) to obtain

$$i_L(t_7)-i_L(t_0)=\frac{1}{L}\left[T\bullet V_{PV}-\frac{k}{\bar{I}_L}\bullet T\bullet(V_a\bullet V_{ab}+V_c\bullet V_{cb})\right]=\frac{1}{L}\left[T\bullet V_{PV}-\frac{k}{\bar{I}_L}\bullet T\bullet 3U^2\right] \quad (15)$$

When the circuit starts up, the average current of the inductance goes up and up: $i_L(t_7)-i_L(t_0)>0$ namely

$$\bar{I}_L>\frac{3U^2\bullet k}{V_{pv}} \quad (16)$$

Substitute equation (16) into equation (6) and equation (7) respectively to obtain

$$\bar{D}_{11}<\frac{V_{PV}}{3U^2}\bullet V_a \quad , \quad \bar{D}_{12}<\frac{V_{PV}}{3U^2}\bullet V_c$$

When we reach a steady state:

$$i_L(t_7)-i_L(t_0)=0 \quad (17)$$

From type (17) , type (15) can get

$$\bar{I}_L=\frac{3U^2\bullet k}{V_{pv}} \quad (18)$$

Substitute equation (18) into equation (6) and equation (7) respectively to obtain

$$\bar{D}_{11}=\frac{V_{PV}}{3U^2}\bullet V_a \quad , \quad \bar{D}_{12}=\frac{V_{PV}}{3U^2}\bullet V_c \qquad P_{\text{out}}=\mathrm{k}\bullet 3U^2=V_{PV}\bullet\bar{I}_L$$

4. Theoretical Analysis of MPPT Model

Based on the above analysis, the maximum power tracking (MPPT) simulation of the main circuit was carried out in Matlab7.0 simulation environment for further in-depth analysis:

Because of stability, $\bar{D}_{11}=\frac{V_{PV}}{3U^2}\bullet V_a$, $\bar{D}_{12}=\frac{V_{PV}}{3U^2}\bullet V_c$. At start-up, because it's smaller, so $\bar{D}_{11}<\frac{V_{PV}}{3U^2}\bullet V_a$, $\bar{D}_{12}<\frac{V_{PV}}{3U^2}\bullet V_c$ to ensure that the current of $\bar{I}_L$ is constantly rising. While the current of $\bar{I}_L$ is constantly rising, $P_{\text{out}}=V_{PV}\bullet\bar{I}_L$ is also rising continuously, but V_{PV} is falling. When $\bar{I}_L$ rises to a certain point, the output power reaches the maximum. If $\bar{I}_L$ continues to increase, it will cause the output power to drop. As shown in Fig.6.

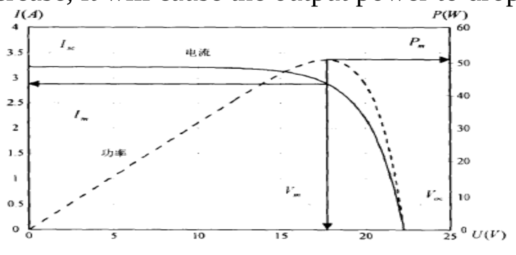

Fig.6 Just started P - V curve diagram

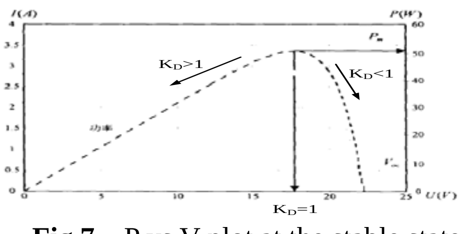

Fig.7 P vs V plot at the stable state

So tentative idea gives a definition general formula:

$$\bar{D}_{11}=K_D\bullet\frac{V_{PV}}{3U^2}\bullet|V_a| \quad , \quad \bar{D}_{12}=K_D\bullet\frac{V_{PV}}{3U^2}\bullet|V_c| \qquad (0<K_D\le 2)$$

When initial start-up, the current $\bar{I}_L$ is small and the output power $P_{\text{out}}=V_{PV}\bullet\bar{I}_L$ is also small,

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so K_D is small and $\bar{I}_L$ is rising continuously. When the output power $P_{\text{out}} = V_{PV} \bullet \bar{I}_L$ reaches the maximum output power, K_D =1. Fig.7 shows the P-V curve relationship. From the experimental results, we can conclude that: If the working point is to the left of the maximum power point, it means that $\bar{I}_L$ is too large, it should be reduced by $\bar{I}_L$, ie K_D >1; if the working point is to the right of the maximum power point, it means that $\bar{I}_L$ is too small and should be increased by $\bar{I}_L$. That is K_D <1; if the working point is just at the maximum power point, the description $\bar{I}_L$ is just right, then K_D =1.

5. Simulation and Principle Test

Design example: Single-pole three-phase current-type solar grid-connected inverter, sector and adaptive MPPT control strategy, input voltage Vpv=110V±10%, rated capacity S=1.75kVA, switching frequency Fs=35kHz, capacitance Ca=4.7μF, Cb=4.7μF, Cc=4.7μF, energy storage inductance Li=0.5mH, output filter inductance La=Lb=Lc=0.1mH. In the simulation environment of Matlab7.0, the principle test waveform of the single-pole three-phase current-type solar grid-connected inverter, as shown in Fig.8 and 9, the actual test conversion efficiency can reach over 93.1%, the output waveform quality of the inverter is high, the principle test results are consistent with the theoretical analysis.

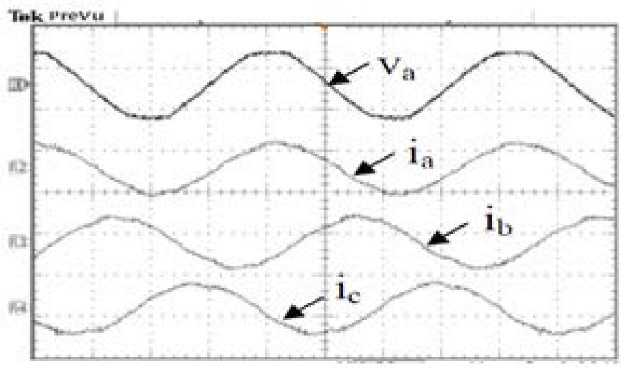

Fig.8 System stabilize export voltage and current waveform picture

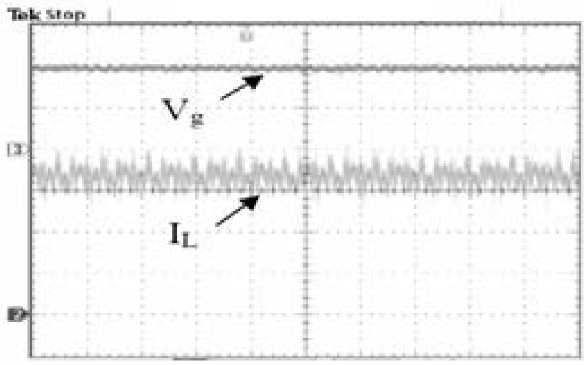

Fig. 9 Inputs voltage with store up can inductance current waveform picture

6. Conclusion

1) Have suggested that a kind of single very type three-phase current type sun energy nets inverter, this inverter circuit structure from from three-phase electrical network, last bridge arm and next bridge arm , store up can circuit etc. form.

2) Circuit control a total of 7 modes, the realization of zero voltage ZVS switch, output cycle converter power devices to achieve zero current ZCS switch design criteria. Advanced sector control method and adaptive MPPT algorithm are adopted to ensure the high efficiency and reliability of the system.

3) Emulation and test result are consistent with theoretical analysis , have confirmed that this kind of single very type three-phase current type sun energy nets advancedness and the correctness of inverter.

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