

# Grid connected inverter with harmonic suppression based on DSP control

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**Abstract.** Based on Grid Technology Based on distributed power generation system, and to achieve the output active power harmonic suppression for the purpose of designing a new type of DSP control inverter. This device uses DSP to detect harmonic current of power grid, the speed of DSP to ensure that the system has instantaneity, eliminates the influence of detection delay of the system, so as to realize the instantaneous detection of harmonics; at the same time, through the detection of DSP signal processing, finally realizes the control of the inverter in the launch of IGBT. The experimental results are given and no harmonics under two kinds of situations, this new device in the active power input power at the same time, also has a good inhibitory effect on the harmonic in the power grid. The results show that the device achieves the expected function, and has better stability and practicability.

## 1. Introduction

With the wide application of the distributed power generation system, the grid problem has attracted more and more attention, if it is idle to produce energy feedback to the grid, will ease the tense situation in the energy supply and demand. The basic requirements of the distributed power generation system of energy feedback is grid side power factor is 1 and the grid current distortion and phase with the grid voltage, the active power back to grid.

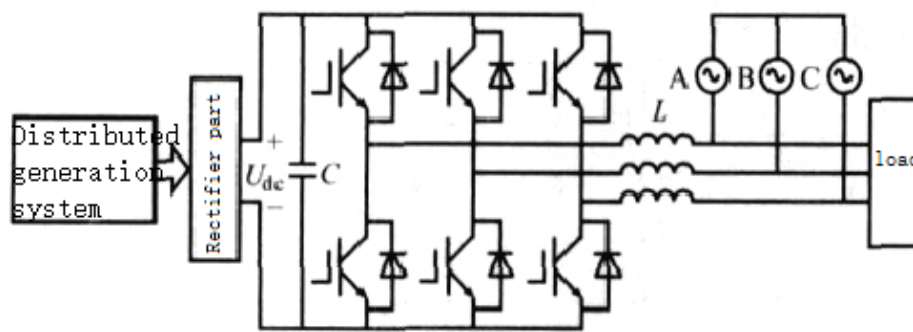
In fact, due to the widespread use of power electronic equipment, the harmonics in power system, the harmonic current of electric equipment of great harm, will reduce the electric power production, transmission and utilization efficiency, so that the electrical equipment overheating, vibration and noise, and the insulation aging and shorten life, and even failure or burned. Harmonics will cause disoperation of relay protection and automatic device, which will lead to confusion of energy metering [1]. If the distributed power generation system can realize the harmonic suppression in the output power at the same time, will greatly improve the quality of power, and makes it more practical and novel.



## 2. Basic analysis of grid connected inverter and harmonic suppression

### 2.1. Structure analysis of grid connected inverter

The high frequency alternating current generated by the high speed permanent magnet generator is rectified to output the stable DC power, and then the DC power is converted into the power supply equipment by the grid connected inverter, or the idle energy is incorporated into the power grid. At present, the grid connected inverter can be divided into parallel, series, series parallel and hybrid according to its connection with the grid. Among them, the parallel inverter is technically mature, and it is a widely used active filter topology. Therefore, the commonly used voltage type three-phase grid connected inverter [2] is adopted. Fig. 1 shows the structure of voltage type three phase grid connected inverter.



**Figure 1.** Structure diagram of voltage type three phase grid connected inverter

In the Figure,  $U_{ga}$  is DC input C is voltage filter capacitor L is AC side filter inductance.

### 2.2. Principle analysis of harmonic detection

It is an important premise to realize harmonic suppression in real time to detect harmonics in the current of power grid, and it is also one of the difficult points to be solved in this system. In many harmonic detection methods, instantaneous reactive power theory [3] is the most widely used. It is calculated by the instantaneous active current and instantaneous reactive current  $i_p$  based  $i_q$ , by calculating the current active component and reactive component can obtain the harmonic current, the harmonic component can be used as anti-command signal of compensation current polarity.

$i_a, i_b, i_c$  Is Instantaneous value of load current -  $e_a$  is phase voltage of a phase power supply  $i_{ah}, i_{bh}, i_{ch}$  is three phase harmonic current signal (1).

$$C_{32} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \quad C = C^{-1} = \begin{bmatrix} \sin \omega t & -\cos \omega t \\ -\cos \omega t & -\sin \omega t \end{bmatrix}, \quad C_{23} = C_{32}^T \quad (1)$$

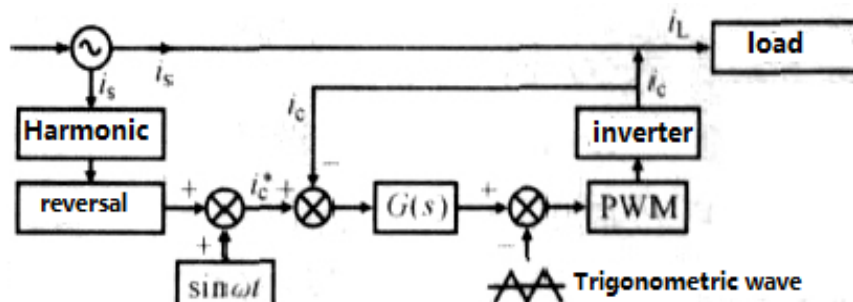
The sinusoidal signal  $\sin \omega t$  and cosine signal  $\cos \omega t$  of the same phase are obtained by the phase-locked loop (PLL) and the sine cosine generation circuit. The instantaneous current value  $i_a, i_b, i_c$  of three-phase circuit is transformed into  $\alpha$  (2),  $\beta$  orthogonal coordinate system.

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = C_{32} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \begin{bmatrix} i_p \\ i_q \end{bmatrix} = C \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (2)$$

Then  $i_p$  and  $i_q$  are calculated. Because the active power has become  $i_p$ ,  $i_q$  direct form in the new coordinates, so as long as the use of low pass filter (LPF) can be filtered out, so after LPF get the DC component of  $i_p$ ,  $i_q$ ,  $i_{af}$ ,  $i_{bf}$ ,  $i_{cf}$ , and  $\alpha$ ,  $\beta$  is produced from the fundamental current  $i_{af}$ ,  $i_{bf}$ ,  $i_{cf}$  it can be  $i_a$ ,  $i_b$ ,  $i_c$ ,  $i_{af}$ ,  $i_{bf}$ ,  $i_{cf}$  from the alpha, beta coordinates conversion come back again, so as to obtain a. Subtract  $i_{ah}$ ,  $i_{bh}$ ,  $i_{ch}$  from a to get  $i_{ah}$ ,  $i_{bh}$ ,  $i_{ch}$ . The harmonic signals in the grid current can be detected by using the  $i_p$ - $i_q$  method.

### 2.3. Analysis of signal processing and control principle

After detecting the harmonic current, it is necessary to process the signal and then control the inverter. Fig.2 shows the signal processing and control scheme of the system. From the diagram, the inverse polarity of the harmonic component is added to the sinusoidal signal  $\sin\omega t$  which is in phase with the grid voltage as the instruction signal  $i_c^*$ . The deviation between the current actual value  $i_c$  and  $i_c^*$  of the detection link  $\Delta i_c$  is obtained to process the control signal, and the control signal is compared with the high frequency triangular modulation wave in real time, and the obtained PWM signal is used as the control signal of each switch component of the inverter [4].



**Figure 2.** signal processing and PWM control chart

Different from the ordinary SPWM control mode, the control method does not directly compare them  $i_c^*$  with the triangle wave, but the  $\Delta i_c$  is processed by the PI link and then compared with the triangle wave. Such a control system is designed based on the minimization of the  $\Delta i_c$  control.

## 3. system software and hardware design

### 3.1. System hardware design

The hardware circuit of the digital voltage type grid connected inverter adds a DSP link to the AC side of the voltage type three-phase grid connected inverter in Fig. 1. The switching device adopts independent IGBT, the upper bridge arm had HCPL- type 316J current protection control chip, under the bridge arm with over-current protection function of HCPL- type 3120 control chip, digital control using DSP2407, AC frequency three-phase power [5].

### 3.2. System software design

Because of the harmonic detection algorithm in complex and real-time requirement of the system is high, the general microprocessor, such as 51 series, 96 series speed cannot meet the real-time requirements. So, the previous algorithm consists mostly of hardware, although high real-time, but requires multiple hardware multiplier, the components of high precision, so the circuit is complex, and the cost is high. DSP is a dedicated processor high-speed real-time processing after the analog signal into a digital signal in the new DSP is more suitable for processing large amounts of data, has the performance of high speed, high resolution, strong operation ability etc. Therefore, using DSP to realize harmonic and reactive current detection and calculation can ensure real-time, and the system structure is simple. Fig. 3 shows the flow chart of the main program. As shown in the figure, the whole system sampling, closed-loop control and the algorithm is implemented in DSP2407, the digital control system based on DSP as the core, to complete the A/D sampling, transform and digital low-pass filter, and the filter harmonic inverse transform to obtain a command signal and control signal then, according to the control signal to calculate the corresponding PWM signals.

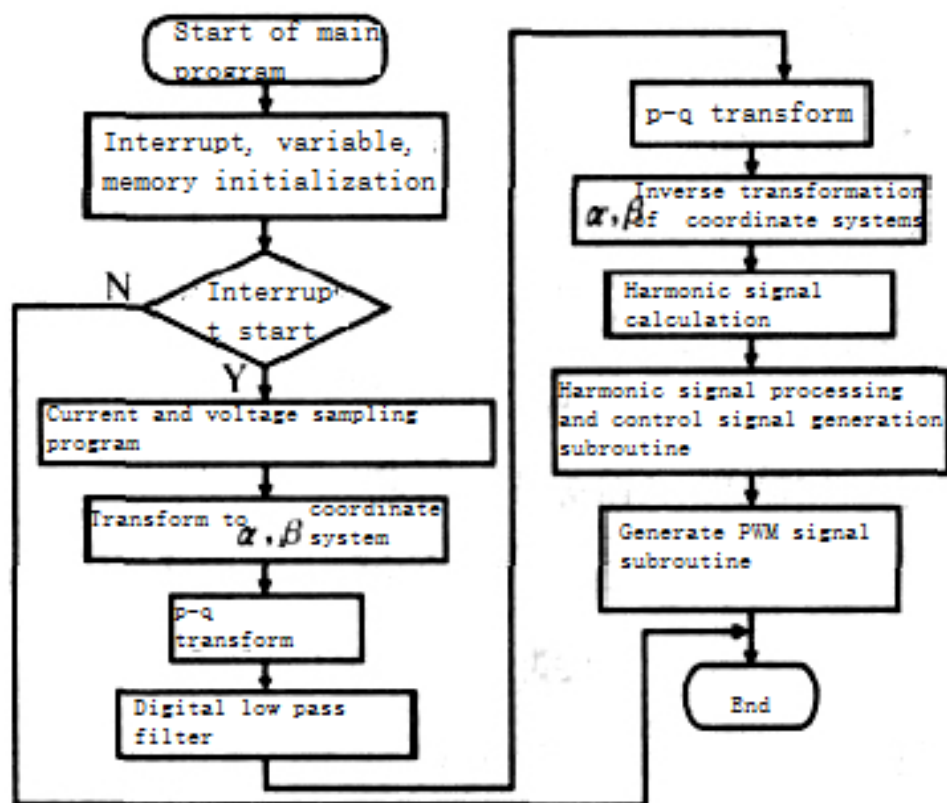
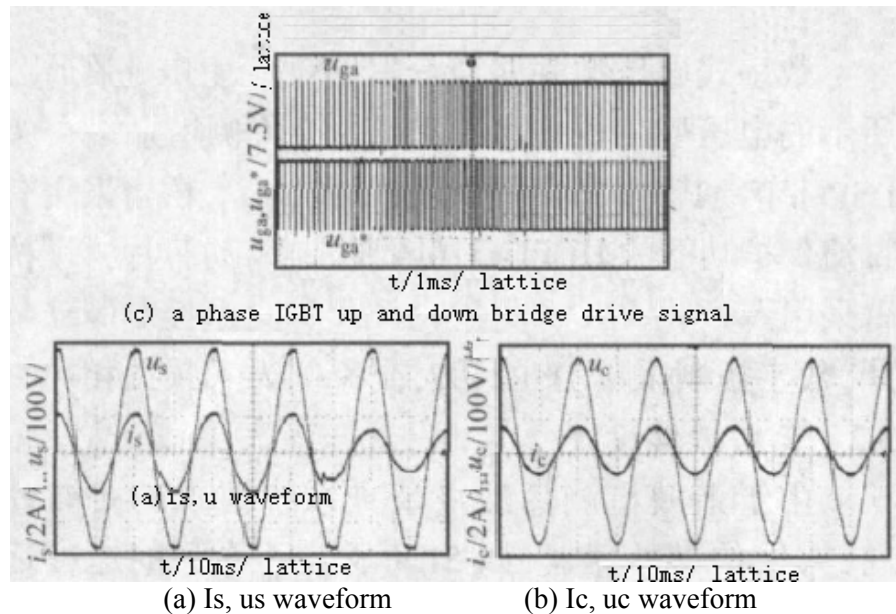


Figure 3. flow chart of main program

### 4. experimental results analysis

On the basis of the above theoretical analysis, a voltage type three-phase grid connected inverter based on DSP2407 control is designed with 6K W. After debugging in the local power grid, the external power grid is connected to the local power grid after the high power transformer, and the inverter is connected to the beginning of the local power grid. The electric equipment is electric furnace, Rectifier Bridge, electric lamp and so on. When there is no harmonic source in the electrical equipment  $U_s$ , the device can return the electric energy to the grid when the power factor is 1; and when the harmonic source exists in the electric equipment, the device can output active power and realize harmonic suppression simultaneously. When the load is pure resistance load, its terminal

current and voltage phase, the current is 2A. Fig. 4 shows the experimental waveforms without harmonics.

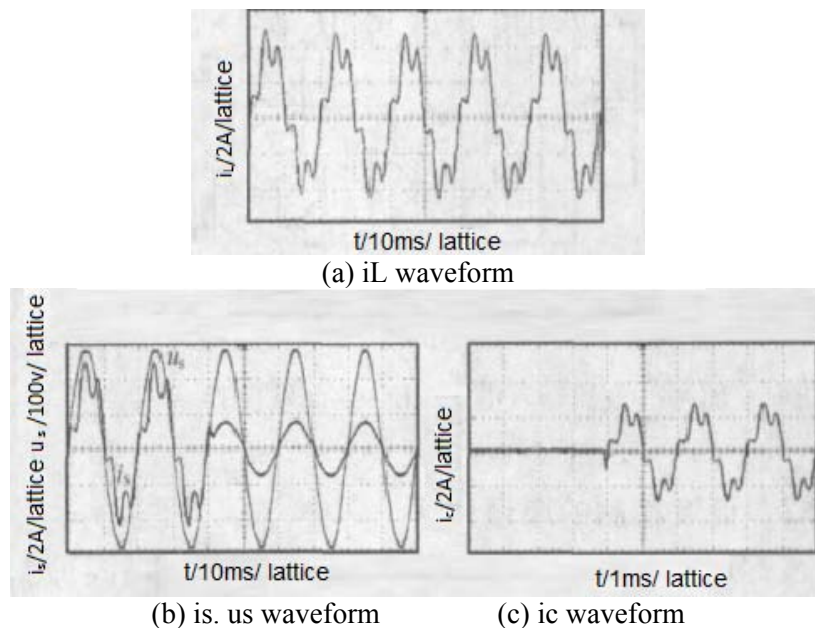


**Figure 4.** Experimental results in the presence of no harmonics

Fig. 4a is the PWM driving signal a of the bridge arm on the  $U_{ga}$  phase of the inverter and the PWM driving signal  $U_{ga}$  waveform of the lower bridge arm, the turn-on voltage is +15V, and the turn off voltage is 5V. The dead time of the upper and lower bridge arm is about 2 s; the figure 4b is the grid current  $i_s$  and the voltage waveform. When  $t=65ms$ , the inverter starts to work, input current to the grid, and the output current of the grid decreases; figure 4C is the current and voltage  $U_c$  waveform of the grid connected end when the inverter works stably. The phase of  $i_c$  is basically the same as that of  $U_c$ , and the power factor is 1 to output active power  $i_c$  to the grid. Fig. 7 shows the experimental waveform when there is harmonic.

$i_L/2A$ /lattice  $t/10ms$ / lattice (a)  $i_L$  waveform (b)  $i_s, u_s$  waveform (c)  $i_c$  waveform  
 $i_s/2A$ /lattice  $u_s/100V$ / lattice  $i_c/2A$ /lattice

Fig. 5a is the current  $i_L$  waveform of the harmonic load, the current is 5A; the graph 5b is the grid current  $i_s$  and the grid voltage  $U_s$  waveform. When  $t=40ms$ , the inverter starts to work, input current to the grid and realize harmonic suppression, then the output current of the grid is reduced and the current waveform is changed back to sine wave; FIG. 5c is the current  $i_c$  waveform of the grid connected end when the inverter works. The inverter starts working at  $t=40ms$ , and inputs active current and harmonic compensation current to the grid. It can be seen that the inverter achieves harmonic suppression and improves the power quality while inputting active power into the grid.



**Figure 5.** experimental waveforms in presence of harmonics

## 5. Conclusion

The principle and control scheme of harmonic suppression and grid connected inverter are analyzed. The DSP implementation of harmonic suppression is focused on, and a three-phase grid connected inverter with harmonic suppression based on DSP control is designed. The experimental results show that the device is innovative, widely used, and has good stability.

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