Research on Three-phase Variable Frequency Power Supply
Based on DSP and SVPWM Technology

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Abstract. Starting from the defects of analog power supply. Based on the analysis of space vector pulse width modulation algorithm, a three-phase variable frequency variable amplitude inverter power supply based on SVPWM technology is studied. On this basis, the PI control algorithm for closed-loop control of inverter power supply is also proposed. In order to improve the system response speed, the DSP with powerful digital signal processing capability was designed as the hardware platform, and various related verification experiments were completed. The results show that the system realizes a voltage-regulated output with a step of 1 V and a range of 40 V and an FM output with a step of 2 Hz and a range of 50 Hz to 1 kHz. The system has small load regulation rate, excellent performance and good application prospects.

1. Introduction
The traditional variable frequency power supply uses the SPWM algorithm to control the inverter, and has achieved certain applications in the fields of industry and transportation. However, with the development of the times, digital and intelligent technologies are becoming more and more advanced. The control accuracy and voltage utilization based on SPWM can no longer meet our requirements. In this paper, based on the powerful digital signal processing capability of DSP., According to the three-phase full-bridge inverter circuit structure, a three-phase inverter power supply design based on SVPWM is completed.

2. System hardware design
The system schematic is shown in Figure 1. First, the 220VAC power is transformed by a 48V autotransformer, and the rectifier circuit rectifies and filters 48VDC to form a stable DC power supply to the full-bridge inverter circuit. The full-bridge inverter circuit mainly realizes DC/AC power conversion, and the DSP-controlled full-bridge inverter circuit converts the DC power waveform into a three-phase SVPWM waveform. The LC filter circuit filters the converted waveform of the inverter circuit to form a standard sine wave. The voltage and current detection conditioning circuit feeds back the output sine wave value to the DSP to form an overall control loop.
2.1. Uncontrolled rectifier circuit design

Using a rectifier bridge and filtering, a relatively stable voltage is obtained. The circuit is shown in Figure 2. \( V_{dc} \) is the rectified DC voltage. The circuit implements an AC to DC conversion. The voltage input at the input (P1) is the voltage obtained by the mains after being transformed by the 48 V autotransformer, and then rectified by the bridge rectifier. The filtering adopts the multi-capacitor parallel connection, which can better filter the voltage ripple. Indirectly a fuse (F1) to protect the following components, or to prevent capacitor damage when the rear circuit is shorted, and finally get the DC output voltage \( V_{dc} \).

2.2. Isolated drive circuit design

In the circuit of the weak current system controlling the high-power system, the strong electric terminal and the weak electric terminal must be isolated by appropriate isolation measures, and an appropriate driving circuit must be designed to realize the weak electric control high-voltage circuit. In this system, isolation measures must be taken between the DSP control terminal and the full-bridge inverter circuit. The designed circuit is shown in Figure 3. Because the rectifier circuit is a three-phase bridge rectifier current, the isolation driver circuit needs to design 6 channels. The schematic diagram of the driving circuit is the same. Figure 3 only provides the circuit schematic of one of the channels. After the TLP250 is isolated, the control signals Q1k to Q6k of the output arm are output.
2.3. Three-phase bridge rectifier circuit design

![Three-phase bridge rectifier circuit](image)

The three-phase bridge rectifier circuit uses six IRF540 MOS tubes to form six bridge arms. The control signals of each arm in the bridge are controlled by 2.2. The output signal of the isolated driving circuit in the section is controlled, and the design is performed in a manner corresponding to the number of the MOS transistor, that is, the control signal of the MOS transistor Q1 is numbered by Q1k, and so on. Each arm turns on under the control signal, and the upper and lower arms cannot be turned on at the same time. At the same time, the conduction will cause the bridge arm to pass through, causing the circuit to burn. Therefore, the time at which the phases of the bridge arms begin to conduct is 120°, which prevents the circuit from passing through. The circuit schematic is shown in Figure 4.

2.4. LC passive filter circuit design

Waveform after full-bridge inversion needs to be processed by the filter circuit. This design uses LC low-pass filtering. The characteristic impedance \( R = \sqrt{L/C} \), load \( R_L = V_o/L_o \), cutoff frequency is taken as 400 Hz, and \( R = (0.5 \text{ to } 0.8) R_L \) by the characteristic impedance method, that is, the Q value is 0.5 to 0.8, and the cutoff frequency is 400 Hz \( (= 3 \text{ to } 8 f_0) \). From the formula \( f = \frac{1}{2\pi \sqrt{LC}} \) can
be obtained $C = \frac{1}{2\pi f_c}$, $L = \frac{R}{2\pi f_c}$. Then design the values of the inductor and capacitor in the filter circuit according to the parameters of the system (output frequency, output voltage, output current). The circuit is shown in Figure 5.

![Figure 5 Filter and current sampling circuit](image)

3. System software design

3.1. SVPWM waveform implementation method and software algorithm

The SVPWM algorithm, also known as space voltage vector PWM, is a modulation algorithm that combines an inverter power supply and an AC motor as a whole to form a circular rotating magnetic field. It divides the circle formed by rotating the space voltage vector into six equal parts, each aliquot representing one sector, and a total of six sectors. The space voltage vector at each moment can be synthesized from six basic space voltage vectors, and two zero vectors can be inserted to adjust its position. The SVPWM program module can be roughly divided into the following steps:

1. Calculate the sector in which the current space voltage vector is located;
2. After obtaining the sector, calculating the action time of two adjacent basic vectors;
3. Calculate the action time of the inserted zero vector;
4. The calculated value is processed and sent to the corresponding PWM register in the DSP. Finally, the 6 PWM pins of the DSP will respectively output SVPWM waves to drive the IGBT in the intelligent power module to turn on and off, and finally output the variable frequency AC to the AC motor.
3.2. PI adjustment subroutine The expression of the PI regulator is as follows:

\[ u(t) = K_p [e(t) + \frac{1}{T_i} \int_{0}^{t} e(\tau) \, d\tau] \]  \hspace{1cm} (1)

Where \( u(t) \) is the output of the regulator; \( e(t) \) is the deviation signal of the regulator. Since the computer processes digital quantities, the above equation must be discretized. The differential equation of the continuous system is replaced by a digital difference equation, in which case the integral term can be expressed in the form of a summation increment.

\[ \int_{0}^{N} e(\tau) \, d\tau = \sum_{i=0}^{N} e(i) \Delta t = T \sum_{i=0}^{N} e(i) \]  \hspace{1cm} (2)

Where \( \Delta t \) is the sampling period, \( T \) must be made small enough to ensure the accuracy of the system; \( e(i) \) is the deviation of the \( i \)-th system sampling. Bringing equation (1) into equation (2) is a discretized PI expression:

\[ u(k) = K_p [e(k) + \frac{T}{T_i} \sum_{i=0}^{N} e(i)] \]  \hspace{1cm} (3)

Where \( u(k) \) is the output of the regulator at the \( k \)-th sample. The equation (3) is referred to as a positional PI control algorithm, and it can be seen that in order to calculate the value of \( u(k) \), the previous deviation signals \( e(i) \) in the integral term are added. This calculation is cumbersome and requires a lot of memory, so make the following changes. According to reasoning, the PI regulator can be written as an output expression when \( (k-1) \) samples are taken:

\[ u(k-1) = K_p [e(k-1) + \frac{T}{T_i} \sum_{i=0}^{N} e(i)] \]  \hspace{1cm} (4)

Use equation (3) minus equation (4)

\[ u(k) = u(k-1) + (K_p + K_i) e(k) - K_p e(k-1) \]  \hspace{1cm} (5)

Let \( K_0 = K_p + K_i \), then the above formula can be changed to:

\[ u(k) = u(k-1) + K_0 e(k) - K_p e(k-1) \]  \hspace{1cm} (6)

In the formula, \( K_p \) is a proportional coefficient; \( K_i \) is an integral coefficient. From the above equation (6), it is sufficient to calculate the \( K \)-th output \( u(k) \) as long as \( u(k-1) \), \( e(k-1) \), and \( e(k) \) are known. According to the algorithm of the digital PI regulator discussed above, the implementation flow chart is as shown in Figure 6.
4. Conclusion
In this paper, DSP is used as the main control chip, and SVPWM is used as the core algorithm to design three-phase variable frequency power supply. The article introduces the hardware framework of the entire system. The initialization and main program of the whole system are explained, and the idea and flow of the SVPWM generation program are described in detail. The PI adjustment subroutine of SVPWM in DSP is given. In summary, the system has certain practical value.

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