Research and design of high-performance DSP control system based on frequency control

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Abstract. With the rapid development of power electronic devices and microprocessors, AC variable frequency and speed regulating system has also made a breakthrough. The thesis introduces the hardware circuit design based on TMS320F28335, and the result of the experiment proves the SVPWM algorithm is correct. It also does some research on VF control system of the inverter and the result of the experiments proves that the control system achieves the purpose, and has a quick dynamic response.

Keywords: Frequency Control System; SVPWM algorithm; VF control system.

1. Introduction

In recent years, AC variable frequency speed regulation devices have been widely used in industry. According to the survey and statistics of relevant national departments, more than 50% of China's power generation is used to promote the work of motors, of which 90% are AC motors. This kind of high-voltage motor is widely used in large and medium-sized enterprises such as electric power, metallurgy, iron and steel, petrochemical and coal mines to drive various load equipment such as fans, pumps and compressors [1]. Most of them adopt direct constant speed drive, which will cause a lot of energy waste every year. Such load conditions vary greatly [2]. If AC speed regulation technology is adopted to realize variable speed operation, the energy-saving effect is obvious. Therefore, China's high-voltage inverter market is very large. According to relevant statistics, the market scale reached 3.9 billion CNY in 2009, and the market scale will continue to grow. It is expected to reach 8.5 billion CNY by 2012.

Due to the late start of the development of high-capacity and High-Performance AC speed regulation system in China, only a few products are put into operation. At present, many necessary occasions are occupied by foreign products [3]. The general price of foreign products is high, which is difficult to be accepted by ordinary users; Moreover, the power grid grade of foreign countries is generally 3KV, while the power grid grade of domestic countries is mostly 6kV and 10kV [4]. There is a problem of power grid grade mismatch when frequency converters are directly imported from abroad. The above reasons correspondingly limit the popularization and application of this kind of system in China. Therefore, it is of great practical significance to develop a high-voltage, large capacity and high-performance frequency conversion speed regulation device with reliable performance and reasonable price and put it into mass production as soon as possible [5]. At the same time, the problem of harmonic pollution of uncontrollable rectifier has been paid more and more attention [6]. The application of PWM rectifier to solve harmonic pollution has been widely recognized.

In view of the above problems, this system designs an experimental system with TMS320F28335 as the control core, and makes an experimental study on the control of Dual PWM Variable frequency speed regulation system.

2. Overall system design

The hardware of the experimental platform of the three-phase PWM frequency converter system is composed of two parts: the main circuit and the control circuit. As shown in Figure 1.

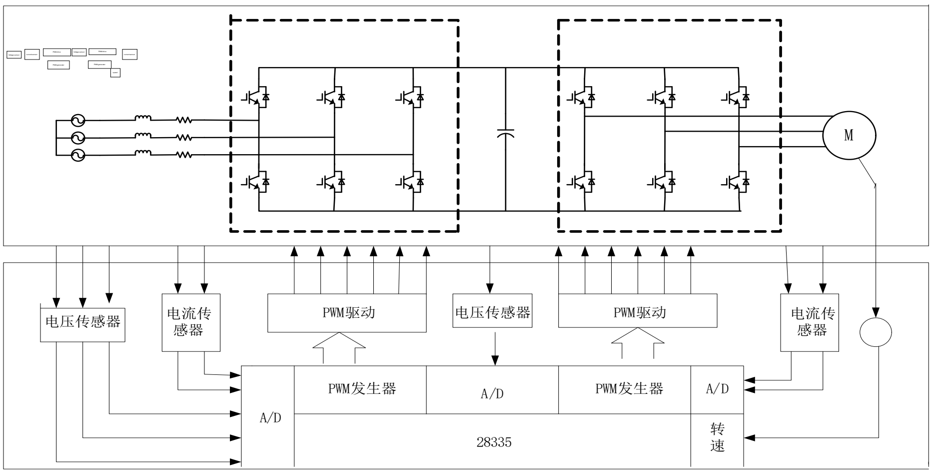

Figure 1. Diagram of the system

3. System hardware circuit design

The system designs the DSP peripheral circuit, ADC interface circuit, code disk interface circuit and level conversion circuit in the control circuit. The key parts are introduced in detail below.

3.1 DSP peripheral circuit

The peripheral circuits of DSP mainly include: power supply circuit, clock circuit, reset circuit, JTAG interface circuit and external storage circuit.

(1) Power circuit

The voltage of I / O pin and programmable flash of TMS320F28335 is 3.3V, while the power supply voltage of the core is 1.9V. Therefore, DSP chip needs 3.3V and 1.9V power supply. Here, the power chip TPS73HD301 specially designed by TI company for DSP control system is adopted. The input voltage of the chip is 5V, and the output is adjustable with fixed 3.3V and 1.2v-9.75v. The maximum output of each channel is 750ma. The output voltage can be adjusted to 1.9V by adjusting the resistance values of R23 and R24.

(2) Clock circuit

The clock frequency of TMS320F28335 is 150MHz, which is obtained by 30MHz external clock signal through PLL frequency doubling inside DSP. 30MHz active crystal oscillator is used here. Compared with the passive crystal oscillator, the active crystal oscillator does not need the internal oscillator of DSP. The signal quality is good and stable. Moreover, the connection mode is relatively simple and does not need complex configuration circuit.

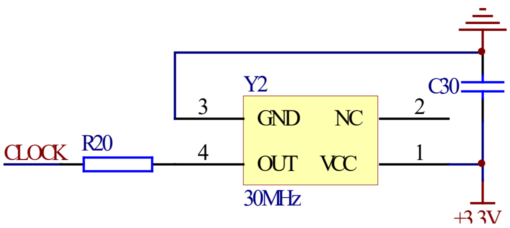

Figure 2. Clock circuit

(3) Reset circuit

In order to prevent the system from crashing, the circuit needs to be reset manually. When the reset button is pressed, a low-level pulse will be generated and sent to the reset pin of DSP. Here, the reset chip sp708r is used. Compared with the conventional reset circuit, the reset chip has higher reliability and simpler circuit. The reset circuit is shown in Figure 3.

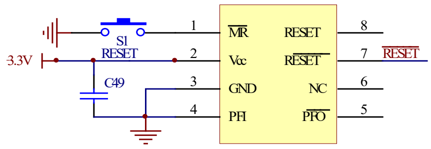

Figure 3. DSP Reset circuit

(4) JTAG interface circuit

TMS320F28335 is connected with the simulator through the standard 14 pin JTAG interface, and the simulator is connected with PC through USB cable, so as to realize the online programming and debugging of DSP. Therefore, JTAG interface is essential in the control system.

(5) External storage circuit

The control system needs to save a large number of parameters, such as motor nameplate parameters, PI regulator parameters, fault codes, etc. Considering that the I / O port voltage of DSP is 3.3V, the 3.3V EEPROM chip 24wc256 is selected. DSP reads and writes 24wc256 through I2C bus.

3.2 ADC interface circuit

In order to realize the VF control of three-level inverter, it is necessary to detect the DC bus voltage and the phase current of asynchronous motor. For the ADC module of TMS320F28335, the input range of analog quantity is 0-3v, and the output values of voltage and current sensors are often not within this voltage range. Therefore, it is necessary to design ADC interface circuit to quantify the voltage value detected by the sensor, Meet the requirements of TMS320F28335 for analog input.

The voltage detection interface circuit is shown in Figure 4.

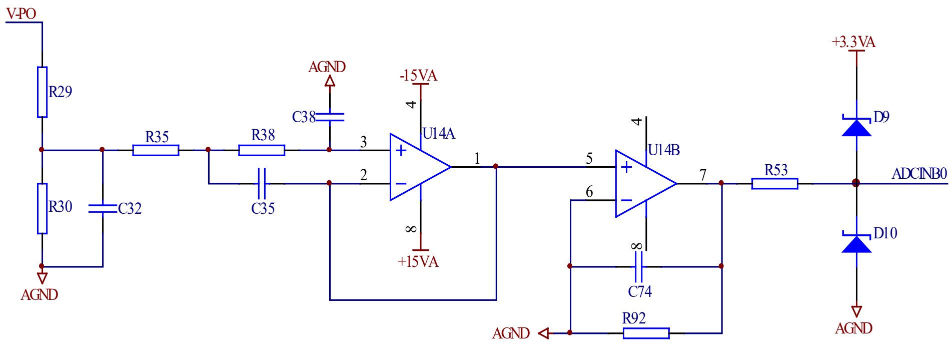

Figure 4. Voltage detection circuit

As V_{PO} for example, the voltage value of the voltage measurement value is adjusted through R29 and R30 partial voltage; Filter the measured voltage through the active filter circuit composed of R35, R38, C35, C38 and u14a; Adjust the output resistance through c74, R92 and u14b; The analog input is limited by zener diodes D9 and D10 to prevent the input voltage from being too large and burning out the ADC module of DSP.

4. Software design of system

The control algorithm of the system adopts VF control. VF control refers to keeping the ratio of voltage and frequency unchanged in the speed regulation process, that is, changing the power frequency while ensuring the constant stator flux of the motor.

The effective value of induced electromotive force of stator winding of AC asynchronous motor is:

$$E = kf\phi \approx U \tag{1}$$

Where, k is the constant, ϕ is the stator flux, U is the stator voltage, f is the frequency, and E is the induced potential.

During variable frequency speed regulation, when U remains unchanged, if f decreases and ϕ increases, it will cause magnetic flux saturation, current waveform distortion, weaken electromagnetic torque and affect mechanical characteristics. If f increases and ϕ decreases, it will lead to the decrease of load capacity. Therefore, while changing f, change U and keep $U / f = k\phi$ constant. At the same time, the stator voltage drop at low voltage shall also be considered.

Because VF control has the advantages of simple software and hardware implementation and reasonable cost performance, it has been widely used in AC speed regulation.

The modulation algorithm adopts SVPWM control. The core of the algorithm is to ensure that the running track of voltage space vector (three-phase stator voltage vector sum) is circular, and produce output with less harmonic content and high DC bus voltage utilization. According to the volt second balance principle, the required reference voltage space vector can be obtained by using the basic voltage vector and sequence combination determined by the eight switching states of the inverter power switch and the adjustment of the on time of the switch, so as to realize the variable frequency speed regulation of the AC motor. This design is based on the basic algorithm. The SVPWM algorithm of eliminating even harmonics is adopted, and good results are obtained.

Based on VF control mode and SVPWM algorithm, this paper designs a frequency conversion speed regulation scheme of three-phase asynchronous motor realized by TMS320F28335.

The algorithm block diagram is shown in Figure 5.

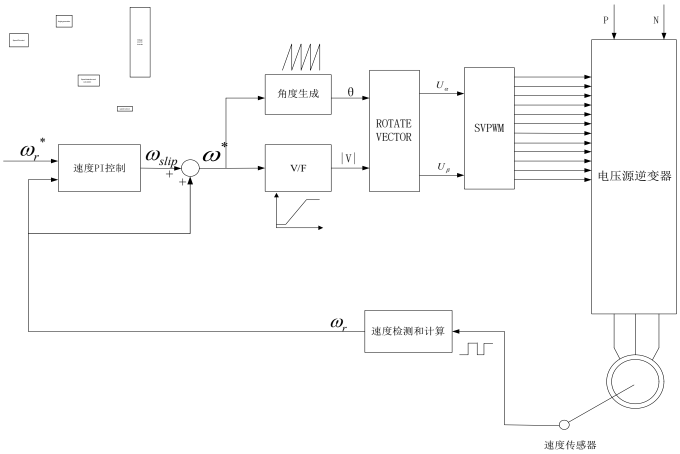

Figure 5. Block diagram of VF control system

The MATLAB simulation results under no-load condition are shown in the figure below. The given speed is 900rpm, which are speed and current waveforms respectively:

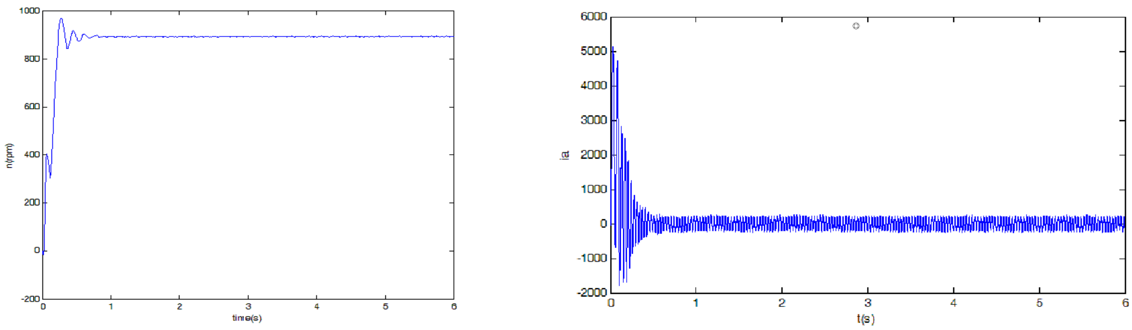

Figure 6. (a) Asynchronous motor speed; (b) A phase current

The simulation results show that the motor has good dynamic response and stable operation. The feasibility of the algorithm is verified theoretically.

The rectifier side adopts voltage-oriented control, which is similar to the vector control mode of asynchronous motor. The synchronous rotation coordinate system is oriented on the grid voltage vector, and the unit power factor operation of PWM rectifier is realized by controlling the current vector and grid voltage vector in the same direction.

In the program flow of this design, the state of the motor is divided into four states: system idle, system start, system operation and system stop. The interrupt system adopts epwm interrupt and timer interrupt, which will not be repeated here. The following only takes the main program as an example.

In order to verify the control system strategy, the experimental platform of Dual PWM frequency converter as shown in the figure is built.

SVPWM modulation algorithm is the basis of variable frequency control system. The improved three-level SVPWM algorithm has been verified by Simulink. In order to further verify the algorithm, the SVPWM algorithm is tested on the experimental platform with DSP as the control core.

It is found that the waveform of the harmonic current detected in the given frequency of the motor is the same as the waveform of the current detected in the given frequency of the ADC, as shown in the oscillograph, and the waveform of the current detected in the given frequency of the motor can be analyzed through the oscillograph. It is found that the harmonic phase of the motor can be detected by the oscillograph.

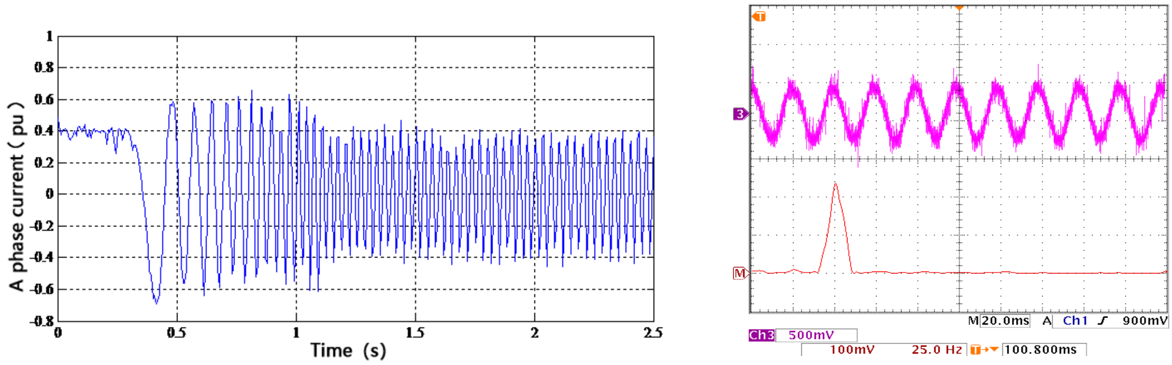

Figure 7. current waveform and FFT analysis

The speed waveform under no-load is as follows, which is consistent with the simulation results and has good dynamic performance.

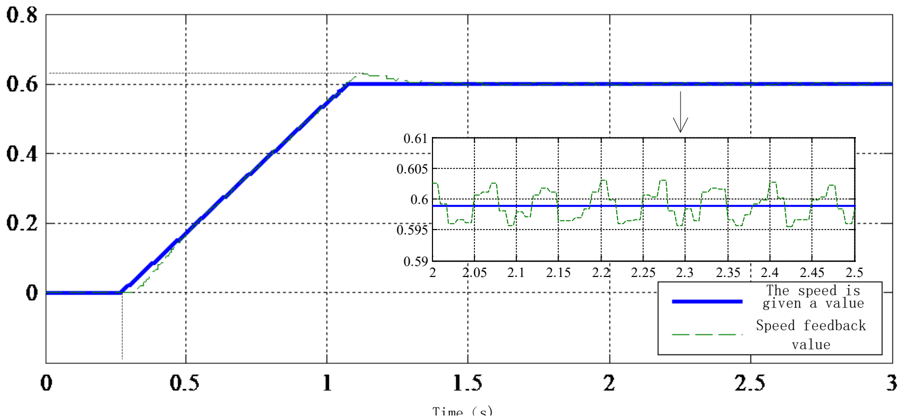

Figure 8. speed waveforms

5. Conclusions

To sum up, this design develops a hardware control circuit with TMS320F28335 of TI company as the core, and on this basis, an experimental platform of Dual PWM frequency converter is built. On the platform, the SVPWM algorithm described above is tested, and the correctness of SVPWM algorithm can be further verified through the experimental waveform; The VF control system is experimentally studied. The no-load experiment of the motor shows that the control system realizes the integrated frequency conversion control of asynchronous motor and has good dynamic performance.

Acknowledgements

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