Design of Control Circuit and Control Strategy of Permanent Magnet Synchronous Motor Based On HT32

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Abstract. This article uses the HT32F1765 single-chip microcomputer introduced by Taiwan's Holtek company as the control core of the system to explore the design of the control circuit and control strategy of the permanent magnet synchronous motor. The main circuit part is the AC-DC-AC frequency conversion main circuit composed of rectification, filtering, inverter, etc., and the control part adopts the regular sampling method to generate spwm waves for control. Finally, the HT32F1765 is used to realize the frequency conversion speed control of the permanent magnet synchronous circuit.

Keywords: Variable Frequency Speed Regulation, Permanent Magnet Synchronous Motor, Digital, SPWM Wave, Three-Phase Bridge Inverter

1. Introduction
With the development of power electronic device manufacturing technology and computer technology, modern control theory is gradually applied to AC speed regulation system. With the development and popularization of microcomputers and large-scale integrated circuits, AC speed regulation technology is gradually moving towards high frequency and intelligence. [1] In recent years, various types of high-performance microprocessors and microcontrollers have achieved considerable development, and the replacement of traditional analog control by digital control technology is bound to be the future trend. At present, the microcontrollers commonly used in electric drives include: single-chip microcomputer (SCM), digital signal processor (DSP), advanced application-specific integrated circuit (ASIC) with microprocessor, and so on. [2-3]

The HT32F1755/1765/2755 series Holtek MCU is a 32-bit high-performance low-power MCU based on the ARM® CortexTM-M3 processor core. This design is based on Holtek’s HT32F1765 single-chip microcomputer, which combines motor control theory, power electronics technology and micro-control technology to design and research the AC variable frequency speed regulation system of permanent magnet synchronous motors.

2. Design
The frequency conversion speed regulation system of permanent magnet synchronous motor designed by this scheme uses Holtek’s HT32F1765 microcontroller as the control core to realize the frequency
conversion control of permanent magnet synchronous motor. The hardware circuit of the entire control system includes a power supply module, a controller module, and a power control module. [4-6]The specific structure diagram is shown in Fig.1:

![System block diagram design](image)

**Fig 1. System block diagram design**

The main circuit part of the middle is rectifier, filter, inverter, etc. which constitute the main circuit of AC-DC-AC frequency conversion. In this design, the rectification part adopts full-bridge uncontrollable rectification. The filtering link uses a π-type filter composed of capacitors and inductors, and filters of different orders are selected according to the size of the waveform ripple. Adopt high-power period IGBT to form a three-phase bridge inverter circuit.

Its main function is to use an uncontrollable bridge rectifier module to convert AC to DC, and then use the large capacitor in the π-type filter to first convert the pulsating DC into a DC with a smaller ripple. The inductance in the π-type filter can be very good. Improve the ripple coefficient, and finally generate a three-phase waveform with adjustable voltage and frequency through the IGBT inverter circuit to drive the permanent magnet synchronous motor.

3. The Realization of SPWM Control

The basic principle of sine pulse width modulation (SPWM): compare a set of isosceles triangle waves (carrier waves) with a sine wave. As shown in Figure 2[7], the time when they intersect is used as the time point when the switch tube is turned on and off. When the sine wave value is greater than the carrier, the corresponding switching device is turned on: when the sine wave value is less than the carrier, the corresponding switching device is turned off. [8]

Among them, the frequency and amplitude of the sine wave are controllable. As shown in Fig.2, by changing the frequency of the sine wave, the output frequency of the inverter can be changed, thereby changing the speed of the motor; changing the amplitude of the sine wave also changes the intersection point of the sine wave and the carrier, so that the output pulse sequence The width changes, which in turn changes the output voltage.

![SPWM wave generation](image)

**Fig 2. SPWM wave generation**

SPWM waves can be generated by pure hardware circuits, triangle wave generators, sine wave generators, comparators and other circuits, or they can be directly generated by single-chip microcomputers. In order to reduce interference and simplify the circuit, this article uses a single-chip
microcomputer to directly generate. Among the commonly used methods are: regular sampling, natural sampling, and low-order harmonic elimination. [9-10]

The regular sampling method is a widely used method, its effect is close to the natural sampling method and the low-order harmonic elimination method, and the amount of calculation is relatively small. Although the waveforms obtained by the natural sampling method and the low-order harmonic elimination method are close to the sine wave, the calculation is relatively complicated, so they are not used much in engineering. So this article adopts regular sampling method to generate SPWM wave.

4. Three-Phase Full-Bridge Inverter Circuit Design
Inverter technology (DC/AC) is an important part of power electronics technology. The so-called inverter circuit is a circuit that converts direct current into alternating current. This transformation plays an extremely important role in energy saving, environmental protection, cost reduction, and increase in output. Because the AC-DC-AC inverter can easily invert direct current into alternating current. Therefore, it has significant advantages in terms of the frequency adjustment range and the improvement of the mechanical characteristics of the motor, so it has been widely used.

According to the nature of the DC side power supply, inverter circuits can be divided into the following two types: the DC side is a current source called a current-type inverter circuit, and the DC side is a voltage source called a voltage-type inverter circuit. They are called current source inverter circuits and voltage source inverter circuits, respectively. The current-type inverter circuit is connected with a large inductance on the DC side, the DC current is basically free of pulsation, and the DC loop presents the characteristics of high impedance. The voltage-type inverter circuit is connected with a large capacitor on the DC side, the DC voltage is basically free of pulsation, and the DC loop presents the characteristics of low impedance.

In the three-phase inverter circuit, the most widely used is the three-phase bridge inverter circuit. As shown in Fig.3, it is a voltage-type inverter circuit that uses IGBTs as switching devices.

![Three-phase inverter circuit](image)

**Fig 3. Three-phase inverter circuit**

The inverter circuit of this design uses a three-phase full-control bridge circuit composed of IGBTs. The circuit principle is shown in Figure 2.9. IGBT is a composite power electronic device that appeared in the 1980s. It has the characteristics of high withstand voltage, large current, high switching frequency, and low control power. Therefore, this design uses IGBT.

IGBT parameters are as follows:
The forward and reverse peak voltage of IGBT is:

\[ U_m = \sqrt{2} \times 380 = 537 \text{V} \]  

(1)

Taking into account the safety factor of 2 to 3 times, the withstand voltage value is 1200V. Peak on-state current:

\[ I_m = 2\sqrt{2}I_N = 2\sqrt{2} \times 5 = 14.2 \text{A} \]  

(2)
Considering the safety factor of 1.5-2 times, the current rating is 24A.

The calculation of withstand voltage and freewheeling of the freewheeling diode is the same as above. Considering the market supply, the actually selected IGBT model is G4PH50UD, and its rated operating parameters are: 24A/1200V. [11]

5. Inverter Control Strategy Design
To consider the design of the control strategy, the conduction mode of the voltage-type three-phase inverter bridge must first be explored. The characteristics of the bridge inverter are: when it is turned on, the upper and lower 180 degrees, the total 360 degrees conduction, the left and right total conduction 360 degrees, to ensure that the upper and lower left, right, and left sides are all 360 degrees conduction, that is, the amount of sine is exactly one week. The three-phase inverter is 120 degrees left and right conduction.

It can be seen that at any instant, three bridge arms will be turned on at the same time. At a certain moment, it may be that the upper pipe and the lower two pipes are conducting at the same time, or it may be that the upper two pipes and the lower pipe are conducting at the same time. Because in each commutation, it is carried out between the upper and lower bridge arms of the same phase. Therefore, it is also called longitudinal commutation.

The characteristic of three-phase alternating current is that the voltage phase of the three phases is 120 degrees different from each other, the second phase is 120 degrees behind the first phase, and the third phase is 120 degrees ahead of the first phase. Converted to the cycle is leading or lagging T/3.

Combining Figure 3, the turn-on phase sequence can be obtained as:
- The first T/6: V1, V6, and V5 are open, and V4, V3, and V2 are closed;
- The second T/6: V1, V6, and V2 are open, and V4, V3, and V5 are closed;
- The third T/6: V1, V3, and V2 are open, and V4, V6, and V5 are closed;
- The fourth T/6: V4, V3, V2 are open, V1, V6, V5 are closed;
- The fifth T/6: V4, V3, V5 are open, V1, V6, V2 are closed;
- Sixth T/6: V4, V6, V5 are open, V1, V3, V2 are closed;

The following analyzes the working waveform of the inverter circuit:
- For phase A, when V1 is open, \( UA0=1/2Ud \); When V4 is open, \( UA0=-1/2Ud \);
- Therefore, the waveform of \( UA0 \) is a rectangular wave, and its amplitude is \( 1/2Ud \). The output waveforms of Phase B and Phase C are similar to Phase A, except that they differ in phase by 120 degrees.

6. Summary
Frequency conversion speed regulation technology, as an ideal power-saving speed regulation technology recognized in the world, has penetrated into various fields of the national economy. The high-energy low-consumption permanent magnet synchronous motor frequency conversion speed regulation system has a considerable effect on the development of the national economy, and it will also be the development direction of the entire electric drive field.

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