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Brushless DC Motor Control System Design Based on DSP2812

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Abstract. By comparison various control methods currently for permanent magnet brushless DC motor, on the basis of motor principle analysis, a current smallest and most real-time all-digital rare earth permanent magnet brushless DC motor control system is designed. The high-speed digital signal processor DSP2812 is applied as the main control unit. The fuzzy PID control algorithm is used to control rectifier regulator and speed, which the speed and current is double closed loop in the system. The principle of control system, control strategy and software is analyzed in this paper. The system has some features such as less overshoot, rapid response speed, good performance of anti-jamming, simple structure, high control precision, flexible in changing control policies and so on. Validity of the design is verified by prototype test.

1 Introduction

Permanent magnet brushless DC motor is a superior speed performance, simple structure, reliable operation, easy maintenance electromechanical integration motor. It is now widely used in servo control, medical equipment, instrumentation, robotics, household appliances, computers and military and other fields [1].

In general, there are three kinds of permanent magnet brushless DC motor control method currently such as the utilize of ASIC controller chip, on the basis of the series single-chip microcomputer control and applying the high-performance digital signal processor control. The control system constituted by ASIC controller chip is simple, low cost. Bur since the IC control chip can complete all the work from the position detection decoding to the PWM modulation output in the hardware, the system functions can not be further expanded. In most cases SCM control system is applied. However, from the two aspects: the working speed and accuracy, brushless DC motor control system based on the general SCM could not be compared with high-performance digital signal processor. Rather than to obtain approximate results by look-up table method, rapid DSP computing capability enables the digital control system to calculate in real time. The internal structure of control system can achieve more complex control algorithms, so that the speed loop and current loop can be implemented in digital form, and a full digital brushless DC motor control system is achieved.

In this paper, the control scheme based on the DSP2812 brushless DC motor is presented Current and speed double closed-loop control strategy is used to achieve precise control for whole system.

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This paper is organized as follows. Section 2 describes the constitute of the driving system. In Section 3 and 4, we describe the motor mathematical model and electric running control analysis respectively. Section 5 describes software implementation. This leads to a concrete parameter selection which can guarantee normal and safety operation of the system. We conclude the section by a detailed prototype test.

2 Constitute of the driving system

The system block diagram is shown in Figure1.The DSP is mainly responsible for receiving circuit feedback signal from current sensors and position sensors, and sending control commands to produce motor drive signals [2].The pulse signal of rotor position sensor is captured by capturing unit to determine the rotor position, And then appropriate driver logic level is outputted to drive control chip, and the motor is driven to rotate by the MOSFET. After the pulse signal from position sensor is captured by the controller, the current speed of the motor is calculated, and the motor speed is controlled to follow the set speed by control program. The motor current is gathered by controller with A/D and current detection circuit. Motor current is control by PID operation. Once having abnormal conditions such as overload, low voltage drive timing and so on, fault protection can be realized by driver protection circuit.

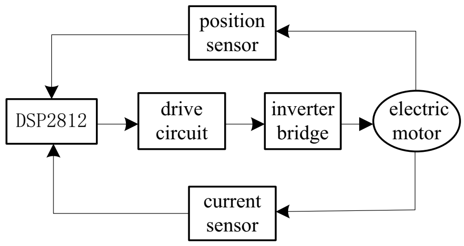

Figure 1. System Block Diagram

3 Motor mathematical model

Suppose that the motor phase winding is completely symmetrical, and that the air-gap magnetic field EMF waveform is greater than 120 degrees trapezoidal wave, the self and mutual inductances of the motor windings can be considered constant, and the motor equivalent circuit can be described as Figure 2. Where u_A , u_B , u_C are A , B , C phase winding terminal voltage respectively; e_A , e_B , e_C are A , B , C phase winding back potential respectively; R is a phase resistance; And L-M is a phase winding equivalent inductance.

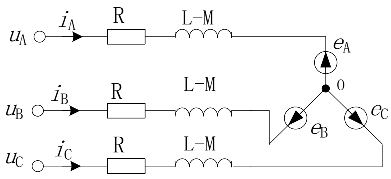

Figure 2. Equivalent circuit of motor

The voltage balance equation of the motor equivalent circuit can be expressed as

$$\begin{bmatrix} u_A \\ u_B \\ u_C \end{bmatrix} = \begin{bmatrix} \mathrm{R} & 0 & 0 \\ 0 & \mathrm{R} & 0 \\ 0 & 0 & \mathrm{R} \end{bmatrix} \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} + \begin{bmatrix} \mathrm{L-M} & 0 & 0 \\ 0 & \mathrm{L-M} & 0 \\ 0 & 0 & \mathrm{L-M} \end{bmatrix} p \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} + \begin{bmatrix} e_A \\ e_B \\ e_C \end{bmatrix} \tag{1}$$

And

$$i_A + i_B + i_C = 0 \tag{2}$$

Electromagnetic torque is

$$\mathrm{T} = \frac{1}{\omega}(e_A i_A + e_B i_B + e_C i_C) \tag{3}$$

p is a differential operator (d/dt) in the formula (1). ω is the rotor mechanical angular velocity in the formula (3).

4 Electric running control analysis

The speed and current double closed-loop PID control is achieved by software system. The PID control algorithm is the incremental control algorithm. The adjustment process is a new current pulse width modulation (PWM) signal generating process, and adjusting the width of the PWM signal can adjust the average current.

Two-phase conduction six states control method is used in electric running inverter bridge circuit. At any time, only upper and lower two power switch is turned on which are belong to different bridge arms. Speed is controlled through the lower bridge arm power switch working on PWM state. Control signal waveform of six power tubes is shown in Figure 3.

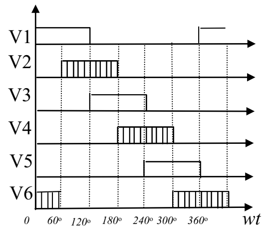

Figure 3. The control signal wave form of electromotor

For example, when the power switch V1 in the inverter bridge circuit upper bridge arm and the power switch V2 in the lower bridge arm are on conductive magnetic state, working circuit is positive battery terminal→ V1 → A phase winding → C phase winding → V2 →negative battery terminal. Ignoring the pressure drop of conducting pipe, the electric running equivalent circuit of the magnetic state is shown in Figure4, according to Kirchhoff's voltage law, combined with the formula (1), the loop voltage equation can be obtained

$$u_A - u_C = (\mathrm{L-M})\frac{d}{dt}(i_A - i_C) + R((i_A - i_C) + (\mathrm{e}_A - e_C) \tag{4}$$

Let

$i = i_A = -i_C$;

$u_A - u_C = U$ is battery voltage;

$\mathrm{e}_A - e_C = E$ is the phase potential when trapezoidal wave gap magnetic field waveform flat top width is greater than 120°.

According to the three elements method, we can obtain

$$i_{(\infty)} = \frac{U - 2E}{2R} \tag{5}$$

$$\tau = \frac{\mathrm{L-M}}{R} \tag{6}$$

Let $i_{(0+)} = i_0$, with formula (5) and (6), circuit current can be obtained

$$i = \frac{U-2E}{2R} + (i_0 - \frac{U-2E}{2R})e^{-tR/\mathrm{L-M}} \tag{7}$$

Electromagnetic torque of the motor is

$$\mathrm{T} = \frac{1}{\omega}(e_A i_A + e_C i_C) = \frac{2Ei}{w} \tag{8}$$

PWM can be conducted by V2, then average current can be controlled, and thus the average electromagnetic torque can be changed. The magnetic state of electrical angle of 60° is analyzed here, and the other same five magnetic states can be also analyzed in the same way.

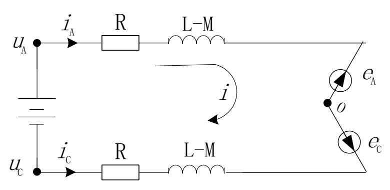

Figure 4. Equivalent circuit of electric running

5 Software implementation

System software consists of two parts which is the main program and interrupt routines. The main program includes system initialization, capture the current position and set the interrupt flag. Program flow chart of main program is shown in Figure 5. Subroutines are mainly position capture interrupt subroutine, A/D interrupt service subroutine, the timer interrupt subroutine, fault protection interrupt subroutine. The motor commutation and current loop adjustment is the core components of software.

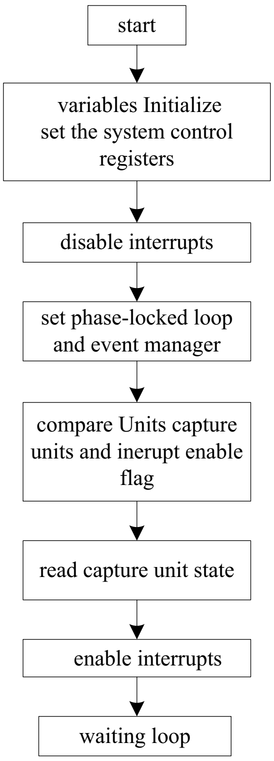

Figure 5. Program flow chart of main program

5.1 Position capture interrupt subroutine

The rotor position signal is required to timely, accurate detected by control systems. And then the corresponding output state of the PWM circuit is determined. It can ensure that the motor stator windings commutate in real time and precise in real time and accurately. Therefore, using the capture interrupt mode, we can get the position signal. Program flow chart of position capture interrupt subroutine is shown in Figure 6.

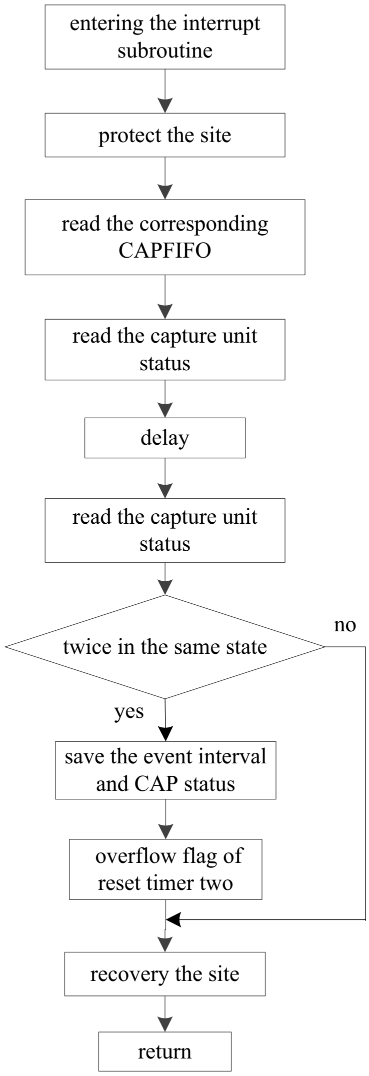

Figure 6. Program flow chart of position capture interrupt subroutine

5.2 A/D interrupt subroutine

In the A/D converter interrupt service routine, the first step is to adjust subroutine using the speed loop PI. A new current reference value by speed adjustment is used to adjust the current ring. Program flow char of A /D interrupt subroutine is shown in Figure 7.

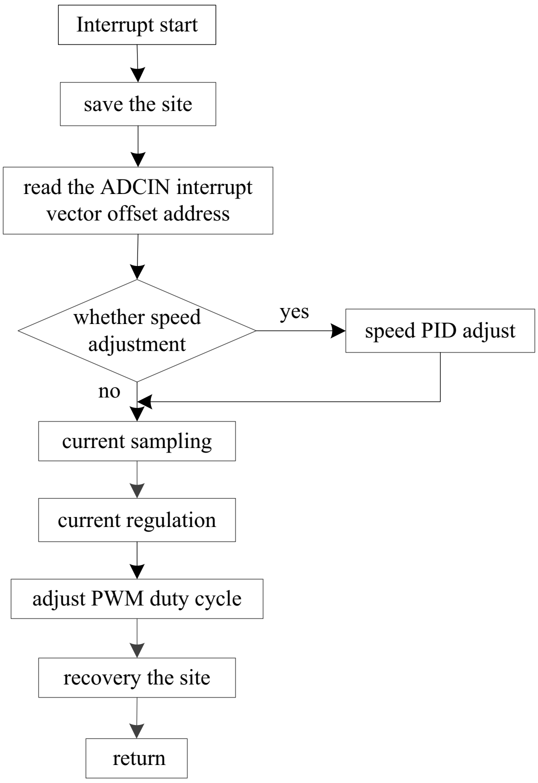

Figure 7. Program flow char of A/D interrupt subroutine

6 Results

The experiment of whole system is conducted, which is used the brushless DC motor controller designed in this paper combined with rare earth permanent magnet motor body. The measured results are as follows:
Rated voltage: 220V (AC)
Rated power: 200W
Rated torque: 2Nm
Overload multiples: 2.0
Base speed: 900r / min
Speed ratio: 1:10
Maximum system efficiency: 86% (motor and controller)

7 Conclusion

The brushless DC motor control system based on DSP2812 have some features such as simple structure, small in size, high precision control, flexible in changing control policies. Feasibility of the design is verified by prototype test.

Acknowledgments

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