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Study on Direct Torque Control of Three Phase Asynchronous Motor

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Abstract. Based on the basic principle of the direct torque control of three phase asynchronous motor, this paper analyzes its mathematical model by using the method of space vector, and establishes the basic structure of the direct torque control of asynchronous motor. The direct torque control system is realized by combining the two aspects of hardware and software with the special digital processor (TMS320LF2407) of motor control. When the rated speed of motor is more than 30%, the current waveform of the system is obtained. It can be seen that under steady state, the current waveform of the system is sinusoidal, and the current fluctuates little.

Introduction

Three phase asynchronous motor direct torque control technology[1] is another High-Performance AC speed regulation technology developed after vector control. It uses space vector analysis method to directly control the electromagnetic torque and stator flux of the motor. Using the stator magnetic field orientation, the pulse width control signal is generated by the discrete torque two point regulation, and the switching state of the inverter is controlled directly in order to obtain the high dynamic performance of the torque. It has the advantages of novel control idea, simple control structure, direct control means and less reliance on internal parameters of motor. Direct torque control technology has attracted wide attention in AC drive control field. The direct torque control system of three-phase asynchronous motor is studied in this paper.

The Realization of Direct Torque Control

The Principle of Direct Torque Control. The direct torque control[2] is adopted to control the asynchronous motor, and the equivalent circuit of its space vector is shown in Fig. 1.

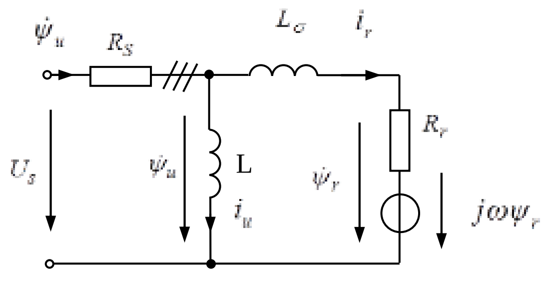

Fig. 1 Space vector equivalent circuit diagram of asynchronous motor

This circuit is used to describe asynchronous motor under orthogonal stator coordinate system (alpha - beta coordinate system). Its various meanings are as follows:

$u_s(t)$—Stator voltage space vector

$i_s(t)$—Stator current space vector

$i_r(t)$—Rotor current space vector

$\psi_u(t)$—Stator flux space vector

$\psi_r(t)$ —Rotor flux space vector

ω—Electric angular velocity (the product of mechanical angular velocity and polar logarithm)

It is also stipulated that the projection of the rotation space vector on the alpha axis is called the alpha component, and the projection on the orthogonal beta axis is called the beta component. As a result, the following basic formulas can be obtained.

$$u_s = R_s i_s + \dot{\psi}_u \tag{1}$$

$$0 = R_r i_r - \dot{\psi}_r + j\omega\psi_r \tag{2}$$

$$\psi_u = L i_u \tag{3}$$

$$\psi_r = \psi_u - L_\sigma i_r \tag{4}$$

Based on the above basic formula and considering the power provided by the rotating magnetic field, the formula of torque can be obtained.

$$T_d = \frac{3}{2}(\psi_{u\alpha} i_{s\beta} - \psi_{u\beta} i_{s\alpha}) = \frac{1}{L_\sigma}\frac{3}{2}|\psi_u||\psi_r|\sin\theta \tag{5}$$

θ： the angle between the rotor flux and the stator flux, that is,Magnetic flux angle.

In the actual operation of the motor, the amplitude of the stator flux is kept to the rated value to make full use of its core. The amplitude of the rotor flux is determined by the load,The torque of the motor can be changed by changing the magnetic flux angle. In the direct torque control system, the rotation speed of the stator flux is controlled by the voltage space vector, so the average rotation speed of the stator flux is changed and the magnetic flux angle is changed to control the torque of the motor. The amount of feedback control required for torque and flux linkage closed-loop control is given by the stator side torque and flux observer model of the motor[3]. In this paper, we use the U-I model to observe the stator flux.

Flux Linkage Observation Model Based on Stator Voltage and Current: U-I Model. According to the space vector equivalent circuit of asynchronous motor, we get the formula of stator flux.

$$\psi_s(t) = \int (u_s(t) - i_s(t)R_s)dt \tag{6}$$

Using the upper form to determine the stator flux linkage of asynchronous motor has an advantage, that is, the stator resistance used in calculation is easy to measure[4].The stator voltage and stator current are also easy to be determined, and the detection accuracy is high enough. Its structure is shown in Fig. 2.

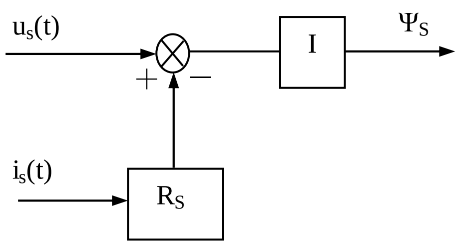

Fig. 2 U-I model of stator flux

When the motor speed is above 30%, the stator flux linkage can be accurately determined by the U-I model, and the structure is simple and robust.

The Basic Composition of Direct Torque Control System. The composition of direct torque control is shown in Fig. 3 [5].

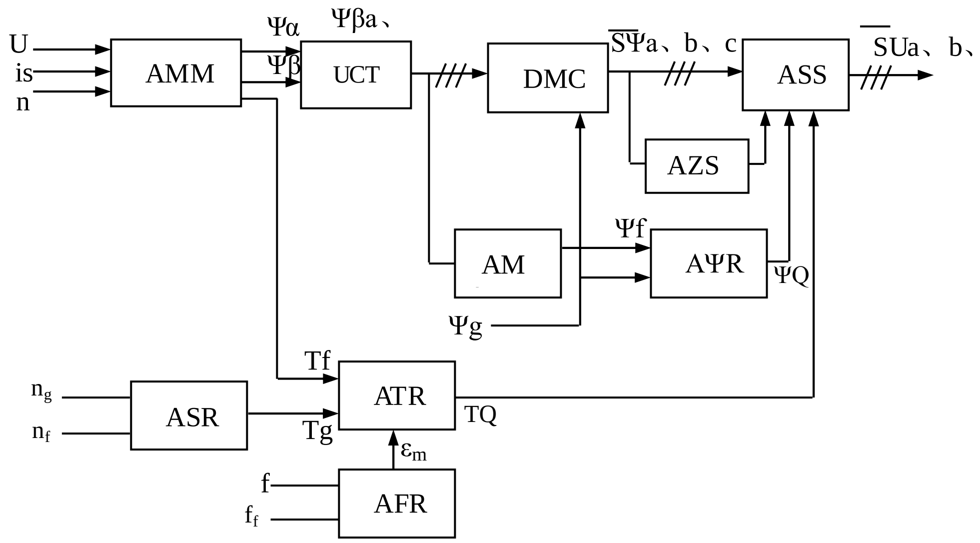

Fig. 3 the basic block diagram of direct torque control

In Figure 3, the meaning of each unit is:
ASS—switch signal selection unit
DMC—magnetic chain self control unit
UCT—coordinate converter
AMM—mathematical model of asynchronous motor
ATR—torque regulator
AΨR—flux regulator
AMA—magnetic chain amplitude component unit
AFR—frequency regulator
ASR—speed regulator
AZS—zero state selection unit

Research on Test Platform Based on DSP

Direct torque control system requires high speed and real-time processing, so the core processing device has high requirements[6]. In order to meet the demand of large computation and high computing speed, and to realize the control of motor speed control,the TMS320LF2407 chip is selected in this paper[7]. The chip is a digital microcontroller for a new generation of motor control. The DSP kernel integrates its high speed operation performance and the ability of high efficiency control for the motor. It creates favorable conditions for the high performance and full digital motor control with DSP as the core.

As the core of the whole control system, TMS320LF2407 chip has powerful on-chip I/O and other peripherals[8]. The event manager in LF2407 is very unique compared with other DSP. It is a peripheral unit optimized for motor control. Four independent up-down/down counting timer, each has its corresponding comparison register, supporting asymmetric PWM waveform, symmetric PWM waveform, and the generation of SVPWM waveform.

Peripherals of TMS320LF2407. (a) PWM output circuit**.** The PWM output circuit consists of a space vector PWM circuit, a dead zone generation unit and a pulse width modulation circuit.The combination of pulse width modulation circuit and full comparison unit can produce six way PWM output with programmable dead time and output polarity.

When the comparison register value is matched with the timer count, the PWM generating unit is triggered. For the SVPWM, the T1CON[11-13] can produce a symmetrical waveform, and the six way control signal is synthesized with the SVPWM controller, then the dead time processing unit is passed, and the actual 6 PWM signal is obtained according to the output level control.

(b)Analog to digital conversion module (ADC)

TMS320LF2407 has two relatively independent ADC modules with a minimum conversion time of 500ns[9]. Each circuit has a circuit of a set of sampling and holding circuits and 8 analog input signals, which can input a total of 16 analog signals.Two ADC modules can work at the same time, that is to say, two analog signals can be converted at the same time, or single conversion or continuous conversion mode. The conversion boot can be triggered by software, internal events, and / or external events, with a two level conversion result register, which can store two continuous conversion results. The two programmable ADC module control registers support interrupt / query operation.

In application, it must be noted that the sampling signal voltage of the ADC input pin must meet the input voltage range (0 to 3.3V), and the maximum can not exceed 3.9V, otherwise the ADC module will be damaged.

(c) serial interface module（SCI、SPI）

The serial interface includes serial communication interface (SCI) module and serial peripheral interface module (SPI). The SCI module supports digital communication between CPU and other asynchronous peripherals using standard non return zero (NRZ) formats. In order to ensure data integrity, SCI checks the received data intermittently, parity, timeout, and frame error. SPI module is usually used for communication between DSP controller and external device or another processor[10].

(d) system protection（WD、RTI）

Watchdog (WD) timer and real-time interrupt module (RTI) monitor software and hardware operation. If the software enters an incorrect cycle or CPU has temporary abnormality, WD timer overflow generates a reset. The RTI module provides interruption of programmable interval, and system reset is achieved when CPU is abnormal[11].

The Design of the Hardware Circuit of the Test Platform. In order to verify the effectiveness of the proposed scheme, we designed a test system, and the overall structure diagram of hardware circuit is shown in Fig. 4.

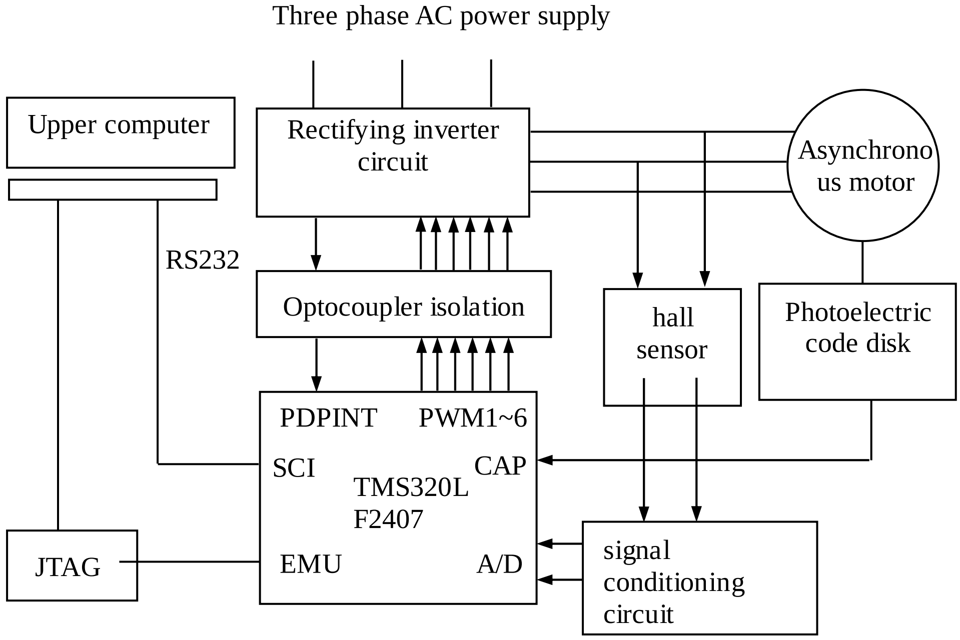

Fig. 4 the overall structure diagram of the system

Software Design of the System. TMS320LF2407 is the central controller of the whole control system. The main functions are: display of motor running state, receive keyboard control, obtain speed information from capture unit, detect stator voltage and current through A/D, complete the calculation of direct torque control and fault interruption protection[12].

The main program flow chart, as shown in Fig. 5, mainly includes the initialization of the variables used, the initialization of each module of the system, the implementation of the algorithm and the control function of the interrupt service subroutine. The flow chart of the direct torque control algorithm is given in Fig.6.

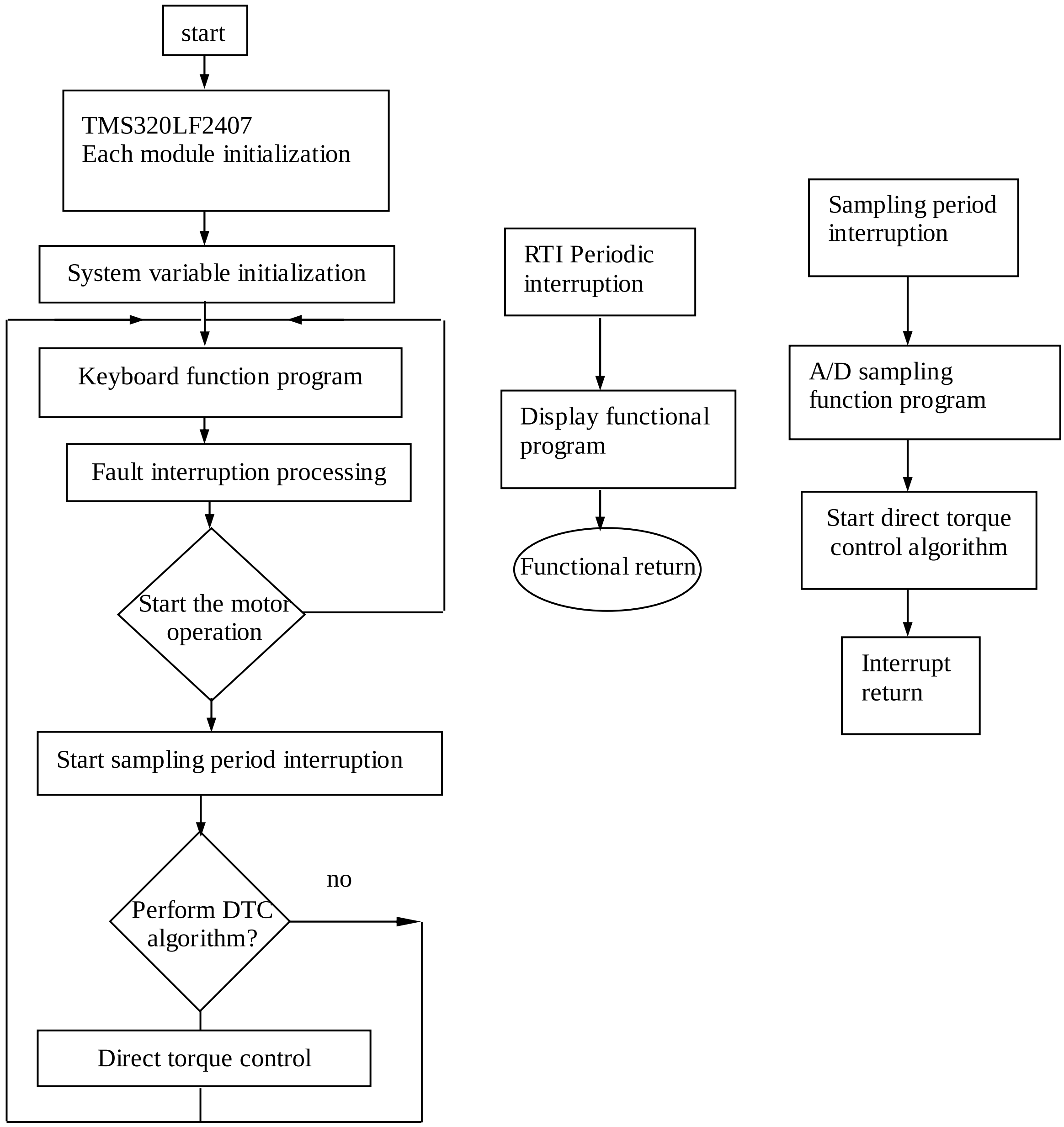

Fig. 5 main program flow chart

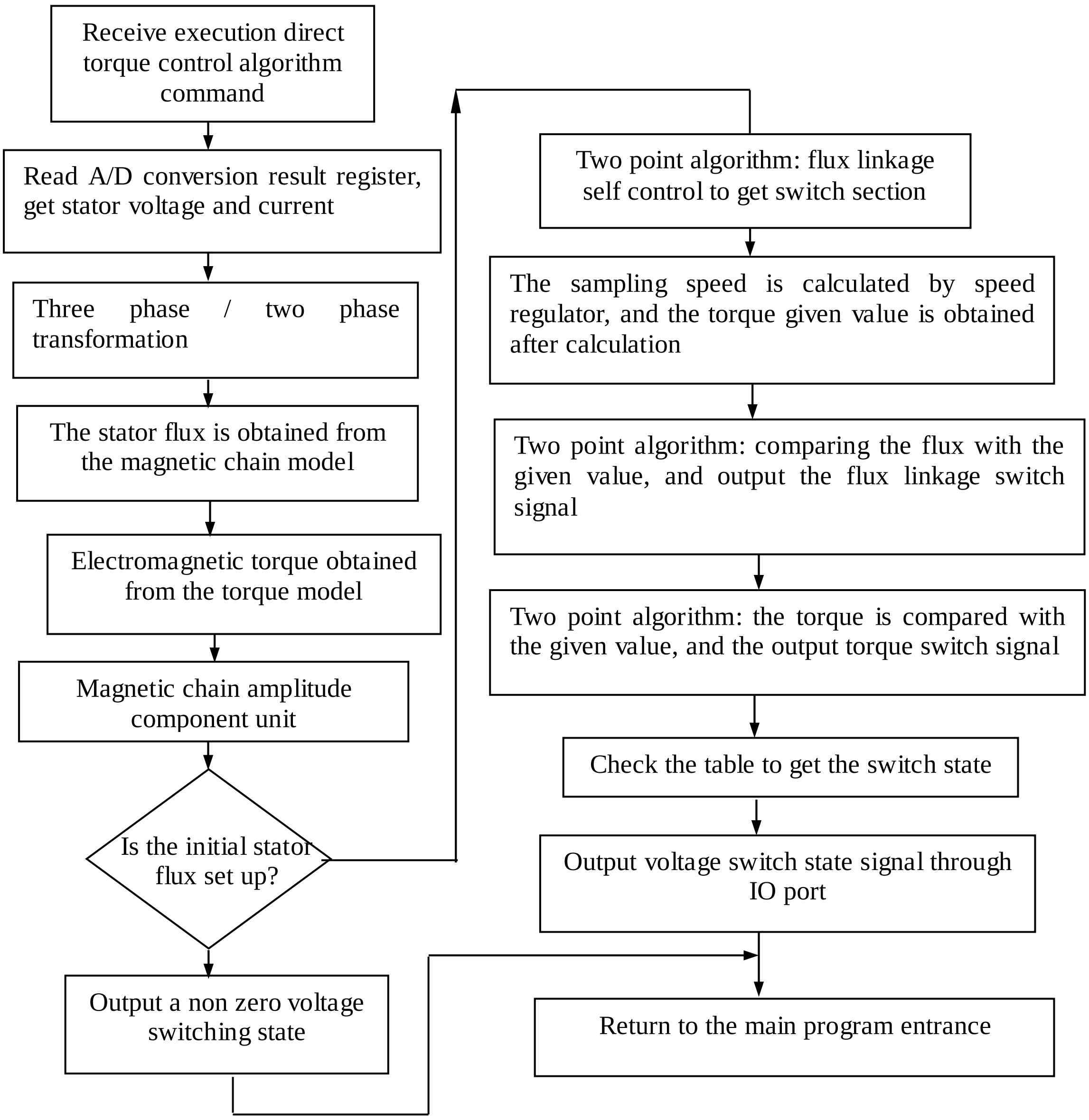

Fig.6 flow chart of direct torque control algorithm

Test Result

Based on the test platform above, when the rated speed of the motor is above 30%， we get the current waveform of the system as shown below.It can be seen that under steady state, the current waveform of the system is sinusoidal, and the current fluctuates little.

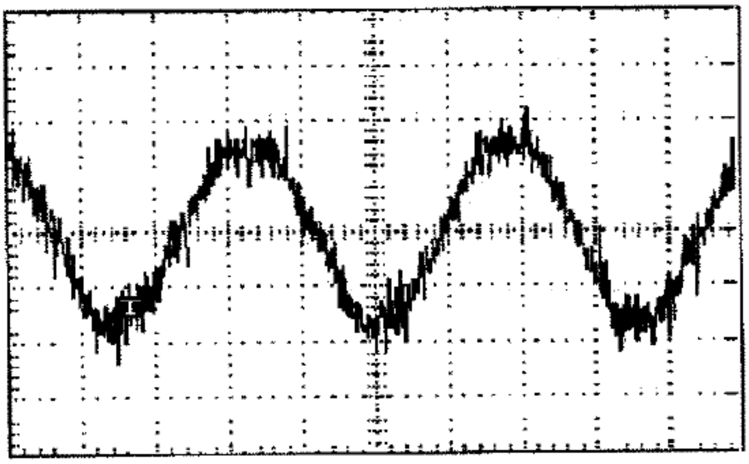

Figure 7 current waveform

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