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**The Vector Control System Design of PMSM Based on DSP Motor Controller**

**Abstract:** A drive vector controller for permanent magnet synchronous motor was researched and designed in this paper. At first, model of PMSM will be introduced and vector control principle and control strategy based on vector control are also determined. According to $dq$ axis coefficient model of permanent magnet synchronous motor, $i_d = 0$ vector control method is applied as the control strategy of permanent magnet synchronous motor to construct a permanent magnet synchronous motor controller model based on vector control. The digital signal processor (DSP) TMS320F28035 made by TI Company is adopted as core of the control system. The controller adopts internal A/D to sampling the voltage and current signal. And using incremental photoelectric encoder and the DSP with enhanced orthogonal coded pulse (EQEP) module measure speed and position. The experimental results show that the control system has the advantages of fast response and stable control effect.

**Keywords:** PMSM, vector controller, DSP, EQEP

1 **Introduction**

In the modern industrial production, the motor and its control system occupies a pivotal position. The development of motor control systems with higher operating accuracy, greater speed range, and shorter regulation times is a popular research area in the field of modern industrial control. The permanent magnet synchronous motor has become the mainstream motor in the industrial servo system because of its excellent characteristics. Therefore, it is more and more important to study the design of the control system of permanent magnet synchronous motor which can meet the requirements of modern industrial control.

The crucial technology of researching electric cars is how to make driving controller to work efficiently and steadily. This project uses TI’s digital signal processor...
(DSP) TMS320F28035 chip as the control core of the system. It combines high-performance DSP cores and rich microcontroller peripheral functions to provide an ideal solution for motor control system applications. It simplifies the design of the system, improves the controller’s real-time processing capability and speed performance, enhances the system’s reliability and integration, and is more perfect.

In the actual production process, it has much difference among the models of the drive motor and different motor solutions are in the research and demonstration process. PMSM has obvious advantages over other types of motors, such as permanent magnet synchronous generators because of its use of permanent magnets instead of the original excitation mechanism which causes the volume reduce.

Due to simple control theory of BLDC [2] motor and the structure of the similar as PMSM, controlling theory of BLDC motor should be mastered in the early stages. The PMSM mode is a nonlinear, multi-variable system with strong coupling [10]. The mathematical model of PMSM is established to understand the basic structure and operation principle of the motor on the basis of vector control. Then the PMSM motor controller running in the analysis, and uses the electronic design automatic (EDA) software design controller schematic. This paper presents design a small-power controller based on TMS320F28035 [4] which is used to verify the correctness of the control algorithm and the feasibility of driving the high power motor scheme.

2 Pmsm Mathematic Model

Permanent magnet synchronous motor is actually an AC motor; the stator operation is a phase difference of the three-phase alternating current, while the rotor is a permanent magnet. The vector control theory can help the AC motor including PMSM to be controlled like a DC motor. The most obvious advantage of this kind of motor is that the AC energy is provided by DC, so that the motor can be precisely controlled and the life of the brush is solved. Through the coordinate transformation, the potential of the armature in the stationary two-phase coordinate system can be decomposed into the straight axis potential and the cross axis. From a mathematical point of view, the coordinate transformation is the original set of variables in the equation with a new set of variables instead. Linear transformation refers to the linear relationship between the old and new variables.

The coordinate transformation used in the motor is a linear transformation [7]. Permanent magnet synchronous motor mathematical model of the establishment, we should first establish the motor reference space coordinates. As with the induction motor, the axis of the sinusoidal magnetic potential wave generated by the forward current flowing through the phase winding is defined as the axis of the phase winding and the A axis is used as the spatial reference coordinate of the ABC shaft [9]. Assuming that the positive direction of the induced electromotive force.
The positive direction of the current opposite; counter clockwise direction for the rotation and electromagnetic torque in the positive direction, the positive direction of the load torque is the opposite. Figure 1 shows the ABC axis spatial reference coordinate system of the motor permanent magnet synchronous motor.

![Fig. 1: ABC reference frame of PMSM](image)

### 3 Hardware Design

The motor control system is given by figure 2 including DSP control circuit, three phase inverter, human-machine interface circuit and detection and protection circuit. The single chip DC/DC conversion integrated circuit Switch DPA made by Power Integrations Company will be adopted as power circuit. Because of the advantages of the TMS320F28035 in controlling motors (TMS320C2XX), this paper chooses TMS320F28035 as main control unit. The DSP control system can generate Corresponding PWM signals to make the motor work normally through sampled phase currents from the inverter [5].
3.1 Power Circuit

Power master chip with DPA425 chip. The DPA425 is a highly integrated DC / DC power control chip designed by PI (Power Integration). It integrates a 200V high frequency power MOSFET and controls PWM control, operating frequency selection, input over voltage detection, programmable current limit, ON / OFF switch control, external clock synchronization, soft start and turn off auto restart, Thermal shutdown protection and other functions set in one. With very few external components can achieve many functions, not only to simplify the design, save space, and can reduce costs. DPA425 support forward and fly back mode, high frequency, chip package; if the external components and transformers using chip components and planar transformers, and the use of aluminum plate design, you can achieve modular design [1].

The main features of the DPA425 are: set 220V high voltage MOSFET and pulse width modulator with one, support forward and fly back mode; built-in automatic restart circuit for the output overload and open circuit protection. Through a pin can be set to 300KHZ or 400KHZ switching frequency and can be input low voltage shutdown protection. By monitoring the voltage drop across the MOSFET on-resistance R, you can achieve over-current protection, eliminating the need for external current detection circuit, the output using synchronous rectifier circuit, power conversion efficiency greater than 90%, with a soft start function [11].
DPA425 composition of the DC converter circuit shown in figure 3, using a single-ended fly back topology, the input voltage range of 36V~72V, the output voltage stabilized at 15V, the maximum output power of 45W, full load power efficiency of up to 80%, while Chip DPA425 operating frequency of 300KHZ. The work flow is as follows: DC voltage through the C1 filter ripple, and then all the way through the transformer T1 primary winding DPA425 internal power MOSFET drain, the other signal by R4, R5 step-down and sent to the DPA425 L feet, Provide start voltage for DPA425. The starting voltage charges the capacitor C3 through the C pin. When the charging reaches a certain threshold voltage, the internal control circuit is activated and the output PWM signal drives the internal power MOSFET to operate.

Fig. 3: Power circuit

3.2 Drive circuit and Three Phase circuit

The PWM current signal from DSP is very small so that cannot drive MOSFET tube directly [3]. The drive circuit must amplify current signal to drive more high power motor. Drive circuit is based on IR2127, which of A-phase is taken as an example shown in figure 4. In order to protect the driver chip will not be returned by the inverter circuit to burn the current, in the drive chip after the increase in the push-pull output circuit, which not only increases the drive capability, but also a good protection of the driver chip.
For the small and medium-power permanent magnet synchronous motor controller, the main circuit is generally used AC-DC-AC voltage converter, the inverter for the six-arm inverter bridge, six switch original anti-parallel freewheeling diode, according to a certain strategy control, Output three-phase AC. This main circuit topology has been proven, reliable performance. When the motor start or have high power output, phase current must be great, and current of MOSFET tubes are up to dozen amps in general. To acquire higher current out, MOSFET tubes must be placed in parallel. Therefore, body diode on the power MOSFET can be mainly to prevent the back-EMF to breakdown MOS tube. Here power MOSFET selects IXFA180, PWM amplifying uses IR2127. Three Phase circuit which of C-phase is taken as an example is shown in Fig 4. Two sampling resistor in the three phase circuit as shown in Figure 4 is mainly to take sampling C-phase voltage to protect MOS tubes to be breakdown. There is a sampling resistance to sense C-phase currents on below bridge arms. The purposes of sensing phase currents is to obtain new PWM duty cycles to drive motor to work as desired.

Fig. 4: Drive circuit

### 3.3 Phase Current Phase Voltage Detection Circuit

Phase current detection circuit is mainly through the detection of the corresponding voltage, according to Ohm’s law in the program to achieve. The signal through the 0-3.3V limiter circuit input to the DSP chip integrated AD [8]. The detected phase current is mainly based on the reference speed to produce the corresponding PWM wave. Phase voltage detection principle and phase current detection principle is similar to its use is mainly to detect whether the phase voltage is too large, the pro-
tection of the circuit. The phase current phase voltage detection circuit is shown as figure 5.

Fig. 5: Detection circuit

### 3.4 Chopper Circuit

As the name suggests chopping means cutting the current pulse peak, to prevent the motor in the start and braking when the current is too large burned MOS tube, so to adjust the current limit. The current chopper circuit first amplifies the measured three-phase current, and then compares the reference value and the input value through the comparator. Then the output signal is input to the DSP chip. The DSP chip outputs the PWM wave according to the signal output. The opening of the tube is closed to the purpose of limiting the current. The chopper circuit is shown as figure 6.

Fig. 6: Chopper circuit

### 4 Test Result Analysis

Because of the drive circuit and three phase inverter circuit are integrated to the main control board, to build an experimental platform, there still need the host
computer and PMSM of 72W. In addition, the main circuit board there are other circuits such as the sampling circuit, communication circuit, photoelectric encoder circuit and the main control chip TMS320F28035 minimum system circuit. Driving signal of the three phase inverter is provided by the main control board which is separated by the six PWM signal. In the early stages of the experiment, the main control board receives a variety of sampling signal through SCI communication from host computer to control switch signal to adjust speed. But the main control board must receive the external voltage signal to achieve the purpose of adjusting speed in the end. Experiment platform assembled is given by figure 7. The software design of the motor control system needs MATLAB simulation to write the relevant code. Then the relevant code needs to be downloading to the TMS320F28035 with the Code composer studio (CCS) compiler. And the type of CCS compiler is XDS v100. There are mainly two module chosen, for example debugged online or flash. After the relevant code is downloading to chip, the output of drive signals may be observed. The output waveform is monitored through an oscilloscope which is TDS 2012.

Fig. 7: The power circuit physical map
5 Conclusion

In this paper, based on the analysis of the characteristics of TI’s high-speed digital signal processor (DSP) TMS320F28035, the permanent magnet synchronous motor servo control system based on the DSP is designed through its special development platform. The controller, power conversion unit and Position detection unit design, and on the basis of the design of a variety of protection circuits. The experimental results show that the control system is stable and reliable and can drive more powerful motor with a number of MOS tube in parallel manner.

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