# Research of the Method for Position Detection of the Rotor in the Interior Permanent Magnet Synchronous Motor

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**Abstract.**The vector control of interior permanent magnet synchronous motor (IPMSM) needs detect the position of rotor. In this paper, the position sensor of IPMSM is rotating transformer and we designed the decoding circuit based on AU6802N1.At last, we measure the rotor position through the control system based on TMS320F28335 and do the test without load to verify the accuracy of the rotor position detection.

## Introduction

The AC servo motor can be modeled as the one with armature winding and excitation winding which rotate synchronously with the rotor by using vector control method. Thus, DC speed control system theory is applied to the control of IPMSM to achieve high-performance control effect[1]. Clark transformation is to convert three-phase static coordinate system to the two-phase one. Park transformation is to convert the two-phase stationary coordinate system into a two-phase rotating coordinate system which is rotating with the magnetic field of the rotor. By Clark and Park two kinds of coordinate transformation, vector control method decouples three-phase ABC axis current to d-axis exciting current and q-axis torque one. The vector control method could equal the AC motor control to the DC one[2].

Park transformation need to use the position angle of the rotor magnetic field, so the premise of the vector control is the exact location of the magnetic field of the rotor. We can obtain this accurate position by installing absolute encoder or Hall element, or it needs to rotate the rotor to a predetermined position at the beginning of starting the motor. Meanwhile, the installation of the position sensor will also generate some problems. That is to say, there is a certain deviations between the position measured by the sensor and the actual position of the rotor[3]. Thus, we need to measure the angle of deviation in the practical application,which is called compensation angle. Based on studying the theory of IPMSM vector control method, the essay describes a method of measuring the compensation angle of the rotor position. In this essay, a decoding circuit of resolver based on AU6802N1 is designed and it could verify the accuracy of the rotor position measurement[4].

## Vector Control Principle

Figure 1 is the vector control system block diagram of a double-loop interior permanent magnet synchronous motor. Wherein we can get the motor speed $n$ by detecting the angle $\theta$ to

differentiate, obtain a given cross-axis current $i_q^*$ by PI calculation after comparing with the given speed $\omega$ and convert the three-phase AC $i_a$ and $i_b$ into the d and q-axis current rotating synchronously with the rotor. Then we obtain the d-axis and q-axis voltage $u_d^*$、$u_q^*$ of the stator in the rotating coordinate system by IP calculating with the given $i_q^*$、$i_d^*$ And then we get Park inverse transformation with these two amounts. So we can get the $\alpha$-axis and $\beta$-axis voltages $u_\alpha^*$ and $u_\beta^*$ of stator in a fixed two-phase coordinate system. However, regarding these two quantities as the inputs which SVPWM desires, six-way output PWM controls six IGBT of the voltage-source inverter to turn on and turn off[5]. In the whole control system, the calculation of motor actual speed and the electrical angles of Park and Park inverse transformation are all the position angles of the rotor which are detecting by the rotor detection circuit. You can see that the accurate measurement of the rotor position is an important part of achieving IPMSM vector controlling.
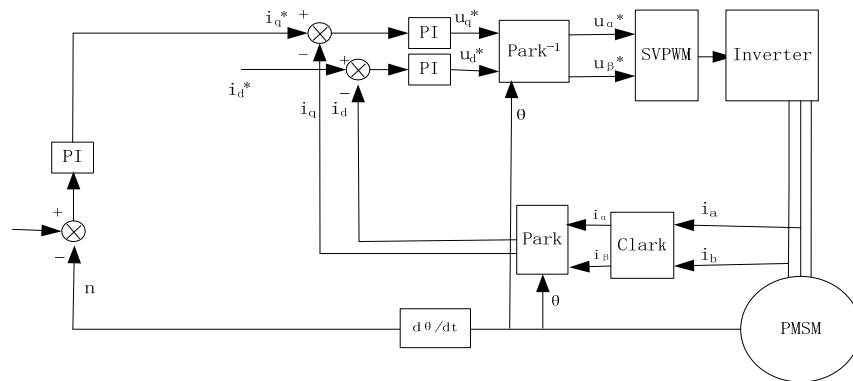


Fig. 1 the vector control system block diagram of a double-loop interior permanent magnet synchronous motor

In this article, we describes a method for measuring the rotor position compensate angle directionally based on the voltage vector, and while we build a rotor position detection circuit through the decoder chip AU6802N1. Using this measurement method, the current sensor doesn't need to work, and the system is also simple and easy to achieve.


**The measurement methods of the rotor position compensation angle**

When measuring the initial position of the IPMSM rotor, we choose mainstream injection. Then by decoding circuit based on AU6802N1, the forced lock shaft method of the motor can decode positive and cosine signals transmitted from the resolver. That is to say, DC injection makes the stators to generate   Magnetomotive force vectors which is set the direction in the coordinate space. This Magnetomotive force vectors can attract the d-axis of the rotor to fix in this direction.

We use a fixed voltage vector method to make the stators of IPMSM to generate Magnetomotive force vector for being forced to set the direction in the coordinate space. So IPMSM operates at a voltage vector state with a fixed angle. This voltage angle needs to be given artificially. Regarding TMS320F28335 as the master chip, this article achieves that this voltage vector with fixed angle can be given in the program. The specific implementation principle is as follows:

From figure 1 we know that the input $u_\alpha^*$、$u_\beta^*$ is obtained by Park inverse transformation, the input of which is $u_d^*$、$u_q^*$. Here we make $u_d^*$=0. Through an external given and considering the limitation DC bus voltage, we give an enough large value. At the same time, set the electrical angle $\theta = \theta_e^{force}$, $\theta_e^{force}$ of Park inverse transformation as the position of d-axis of the current vector which is given artificially. Then the direction of Magnetomotive force vector will be generated

by $\theta_e^{real} = \theta_e^{force} + 90$. Then d –axis of IPMSM rotor will aligned with the direction of this Magnetomotive force vector.

**The design of the decoding circuit based on AU6802N1**

R / D converter chip AU6802N1 is produced by Japanese Tamagawa company. AU6802N1 can easily converse the axis angular displacement signal (analog signal) of the resolver to digital signal required by the control system correspondingly. AU6802N1 owns a variety of standard signal output mode[6]. The serial output mode is used in this article. Figure 2 is the 10k excitation signal interface circuit generated by the dual power. Select R1、R2 as the excitation signal interface of the resolver and $V_{EXT}$ is 15v. The decoding precision of AU6802N1 is selected 12.   Figure 3 is the circuit of resolver output sine and cosine signal input[7] .
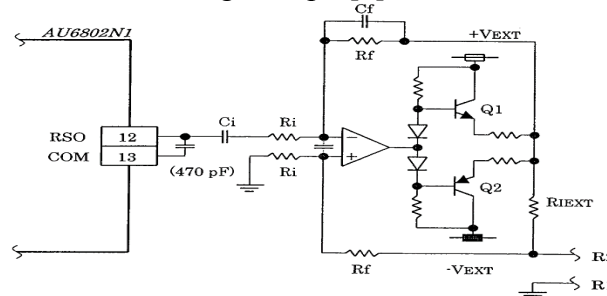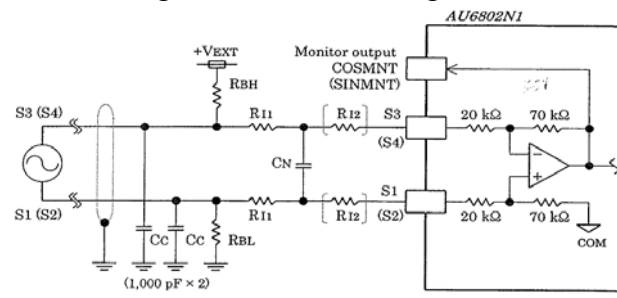


Fig. 2 The excitation signal circuit



Fig. 3 The sine and cosine signal input circuit

**The initial position measurement of the orienting rotor of the voltage vector**

Figure 4 is a motor control system for initial position measurement of the rotor of a permanent magnet synchronous. The digital quantity read by the master chip can be conserved as the electrical angle. And then compare the result which 90 degrees is plus in the given coordinate transformation electrical angle with this electrical angle to get the compensation angle at the last.
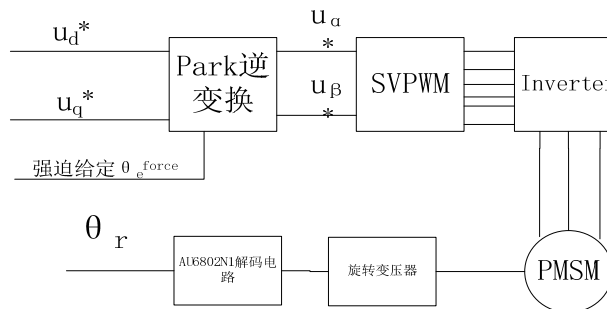


Fig. 4 The motor control system for initial position measurement of the rotor
In the figure, we set a value forcedly for the magnetic field position of the rotor. Set i = 0 and give j a sufficiently large value. Then get a voltage vector $\mu_\alpha^*$ and $\mu_\beta^*$ on the stationary frame after Park inverse transform. The special equation is as follows:

$$\begin{bmatrix} u_\alpha^* \\ u_\beta^* \end{bmatrix} = \begin{bmatrix} \cos\theta_e^{force} & -\sin\theta_e^{force} \\ \sin\theta_e^{force} & \cos\theta_e^{force} \end{bmatrix} \begin{bmatrix} u_d^* \\ u_q^* \end{bmatrix}$$

Regard $\mu_\alpha^*$ and $\mu_\beta^*$ as the input of SVPWM. Generate the pulse signal of power devices required by the voltage source inverter. Force d axis of the rotor to converse to a stable position $\theta_e^{force}$. Get the position angle $\theta_r$ by the decoding circuit and calculate the compensation angle $\theta_c = \theta_e^{force} + 90 - \theta_r$.

## The experiment results

The experiment control system uses 32-bit floating-point digital signal processing chip TMS320F28335 to achieve the whole process. Sampling period is 100us. The rotor position can be measured by the rotary transformer of Tamagawa and the decoding circuitry based on AU6802N1. There is a serial bus connection by McBsp (as SPI mode) interface between DSP and the decoder chip. MPU used in the experiment is as shown in Figure 5:
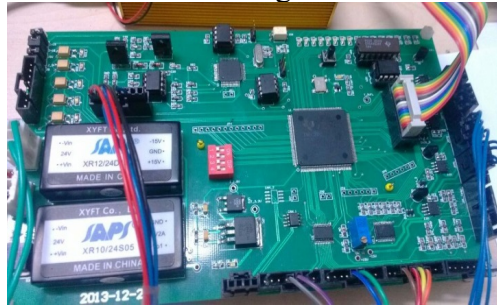

Fig. 5 The experimental MPU

The 3 parameters of the PMSM are used in the experiment:Rated power is 40KW,Rated speed is5000r/min,Rated torque is70N.m,Stator resistance is $0.0124\,\Omega$,When the main control plate is generated by the 10K sine wave excitation signal sent to the rotating transformer,The COS+,COS-and SIN+,SIN- generated sine signal like Fig. 6.
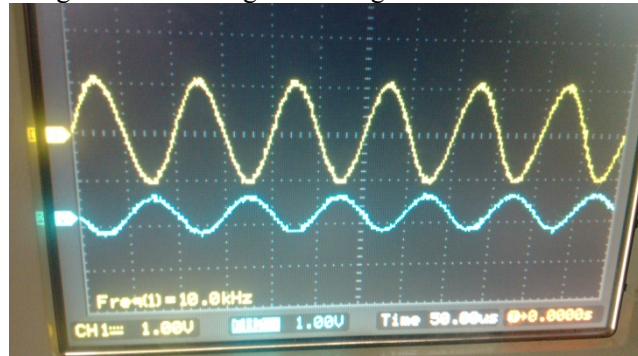

Fig. 6 The waveform of the resolver

After the outgoing signal of the resolver decoded based on AU6802N1, the transmission data waveform is as shown in figure 7:
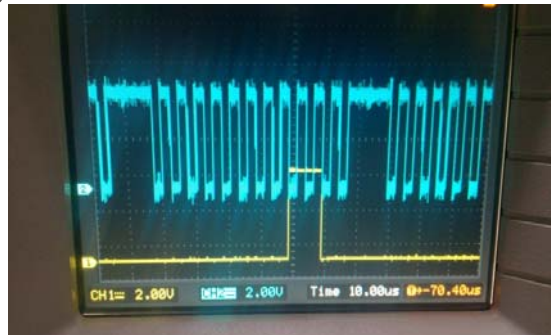

Fig. 7 The serial communication waveform of the rotor position

The experimental motor is unloaded. $\theta_e^{force}$ is set by the program. The stator generates Magnetomotive force vector with $\theta_e^{real} = \theta_e^{force} + 90$ direction on the space. It makes d-axis of the PMSM rotor aligned and get into a stable state of the lock shaft. By chip AU6802N1N, we can read out the digital quantity and obtain the electrical angle. Because there are always errors in every measurement, we take the average of several measurement as the compensation angle. This measurement results are substituted into the vector control program to do no-load test. The the rotor has good effect rotation. So the current waveform of the stator is measured as shown in figure 8:
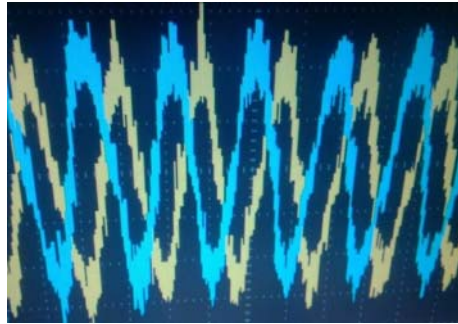


Fig. 8 The phase current waveform of the stator

## Summary

Nowadays, IPMSM is used more widely. When the control strategy uses the vector control, it needs to know the position of the rotor exactly. Then the oriented control of the rotor field will be achieved. However, IPMSM regards the resolver as the position sensor. So there is a compensation angle between the actual measured position electrical angle of the rotor with the true one. In this article, we change the angles with the given Park so that it produces a fixed direction vector mmfs for the stator and make the motor into a stable state of the lock shaft. We design a decoding circuit based on AU6802N1. This circuit can transform the analog signal of the rotary transformer into a digital signal. And it communicates through SPI bus way and the master chip TMS320F28335. Then by measuring the compensation angle of the typical electrical angle repeatedly, we can calculate the average. The load experiment results show that the compensation angle measurement methods used in this paper is simple and accurate.

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