# A Novel Off-line Parameter Identification Method Based on IRCMF312 for PMSM

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**Abstract — A novel Permanent Magnet Synchronous Motor (PMSM) off-line parameter identification scheme without additional circuit is proposed in this paper. The paper analysised the model of PMSM and the method of its vector control firstly. Then, in order to construct PMSM parameter identification program, the paper study various states of PMSM under the law of motion. At last, the paper simulated the program in the Matlab/Simulink environment. The paper adopted sensorless vector control technology to verify the results in IRMCF312 control chip. In this paper, the control experimental system is developed based on the off-line identification function. All of the proposed methods are tested by a 2.5kW PMSM, and the experiment and simulation results demonstrate the validity of the off-line parameter identification method.**

**Keywords: PMSM, Parameter Identification, d-q axis inductance**

## I. Introduction

PMSM is widely used for some high-performance occasions, due to its high power density and fast dynamic response ability [1]. In the permanent magnet synchronous drive system, the performance of many control strategies all strongly rely on the accuracy of the parameter. Therefore how to acquire the parameter exactly becomes the key to improve the vector control system performance. Generally, motor parameter identification primarily is through manual testing, no-load, blocking test and other methods. And online identification technology had high system requirements [2]-[5].

The paper designed the corresponding identify control modules of off-line automatic parameters recognition from the system control point of view. Firstly, analysis the model of PMSM and the method of its vector control. Then, in order to construct PMSM parameter identification program, the paper study various states of PMSM under the law of motion. At last, the paper simulated the program in the Matlab/Simulink environment. The paper adopted sensorless vector control technology to verify the results in IRMCF312 control chip. The IRMCF312 provides a built-in closed loop sensorless control algorithm. Motion control programming is achieved by using a dedicated graphical compiler integrated into the MATLAB/Simulink development. Two permanent magnet motors and PFC can be controlled by a single chip without requiring motor position sensors.

In this paper, the control experimental system is developed based on the off-line identification function. All of the proposed methods are tested by a 2.5kW PMSM, and the experiment and simulation results demonstrate the validity of the off-line parameter identification method.

## II. PMSM Mathematical Model

In the synchronization reference frame, the steady-state mathematical model of PMSM is shown as followed:

$$\begin{aligned} u_d &= Ri_d + p\psi_d - \omega_r\psi_q \\ u_q &= Ri_q + p\psi_q + \omega_r\psi_d \end{aligned} \tag{1}$$

Where $u_{dq}$ 、 $i_{dq}$ and $\psi_{dq}$ are the stator voltage, the stator current and magnetic flux under the *d-q a*xis respectively; $R$ is the stator resistance; $\omega_r$ is electricity velocity. The flux linkage equation is as followed:

$$\begin{aligned} \psi_d &= L_d i_d + \psi_r \\ \psi_q &= L_q i_q \end{aligned} \tag{2}$$

From equation (1) and (2), the stator voltage vector equation under the *d-q* axis can be obtained:

$$\begin{aligned} u_d &= Ri_d + pL_d i_d - \omega_r L_q i_q \\ u_q &= Ri_q + pL_q i_q + \omega_r L_d i_d + \omega_r \psi_r \end{aligned} \tag{3}$$

## III. Identification Scheme Simulation Analysis

Fig.1 is the invert principle diagram of PMSM three-phrase [6].

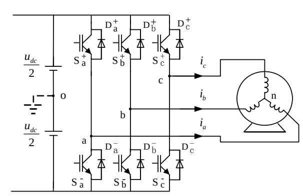


Fig.1 PMSM three-phase inverter diagram

### A. Identification of stator resistance $R_s$

The test method on stator resistance is DC voltammetry, the specific process is to use the inverter to make the high-frequency chopper on the DC bus voltage, to keep duty factor constant to acquire the equivalent DC low voltage [7]. Resistance could be obtained according to the size of Ohm's law. In the identification process, the errors caused by voltage drop of switching device and switching delay are analyzed, and a method to eliminate errors is proposed.

$$R = \frac{2}{3}\frac{V_d}{I_d} \tag{4}$$

*B. Identification of back-EMF $K_e$*

This paper proposes a novel identification scheme of back-EMF $K_e$. The control technology of PMSM is double-closed loop space vector control based on sensorless technology. When the motor is running at the speed $n$, a sudden cut on the given $I_d$, $I_q$ is taken, namely forcing the given current signal and output torque zero in a certain way, so that the motor will slow down to stall.Since the mechanical time constant of motor is larger than electrical time constant, the output instantaneous voltage of the PI current is equal to back-EMF of motor. The given voltage at this time is tested, and then back-EMF $K_e$ is acquired according to the relation of voltage and rotate speed.

$$K_e = \frac{E}{n} \times 1000 \, (\text{volt / krpm}) \tag{5}$$

*C. Identification of $L_d$*

The identification principle of d-axis inductance is as followed: applying a fixed direction of vector voltage to the motor, fixing the d-axis position, d-axis current is changed with the position. When the position is fixed, the d-axis direction of PMSM is the same as the direction of the stator voltage vector and stays still.

$$u_d = Ri_d + pL_d i_d \tag{6}$$

The current response to d-axis voltage step input is:

$$i(t) = \frac{U}{R}(1 - e^{-\frac{R}{L_d}t}) \tag{7}$$

When $R_t$=$L_d$, the current increases to the 0.632 times of steady-state value. So：

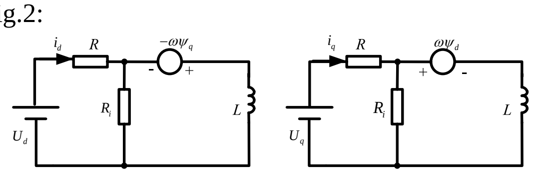
$$L_d = t_{0.632} \cdot R \tag{8}$$

*D. Identification of $L_q$*

The paper also applied a fixed position to q-axis. PMSM possessed a similar electromagnetic relationship with electric excitation salient pole synchronous-induction motor, so that two-reaction theory could be also adopt to study on PMSM. When motor is running at an asynchronous speed, the voltage formula of PMSM based on the two-reaction could be written as:

$$U = E_0 + I_1 R + jI_d X_d + jI_q X_q \tag{9}$$

The equivalent circuit of PMSM under d-q axis is shown in Fig.2:




a) *d*-axis equivalent circuit b) *q*-axis equivalent circuit

Fig.2 *d- q*axis equivalent circuit

Ignoring iron loss resistance, the voltage formula is:

$$\begin{aligned} U_d &= Ri_d - L_q i_q \omega \\ U_q &= Ri_q - L_d i_d \omega + \omega \psi_f \end{aligned} \tag{10}$$

The inductance expression can be obtained by the latest formula:

$$L_q = \frac{Ri_d - U_d}{\omega i_q} \tag{11}$$

From the above type, these parameters could be easily obtained.

## IV. THE TEST RESULTS

Based on the identification theory above, the relevant models are built and simulated in the Matlab/Simulink. Applied in a set of 2.5kw synchronous motor vector control system, the scheme is proved to be effective by experiments and simulation analysis. Figure 3 is the contrast of identification result and actual value of $R_S$. The abscissa denotes for sampling points, Y-coordinate ratio for each frame is 0.655mΩ. Results are shown in the Table1 below. Generally speaking, each parameters can be accurate identified, finally achieve the desired result with the error less than 11%.

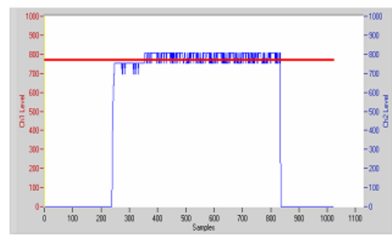


Fig.3 identification result and actual value of $R_S$ in iMotion

Table 1 Identification result

| name | real | identification |
|---|---|---|
| $R_s$ (Ω) | 0.51 | 0.521 |
| $K_e$ (V/krpm) | 18.75 | 19.61 |
| $L_d$ (mH) | 5.6 | 5.76 |
| $L_q$(mH) | 16.8 | 18.7 |

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