平成 27 年電気学会全国大会

Online q-axis Inductance Identification of IPM Synchronous Motor Based on Relationship between Its Parameter Mismatch and Current Norm

Ji Xiang*, Toshihiko Noguchi (Shizuoka University)

This paper proposes a new approach to achieve on-line identification of the q-axis inductance of the interior permanent magnet synchronous motor (IPMSM) based on the relationship between the mismatch of L_q and the d-axis feedback current. The value of the d-axis feedback current depends on the mismatch of L_q, and the consecutive samplings of the d-axis feedback current make it possible to calculate the true value of L_q. The proposed identification technique is examined through some computer simulations. The simulation result demonstrates the fast convergence of the identified value to the true one with a small error.

Keywords：interior permanent magnet synchronous motor, online, parameter, identification, P control, PI control

1. Introduction

In recent years, interior permanent magnet (IPM) motors are widely used in a variety of industry, home appliance and automotive applications, owing to their high-efficiency and high-power-density features. The IPM motor is usually controlled by means of a field-orientation technique (vector control), and requires a current controller on the synchronous rotating reference frame (dq-reference-frame) for the instantaneous torque and the magnetic flux control. The current control on the dq-reference-frame mainly consists of the coordinate transformation, the PI regulation, and the decoupling compensation, which is based on the mathematical model of the motor. Figure 1 shows the field-oriented control system of the IPM motor. As can be seen in the figure, it is indispensable for the controller not only to detect the magnetic-pole-position and the motor currents, but also to know the motor parameters accurately because the controller has an inverse model of the motor. Identification of the motor parameters is significantly important to control the motor properly in starting up of the control as well as the running operation, and the on-line parameter identification is particularly required during the running condition. This paper proposes a novel technique to achieve the on-line identification of the IPM motor parameters, which requires only the d-axis feedback current information of the motor. The proposed technique employs a P regulator instead of the PI regulator in the d-axis current control loop. Using this technique L_q can be estimated by checking the d-axis feedback current when the motor is working in the steady state. Some computer simulations have been conducted to check the identification performance of the proposed technique in the paper.

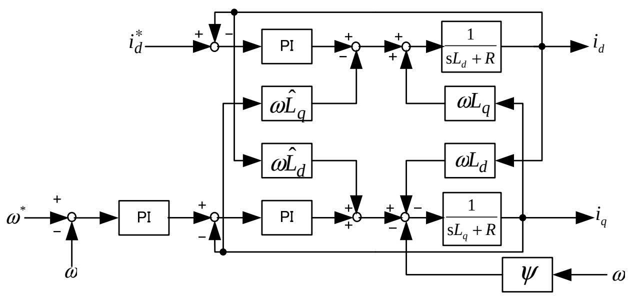
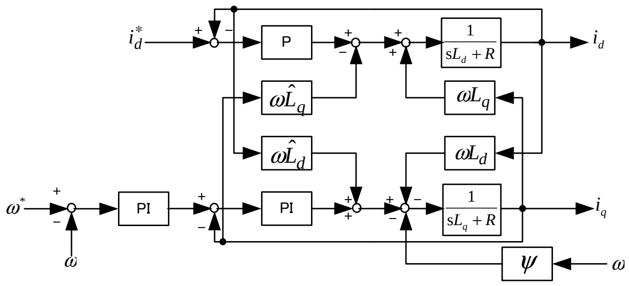
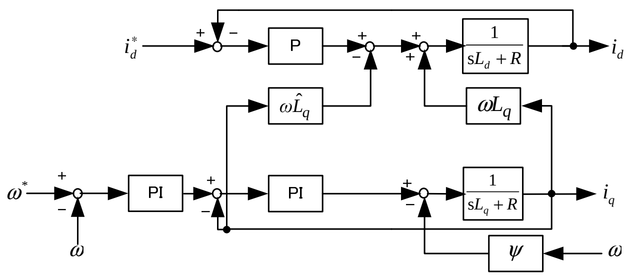


Fig. 1. Field-oriented control system of IPM motor.



(a) Proposed L_q identification system.



(b) Simplified L_q identification system.

Fig. 2. Online L_q identification system.

2015/3/24～26　東京

Table 1. Parameters of test IPMSM.

Number of poles	4
Winding resistance	4.3 Ω
Gain of d-axis P regulator	1 V/A
q-axis inductance	67 mH
d-axis inductance	27 mH
Setup *d*-axis inductance	1.0 mH
Field flux linkage	0.544 Wb
Setup field flux linkage	1.0 Wb
Rotation speed	6000 r/min

2. Proposed Identification Technique

Figure 2(a) shows the proposed L_q identification system. In the system, the PI regulator used in the d-axis current control loop is replaced with a P regulator. Because the P regulator is unable to eliminate the steady-state error, the mismatch of L_q affects the d-axis feedback current. Figure 2(b) shows the simplified L_q identification system. From Fig. 2(b), the rotation speed is equal to its command, and the q-axis current is stable when the motor is operated in the steady state because both of the controllers consist of the PI regulators. By setting the d-axis current command at zero, the d-axis feedback current can be expressed as

$$I_d = \frac{\omega I_q}{K_{pd} + R}(L_q - \hat{L}_q)\ . \qquad (1)$$

From (1), it is found that the mismatch of L_q has a linear relationship with the d-axis feedback current I_d when the command of the d-axis current is set at zero. Based on this linear characteristic, it is possible to estimate the true value of L_q. As shown in Fig. 3. The basic mathematic knowledge tells that if two points on the line is known the whole equation of the line is known.

By setting two different values of L_q to the system, which may have the parameter mismatch, two corresponding d-axis feedback current values are recorded in the memory. Assuming that the following consecutive sampling actions are performed:

$I_d = I_{d1}$ when $\hat{L}_q = L_{q1}$, and

$I_d = I_{d2}$ when $\hat{L}_q = L_{q2}$,

the true value of L_q can be calculated by the following equation:

$$L_q = \frac{I_{d1}L_{q2} - I_{d2}L_{q1}}{I_{d1} - I_{d2}}\ . \qquad (2)$$

Equation (2) implies that the true value of L_q can be calculated regardless of any parameters and any variables used in (1). Therefore, the proposed identification technique requires only the d-axis feedback current information to estimate L_q.

3. Simulation Result

Some computer simulations have been conducted to verify the identification performance of the proposed technique. Table 1 shows the test motor parameters which are used in the simulations.

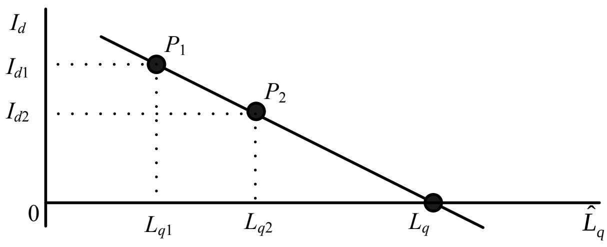


Fig. 3. L_q identification description.

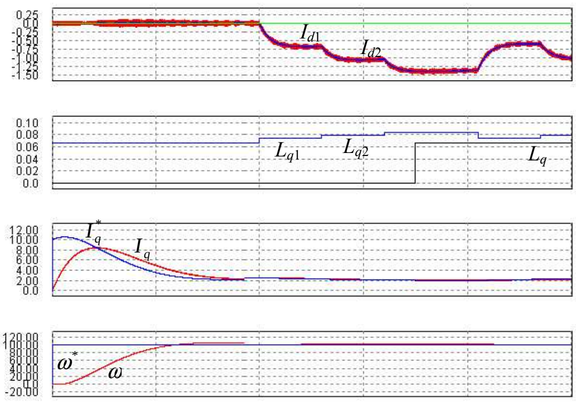


Fig. 4. Simulation result of L_q identification.

One of the simulation results is shown in Fig. 4. The rotation speed and the q-axis current are controlled to be equal to their commands. As $\hat{L}_q$ of the controller changes from L_{q1} to L_{q2} and so on, the d-axis feedback current also accordingly changes. The final identification result is 66.48 mH, where the true value is 67 mH. The identification error is 0.78%, and the convergence time for the identification is only 0.08 s.

4. Conclusion

The online parameter identification technique of the IPM motor has been proposed in this paper. The most unique features of the technique are capability to identify L_q by using only the motor d-axis feedback current information, and robustness to the winding resistance variation as well as the control variables. According to the simulation result, the proposed technique can estimate L_q within the identification error of 0.78%.

Reference

(1) Xiang Ji・Toshihiko Noguchi：「Off-line Parameter Identification of Interior Permanent Magnet Motor by Searching Minimum Point of Current Norm Characteristics」 International Symposium on Power Electronics, Electrical Drives, Automation and Motion pp. 282-287(2014)