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

Xiang Ji$^{a)}$ Student Member, Toshihiko Noguchi$^{*}$$^{*}$ Member

(Manuscript received May 22, 2015, revised June 22, 2015)

This paper proposes a new approach to achieve online 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 has been examined through some experimental tests. The test results demonstrate the fast convergence of the identified $L_q$ to the true one with a small error.

Keywords: interior permanent magnet synchronous motor, parameter, identification, P regulator

1. Introduction

IPM synchronous motors are usually controlled by means of a field-orientation technique (vector control), and require 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$^{(1)}$. 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 online 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 method makes the identification robust to the winding resistance variation caused by the temperature change. Some experimental tests have been conducted to check the identification performance of the proposed technique in the paper.

2. Identification Technique and Experimental Results

In the system shown in Fig. 2, 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. On the other hand, the rotation speed follows its command without the steady state error, and the $q$-axis current is kept stable when the motor is operated in the steady state because both of the controllers have 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_d + R} (L_q - \hat{L}_q). \quad \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdOTS

From (1), it is found that the mismatch of $L_q$ has a linear relationship when the $d$-axis current command is set at zero. By setting consecutively two different arbitrary values of $\hat{L}_q$ to the system, the resultant two corresponding $d$-axis feedback current values are recorded in the memory$^{(2)(3)}$. Assuming that the following consecutive sampling actions are performed:
Online IPMSM q-axis inductance identification by using current (Xiang Ji et al.)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R$</td>
<td>Winding resistance</td>
<td>0.48 Ω</td>
</tr>
<tr>
<td>$L_d$</td>
<td>d-axis inductance</td>
<td>13.0 mH</td>
</tr>
<tr>
<td>$L_q$</td>
<td>q-axis inductance</td>
<td>28.5 mH</td>
</tr>
<tr>
<td>$\psi$</td>
<td>Magnetic flux linkage</td>
<td>0.0674 Wb</td>
</tr>
<tr>
<td>$K_d$</td>
<td>d-axis P regulator gain</td>
<td>5.0 V/A</td>
</tr>
</tbody>
</table>

Some experimental tests were conducted to confirm the current characteristic and the $L_q$ identification. The equipment parameters are listed in Table 1. Figure 3 shows that the $i_d$ also varies when $\hat{L}_q$ is changed and shows a linear characteristic with respect to $\hat{L}_q$. Identification results by the proposed method are also shown in Fig. 3(a). Figure 4 gives an experimental result by adopting the proposed method with a reduced P regulator gain $K_d = 1.0$. By calculating (2), the identification result is 27.3 mH and the error is 4.2%. Comparing with experimental result shown in Fig. 3(b), the current response shown in Fig. 4(b) is slower than that of Fig. 3(b) because $K_d$ is reduced from 5.0 to 1.0. Even though the current response becomes slower by reducing $K_d$, the identification result is close to the true value.

3. Conclusion

The online parameter identification technique of the IPM motor has been proposed in this paper. The most unique feature of the technique is capability to identify $L_q$ by using only the motor d-axis feedback current information. According to the experimental results, the proposed technique can estimate $L_q$ within the identification error of 4.2%.

References

