Speed estimation and Parameters Identification simultaneously of PMSM based on MRAS

XIAOJUN LIU , GUANGMING ZHANG, LEI MEI and DEMING WANG
College of electrical engineering and control science
Nanjing Tech University
NO.30 Puzhu Road(S), Nanjing, Jiangsu
CHINA
xjl@njtech.edu.cn

Abstract: - This paper deals with the Permanent Magnet Synchronous Motor (PMSM)parameters identification and speed estimation problems. It proposes a solution to adjust PI parameters of speed observer and identifies stator resistance, d-axis and q-axis inductance. In fact, there are a lot of methods for estimating the speed. For example, high frequency injection, Kalman filter and model reference adaptive system(MRAS). However, with the motor running, some parameters will change. Such as the stator resistance will change with the increase of temperature. These parameters are useful for estimating the speed. So, it is necessary to identify parameters. In this paper, MRAS is the theoretical basis. First, the adaptive law of speed observer is constructed through Popov stability and propose a method to adjust PI parameters for the speed observer. This method has a strong adaptability and transplantation. Then, the adaptive laws of stator resistance, d-axis and q-axis inductance are constructed through Lyapunov stability and the Popov stability, respectively and compare their results. The stability of the proposed observers are also discussed. Last, this paper uses field oriented control(FOC) strategy and illustrates the obtained results through simulation.

Key-Words: - Permanent magnet synchronous motor. Parameter identification. Speed estimation. Model reference adaptive. Adjust PI parameters. Stability.

1 Introduction

In recent years, with the development of power electronic technology, AC servo system has been paid more and more attention and research. The PMSM has the advantages of small size, high efficiency and high power density, which plays an important role in AC servo system and has been widely used in high performance drive system[1-3]. At present, FOC or direct torque control (DTC) is usually used in the drive of PMSM for control strategy. However, either for the control strategy, the speed and rotor position angle are required. At present, there are two schemes for obtaining the two parameters, namely, the sensors and sensorless. In sensor, this can directly obtain the position information through installing encoder and hall sensor. But this scheme will undoubtedly increase the cost of the design of the system, and the adaptability is also relatively weak .In sensorless, first proposed and most simple method is back electromotive force, but at the low speed, the back electromotive force is small and the accuracy is not high. Another more mature method is high frequency signal injection, This approach relies on external incentives and also requires the motor itself has a convex polarity, it doesn't apply at high speed[1]. With the development of modern control theory, sliding mode observer, MRAS, Kalman filter, and other sensorless scheme are also developed[4]. These methods are more and more concerned by researchers for their good robustness. On the other hand, the parameter value of PMSM is very important for the control of the system[3]. With the increase of temperature, the resistance and inductance of the motor windings will change[5.6]. For sensorless control, these parameters are important. So, it is necessary to identify these parameters at the same time as estimating speed.

MRAS has the advantages of simple algorithm, easy to implement in the digital control system, and has the advantages of faster adaptive speed. This has been proposed and applied to the PMSM sensorless control[7]. There are two different models. One is the reference model and the other is the adjustable model including the identified parameters. The deviation signal of the output of the two models send to the adaptive mechanism, and then the output of the adaptive mechanism are the identified parameters [8]. From the current research, the emphases of MRAS method parameter identification are the establishment of adjustable model and the construction of adaptive law in adaptive mechanism. They are related to the accuracy of the identification and the stability of the system.

For speed estimation, there are two equations as adjustable model. One is stator flux linkage equation[9], and another is stator current equation. However, for parameters identification, there is only stator current equation. So, this paper chooses stator current equation as adjustable model. For the adaptive law, there are also two method, Lyapunov stability and the Popov stability, respectively. There is a PI regulator in adaptive law using Popov stability. But using Lyapunov stability, there is only a integrator[10.11].

In [12-15], the basic theoretical knowledge of MRAS theory for estimating PMSM speed was given, and the q axis and d axis equation of stator current using for adjustable model was described. The adaptive law was constructed by Popov stability theory. These establish the theoretical foundation for this paper. In [16], it identified the stator resistance, d-axis and q-axis inductance and rotor flux linkage, but speed is acquired by sensor. In[17], used MRAS made sensorless control in the case of load changes. This fully demonstrates the good robustness of the MRAS. In[18], used fuzzy controller to adjust the parameters of the PI regulator in the speed observer based on MRAS. The whole system had a good dynamic and steady performance in a wide speed range. In[10.11], constructed adaptive law by Popov stability and Lyapunov stability analysis method for parameter identification, and made a contrast. But the speed was also acquired by sensor. In[19-21], they established different adaptive laws according to different stability. The performance of the system is different from that of the adaptive law. In[22], the stability of MRAS system was analyzed and the transfer function of the system was constructed with the modern control theory, and analyzed the transfer function. It also identified stator resistance based on these.

In summary, the problem of using MRAS to estimate the speed or identify parameters is the construction of adaptive law. If using Popov stability, the problem is adjusting PI parameters of speed observer.

First of all, this paper use q axis and d axis equations of stator current as adjustable model. Then, for speed estimation, the adaptive law is constructed by Popov stability. The stability is analyzed through modern control theory and the transfer function of the speed observer is constructed. The PI regulator in the speed observer can be used as the adjustable link, and use root locus analysis to adjust the ratio of PI. This method is simple and effective, and avoid the complex algorithm of fuzzy PI in [18]. For parameters identification, the adaptive laws are constructed through Lyapunov stability and the Popov stability, respectively. By comparison, it can be seen that the former is better than the latter. Also, if you use the latter, it need to adjust the PI parameters and consider the problem of rank, this has brought inconvenience. Final, this paper use FOC as a control strategy and give the result verification through simulation. It can be seen that the viewpoints and methods proposed in this paper are feasible and effective.

2 Speed estimation

2.1 Mathematical model of PMSM

The stator voltage equation of the surface mounting PMSM in d-q axis:

$$\begin{bmatrix} u_d \\ u_q \end{bmatrix} = \begin{bmatrix} R_s + DL_d & -\omega_r L_q \\ \omega_r L_d & R_s + DL_q \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} 0 \\ \psi_r \omega_r \end{bmatrix} \quad (1)$$

Where

u_d , u_q , i_d , i_q are the stator voltage and current of the motor in the d-q axis.

R_s , L_d , L_q are the stator resistance and the inductance of the d-q axis.

D is differential operator.

ω_r and ψ_r are rotor electric angular speed and flux.

According to the equation (1), the stator current state equation can be obtained.

$$D\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} -\dfrac{R_s}{L_s} & \omega_r \\ -\omega_r & -\dfrac{R_s}{L_s} \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} \dfrac{u_d}{L_s} \\ \dfrac{u_q - \psi_r \omega_r}{L_s} \end{bmatrix} \quad (2)$$

For surface mounting PMSM, $L_d = L_q = L_s$ Motor use for reference model and the equation (2) use for adjustable model. For speed estimation, R_s and L_s can be regarded as fixed values So, the adjustable model for speed estimation can be given.

$$D\begin{bmatrix} \hat{i}_d \\ \hat{i}_q \end{bmatrix} = \begin{bmatrix} -\dfrac{R_s}{L_s} & \hat{\omega}_r \\ -\hat{\omega}_r & -\dfrac{R_s}{L_s} \end{bmatrix} \begin{bmatrix} \hat{i}_d \\ \hat{i}_q \end{bmatrix} + \begin{bmatrix} \dfrac{u_d}{L_s} \\ \dfrac{u_q - \psi_r \hat{\omega}_r}{L_s} \end{bmatrix} \quad (3)$$

Defined state error:

$$\varepsilon_d = i_d - \hat{i}_d , \varepsilon_q = i_q - \hat{i}_q \quad (4)$$

The state error equation of equation (2) subtracting equation (3) can be given.

$$D\begin{bmatrix}\varepsilon_d\\ \varepsilon_q\end{bmatrix}=\begin{bmatrix}-\dfrac{R_s}{L_s} & \hat{\omega}_r\\ -\hat{\omega}_r & -\dfrac{R_s}{L_s}\end{bmatrix}\begin{bmatrix}\varepsilon_d\\ \varepsilon_q\end{bmatrix}+\begin{bmatrix}i_q\\ -i_d-\dfrac{\psi_r}{L_s}\end{bmatrix}\left(\omega_r-\hat{\omega}_r\right) \tag{5}$$

Written state space expression:

$$D\varepsilon = A\varepsilon + Bu \tag{6}$$

2.2 Adaptive of speed observer design

MRAS basic block diagram of speed estimation is shown in Figure 1.

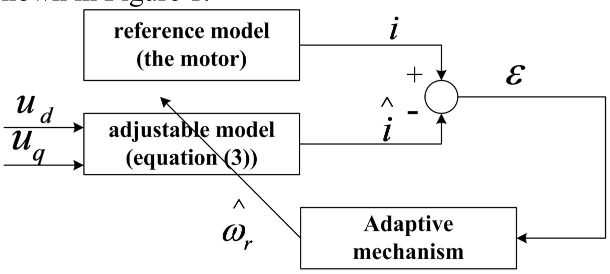

Figure 1: MRAS basic block diagram of speed estimation

Obviously, the stability and precision of the system is related to the construction of the adaptive mechanism. From Figure 1, it can be seen that the adaptive mechanism is related to the state error equation (5). The structural diagram of the equation (5) is shown in Figure 2:

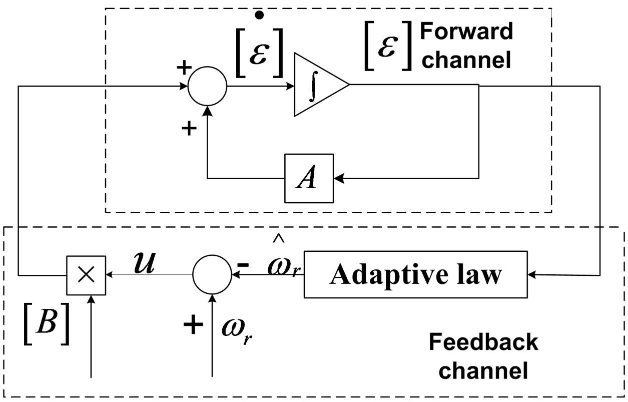

Figure 2: Equation (5) structure diagram

For speed estimation, the adaptive law is constructed by Popov stability. So, the conditions for the stability of Figure 2 are about two sides. One is the zero pole of the transfer function of the forward channel in the left half of the s domain. Another is feedback channel to satisfy Popov stability.

For first condition, the transfer function of forward channel can be deduced according to modern control theory. Its state space expression is:

$$\begin{aligned}\dot{\varepsilon} &= A\varepsilon + u\\ y &= \varepsilon\end{aligned} \tag{7}$$

transfer function:

$$H(s)=\frac{s+\dfrac{R_s}{L_s}}{s^2+2\dfrac{R_s}{L_s}s+\left(\dfrac{R_s}{L_s}\right)^2+\hat{\omega}_r^{\,2}} \tag{8}$$

Its pole-zero loci is shown in Figure 3 for a range of $\hat{\omega}_r$ starting at -200 up to 200rad/s. From the graph, we can see that with the increase of the speed, the poles also have negative real parts. So this condition is confirmed.

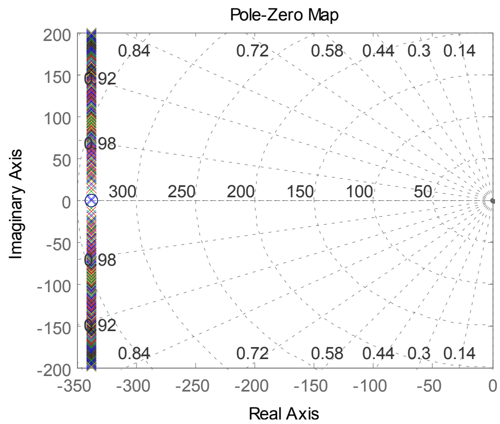

Figure 3: The pole-zero loci of H(s) about range of $\hat{\omega}_r$ starting at -200 up to 200rad/s

For second condition, the derivation of Popov stability is introduced in above literature, and it's not described in this article. The adaptive law can be constructed by Popov stability.

$$\hat{\omega}=K_i\int(\varepsilon_d i_q-\varepsilon_q i_d-\varepsilon_q\frac{\psi_r}{L_s})dt+ K_p\left(\varepsilon_d i_q-\varepsilon_q i_d-\varepsilon_q\frac{\psi_r}{L_s}\right)+\hat{\omega}_r(0) \tag{9}$$

2.3 PI parameter adjustment of speed observer

The adaptive law of the observer is constructed in 2.2, equation (9). So, the MRAS structure diagram can be obtained in Figure 4.

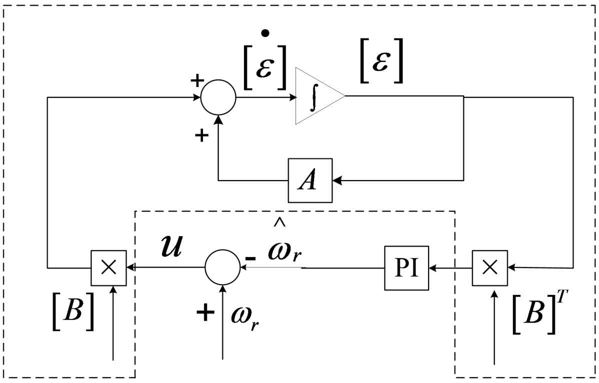

Figure 4: MRAS structure diagram

The dotted line in Figure 4 is represented by the state space expression.

$$\begin{aligned}\dot{\varepsilon} &= A\varepsilon + Bu \\ y &= B^T\varepsilon\end{aligned} \tag{10}$$

So, its transfer function is:

$$G(s)=\frac{\left(s+\frac{R_s}{L_s}\right)\left(i_q^{\,2}+\left(i_d+\frac{\psi_r}{L_s}\right)^2\right)}{s^2+2\frac{R_s}{L_s}s+\left(\frac{R_s}{L_s}\right)^2+\hat{\omega}_r^{\,2}} \tag{11}$$

It can be find that this has the same zero pole distribution with equation (8).
Further simplify about figure 4:

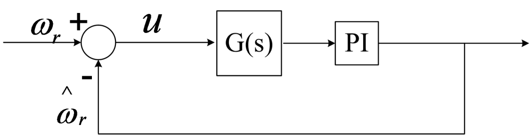

Figure 5: MRAS simplified structure diagram

So, this can be used to adjust the parameters of the PI regulator by using the root locus analysis method for the simplified structure diagram of Figure 5, and make the system to achieve the desired results. Because the value of i_d and i_q are relatively small. so they can be neglected. This can get the open-loop transfer function of system.

$$G_c(s)=\frac{k^*\left(s+\frac{R_s}{L_s}\right)(s+z)}{s^3+2\frac{R_s}{L_s}s^2+\left(\left(\frac{R_s}{L_s}\right)^2+\hat{\omega}_r^{\,2}\right)s} \tag{12}$$

Where, $k^*=k_p\frac{\psi_r^{\,2}}{L_s^{\,2}}, z=\frac{k_i}{k_p}$.

So, this can determine the value of k^* and z to make the system to achieve the desired results, thus determining the value of k_i and k_p.

Firstly, it need to confirm z. With the increase of z, the root locus bend to S domain left half plane, as shown in Figure 6.

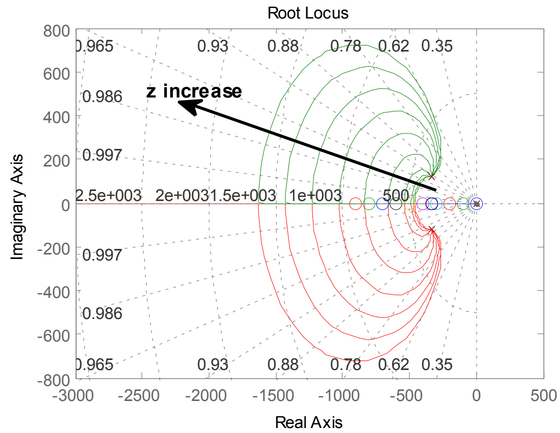

Figure 6: the root locus of different z

In fact, the value of ξ in general systems is 0.707 by automatic control principle. So, this can determine the range of z in Figure 6 to make it has closed loop poles of ξ equal to 0.707. Through the test, it can obtain that z≥670.

Then, find two closed loop poles of ξ equal to 0.707(Imaginary part symmetry). This can determine the value of k^* and find another negative real pole according to the value of k^*. Through the test, the table 1 of the data can be earned.

Table 1: Closed loop poles of different z values

No.	z	Imaginary part poles	Negative real pole	k^*
(1)	670	358±358i	-300	340
(2)	750	292±292i	-282	190
(3)	800	279±278i	-277	159
(4)	1000	255±256i	-273	105
(5)	2000	227±228i	-263	40.2

Finally, according to the above data can get the system step response, as shown in Figure 7. So, it can be find the data of meeting the system performance to determine the parameters of the PI regulator.

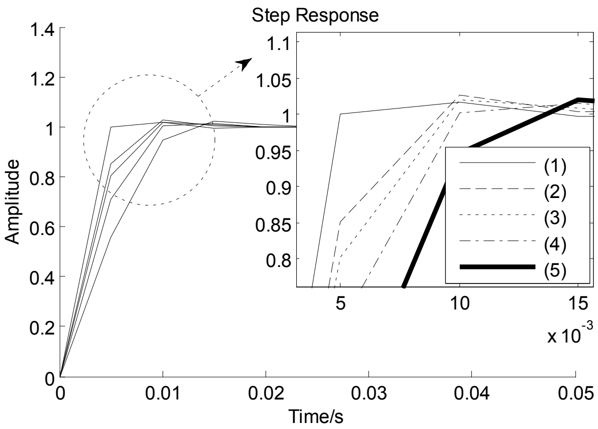

Figure 7: the system step response according to Table1

It can be seen from the figure that the performance of No.(1)is better. This means that the imaginary part poles are in the left side of the negative real pole and the lateral distance is the largest. This can determine the parameters of the PI regulator.

The above analysis is aimed at $\hat{\omega}_r$ equal to 120rad/s. So in the case of the No.(1), the system step response under different $\hat{\omega}_r$.

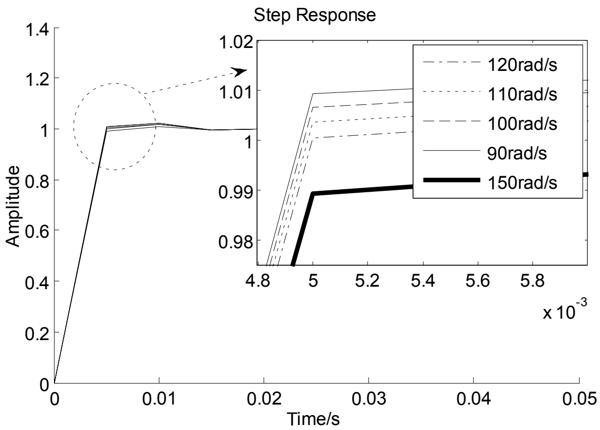

Figure 8: the system step response of different $\hat{\omega}_r$ according to No.(1)

From figure, it can be seen that the step responses of the system are similar to 120 when under 120, and the response time is better than 120. But when higher than 120, the system performance becomes bad. So, in the PMSM speed control system, the value of $\hat{\omega}_r$ should be appropriate. And this can make the observer have a good response in a wide range of speed.

3 Parameters Identification

3.1 Adaptive law parameters identification based on Lyapunov stability

Because speed estimation is based on Popov stability, parameters identification does not need to consider the problem of rank based on Lyapunov stability .

For parameters identification, ω_r can be regarded as fixed values. So, the adjustable model for adjustable parameters can be given.

$$D\begin{bmatrix}\hat{i}_d\\ \hat{i}_q\end{bmatrix}=\begin{bmatrix}-\hat{a} & \omega_r\\ -\omega_r & -\hat{a}\end{bmatrix}\begin{bmatrix}\hat{i}_d\\ \hat{i}_q\end{bmatrix}+\begin{bmatrix}u_d\hat{b}\\ \left(u_q-\psi_r\omega_r\right)\hat{b}\end{bmatrix} \tag{13}$$

Where, $\hat{a}=\dfrac{\hat{R}_s}{\hat{L}_s}, \hat{b}=\hat{L}_s$.

The state error equation of equation (2) subtracting equation (13) can be given.

$$D\begin{bmatrix}\varepsilon_d\\ \varepsilon_q\end{bmatrix}=\begin{bmatrix}-\hat{a} & \omega_r\\ -\omega_r & -\hat{a}\end{bmatrix}\begin{bmatrix}\varepsilon_d\\ \varepsilon_q\end{bmatrix}+\begin{bmatrix}-i_d\\ -i_q\end{bmatrix}\left(a-\hat{a}\right)+\begin{bmatrix}u_d\\ u_q-\psi_r\omega_r\end{bmatrix}\left(b-\hat{b}\right) \tag{14}$$

Written state space expression:

$$D\varepsilon=A_1\varepsilon+B_1u_1+Cu_2 \tag{15}$$

So, MRAS basic block diagram of parameters identification is shown in Figure 9.

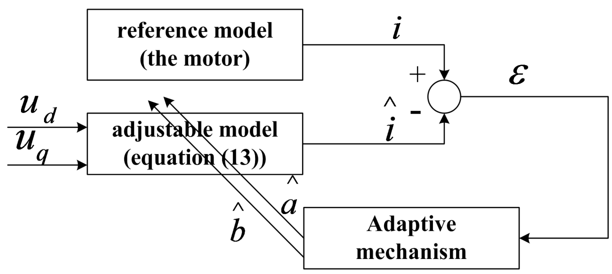

Figure 9: MRAS basic block diagram of parameters identification

There are two methods to construct adaptive law. One is Lyapunov stability and another is the Popov stability.

Definition $\phi^T=\begin{pmatrix}u_1 & u_2\end{pmatrix}$, $s=\begin{pmatrix}B_1 & C\end{pmatrix}^T$

Equation (15) becomes:

$$D\varepsilon=A_1\varepsilon+\phi^T s \tag{16}$$

The design of the Lyapunov equation:

$$V(X)=\frac{1}{2}\left(\varepsilon^T P\varepsilon+\phi^T\Gamma\phi\right) \tag{17}$$

Where, $P=\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix},\Gamma=\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix}$.

According to Lyapunov stability second method. If the system is stable, two conditions should be met. One is $V(X)$ positive definite, another is $\dot{V}(X)$ negative definite. Because the P and Γ are positive definite, $V(X)$ is positive definite.

$$\dot{V}(X)=\frac{1}{2}\left(\dot{\varepsilon}^T P\varepsilon+\varepsilon^T P\dot{\varepsilon}\right)+\frac{1}{2}\left(\dot{\phi}^T\Gamma\phi+\phi^T\Gamma\dot{\phi}\right) \tag{18}$$

Where

$$\dot{\varepsilon}^T P\varepsilon=\varepsilon^T A_1^T P\varepsilon+s^T\phi P\varepsilon$$

$$\varepsilon^T P\dot{\varepsilon}=\varepsilon^T P\left(A_1\varepsilon\right)+\varepsilon^T P\left(\phi^T s\right)$$

$$\dot{\phi}^T\Gamma\phi+\phi^T\Gamma\dot{\phi}=2\left(u_1\dot{u}_1+u_2\dot{u}_2\right)$$

So, Equation(18) becomes

$$\dot{V}(X)=\frac{1}{2}\varepsilon^T\left(PA_1+A_1^T P\right)\varepsilon+\frac{1}{2}\left(s^T\phi P\varepsilon+\varepsilon^T P\left(\phi^T s\right)\right)+\left(u_1\dot{u}_1+u_2\dot{u}_2\right) \tag{19}$$

Because $PA_1+A_1^T P=\begin{bmatrix}-a & 0\\ 0 & -a\end{bmatrix}$ is negative definite, $\frac{1}{2}\varepsilon^T\left(PA_1+A_1^T P\right)\varepsilon$ is negative definite.

To meet the condition about $\dot{V}(X)$ is negative definite, we can let

$$\frac{1}{2}\left(s^T\phi P\varepsilon+\varepsilon^T P\left(\phi^T s\right)\right)+\left(u_1\dot{u}_1+u_2\dot{u}_2\right)=0$$

By calculation, we can get:

$$u_1\left(\dot{u}_1-\varepsilon_d i_d-\varepsilon_q i_q\right)+u_2\left(\dot{u}_2+\varepsilon_d u_d+\varepsilon_q u_q-\psi_r\omega_r\right)=0$$

$$\dot{u}_1=\varepsilon_d i_d+\varepsilon_q i_q,\ \dot{u}_2=-\varepsilon_d u_d-\varepsilon_q u_q+\psi_r\omega_r$$

So, the adaptive law can get.

$$\hat{a}=a(0)-\int\left(\varepsilon_d i_d+\varepsilon_q i_q\right)dt$$

$$\hat{b}=b(0)+\int\left(\varepsilon_d u_d+\varepsilon_q u_q-\psi_r\omega_r\right)dt$$

3.2 Adaptive law parameters identification based on Popov stability

Because speed estimation is based on Popov stability, parameters identification need to consider the problem of rank based on Popov stability .

For parameters identification of stator resistance, ω_r and d-axis and q-axis inductance can be regarded as fixed values. So, the adjustable model for adjustable parameters can be given.

$$D\begin{bmatrix}\hat{i}_d\\ \hat{i}_q\end{bmatrix}=\begin{bmatrix}-\frac{\hat{R}_s}{L_s} & \omega_r\\ -\omega_r & -\frac{\hat{R}_s}{L_s}\end{bmatrix}\begin{bmatrix}\hat{i}_d\\ \hat{i}_q\end{bmatrix}+\begin{bmatrix}\frac{u_d}{L_s}\\ \frac{u_q-\psi_r\omega_r}{L_s}\end{bmatrix} \tag{20}$$

The state error equation of equation (2) subtracting equation (20) can be given.

$$D\begin{bmatrix}\varepsilon_d\\ \varepsilon_q\end{bmatrix}=\begin{bmatrix}-\frac{\hat{R}_s}{L_s} & \omega_r\\ -\omega_r & -\frac{\hat{R}_s}{L_s}\end{bmatrix}\begin{bmatrix}\varepsilon_d\\ \varepsilon_q\end{bmatrix}+\begin{bmatrix}-\frac{i_d}{L_s}\\ -\frac{i_q}{L_s}\end{bmatrix}\left(R_s-\hat{R}_s\right) \tag{21}$$

According to 2.2, the adaptive law stator resistance can be derived according to Popov stability.

$$\hat{R}_s=K_{Ri}\int\left(-\frac{\varepsilon_d i_d+\varepsilon_q i_q}{L_s}\right)dt+K_{Rp}\left(-\frac{\varepsilon_d i_d+\varepsilon_q i_q}{L_s}\right)+\hat{R}_s(0) \tag{22}$$

Also, for parameters identification of d-axis and q-axis inductance ω_r and stator resistance can be regarded as fixed values. In the same way, the adaptive law stator resistance can be derived.

$$\frac{1}{\hat{L}_s}=K_{Li}\int\left(\begin{matrix}\varepsilon_d\left(u_d-R_s i_d\right)+\\ \varepsilon_q\left(u_q-R_s i_q-\psi_r\omega_r\right)\end{matrix}\right)dt+K_{Lp}\left(\begin{matrix}\varepsilon_d\left(u_d-R_s i_d\right)+\\ \varepsilon_q\left(u_q-R_s i_q-\psi_r\omega_r\right)\end{matrix}\right)+\frac{1}{\hat{L}_s(0)} \tag{23}$$

For the adjustment of K_{Ri}, K_{Rp}, K_{Li}, K_{Lp}, we can use the method of 2.3.

4 Simulation results

In this paper, the field oriented control (FOC) model of PMSM is built firstly in Matlab/Simulink. Then build the adjustable model and adaptive law, as shown in Figure 10. The parameters involved in this paper are shown in Table 2. To verify the PI parameter adjustment in the speed observer, R_s and L_s can be regarded as fixed values. The PI regulator parameters as determined by the value of the Table 1 are shown in Table 3. And then the parameter identification of R_s and L_s is performed on the basis.

Table 2: Simulation parameters

U_{dc}	PWM period	L_s	R_s	ψ_r
310V	5KHZ	8.5mH	2.8758ohm	0.175V.s

Table 3: PI regulator parameters

No.	k_p	k_i
(1)	0.8	536
(2)	0.45	337.5
(3)	0.37	296
(4)	0.25	250
(5)	0.1	200

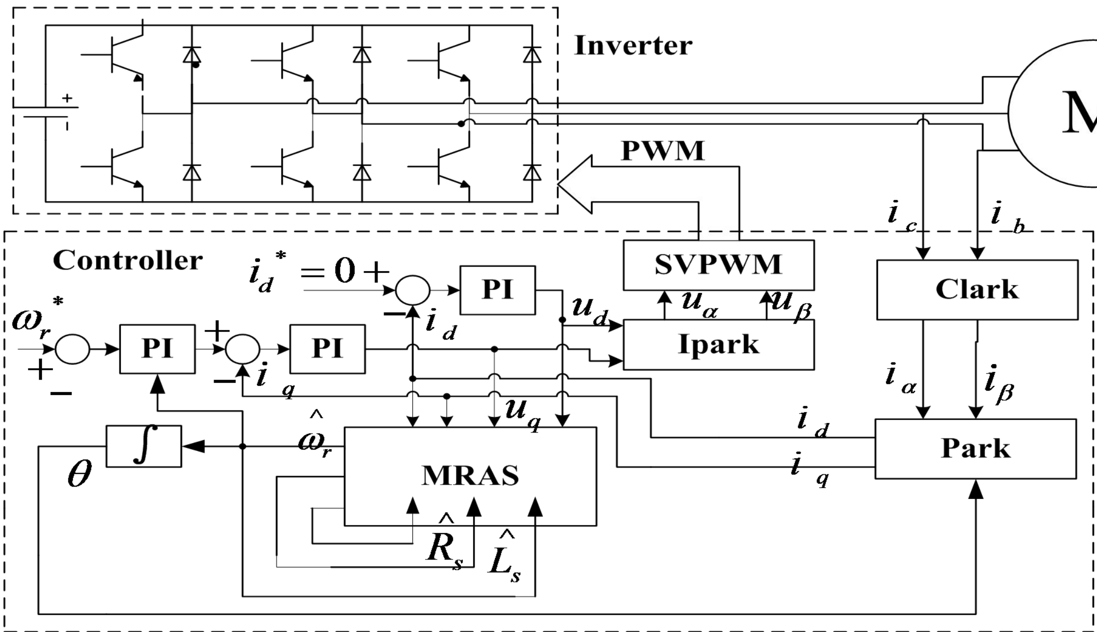

Figure 10: The Control block diagram of speed estimation and parameters identification of PMSM

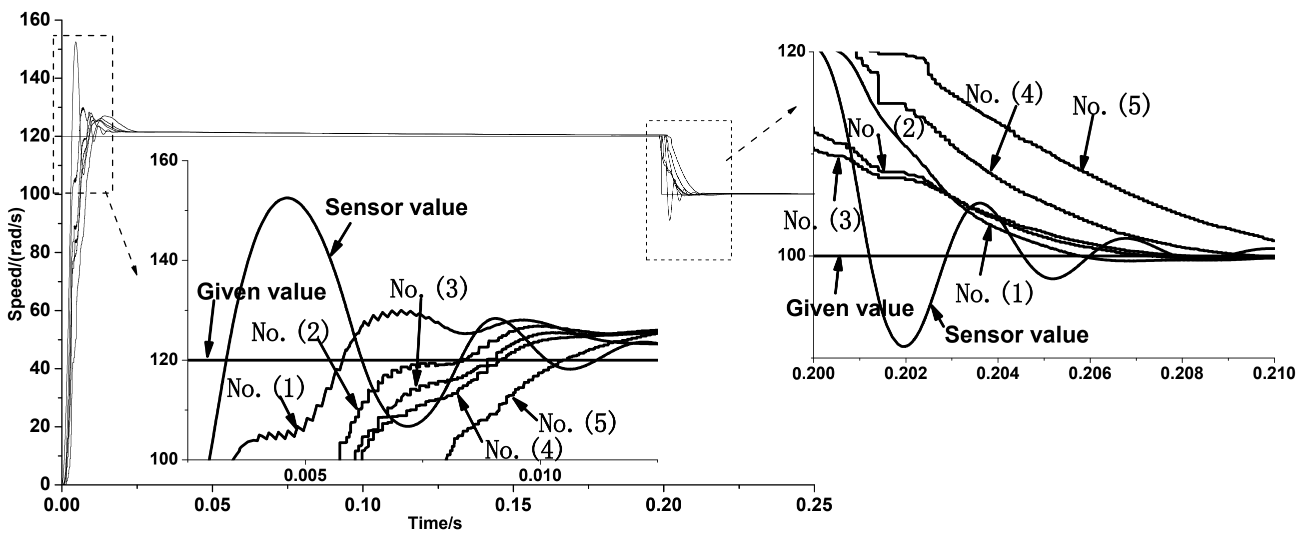

Figure 11: Simulation results of speed without parameters identification

As shown in Figure 11. In the case of the No.1, the speed response of the observer has good dynamic performance. Then, the given rotational speed mutation 100rad/s, the observer is still in good response.

Then the parameters identification is performed. we can use the method of 2.3 to determine the values of K_{Ri}, K_{Rp}, K_{Li}, K_{Lp}, as shown in Table 4.

Table 4: the values of K_{Ri}, K_{Rp}, K_{Li}, K_{Lp}

K_{Ri}	K_{Rp}	K_{Li}	K_{Lp}
911.2	1.36	67	0.1

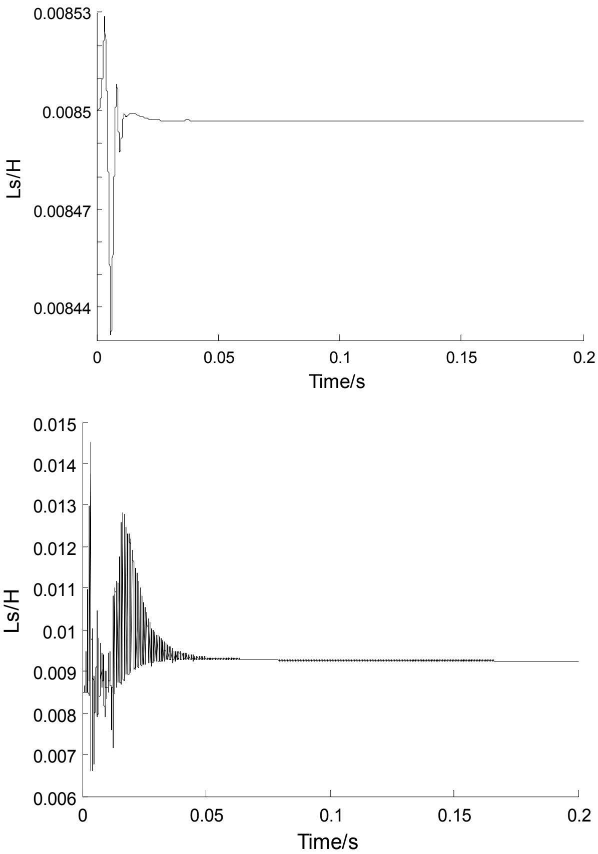

Figure 12: the parameter identification of L_s based on Lyapunov stability(up) and Popov stability(down)

As can be seen from the Figure 12, the up response speed and accuracy are higher than the down.

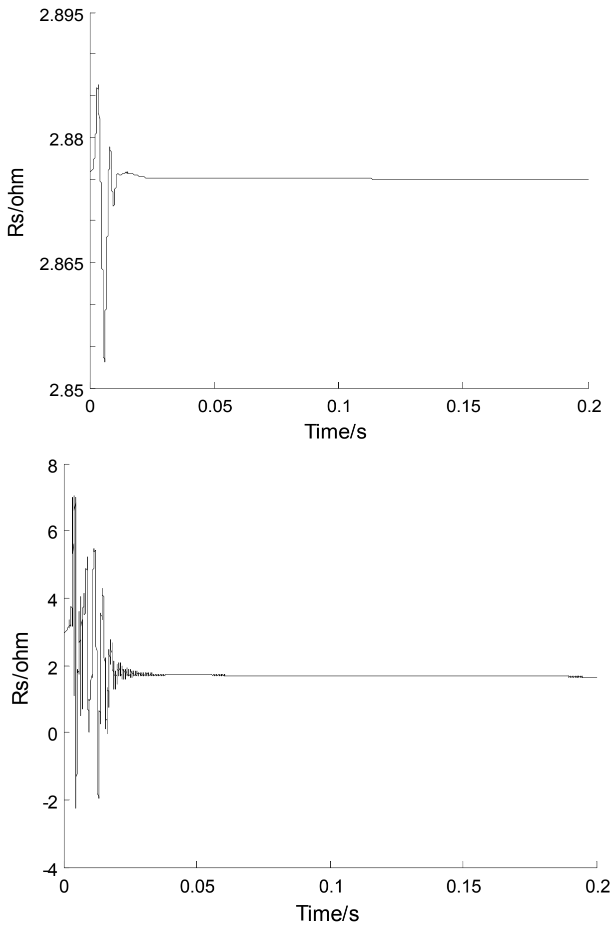

Figure 13: the parameter identification of R_s based on Lyapunov stability(up) and Popov stability(down)

As can be seen from the Figure 13, the up response speed and accuracy are higher than the down.

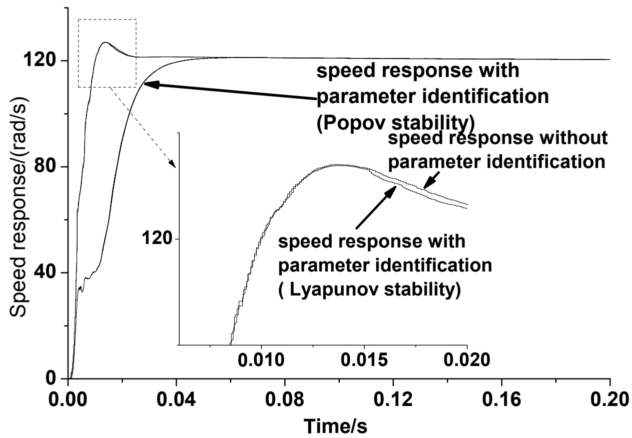

Figure 14: the speed response of different cases

As shown in Figure 14, the speed response with parameter identification based on Lyapunov stability is better than Popov stability. We can use this method to estimate speed and identify parameters simultaneously.

5 Conclusion

In this paper, the model is built according to the stator current d and q axis equations, and the adaptive law of speed estimation is constructed according to the Popov stability. A new method for the PI parameters of the speed observer is proposed. This method can be based on the parameters of the motor to quickly locate the parameters of the PI regulator, which provides a theoretical basis for the PMSM sensorless control.

Then, for the problems of speed estimation and parameters identification simultaneously, the adaptive laws of stator resistance, d-axis and q-axis inductance are constructed through Lyapunov stability and the Popov stability, respectively and compare their results. By comparison can be seen that the former is better than the latter. And the former do not need to adjust the PI parameters. This method can estimate speed and identify parameters simultaneously.

So, this paper solve the problems about PI parameters adjustment of speed observer and parameter identification and speed estimation simultaneously. The feasibility and effectiveness of this method are proved by simulation results.

References:

[1] Y. Jixian, Y. Gangfeng, Z. Bin. Sensorless control of permanent magnet synchronous motors based on MRAS, *Electrical Engineering Magazine*, Vol.32, No.9, 2015, pp. 1222-1228.

[2] D. Yongdong, T. Qingfang, Z. Yujun. Variable Structure MRAS Rotate Speed Identification System for Permanent Magnet Synchronous Motor, *Process Automation Instrumentation*, Vol.35, No.12, 2014, pp. 79-82.

[3] Y. Zongjun, W. Lina. Online Multi-Parameter Identification for Surface-Mounted Permanent Magnet Synchronous Motors, *Transactions Of China Electrotechnical Society*, Vol.29, No.03, 2014, pp. 111-118.

[4] G. Xing, Research on Rotor speed Identification Method for Permanent Magnet Synchronous Motor Based on Improved Model Reference Adaptive System, *Master thesis*: Hunan University, 2013.

[5] C. Yong, Z. Fu, L. Xia et al. Online adaptive parameter identification of PMSM based on the dead-time compensation, *International Journal of Electronics*, Vol.102, No.07, 2015, pp. 1132-1150.

[6] M. Rashed, Peter F. A. MacConnell, A. F. Stronach et al. Sensorless Indirect-Rotor-Field-Orientation Speed Control of a Permanent-Magnet Synchronous Motor With Stator-Resistance Estimation, *Industrial Electronics, IEEE Transactions on*, Vol.54, No.03, 2007, pp. 1664-1675.

[7] Q. Fang, D. Zhiquan, Q. Zhijian et al. A Method of Sensorless Vector Control for PMSM, *Transactions Of China Electrotechnical Society*, Vol.22, No.10, 2007, pp. 30-34.

[8] W. Qinglong, Z. Xing, Z. Chongwei. Double Sliding-mode Model Reference Adaptive System Speed Identification for Vector Control of Permanent Magnet Synchronous Motors, *Proceedings of the CSEE*, Vol.34, No.06, 2014, pp. 897-902.

[9] Q. Fang, Study on the Sensorless PMSM Vector Control System, *Master thesis*: Nanjing University of Aeronautics and Astronautics, 2007.

[10] L. Kan, Research on the Online Multi-parameter Identification of Permanent Magnet Synchrounous Machines, *doctoral dissertation*: Hunan University, 2011.

[11] L. Kan, Z. Qiao, Z. Ziqiang, Z. Jing. Comparison of two novel MRAS based strategies for identifying parameters in permanent magnet synchronous motors, *International Journal of Automation and Computing*, Vol.7, No.4, 2010, pp.516-524.

[12] D. Lindita, S. Aida. Simulation Based Analysis of Two Different Control Strategies for PMSM, *International Journal of Engineering Trends and Technology*, Vol.4, No.4, 2013, pp.596-602.

[13] Q. Zhiyong, Y. Zhengmao. Speed Regulation of a Permanent Magnet Synchronous Motor via Model Reference Adaptive Control, *Advanced Materials Research*, Vol.268-270, 2011, pp. 513-516.

[14] Z. Boze, R. Yi. The Research on Permanent Magnetic Synchronous Motor Vector Control Based on MRAS, *Applied Mechanics and Materials*, Vol.719-720, 2015, pp. 381-387.

[15] F. Shicai, L. Wuqiao, Z Jianxiao et al. A hybrid speed sensorless control strategy for PMSM Based on MRAS and Fuzzy Control, *Power Electronics and Motion Control Conference*, 2012, pp. 2976-2980.

[16] A. Quntao, S. Li, Z ke. An Adaptive On-Line Identification Method for the Parameters of Permanent Maget Synchronous Motor, *Transactions Of China Electrotechnical Society*, Vol.23, No.06, 2008, pp. 31-36.

[17] K. Pradeep, K. Mandeep, D. Surender. Sensor Less Speed Control of PMSM using SVPWM Technique Based on MRAS Method for Various Speed and Load Variations, *Lecture Notes in*

Engineering and Computer Science, Vol.2217, No.1, 2015, pp. 375-380.

[18] Z. Hongshuai, W. Ping, H. Bangcheng. Rotor Position Measurement for High-speed Permanent Magnet Synchronous Motors Based on Fuzzy PI MRAS, *Proceedings of the CSEE*, Vol.32, No.12, 2014, pp. 1889-1896.

[19] Y. Jianguo, F. Zhou, L. Beizhi. Study on Sensorless Control Model Based on a Model Reference Adaptive System with Parameter Optimization, *Applied Mechanics and Materials*, Vol.121-126, 2011, pp. 4770-4778.

[20] D. Zaltni, M.H. Abdelkrim. Synchronous Motor Observability Study and a New Robust MRAS Speed Observer with an Improved Zero-speed Position Estimation Design for Surface PMSM, *WSEAS Transactions on Systems and Control*, Vol.5, No.7, 2010, pp. 567-580.

[21] M.A. Hamida, J. De-Leon, A. Glumineau et al. An Adaptive Interconnected Observer for Sensorless Control of PM Synchronous Motors With Online Parameter Identification, *IEEE Transactions on Industrial Electronics*, Vol.60, No.2, 2013, pp. 739-748.

[22] A. Khlaief, M. Boussak, A. Châari. A MRAS-based stator resistance and speed estimation for sensorless vector controlled IPMSM drive, *Electric Power Systems Research*, Vol.108, 2014, pp. 1-15.