

A Review on Parameters Identification Methods for Asynchronous Motor

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Abstract—The decoupling of excitation current and torque current is realized by Vector control so that the speed regulating performance of asynchronous motor is comparable with that of dc motor. The control precision is directly affected by accuracy of parameter identification in asynchronous motor. In this paper, based on the existing literatures, the existed parameters identification methods both online and offline are analyzed and compared, and the advantages and disadvantages of the various algorithms are listed in tables. Therefore, a comprehensive identification method of adjustable model which makes the least square method as adaptive method of model reference is presented. Finally, the outlook of developing direction for parameters identification of asynchronous motor are put forward to.

Keywords—Vector control; Parameters identification; MRAS; the least square method

I. INTRODUCTION

Since the vector control was presented by Felix Blaschke, the ac speed regulating performance of asynchronous motor is comparable with that of dc motor. Vector control which is through the mathematical formula and the matrix transformation to make decoupling between the excitation current and torque current of asynchronous motor [1], and the control performance of asynchronous motor is enhanced greatly by a similar dc motor control method. Now, the parameters identification methods of asynchronous motor are mainly off-line identification and online identification. Because of the basic parameter of vector control can be provided and the operation is simple, the off-line identification is used most. But in the process of the motor operation, the stator resistance (R_s) and rotor resistance (R_r), and the time constant of Motor rotor ($T_r = L_r / R_r$) are influenced by the change of environment, such as the change of temperature, air humidity, high pressure, dust, and so on. The change of the time constant of rotor is affected by the change of resistance [2], which leads to magnetic field orientation is not accurate, and a better decoupling will not be produced between the excitation current and torque current of asynchronous motor. Finally, inaccuracy and deflection are emerged, and industrial production is also affected.

Off-line identification techniques [3]: (a) on one hand, the motor speed can be made to close to the synchronous speed by

the traditional no-load experiment; On the other hand, the motor speed can be made to be zero by locked-rotor experiment. (b) The motor parameters can be identified through the data of motor structure. (c) Different voltage are injected to motor based on a converter, the motor parameters can be identified by the motor to inspire different voltage. (d) A mathematical program is provided by least-squares, and a fitting curve is gain, which is about the fitting of minimum variance sense and an experimental data of completely measuring. Then the result of identification is obtained.

The excitation component and torque component of stator current are decoupled by formula (1) and formula (2). The ac speed regulating performance of asynchronous motor is compared with dc motor speed control. asynchronous motor's operation, motor parameters are easily influenced by environment. But the off-line identification cannot solve this problem absolutely. In order to control the precision of motor, the online identification of asynchronous motor is required.

At present, there exist 4 types of online identification techniques: (a) recursive least squares [4-5]. The estimated value of objective function is corrected continuously, and the parameter is estimated step by step until the satisfied parameter value is gained. (b) The extended Kalman filter [6] is recursive estimation method [7]. The estimated value of current state is calculated through the estimated value at the state of a moment before and the observed value of current, and this method is used in linear stochastic systems [8-9]. (c) MRAS is used to identified the motor parameter, and a suitable adaptive law is found [10-11]. The output's error between the reference models without identified parameters and the adjustable models with Different voltage are injected to motor based on a converter is a more reliable method than other off-line identification method. This method has many advantages, such higher recognition efficiency, higher precision, more convenient, and so on. The electronic resistance (R_s), leakage inductance of stator and rotor (σ), rotor resistance (R_r), and the mutual inductance (L_m) could be identified through this method. The time constant of rotor ($T_r = L_r / R_r$) can be deduced by the above identified parameters. Then, the stator current of motor is decomposed into torque component (i_{τ}) and excitation component (i_{ψ}) via the mathematical model of vector control and coordinate transformation.

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$$T_e = \frac{p_n L_m}{L_r} i_{st} \psi_r \quad (1)$$

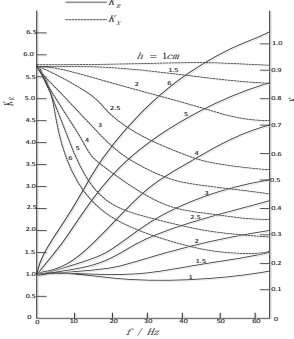
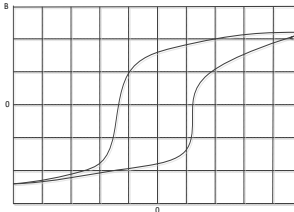
$$\psi_r = \frac{L_m}{T_r P + 1} i_{sm} \quad (2)$$

identified parameters tends to zero finally^[12]. Then the motor's parameters are identified^[13]. (d) The algorithms of artificial and intelligent identification is used to simulate natural biological systems, and totally dependent on its instinct to optimize the existence to adapt to the environment^[14].

II. THE FACTORS OF PARAMETERS

The parameters are in change for moment in the mathematical model of asynchronous motor and effected easily by factors .with changes of environmental factors and asynchronous motor, the parameters is changing. The parameters mainly contain stator resistance (R_s), rotor resistance (R_r), stator inductance (L_s), rotor inductance (L_r), and the mutual inductance between stator and rotor (L_m). The main factors of the change of the asynchronous motor running parameters are shown in table 1:

TABLE I. THE MAIN FACTORS OF THE CHANGE OF THE ASYNCHRONOUS MOTOR RUNNING PARAMETERS

Factors	Influence mechanism	Parameters are influenced	Change law
Temperature changes	The energy change into heat energy in the process of electrical energy transform into mechanical energy, the change of external environment, motor's aging degree and the degree of wear and tear.	Stator resistance of motor (R_s), rotor resistance (R_r)	$R_a = \frac{235 + t_a}{235 + t_b} R_b$ <p>(R_a) is the resistance in the temperature (t_a), (R_b) is the resistance in the temperature (t_b)</p>
Frequency changes	The skin effect is caused by frequency changes of current, which is related to the rotor's slot type of asynchronous motor.	Rotor resistance (R_r), rotor inductance (L_r)	 <p>Fig. 1. The curve is about the relationship between rotor resistance and inductance and frequency</p>
The factors of the saturated magnetic	Asynchronous motor is in the linear part of the B - H curve, while the iron core reluctance is smaller. When the magnetic is saturated, rotor resistance increases, and the inductance decreases ^[10] .	Rotor resistance (R_r), rotor inductance (L_r), the coefficient of leakage inductance (σ)	 <p>Fig. 2. B-H curve</p>
The stray loss	Eddy current loss is produced by magnetic-flux leakage, Eddy current and hysteresis are produced when Winding in the metal structure, higher-order Harmonic losses ^[9] .	stator inductance (L_s), rotor inductance (L_r), mutual inductance (L_m)	

III. THE IDENTIFICATION METHOD OF PARAMETER

A. The off-line identification method

Currently, the off-line identification method is studied in the world and advantages and disadvantages of each method are shown in table 2.

TABLE II. ADVANTAGES AND DISADVANTAGES OF THE OFF-LINE IDENTIFICATION METHOD

Identific ation method	Identification Principle	Identificati on parameters	Advantages	Disadvantages
<i>Locked-rotor method of motor</i>	Rotor winding of asynchronous motor is cut out and rotor is stuck to rotate unusually. Then parameters are calculated through the circuit principle. The equivalent circuit is shown in figure 3.	Resistance, inductance, mutual inductance.	The parameters of resistance, inductance, and mutual inductance can be calculated.	In many conditions, not only this kind of experimental conditions cannot be gotten, but also the load of system is very uneasy to be installed and removed. And the skin effect of rotor is very serious ^[11] .
<i>No-load experiment method</i>	Motor does not drag any load, and the rotor speed of motor is almost equivalent to the synchronous speed. Equivalent circuit is shown in figure 4.	Excitation reactance and the excitation resistance	Convenient is realized. In the case of motor's control precision is not high, the required parameters are measured.	The rotor circuit is ignored, and the identification precision is not high. In many occasions, the load is carried by motor. It is not convenient to no-load removed load.
<i>Auto-tuning method of motor parameters</i>	Different test signal is injected into motor to make the motor in different state. The features of frequency converter are used to perform some procedures. Finally, the purpose of identifying motor's parameters is achieved.	Stator resistance (R_s), leakage inductance (σ) rotor resistance (R_r).	Precision is higher and good reliability.	This method is suitable for being used in a control system with frequency converter, and it is not convenient to be used in the control system with no frequency converter.
<i>The least square method</i>	The experimental data in the whole stage is sampled through a complete measurement. Then the least squares curve is offline calculated and fitted, and the identified results are obtained.	Rotor resistance and inductance.	High precision.	A large amount of data and the experimental data in the whole stage are need to be measured, and measurement and t calculation are tedious.

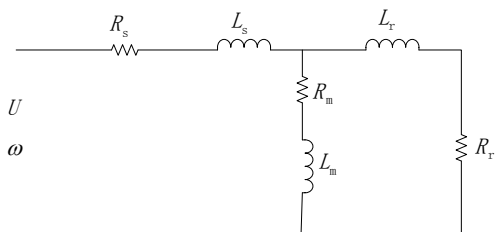


Fig. 3. The equivalent figure of motor cutting-out

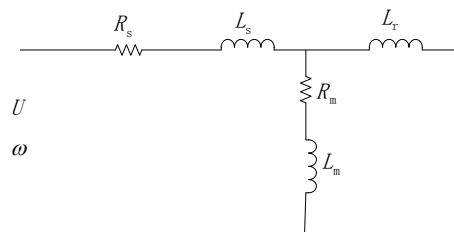


Fig. 4. The equivalent figure of motor no-load

B. Online identification method

The above off-line identification methods are the identification that in the case of motor no-load or in a moment the motor is changing with temperature and environment in the operation process. In a high-precision control system, the off-

line identification cannot meet the requirements. Thus, the parameters are required to be identified online and identified at every moment. Online identification method is shown in table 3.

TABLE III. THE ONLINE IDENTIFICATION METHOD

identification method	Identification principle	Identification parameters	Advantages	Disadvantages
<i>The extended Kalman filter^[7]</i>	The state equations of motor is used directly. The parameters which need to be identified and states are set as quantities of augmented state. The optimal estimation of the state is given solving riccati equations in online ^[8] .	Rotor resistance, mutual inductance, flux linkage	With high identified precision and more parameters. And other unpredictable state can be estimated. Itself has filtering effect and can reduce some interference ^[9] .	The algorithm is complex and good performance of processor is required
<i>MRAS</i>	The actual running of motor is used as the reference model, and the state observation equation of motor is used as the adjustable model. Motor's parameters of the adjustable model are corrected in real time by some measurable deviation	Rotor resistance, stator resistance, mutual inductance.	A small amount of calculation and high precision.	Reference model is difficult to be determined
<i>The improved least square method</i>	The experimental data in the whole stage is sampled through a complete measurement. Then, the least squares curve is calculated offline and fitted, and the identification results are obtained.	Resistance, inductance, time constant of rotor.	High precision and good reliability. Both online and offline identification.	It is Sensitive to noise of measurement and fluctuation of speed. The estimated value exists multi solutions and deviation problems owing to the singularity of structure matrix.
<i>Intelligent algorithm[15]</i>	Neural network and genetic algorithm are included in this method ^[16] . The former makes the function value of error to be minimized by learning system's Input and output. The latter is a kind of random search algorithm, which can simulates the natural evolution ^[17] .	Resistance and inductance	The precision is very high.	The calculation is so huge and the requirement for processor is relatively high.

IV. COMPREHENSIVE IDENTIFICATION SYSTEM

According to the analysis and study of existing literature, the single identification method has defects more or less.

A kind of method that both off-line identification and on-line identification are put forward by author based on existing literatures. The method is combined with model reference adaptive and improved least square method. The adjustable model is constructed by the improved least square method, and the least error is made to be minimized between the reference model and the adjustable model.

A. The principle of model reference adaptive

THE PRINCIPLE OF MODEL REFERENCE ADAPTIVE IS SHOWN IN FIGURE 5.

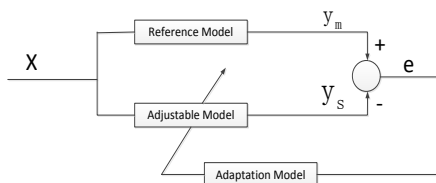


Fig. 5. Principle of model reference adaptive

This system has the same external input(X), while the (X) is input to the reference model and the adjustable model. (y_r) and (y_s) are the output of the reference model and the adjustable model. Finally, the result of $e = |y_r - y_s|$ is calculated to be minimized or zero through the adaptive adjustment. The design of adaptive control mainly includes:

1) *The optimization theory of partial parameters. The structured distance between the reference model and the adjustable model is defined, or two times performance index of state distance. The method of parameter optimization is used to determine the adjustment of parameters of the controller. Rules make the adjustable model closer to reference model to achieve the purpose of identifying parameters.*

2) *Popov super stability theory. Firstly, the model reference adaptive system should be transformed into equivalent nonlinear time-varying feedback system. Namely, the system is formed by a linear forward link and a nonlinear feedback link. A suitable law of adaptive control is gotten*

under the guarantee of meeting the two conditions. This makes the whole nonlinear system is stable, which can ensure the system error tends to zero and achieve the purpose of adaptive control.

B. B. The least square method

A linear relationship exists between the variables (y) and one dimensional variable $x = (x_1, x_2, x_3 \dots x_n)$, namely:

$$y = C_1x_1 + C_2x_2 + C_3x_3 + \dots + C_nx_n$$

The value (C) is estimated based on the observed values (y) and (x) in different time. This method requires repeated computation under the need of update data, this problem is solved by recursive least squares method. A new set of data don't need to be added and calculated again, and the amount of calculation is reduced greatly. The basic idea of recursive least square method is: the new estimate value = the old estimate value + correction term. So that $y = \theta_1x$ and $e = y_m - \theta_1x$ is its minimum.

V. CONCLUSION

Through analyzing and concluding the existing literatures, Conclusions can be gotten as follows:

1) As shown by the table 1, the rotor resistance of asynchronous motor is changed mostly by the environmental factors. As shown by the formula (1) and formula (2), the rotor flux linkage is changed directly by the change of rotor resistance. Then, the decoupling of rotor flux linkage is not sufficient. If a certain control accuracy is required by a control system, a control method which main identifies rotor resistance can be chosen.

2) Offline identification method has many kinds of classes. Being compared with the locked-rotor method of motor no-load experiment method and the least square method, auto-tuning method of motor parameters is used most widely, the technology is most mature, and the identification accuracy is more accurate and reliable.

3) The system which requires high precision of identification, low cost and reliable performance and easy to implement, the least squares method is a better method, because this method can not only realize the off-line identification but also realize the online identification.

4) As to the control system which very high accuracy of identification, intelligent algorithm can be used as the focus of future research methods. This method has the very good control precision.

With the rapid development of the economic in China, the motor's control technology with high precision is widely used in all kinds of industrial fields. The higher requirements for the identification accuracy of asynchronous motor is put forward. At present, China is still relatively backward in terms of manufacturing and control of asynchronous motor. Especially the gap from Western countries in processor manufacturing is large. How to make the motor control more accurate, which

requires higher parameter identification. Although the general industrial production requirements can be satisfied by the identification method of existing parameters, it is not enough in some high precision control system. In genetic algorithm, genetic algorithm and neural network algorithm are continuous optimization and find out the optimal solution, which needs higher requirements for the processor to be put forward. Therefore, the intelligent algorithm has a broad prospect in the future and it can be developed from two aspects. On one hand, the intelligent algorithm could be improved^[18-19]. The algorithm is simple and high precision of parameter identification could be achieved. On the other hand, the performance of processor could be improved so that the processor speed is faster and cheaper.

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