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Research on adaptive vector control system for induction motor

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Abstract

This paper mainly use the induction motor to the study of drainage gas recovery to carry out the control strategy. Firstly, in order to achieve the speed sensorless control of induction motor, the simulation model of speed sensorless vector control system of induction motor is built by using SIMULINK simulation platform. Because of its high precision of speed regulation and good dynamic characteristics, it lays a solid foundation for the follow-up research. Because the dynamic change of motor parameters during the operation of induction motor will affect the accuracy of speed estimation results, it is necessary to identify the parameters of induction motor through the moth algorithm to eliminate the influence of induction motor parameters change on speed estimation. To be embedded in the speed sensorless control system of induction motor is established, the realization of induction motor based on the adaptive rotor flux vector control, in SIMULINK simulation. The simulation results show that the system can effectively improve the robustness of the sensorless control system of induction motor, and greatly improve its speed regulation performance, which verifies the effectiveness of the whole system.

Keywords

Induction motor; Vector control; MRAS; Moth algorithm.

1. Introduction

As an important natural resource, the liquid column will be formed in the process of natral gas expoitation, which will lead to the halt production of gas Wells. This is because it causes excess static water back pressure, but also makes the gas well direct injection energy gradually reduced, which commonly known as "gas well liquid" .We can use the drainage gas recovery process to solve the problem quickly and effectively. Induction motor is widely used in drainage gas recovery and compressor into the type high pressure gas Wells, the bubble discharge agent will be pumped into the wells. This research mainly focuses on the realization of induction motor based on the adaptive rotor flux vector control system and simulation [1]. In the process of drainage gas extraction, the working state of induction motor is easily affected by other factors such as humidity, temperature, chemical substances and vibration of the environment. The speed sensor will be easily get disturbed, such as its accuracy and other components. If the performance of the speed sensor all disappeared, whether the induction motor stay normal and how to maintain a stable operation, this is the situation we need to consider.

Speed sensorless control of induction motor can be divided into the following types according to different control methods :(1) method based on model state observer [2,3] (2) rotor tooth harmonic algorithm [4,5] (3) high-frequency signal injection method [6,7]. (4) Artificial intelligence algorithm. Due to the continuous emergence of many intelligent Control technologies and related theories in the 1990s, such as Expert System, Fuzzy Control and artificial Neural Network [8,9], These artificial intelligence algorithms provide some new ideas and inspirations to the field of AC electric drive system design.Seong-Hwan et al. obtained the

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speed of induction motor and rotor flux data through studying the multi-layer neural network algorithm with hidden layers, and then combined the process nodes of input and output data through the construction of multi-layer recursive structure, so as to realize the effective control of parameter variation control and the error of system noise influence [10]. In theory, through artificial neural network to improve the speed sensorless induction motor control algorithm of seemingly has matured. In fact, in terms of practical application, it is still in the early stage, and professional hardware is needed to support it in order to make it more mature, so further research is needed [11].

2. Research on parameter sensitivity of induction motor based on intelligent optimization algorithm

During the operation of induction motor, the dynamic change of motor parameters will also be affected by temperature, frequency, magnetic saturation and skin effect and other factors. When the parameters such as constant resistance, self-inductance, mutual inductance and rotor resistance change dynamically, it is necessary to adjust the parameters, so as not to affect the accuracy of speed estimation results. The steady-state and dynamic characteristics of the whole system are affected by the accuracy of rotor flux prediction and speed prediction, which is very obvious and often occurs in the speed sensorless control system of induction motor. The current model and voltage model are used in the simulation system. They use the MRAS algorithm and flux observer [12]. In the simulation system, the current model is usually affected by the change of rotor time constant, and the voltage model is affected by the change of constant resistance and electronic inductance.

2.1. Influencing factors of induction motor parameters

In the actual working environment, the surrounding conditions of the induction motor will change, leading to the change of the parameters of the induction motor. The reasons for the dynamic change of the parameters of the induction motor are as follows.

Temperature change

Changes in temperature will lead to changes in equipment resistance. The relationship between equipment stator resistance and rotor resistance and temperature is defined by Formula (2-1)

$$R_b = \frac{t_b + k_1}{t_a + k_1} R_a \tag{2-1}$$

In formula (2-1), R_b is the resistance at t_b temperature, and R_a is the resistance at k_1 temperature. The value of k_1 is generally around 230K, depending on the properties of the conductor. When the temperature changes from 253 k to 373 k, the resistance increases nearly doubled. Unlike the stator winding, the rotor resistance is generally considered to be affected by both the current frequency and conductor temperature.

The frequency change

The frequency of the induction motor dynamic change, can lead to skin effect, specifically is the frequency under the condition of high current or voltage, the outer surface of the conductor will appear a large number of electrons. Once this effect occurs, the current distribution becomes uneven, which is equivalent to an increase in resistance. In other words, changes in rotor current and frequency will result in changes in rotor parameters. When the frequency changes, the curve of rotor resistance and reactance vary with frequency as shown in figure (2-2)[13].

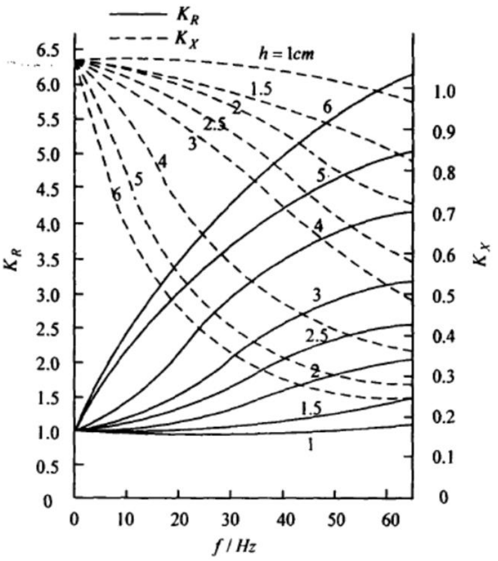

FIG. (2-2) Relationship between resistance, reactance and frequency

In Figure (2-2),h is the depth of the tank, K_R is the rate of increase in resistance, and K_X is the rate of decrease in reactance. The induction motor adjusts the speed by adjusting the frequency of the power supply. When the power frequency increases, due to the skin effect, the deeper of the groove, the greater the increase of its resistance, and the greater the reduction of reactance.

saturation of magnetic circuit

Excitation inductance mainly depends on magnetic saturation degree of core and the length of air gap. When the output is limited within a certain range, when the motor runs to the range of weak magnetic speed regulation, the main flux decreases, magnetic saturation gradually decreases, and the excitation inductance increases synchronously. Magnetic saturation will also affect the rotor leakage resistance and rotor resistance. When the load current passes through the conductor of the rotor, magnetic saturation occurs in the core of the rotor. Due to the influence of magnetic flux leakage, skin effect will also appear in the conductor of the rotor. At this time, the resistance of the rotor will gradually increase, while the leakage reactance of the rotor will gradually decrease.

To sum up, by analyzing the main reasons for parameter changes of induction motor during operation, it can be known that resistance is most susceptible to environmental influence and changes greatly in induction motor operation, while inductance changes little. However, in applications with speed sensorless, stator and rotor resistance are key parameters affecting speed estimation [14]. In order to reduce the complexity of the algorithm and improve its efficiency, only the parameters of rotor time constant and stator resistance are discussed in this paper.

3. Moth algorithm based on parameter identification of induction motor

3.1. Moth algorithm

At present, the search algorithms inspired by rules of biological evolution mainly include genetic algorithm, particle swarm optimization algorithm, ant colony optimization algorithm, differential evolution and some new intelligent optimization algorithms. Moth - flameoptimization (MFO) algorithm is by Seyedeli Mirjalili (Griffith university Australia) in 2015 put forward a new kind of swarm intelligence optimization algorithm, Its inspiration comes from a navigation mode called lateral positioning of moths at night [15]. MFO is a kind of heuristic search algorithm, it has the parallel optimization ability, overall good and not easy to fall into local optimal performance characteristics. When there is an artificial light, always fly

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at the same Angle as the artificial light. Because it is too close to the light source, it will not fly in a straight line, but will approach the light in a spiral path.Seyedali Mirjalili get inspired that he regards moths around the light source of spiral flight process as an optimization process ,and the whole space is the solution space of the problem, every each of a moth corresponding to a solution of the problem, the light source is a relatively optimal solution of problem, because every each of a moth corresponding to a flame which avoid the algorithm trapped in local optimum.

When there are enough moths and light sources, the moths can search most of the solution space during spiral flight, which can ensure the global exploration ability of the algorithm. In the process of optimization, the number of light sources decreases with the increase of the number of iterations, which enables the moth to search the neighborhood space of the better solution, thus ensuring the local optimization ability of the algorithm. MFO is a random heuristic search algorithm based on population. Compared with PSO[16], GA and other algorithms, its biggest characteristic is that its particle search path is spiral, and moths move around the light source in a spiral way instead of straight line, which can not only effectively build model identification model structure. The results of system model parameters can also be obtained.

3.2. Parameter identification process of induction motor

Step1 Enter the parameters and initialize them.

Step2 Randomly initialize the moth population position and evaluate the fitness.

Step3 Adaptively reduces the number of flames, updates the search parameters R and T of moths, and assigns the spatial position of moths to the flame in the order of increasing adaptive value, which is used as the spatial position of the flame in the first generation. When the number of iterations is 1, the number of moths is the number of flames.

Step4 Reorder the fitness value of the updated flame position and moth position, and select the space position with better fitness value to update it as the next generation flame position [17,18].

Step5 Update the moth position according to the flame and flight parameters corresponding to each moth.

Step6 Determines whether the termination condition is reached. If so, jump to Step7; otherwise, jump to Step3.

Step7 Output the optimal result and terminate the program.

4. Adaptive vector control system and simulation of induction motor based on rotor flux orientation

Before this paper, based on FOC speed sensorless control system of induction motor, induction motor control system are built in this chapter, using the described in the previous chapter MFO online parameter identification of induction motor is realized, and the embedded in the established speed sensorless control system of induction motor, The adaptive vector control system of induction motor based on rotor flux orientation is realized and verified in SIMULINK. Due to need only two parameters, respectively the rotor time constant and stator resistance, so set the dimension of MFO algorithm for 2D, algorithm will take place in a two-dimensional space search, the search area is small so the search speed can be faster. It can greatly improve the efficiency of the algorithm and improve the possibility of using it in the actual motor control system.

The speed sensorless control system of induction motor is built on the assumption that motor parameters will not change, but in fact, as described in Section 2.1.1, motor parameters will change during operation due to various influencing factors. So then consider motor parameter changes (mainly the stator resistance and rotor time constant), the motor speed sensorless

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vector control system and its adaptive vector control system simulation, to verify its performance difference.

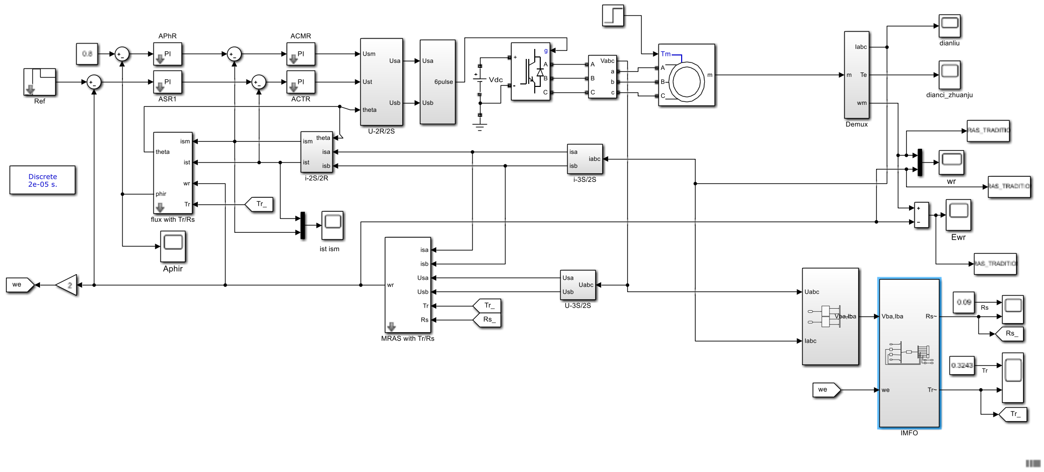

Figure 4-1 Simulation model of adaptive vector control system for induction motor based on rotor flux orientation

To on motor performance under the influence of stator resistance variation, for example, set the motor parameters in operation of the stator resistance due to factors such as temperature changed, its value to the original 1.1 times, in the motor speed sensorless vector control system, the parameters of the MRAS model is still the original parameters. The parameter identification program based on moth fighting fire can identify the variation of parameters in real time and modify the parameters of the speed observer and flux observer in real time.

When at t = 0 s to a motor amplitude is 60 rad/s speed step signal, adaptive in induction motor vector control system, the output of the stator current and speed curve, respectively, as shown in figure 4-2 and figure 4-3.

For comparison, the simulation model of motor speed sensorless vector control system without parameter identification is run under the same setting, and its stator current and speed are shown in Figure 4-4 and Figure 4-5.

As can be seen from Figure 4-4, compared with Figure 4-5, the estimated speed of the vector control system based on rotor magnetic field orientation of induction motor basically coincides with the actual speed, and its current is basically stable, so it can be proved that its performance can meet the actual control requirements. The speed estimation errors of the two systems are shown in Figure 4-6. The left figure is the motor speed sensorless vector control system with parameter identification, and the right figure is the motor speed sensorless vector control system without parameter identification module.

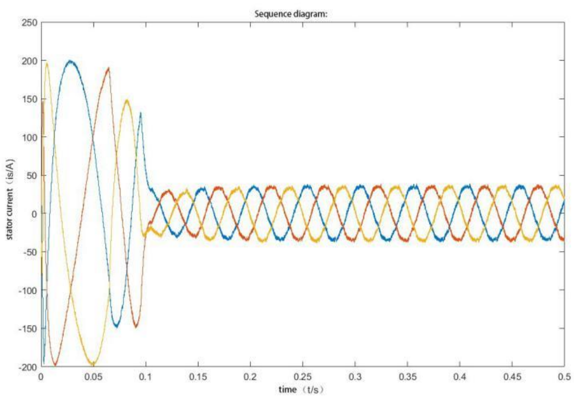

Figure 4-2 Stator current of induction motor adaptive vector control system

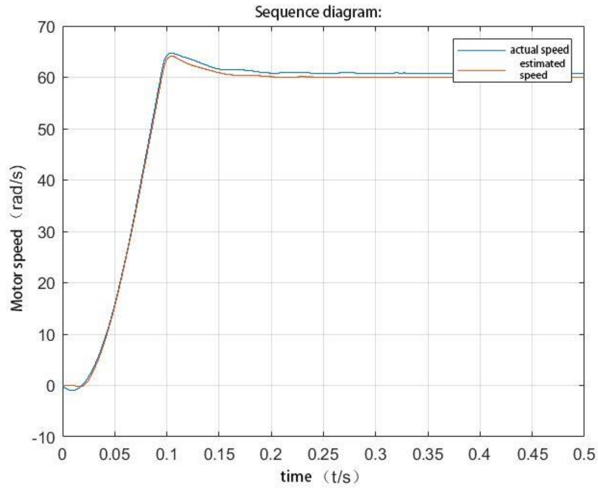

FIG. 4-3 Real speed comparison of induction motor adaptive vector control system

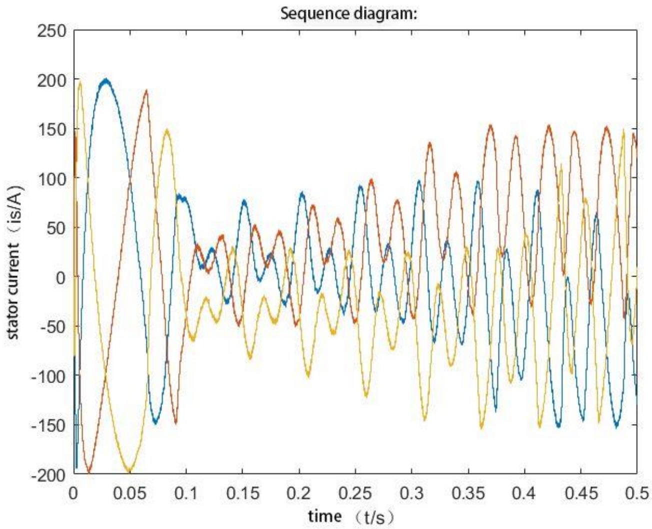

Figure 4-4 Stator current of induction motor vector control system under parameter misalignment

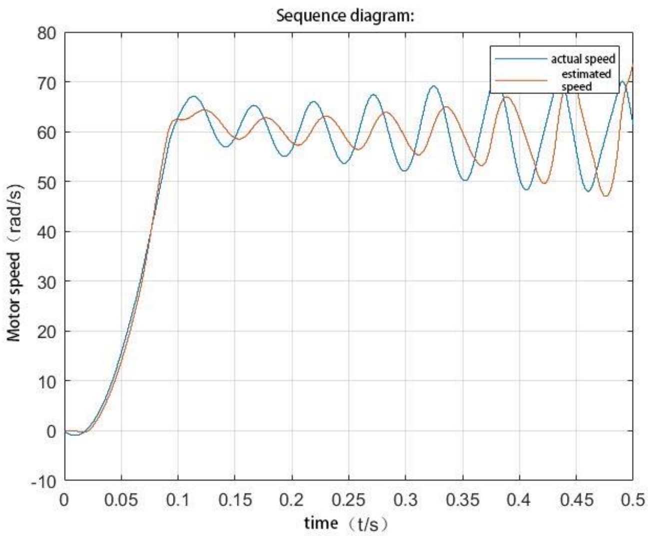

Figure 4-5 Comparison of speed of induction motor without speed sensorless vector control system under parameter misalignment

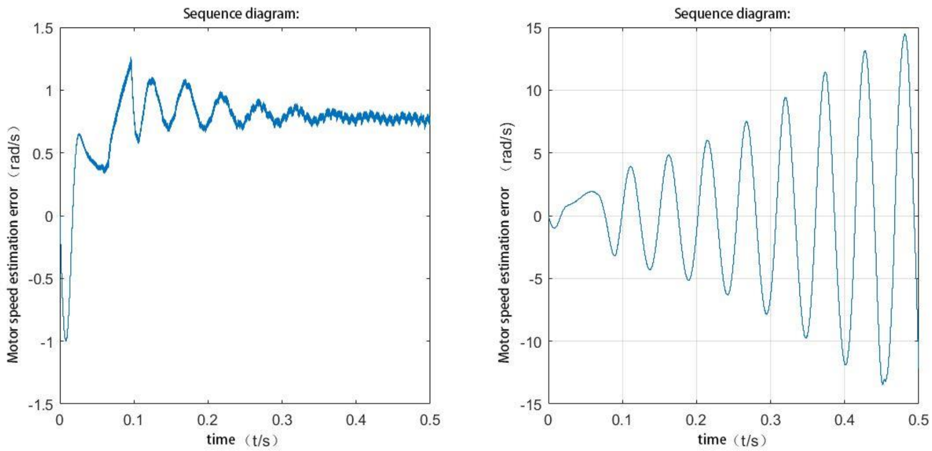

Figure 4-6 Comparison of speed estimation errors of motor speed sensorless vector control system

5. Conclusion

In this paper, a speed sensorless induction motor control system based on FOC is firstly established. On the established induction motor control system, MFO algorithm is used to realize the induction motor online parameter identification, and it is embedded into the established induction motor speed sensorless control system, and then simulation verification in Simulink. It is concluded that it can adapt to the change of induction motor parameters and keep good running state. In this way, the efficiency of the algorithm is greatly improved and the possibility of applying it to the actual motor control system is improved. The control performance of the induction motor for drainage gas recovery is improved and the stable operation of the motor is guaranteed under bad environment. Based on the rotor flux oriented induction motor vector control system, the speed sensorless control system of the motor is studied. On this basis, the control precision of induction motor is improved by intelligent optimization algorithm. In speed sensorless sensor, the practical and mature MRAS speed observer is used to estimate the speed. Online parameter identification of induction motor is designed and combined with MRAS model and rotor flux observer. Simulation experiments are carried out in Simulink environment to verify the effectiveness of the whole system.

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