Identification of Permanent Magnet Synchronous Motor Model Based on Theoretical Model and Proxy Model

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***Abstract*—This article mainly designs and analyzes the parameter identification technology methods for permanent magnet synchronous motors based on theoretical models and surrogate models. Firstly, the importance of parameter identification for permanent magnet synchronous motors was introduced, as well as the current main parameter identification methods and possible problems. Then, a mathematical model of the three-phase permanent magnet synchronous motor was provided for the design and analysis of subsequent parameter identification algorithms; Next, the main parameter identification method, the least squares method, was introduced, and the principle, assumptions, and geometric significance of the least squares method were described. The mathematical expressions of batch processing least squares method, recursive least squares method, forgetting factor recursive least squares method, and multi information least squares method were derived in detail; Secondly, this article combines radial basis function neural networks to design a parameter identification method based on surrogate models, and provides detailed mathematical expressions; Finally, using PMSM simulation data under PID control, ESO based speed and current loop control (C-ESO), and ESO based composite current loop control (COM-ESO), the identification effects of forgetting factor recursive least squares (RLS), multi information recursive least squares (MILS), and RBF proxy model-based parameter identification method (RBF-RLS) were compared and analyzed.**

***Index Terms*—Permanent magnet synchronous motor, theoretical model, proxy model.**

I. INTRODUCTION

With the continuous development of power electronics technology, permanent magnet materials, and control theory, permanent magnet synchronous motors have become increasingly widely used in fields such as CNC machine tools, medical machinery, rail transportation, household appliances, and aerospace due to their advantages of small size, simple structure, high power density, high efficiency, and wide range speed regulation. It is particularly crucial to accelerate the upgrading of the power devices of equipment motion actuators in order to promote the development process of the manufacturing industry. At present, the power device of precision mechanical equipment has developed from traditional gear, pneumatic, and hydraulic transmission to electrical transmission. With the rapid development of digital control technology, power switching devices, permanent magnet materials, and control theory, electrical transmission has also undergone a transformation from DC motor, asynchronous motor drive to permanent magnet synchronous motor drive. With the increasing demand for equipment processing accuracy, work reliability, production efficiency and other indicators, the current equipment manufacturing industry has put forward higher requirements for permanent magnet synchronous motor drive systems in terms of control accuracy, operational efficiency and reliability. Therefore, the development of high-performance permanent magnet synchronous motor drive systems has become the core issue in promoting the high-end development of equipment manufacturing industry.

Most high-performance controllers require real-time and accurate electromagnetic parameters as inputs to the algorithm, but in actual working environments and operating states, the electromagnetic parameters of the motor will change with factors such as temperature rise and magnetic saturation. The temperature rise of the winding will lead to an increase in stator resistance, which on the one hand increases the losses in energy conversion, and on the other hand, excessive temperature reduces the magnetic flux of the permanent magnet, and even causes demagnetization; Magnetic saturation can cause a sudden increase in stator current, thereby affecting the inductance values of the AC and DC axes. Therefore, the variation of electromagnetic parameters with working conditions reduces the steady-state and dynamic performance of the control system, and even leads to the instability of the entire system. Therefore, accurate identification of motor parameters is of great significance for improving the performance of permanent magnet synchronous motor systems. The parameter identification of permanent magnet synchronous motors is usually divided into offline identification and online identification. Offline parameter identification is to identify the parameters of the motor when it is in a stationary state, while online parameter identification is to identify the parameters during the operation of the motor and update the identification results in real time.

Using offline identification methods, it is necessary to apply some excitation signals to the motor or let the motor work in a special state, and then calculate parameters based on the response. The commonly used offline identification methods for stator resistance, inductance, and magnetic flux identification are as follows: (1) Resistance identification: using DC volt ampere method to measure stator resistance, injecting a small DC voltage into the motor, and calculating stator resistance based on the applied voltage and measured current. (2) Inductance identification: The method of identifying inductance by injecting excitation signals is divided into two types: high-frequency injection method and pulse injection method. The high-frequency injection method injects high-frequency voltage into the stator end of the motor. Due to the high frequency of the injected voltage, the resistance and magnetic flux are minimally affected, so only the inductance is considered. Then, the inductance value is estimated based on the generated high-frequency response current. Pulse injection method is to apply voltage to the motor for a period of time to achieve the positioning of the d-axis of the motor. After the position is determined, the same voltage needs to be applied to the motor again to make the stator current rise to a stable value. Based on the measured rise time, the inductance value can be calculated. (3) Magnetic flux identification: Calculate the magnitude of the magnetic flux using the back electromotive force method. Run the motor under vector control with no load, and estimate the magnetic flux value based on the magnitude and frequency of the back electromotive force measured during operation. Using offline methods for parameter identification of PMSM can accurately obtain the parameters of PMSM. However, in offline methods, it often requires the use of other devices to obtain more signals, resulting in more cumbersome data collection and storage for the system.

Although offline identification can obtain more accurate motor parameter identification results, the parameters of the motor will change with the operating conditions and environment during operation. For example, temperature changes can cause changes in stator resistance and magnetic permeability of ferromagnetic materials, resulting in changes in stator inductance and rotor permanent magnet flux. In addition, magnetic saturation can also cause nonlinear changes in magnetic permeability, thereby altering stator inductance and rotor magnetic flux. The use of offline identification often requires storing a large amount of data in tabular form for real-time querying by the controller, which not only complicates the implementation process but also cannot accurately reflect the actual parameters of the motor. Online identification is the process of identifying parameters while the motor is operating normally. When the parameters change, their current values can be obtained in real time. Therefore, online identification is of significant importance in improving the robustness of permanent magnet synchronous motor control systems. On the one hand, obtaining motor parameters online can be used for online calibration of motor controller parameters to achieve better operating performance, and on the other hand, it can also be used for monitoring motor operating status, fault warning, etc. For example, identifying stator resistance can be used to monitor the temperature of the motor stator; Online identification based on rotor magnetic flux can be used to monitor rotor temperature and permanent magnet demagnetization faults. Common online parameter identification algorithms include recursive least squares, state observer, model reference adaptive, Kalman filter, and neural network intelligent algorithms.