A PI control strategy for Surface Permanent Magnet Synchronous Motor

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Abstract: In order to ensure the strong nonlinear parameter characteristics of Surface Permanent Magnet Synchronous Motor (SPMSM), which are commonly found at high speed and high power, and to ensure their good adaptability in the high speed range, this paper proposes a PI control algorithm for Surface Permanent Magnet Synchronous Motor adapted to high power and high speed types according to the characteristics of PI control. In order to verify the reliability, anti-interference and fast response of this control algorithm, system simulation tests were carried out by building a system simulation model, and the feasibility of this control strategy was verified by the simulation test results, which has a positive significance at a wide level for this type of motor.

1. Introduction
Permanent magnet synchronous motor is widely used in various industrial fields nowadays because of its excellent performance characteristics such as high power-to-weight ratio and high maintenance, and among its control algorithms, PI control has been widely used due to its many advantages such as simple structure, easy implementation, and high reliability [1]. However, for the main parameters of the permanent magnet synchronous motor have the characteristics of strong coupling, nonlinearity and other characteristics that are not easy to control, and in the process of actual high power and high speed operation in most of the current industrial fields, the existence of high variables in the load causes the motor to vibrate more and reduce the efficiency. In order to solve this problem and make the motor run steadily at high speed and high torque, a PI control strategy is proposed for the surface-mounted permanent magnet motors [2]. The effect of steady-state operation of the motor at high speed and power is achieved by optimizing the corresponding parameters in this interval when using PI control [3].

In this paper, to address the performance discrepancy problem of conventional permanent magnet synchronous motor at high speed in PI control, this paper designs a new PI control method to improve the stability of the motor at high speed and high power state for the speed control of Surface Permanent Magnet Synchronous Motor (SPMSM) [4]. The new PI control method proposed in this paper increases the given input feedforward and control gain on the basis of the traditional PI control,
uses the space vector method, and coordinates transformation method with integral clamp anti-saturation to enhance the stability and tracking of the tacho control system in the process of fully simplifying the collation and revision of PI parameters.

2. PI control design

The traditional PI control strategy may cause control dysfunctions at high speed and power under the influence of the following external environmental factors.

In common permanent magnet synchronous motor control methods, the actual value of the rotor angular velocity is usually judged by position sensors in comparison with the detected angular velocity by calculus. However, the angular error generated by various position sensors themselves, etc., makes the value subject to large disturbances during actual operation [5].

During the operation of the motor, the stator flux, stator winding resistance, rotor permanent magnet flux, AC inductance, DC inductance and other parameters will change in real time due to the influence of real-time changes in temperature and other factors. Traditional PI parameters are usually obtained based on the calculation of the motor's characteristic parameters, which cause errors in the PI parameters when the motor performance parameters change, affecting the control accuracy.

Due to the limitations of the motor by the process and manufacturing conditions, the actual motor rotational inertia, shaft stress, etc. have certain deviations from the theoretical values, resulting in errors in the PI parameters obtained from theoretical calculations compared to the actual demand values.

For this reason, a multi-case optimal design of the traditional PI control method is required. The multi-case optimal design of PI parameters includes.

When the control system is fed with a continuously varying speed, the control quantity corresponding to the differential state of its input value can be transformed into the response of the differential feed forward link in a timely manner. In the case of ignoring external disturbances, this PI control method can achieve relatively small errors in following the input value, i.e., it can ensure the following of the control system [6].

When the control system inputs a discontinuous step signal as the speed value, the control quantity corresponding to the differential state of the input value is reflected as a pulse signal, taking into account the current step and voltage limit amplitude, the control quantity corresponding to the differential state of the step signal cannot be transformed into the response of the differential feed forward link in time. That is, the differential feedforward link can be regarded as a failure state at this time.

Inside a permanent magnet synchronous motor, the cross-shaft counter-electromotive force presents a constant value when the motor speed varies uniformly. In order to reduce the influence of this counter-electromotive force on the speed following, we compensate the cross-shaft counter-electromotive force. This compensation value can be obtained by multiplying the speed with the cross-shaft counter-electromotive force constant. Similarly, the compensation value of the direct shaft counter-electromotive force can be obtained by multiplying the speed with the constant of the direct shaft counter-electromotive force.

Within practical applications, the variables of rotational speed are not only affected by counter-electromotive force, but also other disturbances such as voltage disturbances, such as bus voltage disturbances affected by overmodulation and dead zone effects, as well as counter-electromotive force. In the traditional PI control method, uniform compensation is performed for each different disturbance, resulting in an overly redundant and complex control algorithm; therefore, the suppression of unknown external disturbances can be implemented by a new PI control method.

Surface-mounted permanent magnet synchronous motors commonly use the traditional PI control strategy, whose control principle is shown in Figure 1.
In the table-mounted permanent magnet synchronous motor control system proposed in this paper, the mechanical angular velocity of the current rotor location can be determined from the transmitted signal of the position sensor. However, there must be a considerable degree of error value in this mechanical angular velocity detection method, which in turn causes a measurement error in the rotor mechanical angular velocity obtained after the final integration calculation. Therefore, it is necessary to incorporate a factor that eliminates this error to reduce the impact on the control system. Here, the error value generated above can be directly integrated instead of the original disturbance to obtain the output torque current given by the PI control in the speed loop.

\[
i_q^* = \frac{1}{b_s} \left[ \omega^* + k_{ps} (\omega^* - \omega_x) + k_{is} \int (\omega^* - \omega_x) dt \right]
\]

Where, \(\omega^*\) is the angular speed of the motor at the given speed; \(\omega_x\) is the motor calculation angular velocity; \(k_{ps}\) is the proportionality coefficient; \(k_{is}\) is the integration coefficient; \(b_s\) is the torque current coefficient.

In order to improve the response speed and control accuracy of the system, on the basis of the traditional PI control, the space vector method, coordinate transformation method with integral clamp anti-saturation and other methods are used to increase the feed forward of the given input and control gain, and the theoretical structure diagram of the new PI control method is obtained, as shown in Figure 2.
angular velocity feedback of the traditional PI control method on the followability and stability of the control system, and in order to verify the effectiveness of the method, system simulation tests are conducted.

3. Simulation experiment
On the MATLAB platform, the propeller system simulation verification of the PI control strategy proposed in this paper is carried out to simulate the motor from starting to reaching the stable speed, and the completed system simulation is shown in Figure 3. Figure 4 and Figure 5 are the motor transformation speed characteristic curves of fixed PI and using the PI method proposed in this paper, respectively, from Figure 4, it can be seen that when fixed PI control is used, the motor starting process The overshoot of motor speed can reach 350rpm when fixed PI control is used, but the overshoot of motor speed drops to 150rpm after using the PI method proposed in this paper, which proves the effectiveness of the PI method proposed in this paper and can effectively suppress the system overshoot of motor speed.

Figure 3. System simulation diagram

Figure 4. Fixed PI modulation
4. Conclusions
This paper designs a new PI control method for surface-mounted permanent magnet synchronous motor, which can be used to improve the speed control part of the control system, reduce the system overshoot of the motor speed and improve the stability of the motor control system; In order to verify the correctness of the method, a system simulation environment is built and system simulation experiments are conducted to prove the effectiveness of the method, which is useful for this surface-mounted permanent magnet synchronous motor control and has a positive significance.

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