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Research on Speed Control System of Brushless DC Motor Based on PID Control

Shuling Feng [1, a]
[1] Jiangxi Province, Nanchang Institute of Science & Technology, Nanchang, Jiangxi, 330103
[a]email,

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Abstract. The so-called brushless DC motor is a nonlinear, multi-variable and highly coupled system, the general PID control is impossible to achieve the desired control effect, but the fuzzy PID controller can be self-tuning through the fuzzy algorithm PID parameters, effectively compensate for the shortcomings of conventional PID, to enhance the control accuracy. In this paper, the control technology of the brushless DC motor and the speed control mode are explored, and the simulation model of the permanent magnet brushless DC motor speed control system is constructed. The adaptive fuzzy PID controller is designed to analyze the speed of the motor at different speed the situation was studied.

Introduction

With the rapid development of modern power technology, permanent magnet brushless DC motor, the new motor has gradually been widely used. It not only has a good speed performance and mechanical characteristics, and easy maintenance, you can use for a long time. However, permanent magnet brushless DC motor speed control system with multi-variable and non-linear characteristics, if still use the past PID control method, it is difficult to achieve the desired control effect. In this paper, PID controller design, combined with the fuzzy algorithm automatically adjust the PID parameters, the traditional PID and fuzzy control effectively combined, used in brushless DC motor speed control system, and then to achieve the high precision control of this motor.

The Brushless DC Motor Mathematical Model

The actual case selected in this study is a three-phase permanent magnet brushless DC motor, the establishment of the relevant dynamic mathematical model. In order to be more convenient to explore

The Voltage Equation. Brushless DC motor is equivalent to each phase winding resistance, inductance and back electromotive force in series. As for the square wave motor, the rotor position changes, the magnetoresistance does not change, which means that both self-inductance or mutual inductance, are constant [1]. If the connection is a three-phase star, the conduction mode is 120 degrees, there is no midline, that in the three-phase symmetrical motor where the current of each phase is 0.

$$i_a + i_b + i_c = 0 \qquad (1)$$

The stator three-phase winding voltage equation is:

$$\begin{bmatrix} U_a \\ U_b \\ U_c \end{bmatrix} = \begin{bmatrix} r & 0 & 0 \\ 0 & r & 0 \\ 0 & 0 & r \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L-M & 0 & 0 \\ 0 & L-M & 0 \\ 0 & 0 & L-M \end{bmatrix} \frac{d}{dt} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \qquad (2)$$

In the formula (2), the stator voltage, current and back electromotive force are (Ua, Ub, Uc), (i_a, i_b, i_c) and (e_a, e_b, e_c), the self- and mutual inductance are L, r and M.

The Torque Equation. If the depth of the rotor and mechanical wear and tear, then the electromagnetic power will all be converted into the kinetic energy of the rotor, and the electromagnetic power of the expression:

$$Pe=e_a i_a+e_b i_b+e_c i_c \qquad (3)$$

So the brushless DC motor electromagnetic torque equation expression is:

$$T_e=\frac{P_e}{w}=\frac{e_a i_a+e_b i_b+e_c i_c}{w} \qquad (4)$$

In the expression (4), w represents the specific angular velocity of the motor rotor, and Te represents the electromagnetic torque. When it is in the process of operation, because this winding is only two-phase conduction, and there is a current flow phenomenon, the current value of the same, but the direction is completely opposite.

The Design of PID Controller

The Main Principle of Adaptive Fuzzy PID Control. The basis of this control idea is to understand the PID three parameters and the deviation rate of change ec and deviation e and other related fuzzy relations, in the control system work process, the continuous development of ec and e, and several moments of this 2 The actual situation of the data, adjust the controller of the three parameters, and then achieve the control objectives, so that the accused object with good dynamic, static performance.

The first step is to calculate the rate of change between the actual speed n and the given nr, and then blur it. After the blurring, the e and ec are changed from the fuzzy reasoning to the output fuzzy set by the fuzzy control rule, After the fuzzy, the output quantities Kp, Ki and Kd of the fuzzy controller are added to the △ kp, Δ ki and Δ kd of the previous period, so that the on-line adjustment of the PID related parameters is achieved. If the conventional PID parameters are k'p, k'i and k'd, the corrections for the PID parameters are △ kp, △ ki and △ kd after fuzzy control is applied to them. At this time, the adaptive fuzzy PID controller outputs kp, ki and kd are:

Kp = k'p +△Kp ki = k'i +△Ki kd = k'd +△Kd

Variable Fuzzy. The fuzzy controller first blurs the actual deviation e and the deviation rate ec to obtain the input variables E and EC of the fuzzy controller. In order to calculate more quickly and easily, the language variable is divided into seven levels. The basic domain of fuzzy variables e and ec is within the range of [-3, + 3]. The author uses the membership function of the membership function and there is a fuzzy relationship between the exact amount of discretization and the value of the linguistic variable. In this way, the exact quantities {-3, -2, -1, 0, 1, 2, 3} on the universe [-3, + 3] can be expressed by using a fuzzy subset. The basic domain of the three fuzzy variables △ kp, △ ki and △ kd after fuzzy reasoning is also [-3, + 3]. This domain is also divided into seven language variables. After the fuzzification, the adjustment quantities △ kp, △ ki and △ kd of the adaptive fuzzy PID controller are obtained.

The Creation of Fuzzy Control Rules. In the adaptive fuzzy PID control process, the effective implementation of kp, ki and kd self-tuning can make the performance of the system change at any time.

First of all, kp control, in the beginning of the adjustment phase, in order to be able to improve the system as soon as possible to respond to the speed, we must select a larger kp value, after entering the medium, this value will need to be appropriately reduced, The existence of overshoot, but also to protect the specific response speed; and in the latter part, then they need to be transferred to some, and then improve the accuracy of the upgrade, reduce the steady-state error [2].

Followed by ki effective control can eliminate the system steady-state error. In the early stages, in order to prevent the occurrence of integral saturation, so the role of this link must continue to weaken, or even set the value of 0; to the medium term, for stability considerations, this time the role of integral role must be moderate; In the latter part, in order to achieve the reduction of steady-state error, we must continue to strengthen the integral effect.

Finally, the control of kd, due to the existence of large inertia links, so the introduction of which will change the dynamic characteristics of the system as a specific target. In the early stages, the effect of differentials must be continually enhanced to prevent the appearance of overshoots; in the medium term, the values need to be small and remain constant to some extent; in later stages, the values must continue to decrease to achieve the role of the control process of continuous reduction.

The Simulation Research of Brushless DC Motor Speed Control System

According to the mathematical model of the brushless DC motor, the actual structure and the adaptive fuzzy PID controller designed in this article, under the window of Matlab7.0 / Simulink, the model of the brushless DC motor speed control system Build and implement simulation.

The Construction of Brushless DC Motor Speed Control System Model. Brushless DC motor speed control system design composition, this modeling selection of current, speed double closed-loop DC speed control system. The difference between the stator phase winding L and the mutual inductance M is 0.0267H, the back electromotive force coefficient k = 0.418V • S / rad, and the moment of inertia J is 0.005kg • m2, rated speed of 1 minute 1500 rpm, rated voltage of 300 volts, brushless DC motor conduction mode for the three-phase Y-linked full control circuit two conduction mode [3].

Selection of Adaptive Fuzzy PID Parameters. On the one hand the first use of the wrong way, select the conventional PID controller of the three parameters, namely kp '= 0.3, ki' = 10, kd '= 0.002. According to the actual situation and past experience, we select e, ec [-3, 3], and the range of the basic domain, and the quantization factor Ke is 0.002, which is the input and the variable value of the output variable. , Kc is 0.001; the scale factors are Kpp = 0.065, Kii = 1.15, Kdd = 0.00015, respectively. △ kp, △ ki and △ kd for the controller output correction, online on the regular parameters to start tuning, and finally get the controller parameters.

The Simulation Results. When the motor is running at low speed. When the given speed is 500 revolutions per minute, the speed curve rises rapidly to the given speed, slightly overshoots and then quickly returns to the given speed, the system response is fast and smooth. Low-speed motor running the maximum speed of 1 minute 516 turn, steady-state running speed of 1 minute 500 turn, speed control system to achieve no static low speed operation.

When the motor is running at high speed. Speed curve in the 0.11s reach the rated speed of 1500 rpm, slightly overshoot after about 0.22s back to the rated speed, the maximum speed is 1514r / min, δ% = 0.93%, the motor can run without high temperature T = 0.5 S sudden increase in 5N / m load, the speed dropped to 1488r / min, at 0.59s when the speed back to 1500r / min, after loading the motor can still no static high-speed operation.

Conclusion

In summary, the author in-depth discussion of the motor speed system control mode, by virtue of the design of PID controller, and fuzzy algorithm through the automatic tuning PID parameters of the channel, the previous PID and fuzzy control effectively combined, and used in brushless DC Motor speed control system, to achieve a permanent magnet brushless DC motor real-time, high-precision control, this approach effectively deal with the past DC motor nonlinear, multi-variable, time-varying and many other shortcomings.

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