ANALYSIS OF BLDC MOTOR NATURE USING DIFFERENT CONTROLLER

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ABSTRACT

The traditional PID control method has the disadvantages of slow response speed, low precision and poor anti-interference ability when controlling the brushless DC motor system. In view of these shortcomings, a fuzzy PID control based brushless DC motor control system was proposed. The principle and characteristics of fuzzy control were introduced; The control principle of PID control based on fuzzy rules was analyzed; The fuzzy subsets were established and fuzzy control rules were established; The simulation of brushless DC motor control system was simulated by Matlab/Simulink. The results showed that the PID control algorithm based on fuzzy logic control improved the dynamic performance and stronger adaptive ability of the DC brushless motor.

Keywords : brushless DC motor; PID control; fuzzy rule

INTRODUCTION

Recently, brushless DC motors (BLDCM) have been widely used in electrical appliances, vehicles, aerospace and military fields because of significant advantages such as simple structure, reliable operation and high efficiency[1,2]. With the continuous expansion of its application range, various control algorithms and strategies have been developed [3]. Among them, the PID control algorithm is the most mature and widely used [4-6]. DC brushless motors generally use PID to achieve speed control [7]. The traditional PID control combines the difference between the actual value and the ideal value of the control target to form a control quantity by linear combination, and controls the controlled object, which has the advantages of simple algorithm and high reliability [8-10]. However, the traditional PID control is only suitable for controlling linear steady-state systems, while brushless DC motors are multi- variable, nonlinear time-varying complex systems. Therefore, the fixed parameters in traditional PID control cannot achieve satisfactory performance for brushless DC motors

The fuzzy control system is an intelligent control system that does not need to know the precise mathematical model of the controlled object. Whether the controlled object is linear or nonlinear, the fuzzy controller can be well controlled and has strong robustness and adaptability. Based on the traditional PID control and fuzzy logic control, the simulation of BLDCM is carried out. The simulation results show that the control performance of the system is significantly elevated, compared to the traditional PID control.

Trapezoidal commutation is inadequate to provide smooth and precise motor control of brushless dc motors, particularly at low speeds. Sinusoidal commutation solves this problem.

This is because the torque produced in a three phase brushless motor (with a sine wave back-EMF) is defined by the following equation:

Shaft Torque = $Kt\,[I_R Sin(\delta) + I_Y Sin(\delta + 120) + I_B Sin(\delta\ o + 240)]$

where:

δ is the electrical angle of the shaft,

Kt is the torque constant of the motor and

I_R, I_Y and I_B are the phase currents.

Assuming phase currents sinusoidal: $I_R = I_0 Sin\delta$; $I_Y = I_0 Sin(\delta + 120)$; $I_B = I0 Sin(\delta + 240)$

Therefore,

Shaft Torque = $1.5I_0xKt$

Sinusoidal commutated brushless motor controllers attempt to drive the three motor windings with three currents that vary smoothly and sinusoidally as the motor turns. The relative phases of these currents are chosen so that they should result in a smoothly rotating current space vector that is always in the quadrature direction with respect to the rotor and has constant magnitude. This eliminates the torque ripple and commutation spikes associated with trapezoidal commutation.

Sinusoidal commutation results in smoothness of control that is generally unachievable with trapezoidal commutation. However, while it is very effective at low motor speeds, it tends to fall apart at high motor speeds This is because as speed goes up the current loop controllers must track a sinusoidal signal of increasing frequency. At the same time they must overcome the motor back-EMF that also increases in amplitude and frequency as speed goes up.

This degradation continues as speed increases. At some point motor current phase shift crosses through 90 degrees. When this happens torque is reduced to zero. With sinusoidal commutation, speeds above this point result in negative torque and are therefore not achievable.

Objective :

1. To Make the Various controller circuit with BLDC motor
2. To analysis the nature of BLDC motor speed with respect to different controller.

LITERATURE SURVEY

J.lygeros et.al. introduced a general formalism for generating a fuzzy plant model. It provides a description for Fuzzification, inference rules and defuzzification in terms of mapping. It demonstrated use of information by developing a general fuzzy logic, rule base plant model. It provides that fuzzy plant model exactly duplicates the behavior of discrete-time linear system.[1]

Pierre Guillemin et.al. implemented a fuzzy logic to regulate speed of universal motor by real time adjustment of motor current. This dissertation work shows how a fuzzy logic approach can be applied to build a closed speed regulation loop form a very low cost tacho-generator. This dissertation work also gives the practical procedure to define the input parameters and to build fuzzy logic rules when using fuzzy logic development tool. [2]

M. Perales et.al. proposed a system used to evaluate a variable speed, pitch angle of wind turbine by fuzzy logic techniques is described. A fuzzy logic control has been proposed based on the speed wind estimation in order to get maximum power and stability of the system. [3]

W.Tan et.al. introduced criteria based on disturbance rejection and system robustness are proposed to assess the performance of PID controllers. The robustness is measured by a two- block structured singular value, and the disturbance rejection is measured by the minimum singular value of the integral gain matrix. Examples show that the criteria can be applied to a variety of processes, whether they are stable, integrating or unstable; single-loop or multi- loop.[4]

QI Peng presented an improved particle swarm optimization (PSO) method for speed control of the brushless BLDC(BLDC) motor. With introducing a shrinkage factor into PSO algorithm, the speed control ability of the BLBLDCmotor can be improved. The brushless BLDCmotor is modeled in Simulink and the PSO algorithm is implemented in MATLAB. Comparing with fuzzy control method, the proposed method is more efficient in improving the step response characteristics, such as, reducing the steady-states error; rising time, settling time and maximum overshoot in speed control of a linear brushless BLDCmotor. [5]

Methodology

Fuzzy control is a method of using human intelligence to control the system, a king of controller based on fuzzy set theory, fuzzy language and fuzzy logic control, and a kind of nonlinear intelligent controller. The fuzzy controller has the following characteristics: good adaptability, easy control, and good robustness. Whether the controlled object is linear or non-linear, the fuzzy controller can perform effective control. The fuzzy control system consists of four parts: the fuzzy process, the knowledge base (database and rule base), fuzzy reasoning and clear calculation, as shown in Fig.1 definitions of input and output variables, fuzzy reasoning and anti-fuzzy algorithms, and the rule base has a group. Language control rules describe control objectives and strategies, usually expressed in relational terms, and are primarily determined by expert control knowledge or long-term accumulated experience.

A. Fuzzy reasoning

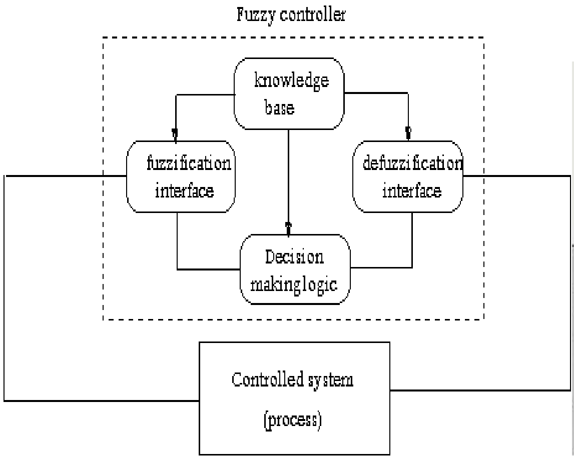
Fuzzy reasoning is based on the input fuzzy quantity, the relationship between fuzzy logic and the fuzzy control rules to simulate human reasoning decision, and obtain the process of fuzzy control quantity. Fuzzy reasoning is the core of fuzzy controllers.

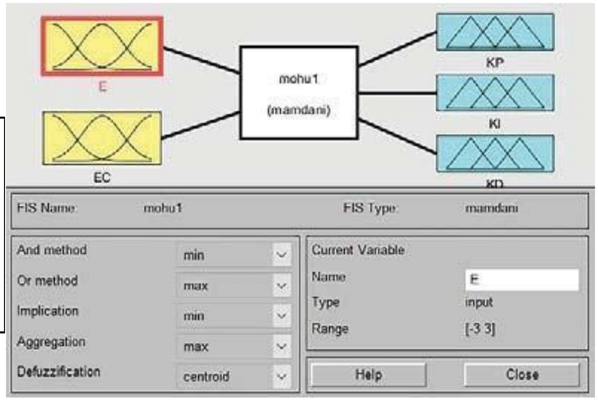
B. Clarification

Clarification is also called anti-fuzzification, which can be regarded as the inverse process of fuzzification. The control quantity obtained by fuzzy reasoning is transformed into the clear quantity of the domain range by some kind of precision algorithm, and then the scale factor becomes the actual control quantity.

FUZZY PID CONTROLLER DESIGN

The structure of the fuzzy PID controller used in the brushless DC motor is shown in Figure 2. In theory, the more the dimension of the fuzzy controller, the finer the control, but the higher the dimension, the more complicated the corresponding fuzzy control rules and control algorithms, so the general dimension does not exceed 3. In this paper, the widely used two-bit fuzzy controller is used, and the difference between the actual speed n and the target speed nref , e and the derivative of e, is the change rate ec as the input quantity. After the fuzzification, e and ec are performed by the fuzzy control rule. Reasoning, and then clear the parameters KP*, KI* and KD*. These parameters modify the parameters obtained by the traditional PID controller, and finally obtain the optimized KP, KI and KD to realize real- time control of the speed of *Establish Membership Function*
A fuzzy controller is established as shown in Fig.3. The fuzzy controller has two input variables: the deviation of the rotational speed e and the derivative of the deviation ec, and the three outputs of KP*, KI* and KD*. For each variable, the appropriate number of words should be selected to describe the input and output variable. Choosing more vocabulary can make the rules more convenient and the system control more precise. If few vocabularies is chose, the rules simple will become simple, but the performance of the controller will be worse. In general, seven words are selected for each input variable and output variable. Therefore, the e and ec fuzzy subsets are defined as {NB, NM, NS, ZO, PS, PM, PB} and mapped to the universe [-3, 3]; the controller KP*, KI* and KD* are output, and their fuzzy subsets are define as {NB, NM, NS, ZO, PS, PM, PB}, mapped to the domain [-3, 3].





Numerous studies have shown that in many membership function curves, it is the most suitable normal fuzzy variable to describe the person's control activities, but its operation is relatively complicated and slow in engineering application, and the fuzzy variable of triangle distribution is simple and rapid. Therefore, the membership function of most triangles is use in this work. The membership function of the input and output variables is set as shown in Fig.4 and Fig.5.

Formulating Fuzzy Rules

The design of control rules is the key to designing fuzzy logic controllers. After the fuzzification process, fuzzy rules need to be formulated to perform fuzzy reasoning. Since the control rules are based on the response characteristics of the controlled object and the expert's control experience, we need to consider the following subjectively:

1. When the speed difference e is relatively large, we can determine that the system is in the response phase. In order to make the motor dynamic response faster, we can make KP larger; but in order to prevent the phenomenon of integral saturation, it appears larger. For the overshoot, we should reduce the integral intensity and make KI = 0. At the same time, KD should be reduced a little to prevent differential saturation.

2. When the input quantities e and ec are in the middle, the motor speed is still in the rising phase. KP, KI and KD should be moderate to prevent overshoot and good system dynamic response.

3. When the speed deviation e is relatively small, the actual speed is close to the set value. We can assume that the system is in the fine adjustment phase. At this stage, the values of KP and KI should be appropriately increased. At the same time, the KD value should be changed from large to small, to make the system quickly stable.

CONCLUSION

In this work, based on the traditional PID control principle, the fuzzy PID controller was designed, and applied to the DC brushless motor speed control, and stimulated by Matlab/Simulink software. Modeling and simulation analysis was carried out, and it could be concluded that the fuzzy PID control method of brushless DC motor speed control exhibited stronger anti-interference ability and robustness, better control precision and dynamics static performance, and achieved an ideal control effect, compared with traditional PID control method.

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