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Model Reference Adaptive Control Of A Brushless Dc Engine

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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 will be used. Genetic Algorithm is a global optimizer to find the optimized PID gains for position control of brushless DC motor. The efficiency of this method will be compared with that of traditional method. The principle and characteristics of fuzzy control will be introduced. The control principle of PID control based on fuzzy rules will be analysed. The fuzzy subsets and fuzzy control rules will be established. The simulation of brushless DC motor control system will be simulated on Matlab or Simulink. The results will be analysed to verify that the algorithm based on fuzzy logic control improves the dynamic performance of the DC brushless motor.

Keywords - Artificial, neural, network, irrigation, precision, agriculture, IoT, Smart Irrigation, PolyHouse.

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 [IRSin (δ) + IY Sin (δ +120) + IB Sin (δ o+240)]

where:

δ is the electrical angle of the shaft,

Kt is the torque constant of the motor and

IR, IY and IB are the phase currents.

Assuming phase currents sinusoidal: IR = I0Sinδ; IY = I0Sin (δ +120); IB = I0Sin (δ +240)

Therefore, Shaft Torque = 1.5I0xKt

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.

Literature Survey:

Ananthababu B et. al has written a Fuzzy Based Speed Control of BLDC Motor with bidirectional DC-DC converter. With reference to the paper proposed we have designed a fuzzy logic controller for the speed control of bidirectional brushless DC motor (BLDC). The speed control is achieved by using fuzzy controller. The fuzzy logic control is used in three phase BLDC motor in order to control the four quadrants operations without any loss of power [1]. Saber Krim et.al written a Fuzzy speed controller for an induction motor associated with the Direct Torque Control: Implementation on the FPGA. Paper proposed an improvement of the Conventional Direct Torque Control (CDTC) of an induction motor is presented using the artificial intelligence to control the motor speed and an implementation on the FPGA (Field Programmable Gate Array) [2]. S. Vijayalakshmi has written a Vehicle control system implementation using CAN protocol. Paper represented that the development and implementation of a digital driving system for a semi-autonomous vehicle to improve the driver-vehicle interface. It uses an ARM based data acquisition system that uses ADC to bring all control data from analog to digital format and visualize through LCD [3]. N. Muruganantham et. al Hybrid has written a Fuzzy PI Controller based speed control of pmbldc motor using soft switching inverter. Paper represented that the comparative analysis between conventional PI, fuzzy, hybrid fuzzy-PI, GA-PI and adaptive neuro-fuzzy inference system (ANFIS) controller based soft switching inverter using transformer, which can generate dc link voltage notches during chopping which minimize the drawbacks of existing soft-switching [4]. Abdelhadi Elbacha, Boulghasoul Zakaria et.al has written a comparative study of rotor time constant online identification of an induction motor using high gain observer and fuzzy compensator. Paper represented that the focus on comparative study between two approaches to estimate this parameter using the indirect vector control of induction motor [5]. R. Kandiban et.al has written a Design of Adaptive Fuzzy PID Controller for Speed control of BLDC motor written by. Paper proposed an improved Adaptive Fuzzy PID controller to control speed of BLDCM. This paper provides an overview of performance conventional PID controller, Fuzzy PID controller and Adaptive Fuzzy PID controller [6]. Vishal Verma et.al has written a Hybrid PI speed controllers for permanent magnet brushless DC motor. Paper represented that a Hybrid Proportional Integral (PI) controller (with fuzzy controller) as Series Hybrid or Parallel Hybrid configuration, for speed control of Permanent Magnet Brushless DC Motor drive for application to intermitted duty loads [7]. Essam Natsheh et.al has written a Comparison between Conventional and Fuzzy Logic PID Controllers for controlling DC motors. Paper proposed that Fuzzy logic and proportional-integral-derivative (PID) controllers are compared for use in direct current (DC) motors positioning system [8]. Tan Chee Siong et.al has written a Implementation of Fuzzy Logic Controller for Permanent Magnet Brushless DC Motor Drives. Paper represented the analysis of Fuzzy Logic controller for permanent magnet brushless DC motor drive [9]. Liye Song et.al has written the study of Fuzzy -PI controller of Permanent magnet Synchronous motor. Paper proposed a new composite control strategy for Permanent Magnet Synchronous Motor (PMSM) drives to achieve fast dynamic response and minimum steady state error [10].

Summary:

SR. No.	Research Paper Name	Author	Year	Observation	Scope to Work
1.	Fuzzy Based Speed Control of BLDC Motor with Bidirectional DC-DC Converter	Ananthababu B, Dr. Ganesh C, Pavithra C V	March 2016	A fuzzy logic controller for the speed control of bidirectional brushless DC motor is used and this method are excellent for speed control, smooth transition between the quadrants and efficient conservation of energy.	It can be stored in a battery instead of wasting kinetic energy. The excess energy Can be stored in the battery based on the mode of operation of the bidirectional converter.
2.	Fuzzy speed controller for an induction motor associated with the Direct Torque Control: Implementation on the FPGA	Saber Krim, Soufien Gdaim, Abdellatif Mtibaa, Mohamed Faouzi Mimouni	April 2015	Direct Torque Control of an induction motor based on a fuzzy speed PI controller is used and the fuzzy logic controller is proposed in order to overcome the conventional PI controller limitations in terms of rapidity, robustness against variation of the reference speed and the influence of the load torque	The Xilinx System Generator Can be use for the hardware implementation and for its simplicity and a rapid design time. The different simulation results will show the effectiveness of the fuzzy PI speed controller as compared to the conventional PI regulator

SR. No.	Research Paper Name	Author	Year	Observation	Scope to work
3.	Vehicle control system implementation Using CAN protocol	S. Vijayalakshmi	June 2013	The proposed high-speed CAN bus system solves the problem of automotive System applications, also has a certain practical value and significance and with ARM as the main controller it makes full use of the high performance of ARM, high-speed reduction of CAN bus communication control	By implementing a digital driving system for a semi-autonomous vehicle to improve the driver-vehicle interface and to covert digital to analog by displaying on LCD
4.	Hybrid Fuzzy-PI controller-based speed control of PMBLDC motor using soft switching inverter	N. Muruganantham Dr. S. Palani	June 2012	The ANFIS controller gives much better dynamic response for the system and all the switches work under soft switching condition and freewheeling diodes are turned off under zero current condition which greatly reduces the reverse recovery problem of the diodes.	In the proposed method very simple auxiliary switches control scheme is needed and the normal operation of the inverter is essentially the same as that of the hard switching inverter as ANFIS is better than others controller.
5.	A Comparative Study of Rotor Time Constant Online Identification of an Induction Motor Using High Gain Observer and Fuzzy Compensator	Abdelhadi Elbachai, Zakaria Boulghasoul, Elmostafa Elwarrak	January 2012	Online rotor time constant identification in Indirect Vector Control of Induction Motor using two approaches, the High Gain Observer and the Fuzzy Compensator	In transient state or steady state conditions, if the fuzzy updating scheme is connected, it can provide excellent tracking performance

Research 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.

Fuzzy reasoning:

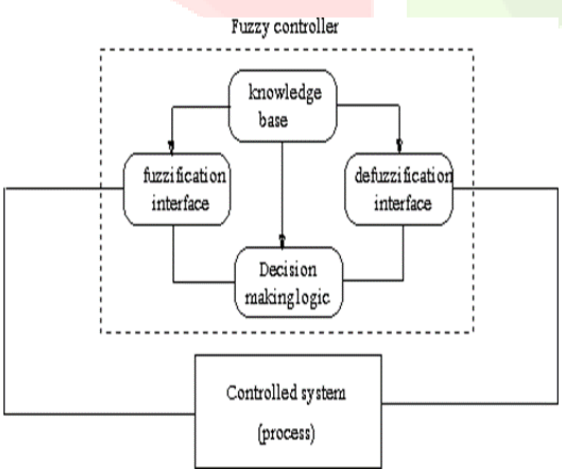
Fuzzy reasoning is based on the input fuzzy quantity, the relationship between fuzzy logic and the fuzzy control rules to simulate human reasoning decision, and obtain the process of fuzzy control quantity. Fuzzy reasoning is the core of fuzzy controllers.

Clarifications:

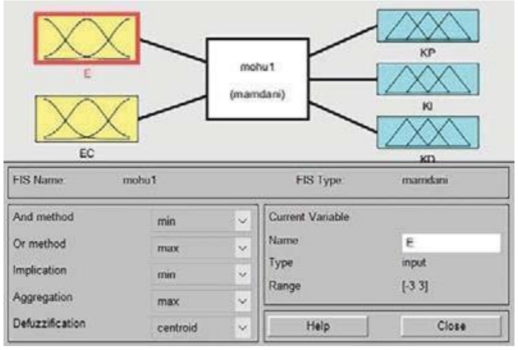
Clarification is also called anti-fuzzification, which can be regarded as the inverse process of fuzzification. The control quantity obtained by fuzzy reasoning is transformed into the clear quantity of the domain range by some kind of precision algorithm, and then the scale factor becomes the actual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



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 defined 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.

A. **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.

RESULTS:

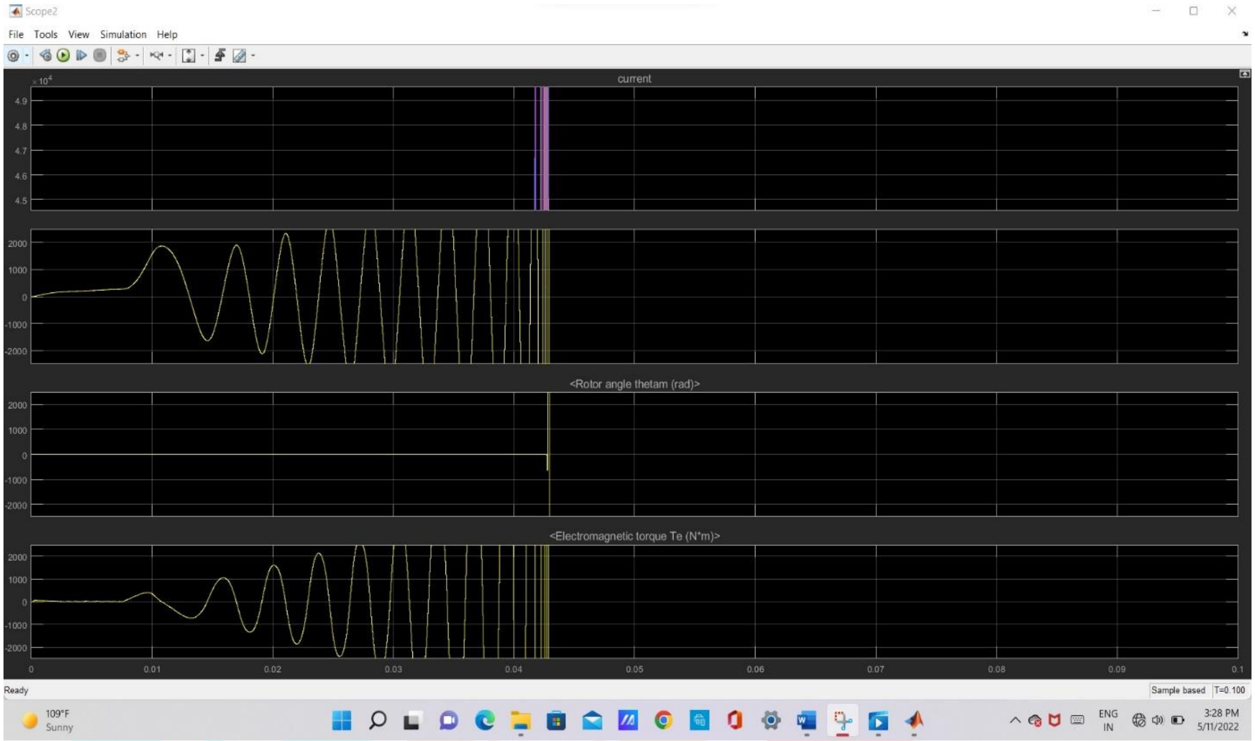


Figure 1: PI Controller design using Simulink MATLAB

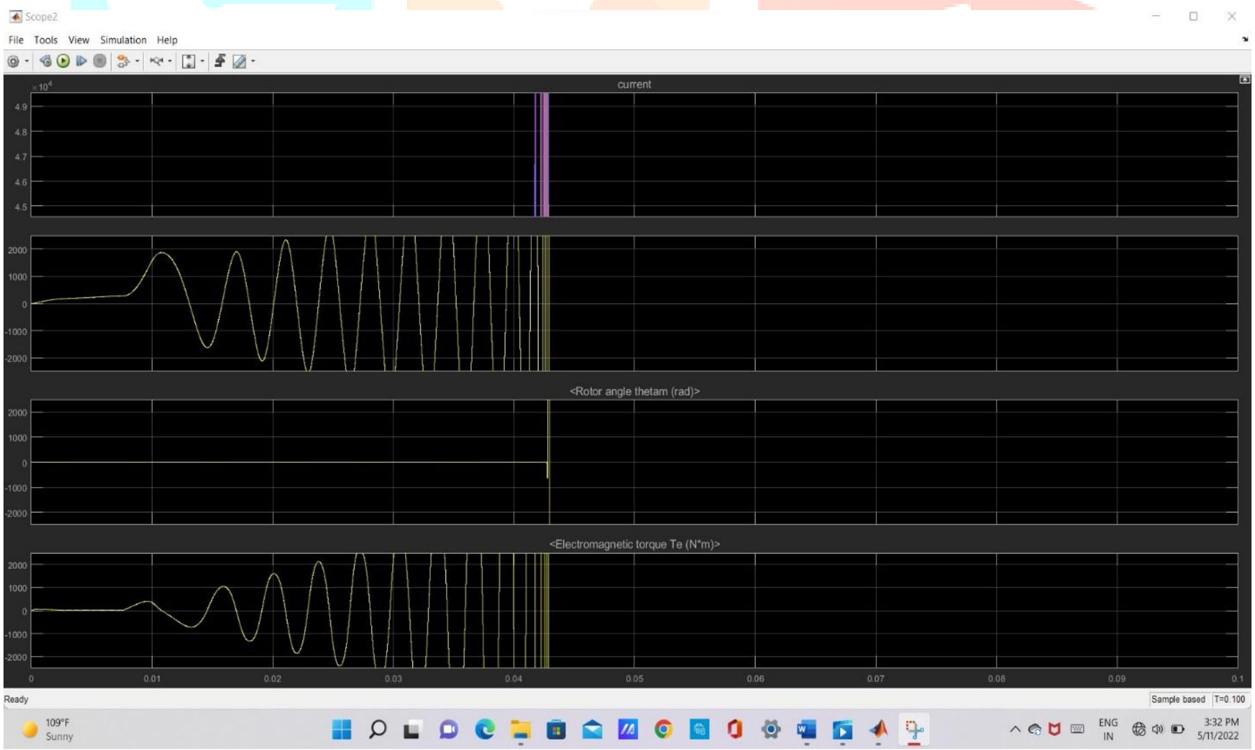


Figure 2: Fuzzy Controller design using Simulink MATLAB

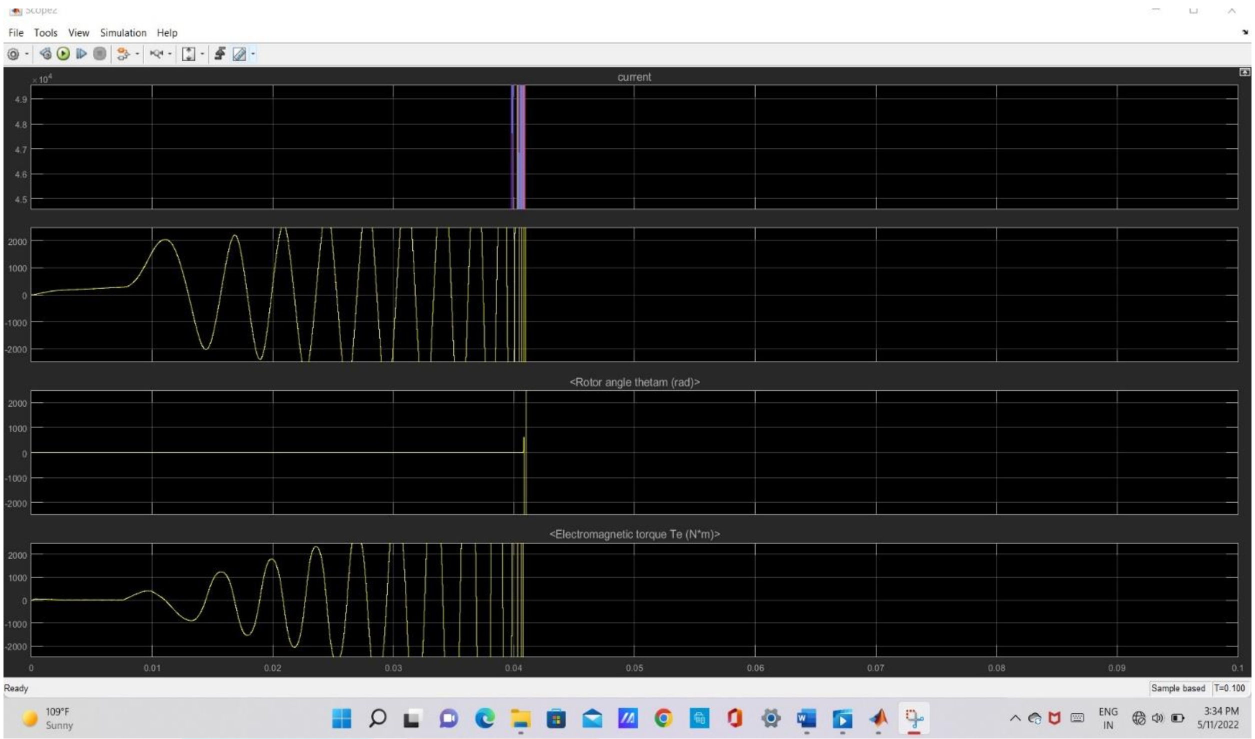


Figure 3: Fuzzy PI Controller design using Simulink MATLAB

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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