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ИНФОРМАТИКА, ВЫЧИСЛИТЕЛЬНАЯ ТЕХНИКА И УПРАВЛЕНИЕ

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Optimization of DC motor speed control based on fuzzy logic-PID controller*

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In this paper the PID controller and the Fuzzy Logic Controller (FLC) are used to control the speed of separately excited DC motors. The proportional, integral and derivate (KP, KI, KD) gains of the PID controller are adjusted according to Fuzzy Logic rules. The FLC cotroller is designed according to fuzzy rules so that the system is fundamentally robust. Twenty-five fuzzy rules for self-tuning of each parameter of the PID controller are considered. The FLC has two inputs; the first one is the motor speed error (the difference between the reference and actual speed) and the second one is a change in the speed error (speed error derivative). The output of the FLC, i.e. the parameters of the PID controller, are used to control the speed of the separately excited DC Motor. This study shows that the precisiom feature of the PID controllers and the flexibllity feature of the fuzzy controller are presented in the fuzzy self-tuning PID controller. The fuzzy self – tuning approach implemented on the conventional PID structure improved the dynamic and static response of the system. The salient features of both conventional and fuzzy self-tuning controller outputs are explored by simulation using MATLAB. The simulation results demonstrate that the proposed self-tuned PID controller i.plementd a good dynamic behavior of the DC motor i.e. perfect speed tracking with a settling time, minimum overshoot and minimum steady state errorws.

Keywords: Fuzzy Logic, Electric motors, DC machine, Differential gain, Power System, PID controller, Optimization technique, and Self-tuning

INTRODUCTION

Electric motors play an important role in all areas of life, providing us with the mechanical capacity we need in many industries. It is also an indispensable part of our everyday life as most household appliances rely on electric motors. DC motors have a number of advantages that are not available in other engine types: they generate a high initial torque that makes them suitable in many applications and provide a wide range of speed. Their control methods are easy and low cost if compared with AC motors. In addition to these advantages, they are free from

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some disadvantages, as they require a constant source of power, as well as their need for early adopters to determine the primary impulse current. Many applications need to set the motor speed at a certain speed level, as well as obtain good response characteristics to speed and on this basis the need to build a control system to do this work emerged [1–3]. Many of its control systems used the proportional control – the differential – the differential (PID), the Fuzzy logic controller, and the Neural Networks Controller. The PID Controller is one of the most widely used in industrial applications. Some sources indicate that the control ratio of PID is more than 95 % in industrial applications. It is characterized by great durability. The dominant control combines the advantages of the dominant (PD) and control (PI) techniques, improving the response of the case and reducing the error of the fixation case to zero [4–6]. (K_p, K_i, K_d) and a lack of sufficient flexibility to adapt when the system is exposed to some external influences and its performance is affected when it is used to control the speed of motors due to the nonlinear characteristics of the motor, including the characteristics of saturation and friction. Due to the difficulty of dealing with a system that possesses nonlinear characteristics because it is not possible to create and deal with a mathematical model. Mamdani (1974) applied the logic of control systems. The advantage of using logic is its ability to control nonlinear systems that cannot be described as simple mathematical equations or to be described as a difficult process [7]. A reasonable technology was found to replace the traditional control technique (PID), which often requires a mathematical, not linear and complex, model. Reasonable logic has successful applications, especially in control systems, compared to the traditional control, which has great flexibility in design. The dominant control gives the designer the ability to control nonlinear systems, and the common logic uses the language knowledge (IF,…, THEN), which is based on human experience. From this point of view, this control was used to synthesize (PID) to suit all operating system conditions [8–11].

1. PID-CONTROLLER

The dominant (PID) is one of the most traditional dominants used in industrial control processes. The PID is also one of the basic control techniques as it provides an easy and efficient solution to many real-time control problems. The PID controller has three types of gain, which can be set to obtain an acceptable response in output. These types are K_p, K_i, and K_d (2) [12–15].

where: KP: Proportional gain. KI: Complementary gain. K_d : Differential gain. The differential integrative proportional control equation is:

$$UPID = K_p \cdot e(t) + K_i \cdot e(t) + K_d \left(\frac{de(t)}{dt} \right). \tag{1}$$

The three gain values can be tuned by trial and error, or using some of the available control rules such as the Zecler-Nikles method. Individual effects of the three gain values on the closed loop system performance can be summarized in Table 1 [16].

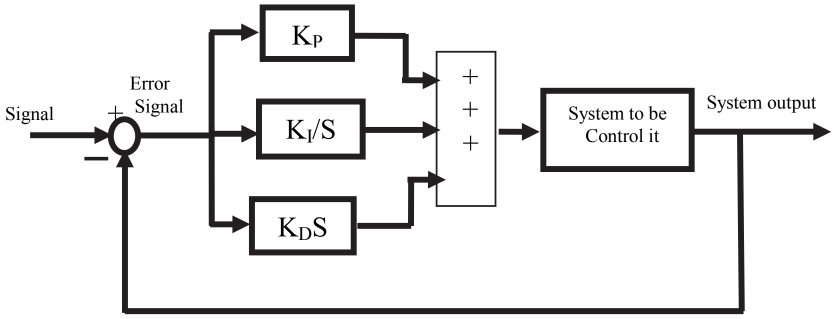

Fig. 1. The mass plan of the differential integral proportional controller

Table 1

The effect of the gain values (K_p, K_d, K_i) on the system response

Increase the value Element	**Boarding Time (Tr)**	**Stability Time (Ts)**	**Evidence status (ess)**	**Overflow limit (over-shoot)**	**Stability**
Proportional (K_p)	Less	Increases slightly	Less	Increase	Its effect is negative
Integrative (K_i)	Slightly less	Increase	Much less	Increase	Its effect is negative
Differential (K_d)	Slightly less	Decrease	Its effect is small	Decrease	Improves stability

2. FUZZY CONTROLLER

In 1974, the world introduced the Fuzzy Logic Controller (Fuzzy Logic Controller), whose logic was based on logic, as these controllers demonstrated their superior performance over traditional control systems because they do not rely on the mathematical equations of the process, (Transfer Function) of the control system, known or unknown, but depends on the human experience of the rules in the form of (If,…, Then). The set of rules that describe the performance of the system is called the rule base of the controlled ruler [17, 18].

FUZZY CONTROLLER STRUCTURE

The controlled rule consists of four basic parts as shown in Figure (2) [19, 20]:

1. Fuzzifier. The process of marginal input values is converted to values based on the input functions of each entry.

2. Fuzzy Inference Engine. This section analyzes the polarized laws and finds the set of output output based on the values of the pointed inputs.

3. Knowledge Base. This section includes the rule of law and the database.

4. Defuzzifier. The unit of conversion of the output of the bounded inference device to a limit value by performing one of the methods of de-fouling.

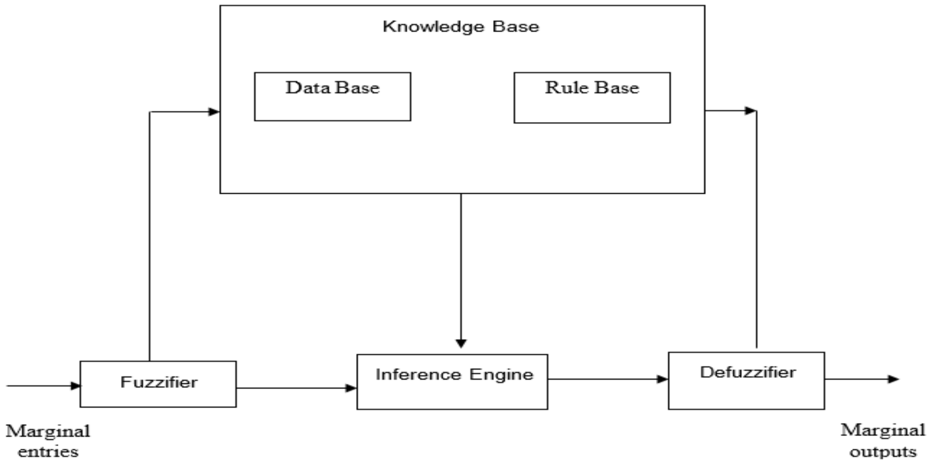

Fig. 2. Fuzzy dominant parts and structure

3. SELF-TUNING OF THE FUZZY SELF TUNING PID CONTROLLER

This control creates a relationship between the dominant control inputs and the gain coefficients of the PID based on the logic theory of the reasonableness in order to provide the best performance of the system response [21]. In this research, the proposed controlled control consists of two inputs, the error signal (e), the speed of reference and the speed of the motor) and the signal of change in the error (de), and consists of three outputs (K_{p1}, K_{i1}, and K_{d1}). Though the error signal and error change of the controlled control work on the tuning of the PID (which is the initial values), K_p, K_i, and K_d) are calculated by the Zikler-Niklas Table. Figure (3) illustrates this relationship the N dominant triple (PID Controller) and the controlling Almillb (Fuzzy Controller) [22].

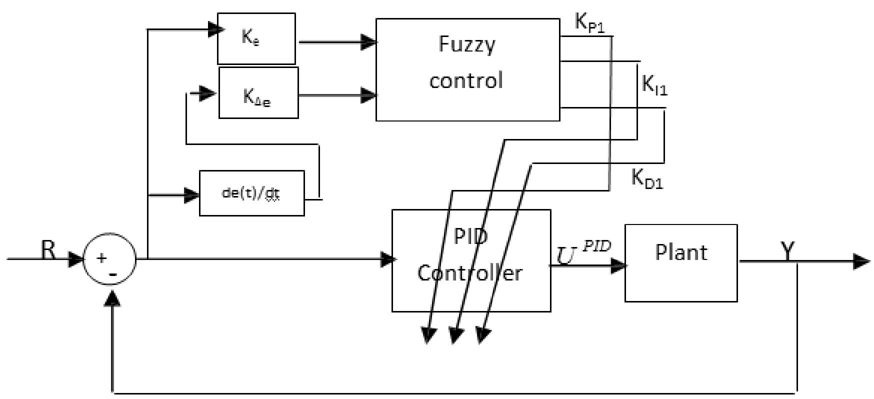

Fig. 3. Controlled and finite control of triple control coefficients

Now the equation of the triple controller (PID) after the hybridization process with the fuzzy logic controller (Fuzzy logic controller) takes the form:

$$UPID = K_{p2} \cdot e(t) + K_{i2} \cdot e(t) + K_{d2}\left(\frac{de(t)}{dt}\right), \tag{2}$$

where (K_{p2}, K_{i2}, K_{d2}) are the new gain coefficients after the link between PID and fuzzy controller:

$$K_{p2} = K_{p1} \cdot K_p, \qquad K_{i2} = K_{i1} \cdot K_i, \qquad K_{d2} = K_{d1} \cdot K_d.$$

where K_p, K_i, K_d, K_{p1}, K_{i1}, K_d are outputs of the fuzzy control that synthesize parameters (PID).

4. POWER SYSTEM

The power system consists of the DCMotor, the Buck Converter and the control system. The DC motor is of a separate type. The engine consists of a fixed part and the other moving part. The moving part contains the product files where the product voltage is changed by the changer circuit to obtain the required speed [23]. The Buck Converter is the modulator with which the Vo output voltage can be obtained less than the input voltage Vs [24]. This type of transformer is simple to install and work and can change the output voltage from a few voltages close to zero to the voltages in the changer [17, 25]. The control system consists of the PID and the Fuzzy logic control, which generates pulses based on the speed of the tube. These pulses are driven by the buck converter circuit to obtain the voltages that are placed on the product circuit. Figure (4) shows the mass diagram of the circuit in the Matlab program.

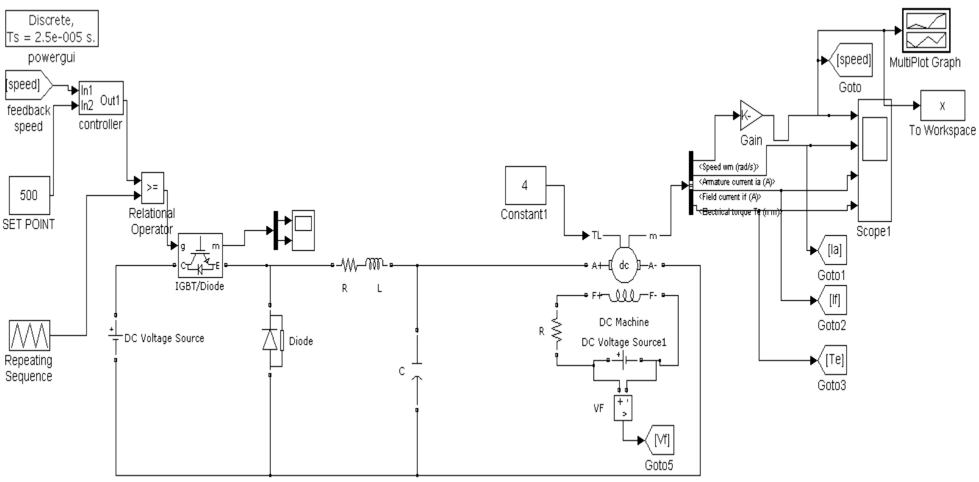

Fig. 4. The mass diagram of the circuit in the Matlab program

5. SIMULATION RESULTS

In this research, a differential integrative proportional control is designed based on the Zicler-Nikles scale. The gain values, which are considered as the initial value, are calculated as the tuning process of the controlled controller to obtain the best response to the speed of the engine which is $K_p = 10.363$, $K_i = 471.07$, $K_d = 0.057$. The results of the comparison between the traditional triple control where the values of the gain elements were found by the Zikler-Nichols table and the self-tuning determinant of the gain elements of the triangular rule.

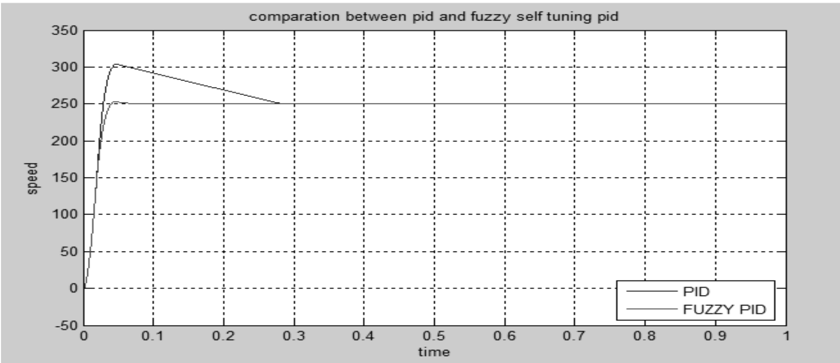

Fig. 5. Motor speed response of the traditional triangular control and the triangular control

Table 2

The motor speed response elements of the traditional triangular control and triangular control

Speed reference 250 rpm	Over shoot, %	Error steady state, %	Setting time (sec)	Rise time (sec)
PID Controller	21.56	0	0.28	0.018
Fuzzy PID Controller	1.2	0	0.078	0.023

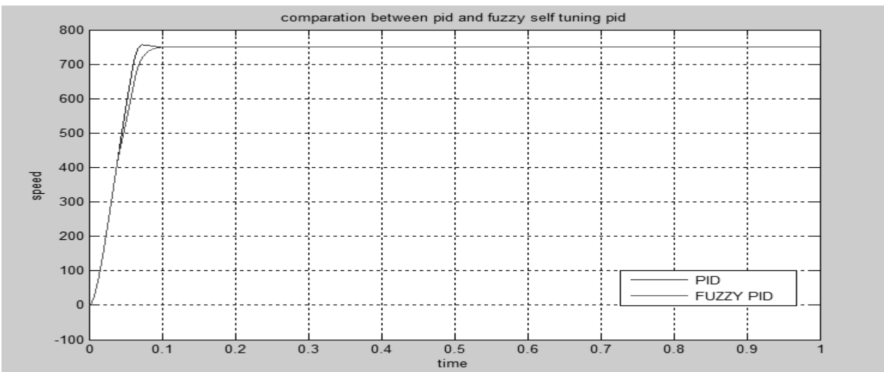

Fig. 6. Motor speed response of the traditional triangular control and triangular control

Table 3

Motor speed response elements of the traditional triangular control and triangular control

Speed reference 750 rpm	Over shoot, %	Error steady state, %	Setting time (sec)	Rise time (sec)
PID Controller	0.83	0	0.12	0.045
Fuzzy PID Controller	0	0	0.1	0.052

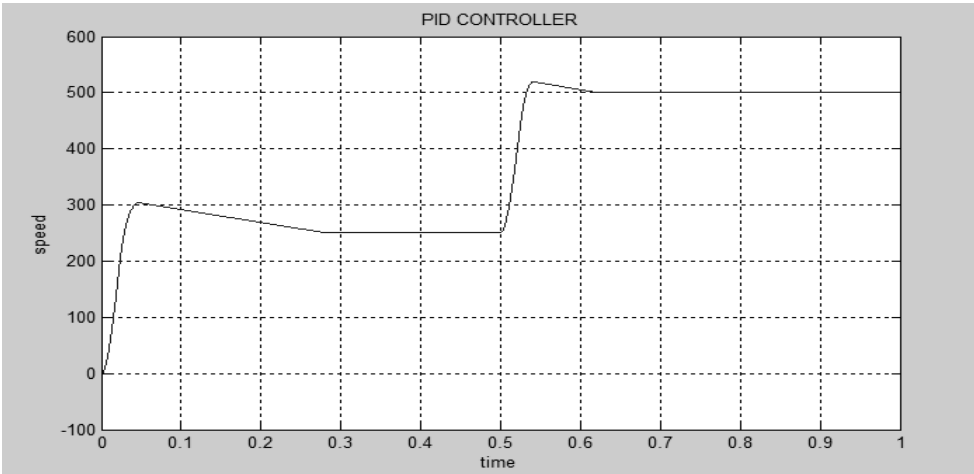

Fig. 7. Motor speed response to the traditional triangular control (PID) where the reference speed has been changed from 250 to 500

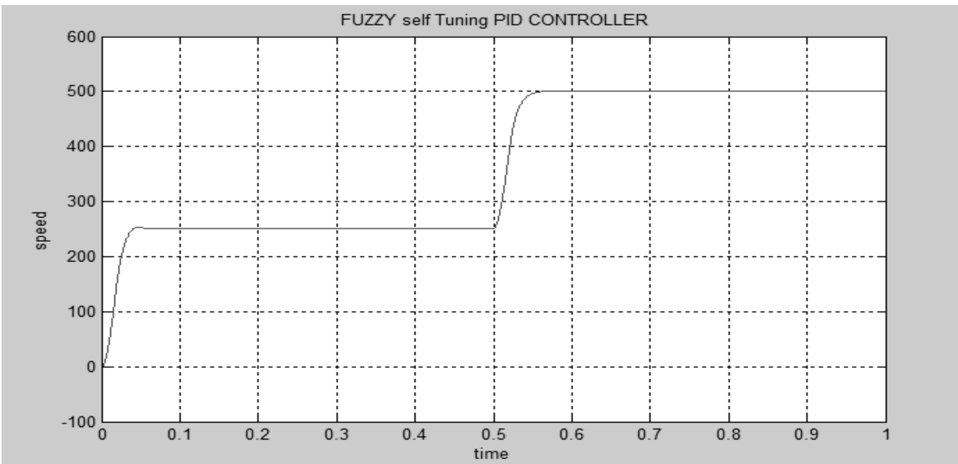

Fig. 8. Speed response of the motor for the PID Fuzzy where the reference speed has been changed from 250 to 500

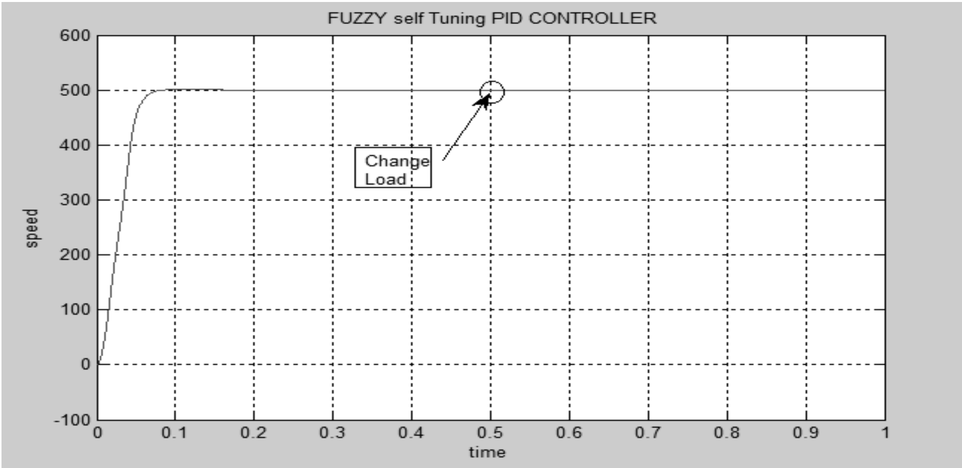

Fig. 9. Motor speed response of the trigonometric control shows the fuzzy control of the load

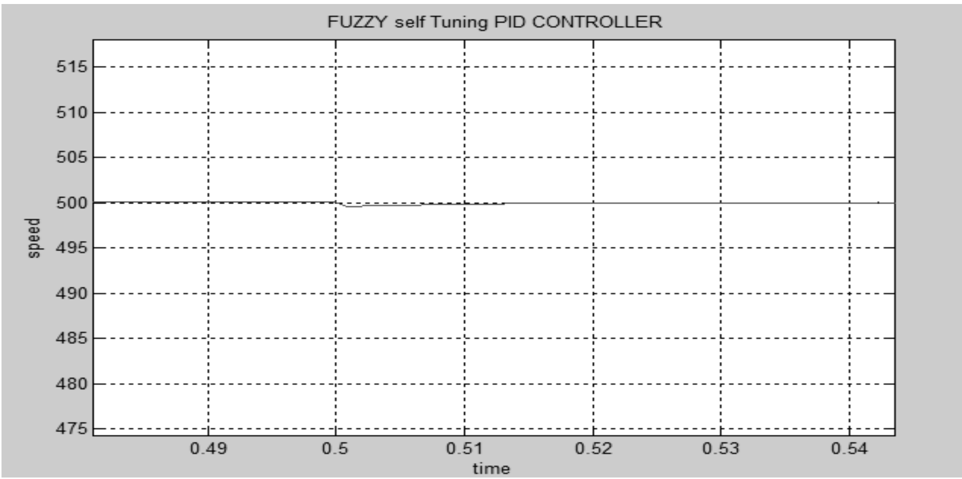

Fig. 10. The amplitude of the motor speed response of the trigonometric control with the fuzzy controlled control of a time load of 0.5sec

CONCLUSIONS

This research is designed to studiy the behavior of the control system of the triple (PID) type of controlling to control the speed of the DC motor type of separate excitation.Theses dominant features have many advantages, namely, it is solid, easy to understand and simple but it also has some problems, e.g. gain coefficients for obtaining good properties because each drive point has different coefficients that perform well for that point only. In this research, the Zicler-Nichols method was used to find the coefficients of the gain. The coefficients were found at a work point of 1000 rpm. Above, it was noted that the more (250). We notice a response to the speed of the motor to be compared to the response of the motor speed (750), where we note a good response to the proximity of the point of finding parameters to solve this problem. A Fuzzy PID is designed, where the logic is applied to the tuning of the gain coefficients so that it produces good performance of the motor speed in all cases. This was proved by the results where the overshoot ratio was reduced to 250, which is far from the point of finding gain transactions in the manner of Z Layer of 21.56 % to 1.2 % through the Almillb logic the same operating conditions as well as the time of stability had reduced timesettling of 0.28 sec to 0.078 sec. The triple controlled control with the traditional triangular control was also tested with a change of the reference speed from 250 to 500 and a sudden load on the motor where the results showed the superiority and durability of the triangular controlled modulator in the logic of the traditional triangular control.

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Оптимизация управления скоростью двигателя постоянного тока на основе ПИД-регулятора с нечеткой логикой*

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Аннотация

В этой статье ПИД-регулятор и контроллер нечеткой логики (FLC) используются для управления скоростью двигателей постоянного тока с независимым возбуждением. Пропорциональные, интегральные и производные (K_p, K_i, K_d) коэффициенты усиления ПИД-регулятора регулируются в соответствии с правилами нечеткой логики. FLC разработан в соответствии с нечеткими правилами, поэтому система является принципиально устойчивой. Рассмотрены более двух десятков нечетких правил самонастройки каждого параметра ПИД-регулятора. FLC имеет два входа: первый – это ошибка скорости двигателя (разница между опорной и фактической скоростью), а второй – изменение погрешности скорости (производная погрешности скорости). Выход FLC, т. е. параметры ПИД-регулятора, используется для управления скоростью отдельно возбужденного двигателя постоянного тока. Это исследование показывает, что точная функция ПИД-регуляторов и гибкость нечеткого регулятора представлены в нечетком самонастраивающемся ПИД-регуляторе. Подход нечеткой самонастройки, реализованный на традиционной структуре ПИД-регулятора, улучшил динамический и статический отклик системы. Существенные особенности как обычных, так и нечетких выходов самонастраивающегося контроллера исследуются путем моделирования с использованием MATLAB. Результаты моделирования показывают, что предлагаемый самонастраивающийся ПИД-регулятор реализует хорошее динамическое поведение двигателя постоянного тока, то есть идеальное отслеживание скорости с временем установления, минимальным перерегулированием и минимальной ошибкой в установившемся состоянии.

Ключевые слова: нечеткая логика, электродвигатели, машина постоянного тока, дифференциальное усиление, система питания, ПИД-регулятор, метод оптимизации и самонастройка

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