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HYBRID FUZZY CONTROL DESIGN FOR DC MOTOR

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Abstract

The controlling speed for DC motors, especially in industry, is always associated with the production technology process, and it dramatically determines the quality of the products. Depending on the nature and requirements of the process, it requires appropriate control methods. To make full use of the advantages of each type of fuzzy controller and classical controller, people often use systems that combine two types of traditional and fuzzy controllers to create a controller that is the new fuzzy controller. In this paper, we present the hybrid fuzzy PID controller for controlling the speed of DC motors.

Keywords: DC motors, Fuzzy controller, Fuzzy-PID

1. INTRODUCTION

The speed of the DC motor can be adjusted to a great extent so as to provide easy control and high performance. Several conventional and numeric controller types are intended for controlling the DC motor speed at its various executing tasks: PID Controller, Fuzzy Logic Controller (FLC) [1]. The combination between them: PID-Particle Swarm Optimization, PID-Neural Networks, PID-Genetic Algorithm. One of the problems that might cause unsuccessful attempts to design a proper controller would be the time-varying nature of parameters [2-6], unknown the plants' parameters and variables that might be changed while working with the speed systems. One of the best-suggested solutions to this problem would be using the new Fuzzy PID Controller called hybrid fuzzy PID controller [7-11]. The hybrid fuzzy PID controller is not sensitive to change and yet would have an adequate response to the system variations. The new Fuzzy PID Controller is a computationally efficient analytic scheme suitable for a real-time closed-loop digital control implementation [12-14]. Numerous computer simulations are included to demonstrate the effectiveness of the controller not only in linear but also in nonlinear systems. The hybrid fuzzy PID Controller can achieve a better response in comparison with classical methods in terms of shorter settling time, less overshoot, and more stability. Thus, the hybrid fuzzy PID controller is adopted in this paper, which is very flexible to control the speed of the DC motor.

2. METHODOLOGY

There have been many studies on the control of the angle of attack of the aircraft [1-3], but this is still an issue of great interest to research. The requirement of the problem of controlling the aircraft's angle of attack is that the controller needs to have good performance and strong stability when the model's parameters change. The robust optimal controller is the most suitable controller to control the angle of attack of the aircraft, however, the control design according to the robust control method often leads to the controller with high order [1-3]. High order controller will cause many disadvantages when implementing control in practice. Therefore, robust control design is often accompanied by a requirement to reduce the controller order [4-12].

The fuzzy hybrid system is a control system in which the control device consists of two components: classical control component and fuzzy control component.
There are two common structures of hybrid fuzzy controller

2.1 FLC is paralleled with classical PID

The hybrid Fuzzy-PID controller can be set up based on two signals, the error e(t) and its derivative e'(t). The fuzzy controller has an excellent performance in the large error region, wherewith its nonlinearity, it is possible to produce a speedy dynamic response. When the process of the system approaches the setpoint (deviation e(t) and its derivative e'(t) is approximately equal to 0), the role of the Fuzzy Logic Controller (FLC) is limited, so the controller works like a typical PID regulator. Figure 1 shows the idea of setting up hybrid Fuzzy-PID, which combination of fuzzy controller and their impact partition

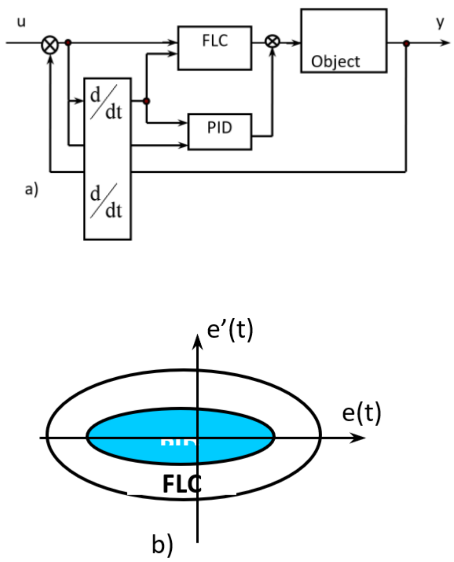

Figure 1. a) Fuzzy control principle; b) Areas of action of the controllers

2.2. FLC as a fuzzy key switch

To perform a fuzzy conversion between the FLC levels and the PID converter, one can set up multiple PID regulators i (i = 1,2 ... n), each selected to optimize the quality according to a specific method. These regulators share the same input information, and their effect depends on the input value. somehow to produce a good feature in a limited region of the input variable as shown in Figure 2. In this case, the transformation rule can be written in the fuzzy system as follows:
If (state of the system) is Ei, then (control signal) = ui
Where i = 1, 2,..., n; Ei is the language variable of the input signal, ui is the function with the parameters of the control action. If at each tuning region, the control action is due to the PID regulator with:

$$u_i = K_{Pi}e + K_{Ii}\int_0^t e(t)dt + K_{Di}\frac{de}{dt} \quad (i = 1, 2, \dots n)$$

Thus, the coefficients of the PIDi regulator depend on the input signals, more generally on the state of the system. If we consider the coefficients K_{Pi}, K_{Di}, and K_{Ii} as the defuzzification results according to the center-average method from three functional fuzzy systems:

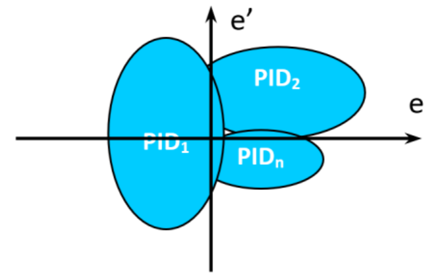

Figure 2. *Active area of the controller*

3. CONTROL DESIGN

The fuzzy controller and the classic PID controller are shown in Figure 3.

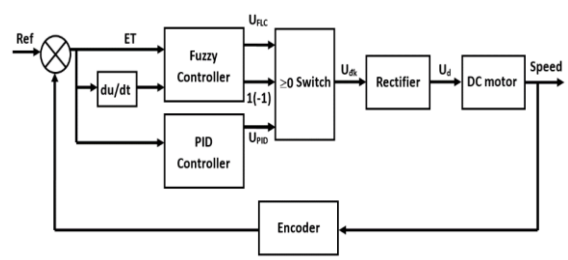

Figure 3. *The Hybrid fuzzy PID controller structure for DC motor speed loop control using commutation Switch*

The Hybrid Fuzzy PID Controller algorithm for speed loop is presented in this paper which of input/output language variables as follows:

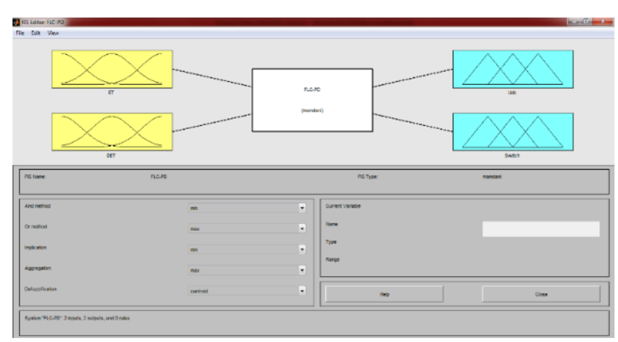

Figure 4. *The input and output language variables for fuzzy controller*

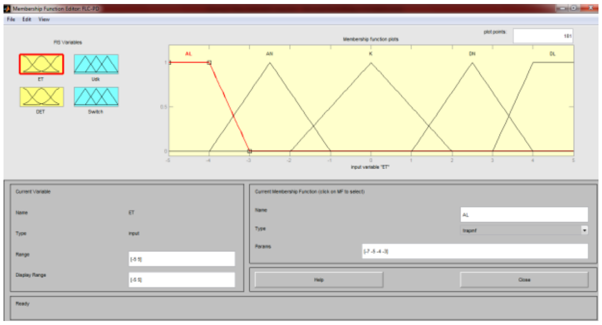

Figure 5. *The membership function for the input language variable ET*

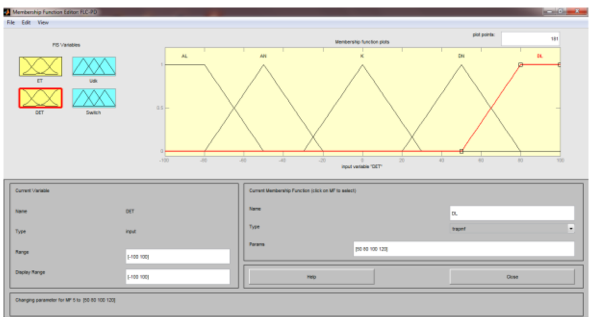

Figure 6. *The membership function for the input language variable DET*

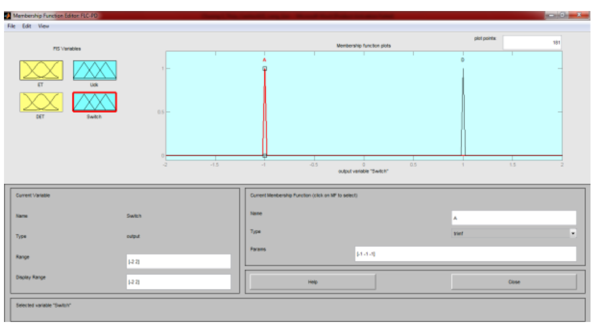

Figure 7. *The membership function for the output language variables switch between PI controller and fuzzy controller*

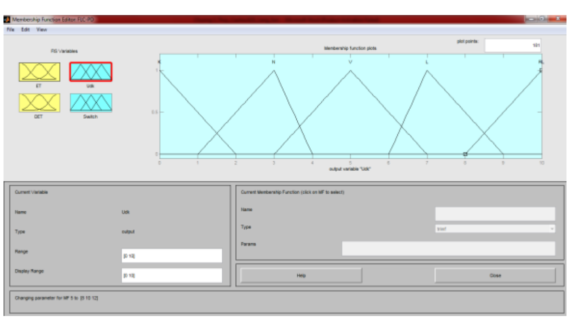

Figure 8. *The membership function for the output language variable Switch switches between two PI controllers and fuzzy controllers*

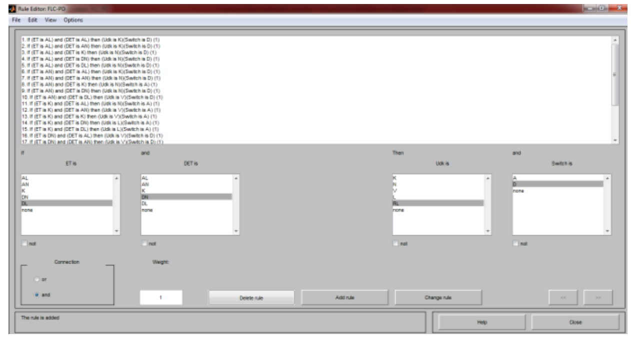

Figure 9. *Setting the control law for fuzzy controller*

The construction of a control rule table for fuzzy controllers in the hybrid fuzzy controller structure is based on control thinking between the relationship between the input error ET and the deviation derivative DET, while taking into account the function of the fuzzy controller. The second function of the fuzzy controller is to open and close the switch for the PI controller to work or the fuzzy controller to work.

U_{dk} / Switch		ET				
		AL	**AN**	**K**	**DN**	**DL**
DET	**AL**	K/D	K/D	N/A	V/D	V/D
	AN	K/D	N/D	V/A	V/D	L/D
	K	N/D	N/A	V/A	L/A	L/D
	DN	N/D	N/D	L/A	L/D	RL/D
	DL	N/D	V/D	L/A	RL/D	RL/D

Table 1. Control rule table for fuzzy controller

4. NUMERICAL SIMULATIONS

To see the superiority of the hybrid fuzzy control structure for the speed stability control problem. Below is a comparison of the simulation results between the classical PID controller (specifically, the P controller) and the proposed hybrid fuzzy controller for the speed loop in the speed stability control problem.

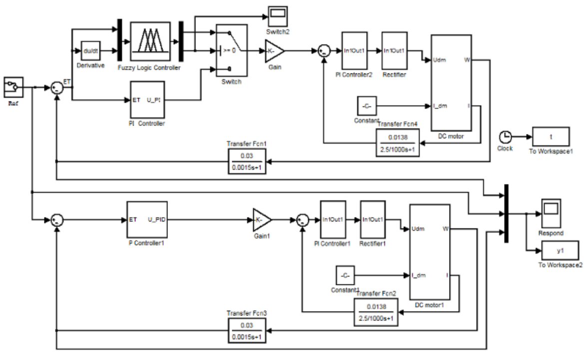

Figure 10. Simulation of the response between the P controller and the hybrid fuzzy controller in the roblem of DC motor speed stability when there is no disturbance

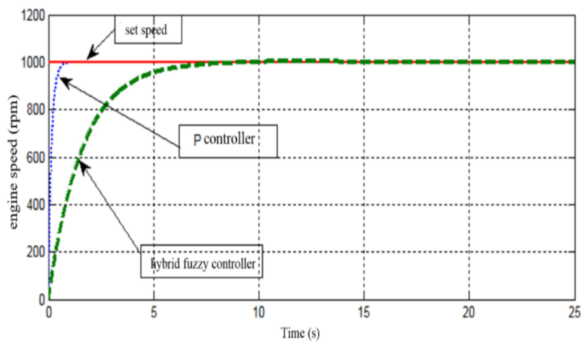

Figure 11. Comparison of the response between the P controller and the hybrid fuzzy controller of the speed loop with a step function input

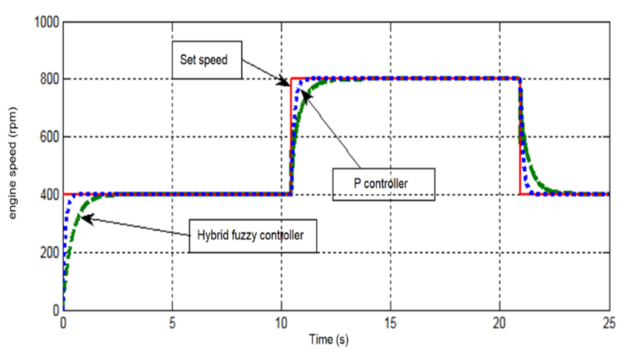

Figure 12. Comparison of the response between the P controller and the hybrid fuzzy controller of the speed loop with a square function input

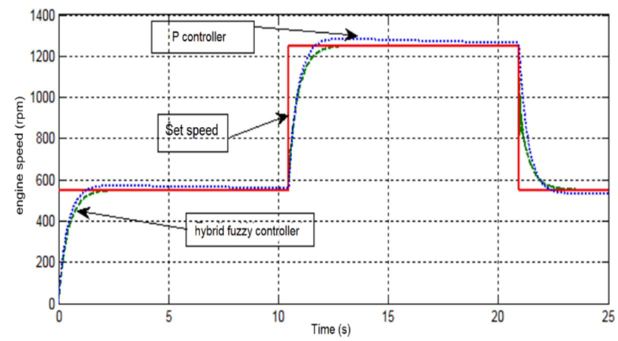

Figure 13. Comparison of the response between the P controller and the hybrid fuzzy PID controller of the speed loop when changing the setting speed

We consider some value of setting speed, and we evaluate the response quality of the system to different speed variables, as shown in Figures 10-13.

5. CONCLUSIONS

In this paper, the author presented an overview of the hybrid fuzzy control system, the design method of the hybrid fuzzy controller, and proposed a hybrid fuzzy control structure to stabilize the DC motor speed. The author has implemented a system simulation structure to compare the simulation results between the classical PID controller (specifically, the P controller) and the proposed hybrid fuzzy PID controller for the DC motor's speed loop instability control problem. The speed loop controller uses the hybrid fuzzy controller with the above control algorithm to achieve good quality and stable operation much more accurately. However, when there is no interference, the control quality of the hybrid fuzzy PID controller also gives a slower response.

6. ACKNOWLEDGEMENT

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