Dc Motors Control base on Fuzzy Adjustment

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Abstract

Background/Objectives: Wide rang of DC motors speed and their easy control are responsible for their widespread operation in industry. The introduced speed control methods for DC motors have developed by knowing new methods in control theory. **Methods/Statistical analysis:** The proposed method has been simulated using the information of a DC machine with software MATLAB and the SIMULINK environment. **Findings:** The results of this study demonstrated that through using FLC method no change is of observed in responses and the time of achieving to ideal speed is very low but in the PID method contrary to FLC method the time of sitting is high. While FLC method have a high limit in the ability of ideal deletion in different conditions of motor operation and decreasing of achieving time to final responses. **Applications/Improvements:** In this research a DC motor speed has been controlled by using Fuzzy control. The effect of load changes, reference speed, and armature voltage have been considered in this controller.

Keywords: Defuzzification, Fuzzification, FLC Control, Fuzzy Rule, PID Control

1. Introduction

DC motors have been the first electrical motors in industry that have been known through their easy control of speed, at multi-watt powers to multi-thousand Kilowatt and with wide voltage range and at different nominal speeds^{1,2}.

Introduced methods for controlling of DC motors are divided into 3 classes^{3, 4}.

1- Classic methods like using of PI and PID controllers.

2- Modern methods (comparative, optimal and ...)

3- Intelligent methods like Fuzzy theory Utilization and neural networks.

The aim of this research is to introduce a method for intelligent speed control of DC motor, using Fuzzy control. The proposed method using software MATLAB and in the SIMULINK environment has been conducted and examined using simulation and in the second section the control methods of motor turn has been introduced. The third section models the DC motor. The forth section continue to explain the Fuzzy control until in the fifth section the proposed method is explained and finally in sixth section the results are introduced.

2. The Methods of DC Motor Turn Control

Figure 1 shows the dynamic model of a DC motor that an object is connected to it with inertia constant, I, by yataghan with damping coefficient B^{5-8} .



Figure 1. Dynamic model of a DC motor.

For this motor we have following equations: $I_{f} = V_{f} | (L_{f} S + R_{f})$ $T = K_{a} \varphi I_{a}$ $\varphi = K_{f} I_{f}$ $T_{m} = K_{a} K_{f} I_{f} I_{a}$

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 $T_m - T_d = (I s + B) \omega (s) \tag{1}$

In which Ka and ϕ are torque constant of motor force and air hole fluid, respectively. There are two methods for controlling of DC motor turn^{9, 10}.

A. Field control system

In the field control system, as it is shown in Figure 2, the armature warrant is constant and the only thing that changes is flow. For this state we have the following equation:



Figure 2. Control system of DC motor field

In which K and ω are torque constant of motor force and angular speed, respectively.

B. Control system of armature voltage

In this state, flow is constant and only the armature voltage changes (Figure 3). In this state we have the following equation:

$$I_{a} = (V_{a} - V_{m}) (R_{a} + L_{a} .S)$$

$$T_{m} = K_{2} . I_{a}$$

$$V_{m} = K.\varphi.\omega = K_{m} .\omega$$
(2)



Figure 3. Control system of armature voltage of DC motor.

3. DC Motor Modeling

Direct current motors have different kinds and different

speed control methods has proposed for them. In this research, DC motor, as shown in Figure 4, has been selected for speed control and speed control in lower speeds than nominal speed has been conducted by the controlling of feed voltage.



Figure 4. DC motor diagram.

The dominated equations of this motor are:

$$V_{t} = L_{a} \frac{di_{a}}{dt} + R_{a} \cdot i_{a} + E_{a}$$

$$E_{a} = K \cdot \omega_{m}$$

$$J \frac{d^{2}\theta}{dt} + B \frac{d\theta}{dt} - T_{l} = K \cdot i_{a}$$
(5)

(3)

In which Ra, La, Ia, Vt are resistance, inductance, current and voltage of armature respectively, Ea motor anti drive force, ω angular speed, T_i load torque, J and B rotatory in ertia and equal friction coefficient in motor axis.

By selecting Ia, ω as state variations as well as Vt and T1 as inputs the above equations can be written in the from of a matrix.

$$\frac{d}{dt} \begin{bmatrix} i_a \\ \omega \end{bmatrix} = \begin{bmatrix} -\frac{R_a}{L_a} & \frac{-k}{L_a} \\ \frac{+K}{J} & \frac{-B}{J} \end{bmatrix} \begin{bmatrix} i_a \\ \omega \end{bmatrix} + \begin{bmatrix} \frac{1}{L} & 0 \\ 0 & \frac{1}{J} \end{bmatrix} \begin{bmatrix} V_t \\ T_1 \end{bmatrix}$$
(4)

In these equations saturation effect, also coupling between field wire coils and armature and armature reaction has been neglected. Considering the above equations DC motor model has been showed in Figure 5.

DC motor characteristics and parameters are as follows. Ra=2, La=0.5, Ki=0.015, Kb=0.015, B=0.2, J=0.02



Figure 5. Control system of armature voltage of DC motor model.

Considering the step input of figure 5 the output is as Figure 6.



Figure 6. output of control system of armature voltage of DC motor model

4. Fuzzy Control

Fuzzy theory was introduced for the first time by Iranian professor Lotfizadeh from Kalifornia University in 1965. Although this theory was objected at first but the developing process of this logic Usage developed its values. In Fuzzy control one membership function μ is considered for each phenomenon that expresses its belonging rate to a set. There is 3 stages in this method. First, Fuzzification stage that is the stage of defining Fuzzy sets for input and output variations. To define these Fuzzy sets, there need to have a primitive knowledge of range definition of each of these variations. In most cases output error I.e the difference between process output and reference signal and their changes or deviations from the Fuzzy system inputs. Therefore error and error variations are calculated as follows:

e(t) = y(t)	
$\Delta e(t) = y(t) - y(t-1)$	(5)

In the next stage or inference stage, we will produce some Fuzzy Rule and by using these formulae we will calculate the control signal rate considering error rate and its deviation. And in the last stage called Defuzzification stage a real rate is obtained for output considering the obtained level in inference stage. There are different methods for Defuzzification that their more widespread usage is center of gravity. In the center of gravity method obtained level in inference stage obtained, it is supposed on horizontal axis, therefore all the values of output variables obtained (the weight of each output value is its membership degree)¹¹⁻¹³.

5. Proposed Method

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The purpose is designing of a controller of resistance rise and time reduction of achieving to ideal state ageist applying one disorder in on process. In this research PID controller has been used for comparison of its response with its proposed method. This controller places in the way of error in Figure 5 and its equation is as follows:

$$\frac{U(s)}{E(s)} = K_p + \frac{K_i}{S} + K_d . S$$

In which Kp is proportional return and Ki integral return and Kd derivation return. By regulating of above parameters the error of continuous state and output changes in respond to step input of Figure 7 can be controlled.

(6)



Figure 7. DC motor model with PID controller

The output is as Figure 8:



Figure 8. output of DC motor model with PID controller

In addition to the difficulty of parameters regulation for having an ideal response the main difficulty of this kind of controller is their correction necessity through the changing of motor conditions that it is not possible to re- regulate parameters during work practically. The designing of introduced Fuzzy controller in this research has done using software Simulink and MATLAB and FUZZY graphics connection. Fuzzy control involves two error inputs and error variations and an output. Fuzzy controller has 49 Rule and the Table 1:

Table 1.Fuzzy contoller rule

\ error	NB	NM	NS	Z	PS	PM	PB
error							
variations							
NB	NB	NB	NB	NB	NS	PS	PB
NM	NB	NB	NM	NM	Ζ	PS	РВ
NS	NB	NB	NS	NS	Ζ	PM	РВ
Z	NB	NB	NS	Ζ	PS	PB	РВ
PS	NB	NM	Ζ	PS	PS	PB	PB
PM	NB	NS	Ζ	PM	PM	PB	РВ
PB	NB	NS	PS	РВ	PB	PB	PB



Figure 9. Input error membership function.



Figure 10. Error variations input membership function.



Figure 11. Output membership function.



Figure 12. Diagram block of DC motor Fuzzy control circuit.

Negative Big = NB Negative Medium = NM Negative Small = NS Positive Small = PS Positive Big = PB Positive Medium = PM Zero = Z

As shown in Figure 9-11, the output of this circuit is the voltage that directs the motor speed.

Figure 12 shows the Fuzzy controller diagram block.

The output of Fuzzy control circuit of DC motor is as Figure 13.





In using of Fuzzy control through FUZZY graphics connection the MAX-MIN mamdani method has been used for Fuzzification and center of granite method has been used for Defuzzification. In the center of granite method we obtained the obtained level in inference stage, supposed it on the horizontal axis, therefore we obtained weighted mean of all values of output variable i , e the weight of each output is its membership degree. The most exact method between Defuzzification methods is above mentioned method because all the points consider their definition domain and membership degree.

6. Conclusion

To obtain the best comparison in PID and FLC control operation and step wave is given to control system input. Results show that through using FLC method no change is of observed in responses and the time of achieving to ideal speed is very low but in the PID method contrary to FLC method the time of sitting is high. While FLC method have a high limit in the ability of ideal deletion in different conditions of motor operation and decreasing of achieving time to final responses.

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