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# Enhancing The Performance Of DC Motor Speed Control Using Fuzzy Logic

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## Abstract

*This paper focuses on speed control of DC motor by conventional PI controller and Fuzzy Logic Controller (FLC). The DC motor is modelled using the state space equations, which are used to create the SIMULINK models of the above methods. The PI controller reduces the steady state error measured between motor speed ($\omega_r$) and reference speed ($\omega_{ref}$), while the Fuzzy Logic Controller (FLC) adjusts fuzzy membership functions to control the motor speed. The response of these methods is compared with each other.*

## 1. Introduction

In the industries, the speed of DC motor is controlled to perform different task and for load changes. The speed control can be achieved by using conventional method as PI controller or Fuzzy controller [1,2].

In PI controller, the objective is to make the motor speed follow the reference speed. Thus PI controller is used to reduce or eliminate the steady state error measured between motor speed $\omega_r$ reference speed $\omega_{ref}$ [3].

Fuzzy logic is used where the system is nonlinear and difficult to calculate mathematical model. Intelligent techniques like Fuzzy logic developed to replace conventional control techniques. Thus, the effects of nonlinearity in conventional methods are reduced using Fuzzy logic. This fuzzy controller is similar to PI controller, when used with the defuzzification method [4,5].

The fuzzy membership functions and rules are modified after applying to PI controller. The output of fuzzy controller is created by rules composed of two inputs and linguistic definitions. The output of FLC can be improved by varying fuzzy membership functions and rules [7].

## 2. DC motor speed control using PI controller

The PI controller is used to control the speed of DC motor by reducing the steady state error measured between motor speed ($\omega_r$) and reference speed ($\omega_{ref}$). The PI controller with DC motor is as shown in block diagram.

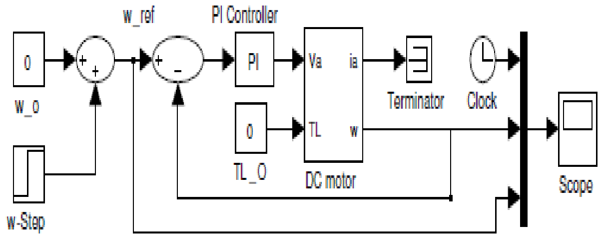


Fig.1:- DC motor speed control using PI Controller

While modelling a DC motor, it can be described by state space equations.

$$\dot{x}_1 = -\frac{R_a}{L_a}x_1 - \frac{K}{L_a}x_2 + \frac{1}{L_a}u \;--(1)$$

$$\dot{x}_2 = \frac{K}{L_a}x_1 - \frac{K}{L_a}x_2 + \frac{1}{L_a}u \;---(2)$$

Where,

$\dot{x}_1$= armature current

$\dot{x}_2$ = motor speed in rad/s

$u$ = voltage applied to armature circuit

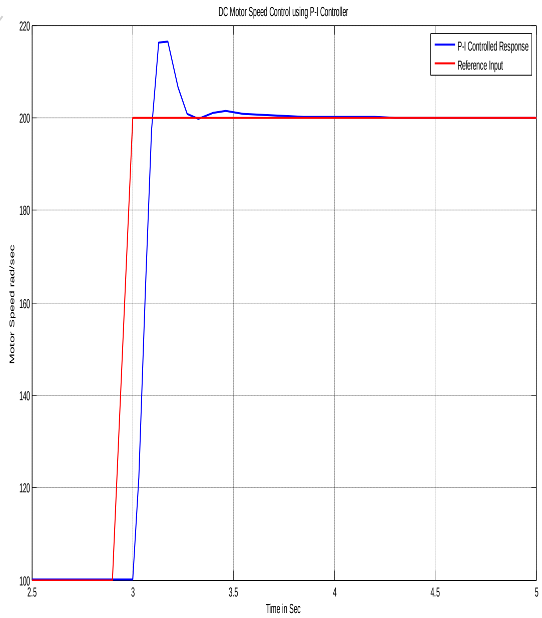


Fig.2:- DC motor speed response with PI controller

DC Motor Parameters used for the model are as shown in the Table1.

**Table 1:- DC Motor Parameters**

| Parameters | Description | Value |
|---|---|---|
| Ra | Armature resistance | 4.67Ω |
| La | Armature inductance | 170e-3 H |

| | | |
|---|---|---|
| J | Moment of inertia | 42.6e-6 Kg-m |
| f | Viscous friction coefficient | 47.3e6Nm/rad/se |
| K | Torque constant | 14.7e-3N-m/A |
| Kb | Back-EMF constant | 14.7e-3Vsec/rad |

## 3. DC motor speed control using Fuzzy Logic

Instead of using system model, FLC operation based on heuristic knowledge and linguistic description is used. The lack of knowledge of developing membership functions and rules can give wrong results. Thus with sufficient knowledge of adjusting the rules and membership functions the performance of FLC can be improved .The design procedure of FLC contains three steps as

A. Defining input and output

B. Defining membership functions and rules

C. Adjusting membership functions and rules.

### *A. Defining Input and Output:*

In FLC error and change in error plays an important role to define controller input. For FLC the inputs are error (E) and change in error ($C_E$).Where E is input is error between the reference speed $\omega_r$ and actual speed $\omega_a$. The output for FLC is the change in armature voltage ($C_U$). The equations of input & output are given by equations:

$$E = e(k) = \omega_r(k) - \omega_a(k) \text{ -------(3)}$$

$$C_E = e(k) - e(k-1) \text{ ---------------(4)}$$

$$C_U = u(k) - u(k-1) \text{ -------------(5)}$$

Block diagram of Fuzzy logic controller including the input and output values is as shown in fig.3.

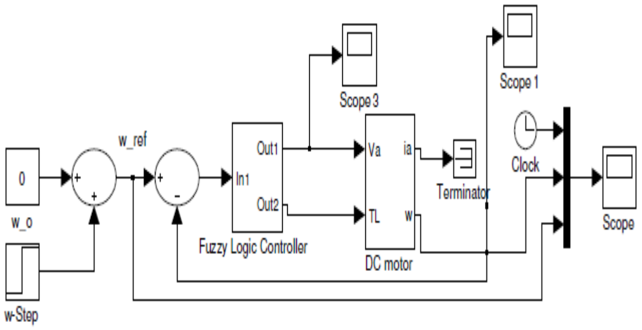


Fig.3:- Block diagram of fuzzy logic controller

### *B. Defining membership functions and rules:*

Table 2 shows the fuzzy linguistic terms used in this paper.

**Table 2:- Fuzzy Linguistic Terms**

| Term | Definition |
|---|---|
| PB | Positive Big |
| PM | Positive Medium |
| PS | Positive Small |
| ZE | Zero |
| NS | Negative Small |
| NM | Negative Medium |
| NB | Negative Big |

Input and output values are defined by seven fuzzy variables, where linguistic terms are used to represent the input and output from numerical and crisp value to linguistic forms. FLC output will be calculated after converting the input and output from crisp value in to linguistic forms. This conversion is done with the help of Fuzzy membership functions.

The fuzzy membership function can be of different shapes such as triangular and trapezoidal.

The FLC uses Fuzzy rules. These rules are in the form of IF_THEN statements If error E is negative big (NB) and change in error (CE) equal to positive big (PB) then change in armature Voltage (CU) is zero (ZE). Table III shows the initial rules.

**Table 3:- Initial Rules**

| E<br>CE | NB | NM | NS | ZE | PS | PM | PB |
|---|---|---|---|---|---|---|---|
| **PB** | ZE | PS | PM | PB | PB | PB | PB |
| **PM** | NS | ZE | PS | PM | PB | PB | PB |
| **PS** | NM | NS | ZE | PS | PM | PB | PB |
| **ZE** | NB | NM | NS | ZE | PS | PM | PB |
| **NS** | NB | NB | NM | NS | ZE | PS | PM |
| **NM** | NB | NB | NB | NM | NS | ZE | PS |
| **NB** | NB | NB | NB | NB | NM | NS | ZE |

With the basic reference of PI control the initial rules are constructed.

The process of defuzzification is required to send out armature voltage. The output in the form of fuzzy sets is converted to crisp value for getting the armature voltage. The center of gravity method is used as defuzzification method.

### *C. Adjusting fuzzy range of membership functions and rules:*

By adjusting the membership functions the performance of FLC can be improved. When the

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the membership function duration is changed , finer control is achieved . The final membership functions are obtained by adjusting membership f unction and rules.

**Table 4:- Final Rules**

| E<br>CE | NB | NM | NS | ZE | PS | PM | PB |
|---|---|---|---|---|---|---|---|
| **PB** | NM | NS | NS | NB | PB | PB | PB |
| **PM** | NM | NM | NS | NB | PB | PB | PB |
| **PS** | NB | NM | NM | ZE | PB | PB | PB |
| **ZE** | NB | NB | NM | ZE | PM | PB | PB |
| **NS** | NB | NB | NB | ZE | PM | PM | PB |
| **NM** | NB | NB | NB | NB | PS | PM | PM |
| **NB** | NB | NB | NB | NB | PS | PS | PM |

## 4. Simulation Results

Speed control system of dc motor using FLC is developed by using basic PI controller. The DC motor speed response for PI controller is as shown in Fig.2.When fuzzy logic controller is developed it gives results as shown in Fig.4.The results can be developed by modifying the membership functions ,The modified results are as shown in Fig.5.

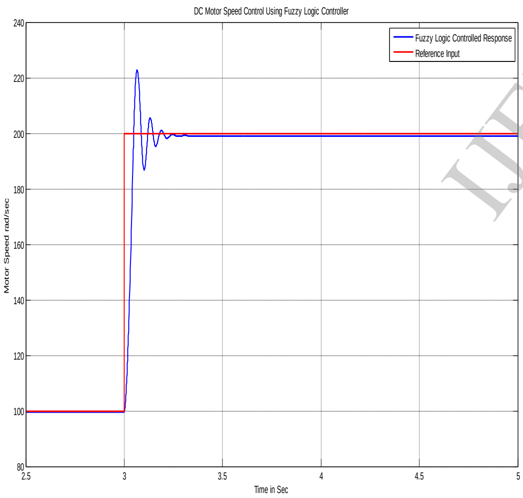


Fig.4:- Dc motor speed response with FLC

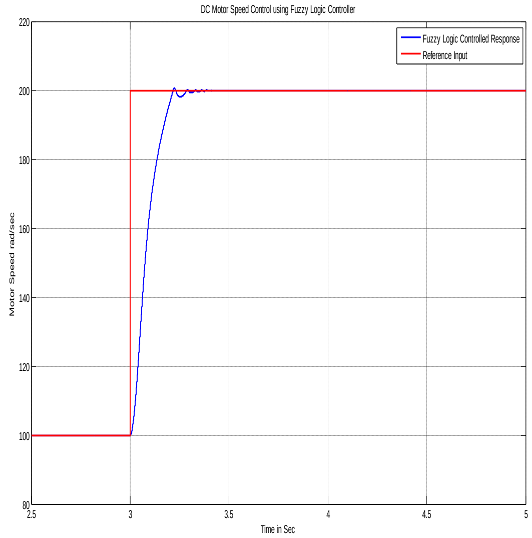


Fig.5:- DC motor speed response with modified FLC

## 5. Conclusion:

From the results obtained by simulating the Mat lab/Simulink models of PI controller and fuzzy logic controller, It is observed that the fuzzy logic controller with modified membership function outperforms the conventional controller. This gives the scope for research to improve performance by incorporating knowledge and modifying membership functions.

The comparison can be understood with the help of following table.

**Table 5:- Comparison of Different Controllers**

| Type of Controller | Overshoot in rpm | Settling Time |
|---|---|---|
| **PI Controller** | 210 rpm | 3.3 sec |
| **FLC** | 222 rpm | 3.25 sec |
| **FLC with modified membership functions** | 201 rpm | 3.2 sec |



## 7. References

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