INTELLIGENT CONTROL TECHNIQUE FOR SPEED CONTROL OF DC MOTOR

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Abstract: PID controllers are probably the most commonly used controller structures in industry. In this work, the conventional PI controller is designed using Zeigler-Nichols tuning method for controlling the speed of DC motor. First the DC motor is represented with a set of mathematical equations. The transfer function of DC motor (second order) is approximated to First Order Plus Time Delay (FOPTD) using two point formula Later, the speed of DC motor is controlled by Fuzzy Logic Controller. The fuzzy logic has minimum overshoot, and minimum transient and steady state parameters, which shows that FLC is more efficient and effective than conventional PI controller**.**

***Index Terms* - DC motor, PID controller, Fuzzy Logic Controller**

I. INTRODUCTION

All control systems suffer from problems related to undesirable overshoot, longer settling times and vibrations and stability while going from one state to another state. Real world systems are nonlinear, accurate modeling is difficult, costly and even impossible in most cases. The conventional digital control systems like classic PID controller solve the above problems approximately but we need to design intelligent and precise control systems to acquiring desired response.

PID controllers are commonly used for motor control applications because of their simple structures and intuitionally comprehensible control algorithms. Controller parameters are generally tuned using Ziegler-Nichols method. Fuzzy logic control (FLC) is one of the most successful applications of fuzzy set theory, introduced by L.A Zadeh [1] in 1973 and applied by Mamdani [2] in 1974 in an attempt to control system that are structurally difficult to model. Since then, FLC has been an extremely active and fruitful research area with many industrial applications reported [3].

Analysis and control of complex, nonlinear and/or time-varying systems is a challenging task using conventional methods because of uncertainties [4]. Fuzzy set theory which led to a new control method called Fuzzy Control which is able to cope with system uncertainties. One of the most important advantages of fuzzy control is that it can be successfully applied to control nonlinear complex systems using an operator experiences or control engineering knowledge without any mathematical model of the plant [5].

II. MATHEMATICAL MODELING OF DC MOTOR

The DC motor system is an electro mechanical system. The electrical system consists of the armature and the field circuit. For purpose of mathematical model development, the armature circuit is considered here since the field is excited by a constant voltage. The mechanical system consists of the rotating part of the motor and load connected to the shaft of the motor. The DC motor speed control system and its equivalent circuit are shown in Fig. 1a and Fig.1b.

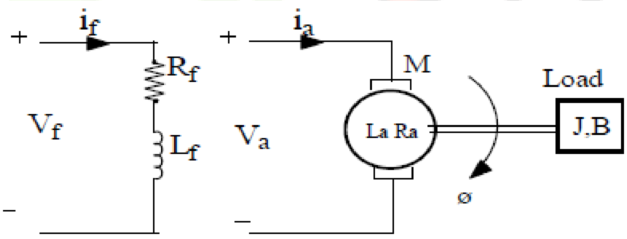

Fig 1 (a) Schematic representation of DC Motor.

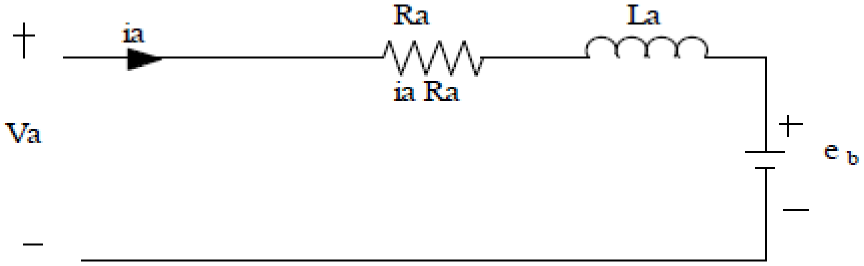

Fig.1 (b) Equivalent circuit of armature.

By applying kirchoff laws and rearranging the equations, the final transfer function from Input field voltage to the resulting speed is given by [6]

$$P(s) = \frac{w(s)}{V_a(s)} = \frac{K}{[(R_a+L_a s)(J_s+B)+K^2]}$$

The above equation shows the mathematical model of the DC motor and the model parameters are identified using specification of the DC motor given in Table 1.

Table 1. DC Motor Specifications.

Moment of Inertia of the rotor	J	= 0.03 kgm^2
Damping (friction) of the mechanical system	b	= 0.019 Nm
Electromotive Force Constant (Back EMF)	K	= 0.1331 Nm/A
Electric Resistance	R	= 6Ω
Electric Inductance	L	= 4.5 mH
Speed	N	= 1500 rpm
Voltage	V	= 24 V
Torque	Tq	= 1Kg-cm
Current	I	= 1 Ampere

The identified second order transfer function model of the DC motor is given as

$$P(s) = \frac{1.01}{0.001025s^2+1.367s+1}$$

Using two point formula, the transfer function of DC motor (second order) is approximated to first order plus time delay as,

$$P(s)=\frac{1.008}{1.105635s+1}e^{-0.1s}$$

III. Design of PI Controller

The control mode of PI Controller has a one-to-one correspondence of the proportional mode as well as the integral mode which eliminates that inherent offset. The block diagram of PI controller is shown in Fig.2.

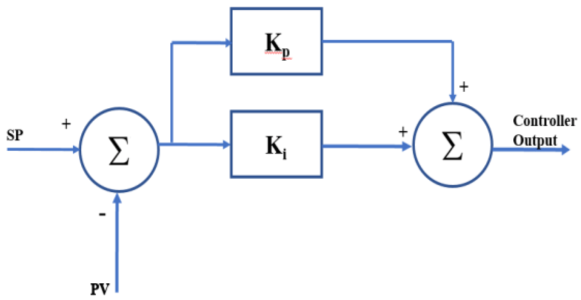

Fig.2. Block diagram of PI Controller

Mathematically, this can be represented as,

$$P = K_p e_p(t) + K_p K_I \int_0^t e_p(\tau)d\tau + P_I(0)$$

PI controller parameters of DC Motor are obtained using Ziegler and Nichols tuning method.

K_c = 9.9507; T_i =0.333; K_i = 29.8521

IV. Real Time Implementation

DC motor Transfer function model and PI controller are designed in real time using operational amplifiers, resistors and capacitors. Design of PI controller with inverter circuit is shown in Fig.3. The developed Transfer function model of DC motor is shown in Fig.4. Also the closed loop control of DC motor with PI controller is shown in Fig.5.

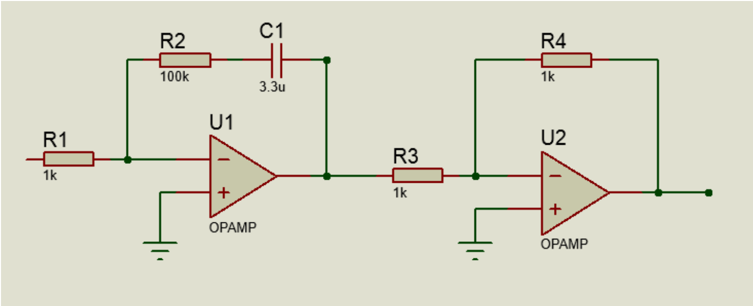

Fig.3. PI Controller with inverter circuit

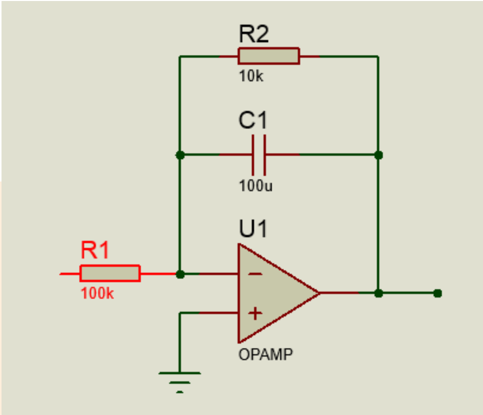

Fig.4. Transfer function model of DC motor.

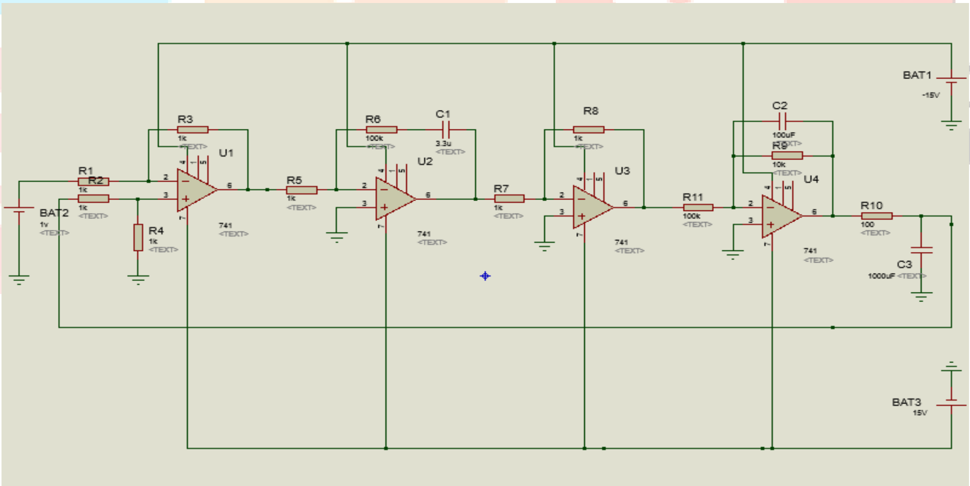

Fig.5. Closed loop control of DC motor with PI controller.

V. Fuzzy Logic Controller

In recent years, fuzzy system applications have received increasing attentions in various areas of control system. Fuzzy Logic Controllers based on fuzzy set theory are used to represent the experience and knowledge of a human operator in terms of linguistic variables that are called fuzzy rules. Since an experienced human operator adjust the system inputs to get a desired output by just looking at the system output without any knowledge on the system's dynamics and interior parameter variations, the implementation of linguistic fuzzy rules based on the procedures done by human operators does not also require a mathematical model of the system. Fuzzy rule table for DC motor is presented in Table2. Fuzzy rule viewer is shown in Fig 8.

Table 2. Rules for controlling dc motor

Δe / *E*	**NL**	**NS**	**Z**	**PS**	**PL**
NL	NL	NL	NL	NS	Z
NS	NL	NL	NS	Z	PS
Z	NL	NS	Z	PS	PL
PS	NS	Z	PS	PL	PL
PL	Z	PS	PL	PL	PL

NL - Negative Large

NS - Negative Small

Z - Zero

PS - Positive Small

PL - Positive Large

Linguistic variables for error, change in error and control are shown in Figs.8, 9 and 10 respectively.

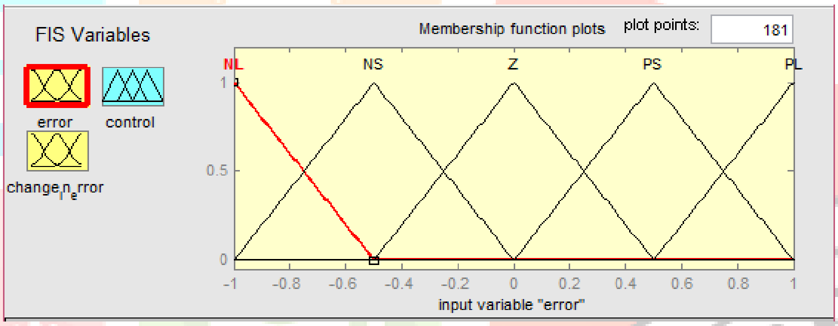

Fig 8: Membership functions for Input-1(error)

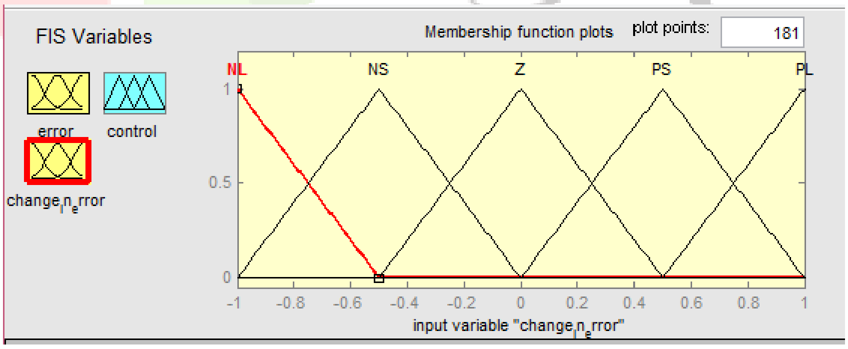

Fig 9: Membership functions for Input-2(change in error)

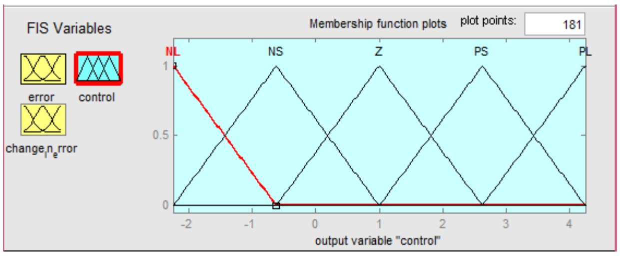

Fig 10: Membership functions for Output (control).

The Fuzzy logic controller rule viewer is presented in Fig.11.

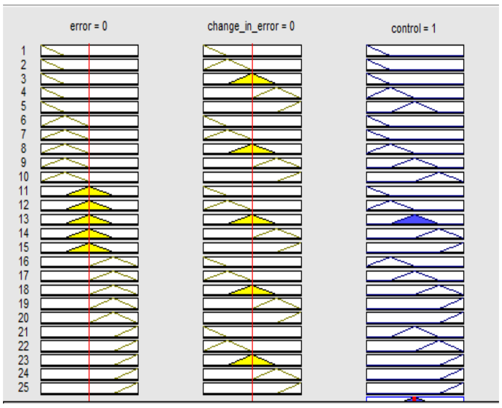

Fig 11. Rule Viewer.

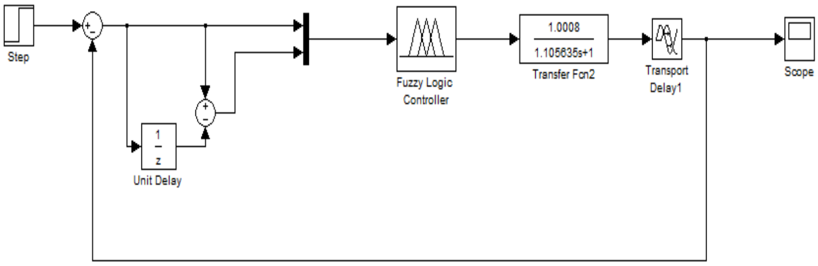

Fig.12 Simulink model of Fuzzy Logic Controller for DC motor.

VI. Results and Discussion

The simulated servo response of DC motor with PI controller and Fuzzy logic controller is shown in Fig. 13 and 14 respectively. From the result it is clear that Fuzzy logic controller produces better result when compared with PI controller in terms of settling time, rise time and Peak overshoot. The designed PI controller is implemented in real-time and its output is recorded and presented in Fig. 15.

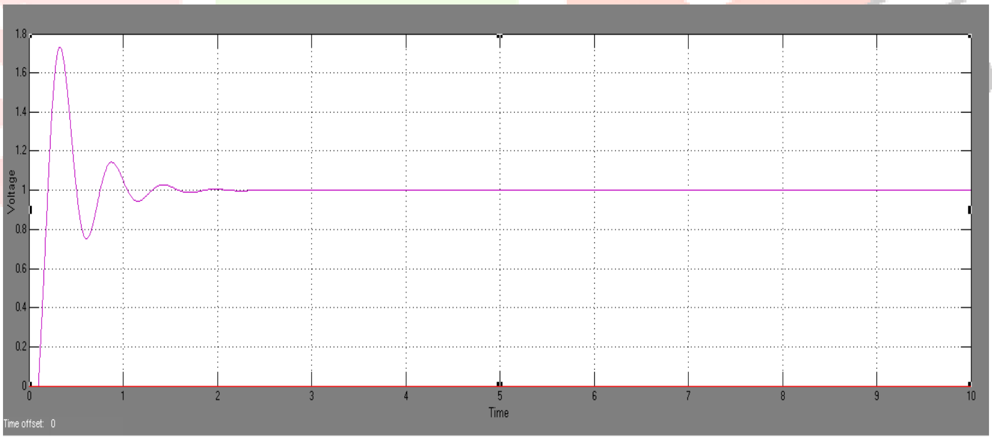

Fig.13. Simulated output of DC motor with PI controller.

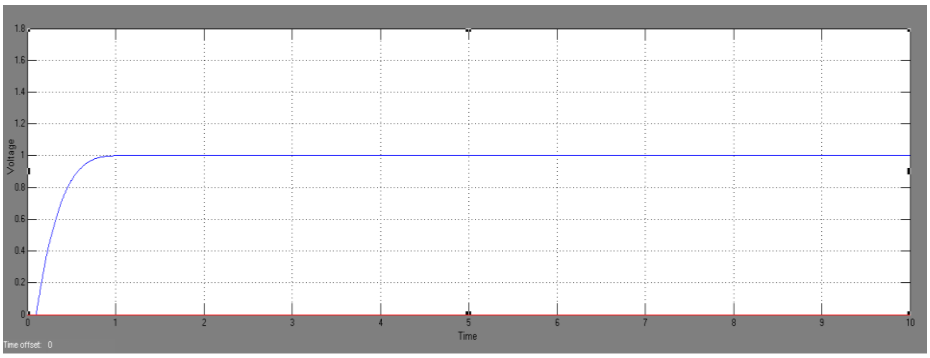

Fig.14 Simulated output of DC motor with Fuzzy logic controller.

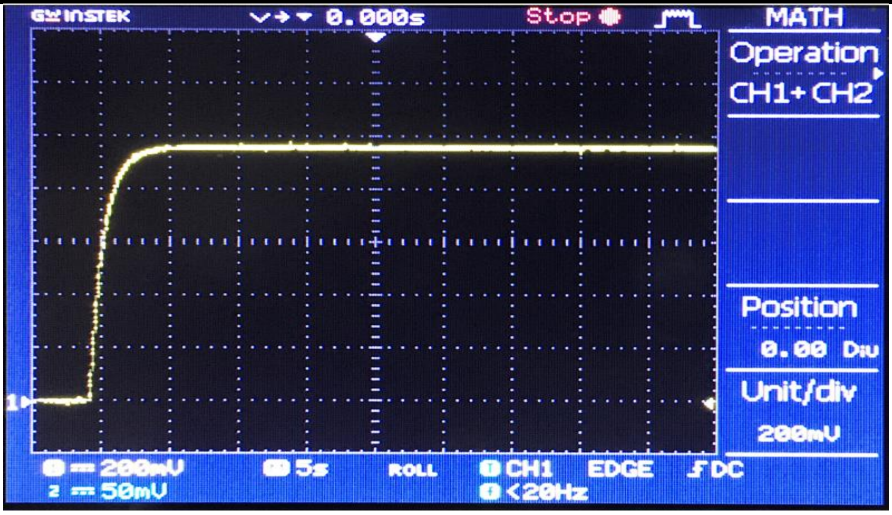

Fig.15. Real time output of DC motor with PI controller.

VII. Conclusion

In this work, Conventional PI and Fuzzy logic controllers are designed and implemented for a DC motor. The performance of a proposed Fuzzy logic controller is tested through simulation studies using MATLAB software. The obtained result using Fuzzy logic controller is compared with that of conventional PI controller. From the result, it is evident that Fuzzy logic controller produces better result when compared with PI controller in terms of settling time, rise time and peak overshoots.

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