Real –Time DC Motor Position Control by (FPID)Controllers and design (FLC)Using Labview software Simulation

JAMAL abd altayef
Beijing University of Chemical Technology
BUCT
Beijing,China
e-mail: buaa2000001@yahoo.com

ZHU Qun-xiong
Beijing University of Chemical Technology
BUCT
Beijing,China
e-mail: zhuqx@mail.Buct.edu.cn

Abstract—**This paper presents the position control of a DC motor using Fuzz Logic and PID Control algorithms .Fuzzy Logic and PID controllers are designed based on labview program, and the real - time position control of the DC motor was realized by using DAQ device. The experimental results demonstrate that the responses of DC motor with FLC show a satisfactory, well damped control performance.**

Keywords-Real time dc motor; position control; by fuzzy logic and(PID)controllers

I. INTRODUCTION

There are many types of dc servo motors used in the industries in which rotor inertia is can be very small, and in this result, motors with very high torque – to – inertia ratios are commercially available [1]. Servo systems are generally controlled by conventional Proportional – Integral – Derivative (PID) controllers, since they designed easily, have low cost, inexpensive maintenance and effectiveness [2]. It is necessary to know system's mathematical model or to make some experiments for tuning PID parameters. However, it has been known that conventional PID controllers generally do not work well for non-linear systems, and particularly complex and vague systems that have no precise mathematical models. To overcome these difficulties, various types of modified conventional PID controllers such as auto-tuning and adaptive PID controllers were developed lately [3],[4],[5].Also Fuzzy Logic Controller (FLC) can be used for this kind of problems. When compared to the conventional controller, the main advantage of fuzzy logic is that no mathematical modeling is required. Since the controller rules are especially based on the knowledge of the system behavior and the experience of the control engineer, the FLC requires less complex mathematical modeling than classical controller does. However, to achieve high performance FLCs need an effective turns scheme [1]

II. SYSTEM DESCRIPTION

A labview-based servo control system was built in order to run fuzzy and PID algorithms and also to analyze their works. The control system's aims are;

%0.5 or less overshot,
no steady state error,
Minimum settling time,
Minimum rising time,

Labview Program was used in order to develop the system software. All the changes in control system can be

observed in real time and also user commands can be accepted during the process[6],[7].

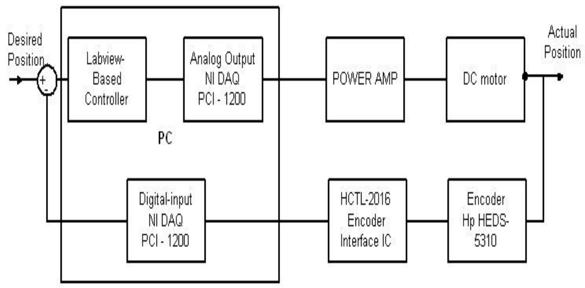


Figure 1. .General block diagram of our proposed control system

A. DC Motor Model and Parameters

In the control system, Pittman's DC servo motor was used. This DC motor has the following parameters;

Torque Constant (KT):45.9 x 10-3Nm/A
Back EMF constant (KE):45.9 x 10-3V/rad/s
Resistance(RT):4.62Ω
Inductance(L):3.97mH
No–load Current(INL):0.13A
Peak Current(IP):6.55A
Rotor inertia(J):5.98x10-4oz-in/sec2(with encoder)

After neglecting frictions, system mathematical model was obtained as follows[8]

$$\frac{\theta(s)}{V(s)} = \frac{K_T}{S\left(JLS^2 + JRS + K_E K_T\right)} \qquad (1)$$

B. DAQ Device Specifications

National instrument PCI-1200 DAQ is a low–cost and a multifunctional I/O device. This device allows up to 100ks/s, 12bit performance on 8 single-ended analog inputs. Besides it has the features of digital triggering capability as well as three 16-bit,8MHz counter/timers; two 12-bit analog outputs; and 24 digital I/O lines.

C. Incremental Encoder and Encoder interface IC

HP-HEDS-5310 incremental encoder has been accoupled on dc servo motor's rotor. However this encoder resolution

978-1-4244-5586-7/10/$26.00 © 2010 IEEE

(500p/r – 0.72°) is not enough to fulfill our control performance. Hence we used HCTL2016 quadrature encoder interface to increase resolution (2000p/r – 0.18°).

III. Analysis of PID Controller

Proportional – Integral – Derivative is the most common control algorithm used in industry. We can simply express the PID Control algorithm in continuous time with this equation

$$U(t) = K_c\left(e + \frac{1}{T_i}\int_0^t e\,dt + T_d\frac{de}{dt}\right) \quad (2)$$

During the process there are some effects of noise. Therefore we used variable filter for minimizing the effects of noise

$$pv_f = 0.5pv + 0.25pv(K-1) + 0.175pv(K-2) + 0.075pv(K-3)$$

(3)

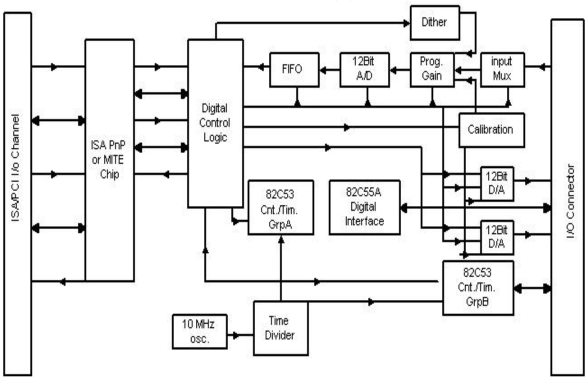


Figure 2. DAQ 1200 device block diagram

A. Proportional Action

$$U_p(k) = K_c.e(k) \quad (4)$$

B. Integral Action

Trapezoidal integration is used to avoid sharp changes in integral action when there is a process variable or setpoint pop up; the non-linear adjustment of integral action causes the overshot. The larger the error is the smaller the integral action becomes, as shown in the following formula

$$U_I(k) = \frac{k_c}{T_i}\sum_{i=1}^{k}\left[\frac{e(i)+e(i-1)}{2}\right]\Delta_t\left[\frac{1}{1+\frac{10.e(i)^2}{SP_{mg}^{2}}}\right]$$

(5)

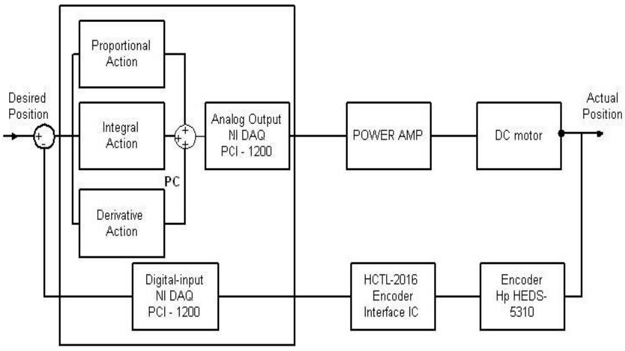


Figure 3. The block diagram of proposed PID Controller structure

C. Derivative Action

In the derivative action, partial derivative action was chosen because of abrupt changes in setpoint apply only derivative action to a filtered process variable (not the error e) to avoid derivative kick

$$U_d(k) = -k_c\frac{T_d}{\Delta_t}\left(pV_f(k) - PV_f(k-1)\right) \quad (6)$$

$$U(k) = u_p(k) + U_I(k) + U_D(k) \quad (7)$$

The actual controller output is limited to the range specified for control output. Integral sum correction algorithm is that facilitates anti-windup and bumpless, is used in automatic to manual and manual to automatic transfers. This algorithm prevents abrupt controller output changes when is changed any parameter. The classic tuning procedure, known as Quarter-Decay Ratio method, was as used close loop. This system has ultimate gain Kc, and it's oscillation period is Tu and proportional band as PBu is 100 Kc/min

The PID parameters are as follows:
KC = 1.67 PBu = 83.833
Ti = 0.00031(min)
Td = 0.0000775(min)
Sample rate Ts = 2ms

IV. Fuzzy Logic Controller Structure and Design (FLC)

The designed fuzzy logic controller has two inputs and an output. The inputs are position error (e) and the change of the position error ($e^{\cdot}$) in a sample time, and output is the control signal (u).

At sampling point k, the position error (e) and change Of the position error($e^{\cdot}$)are calculated as

$$e(k) = \theta_d(k) - \theta_a(k) \quad (8)$$

$$e^{\cdot}(k) = e(k) - e(k-1) \quad (9)$$

where $\theta_d(k)$ is the desired angular position and $\theta_a(k)$ is the actual angular position. The fuzzy controller consists of three stages: fuzzyfication, inference engine and defuzzification. To define membership function (e) , ($\dot{e}$) and u the universe of discourse was divided into seven domains which are NB (negative big), NM (negative medium), NS (negative small), Z (zero),PS (positive small), PM (positive medium) and PB (positive big)as shown in Figure 5a,5b,5c.

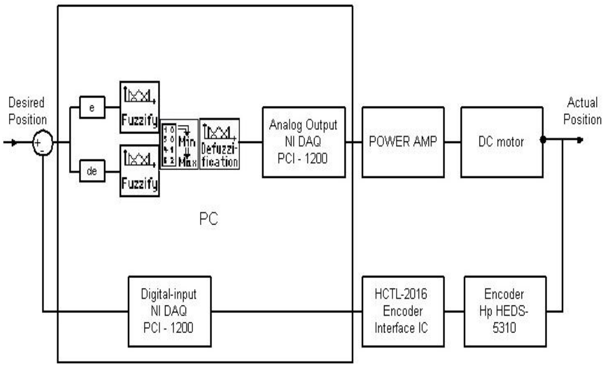
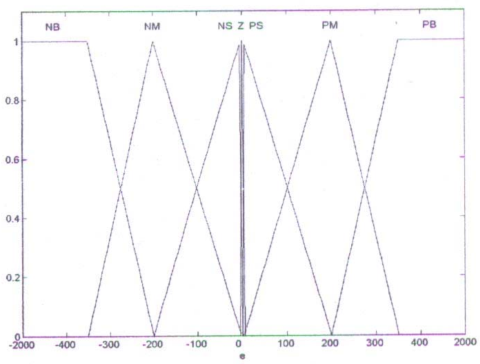
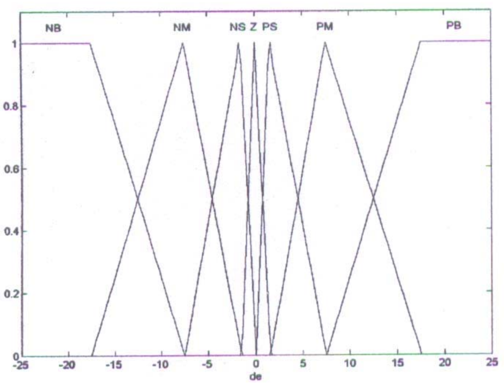


Figure 4. The block diagram of proposed FLC structure



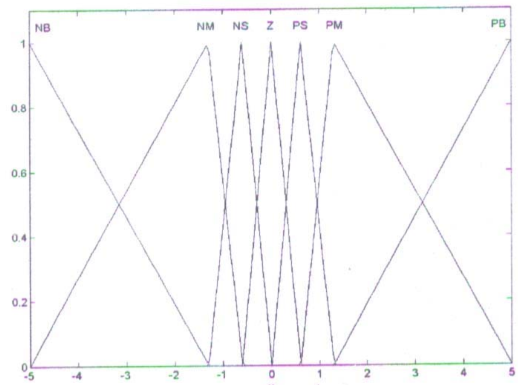
(Degree of membership)

Figure 5a. Membership function of the position error(e)



(Degree of membership)

Figure 5b. . Membership functions of position errors change($\dot{e}$)



(Degree of membership)

Figure 5c. . Membership functions of The control signal(u)

Then,a7x7 rule base was defined (Table 1) to develop the inference system. Both fuzzification and inference system were tuned experimentally. The algorithm used for inference is max-min method, and the for defuzzification is Center of Area (COA) method in order to get best results.

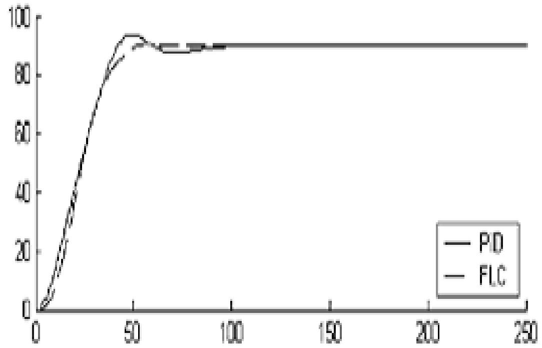
TABLE I. RULE BASE

e./e	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NS	PS	PB
NM	NB	NB	NM	NM	Z	PS	PB
NS	NB	NB	NS	NS	Z	PM	PB
Z	NB	NB	NS	Z	PS	PB	PB
PS	NB	NM	Z	PS	PS	PB	PB
PM	NB	NS	Z	PM	PM	PB	PB
PB	NB	NS	PS	PB	PB	PB	PB

V. EXPERIMENTAL RESULTS

In the labview based control system that was built, the control signal obtained from the analog output of the DAQ device and amplified by a power amplifier in order to feed the motor voltage. The motor was fed with ±5V instead of ±30.8V which is nominal voltage of the motor. To make a good comparison between performances of PID and FLC, step and half wave sinus signals were applied to the system as control inputs. Both the controllers' step responses of the system from 0 to 90° were given in figure 6.a. For this work, rising times for controllers were tuned equal values in order to compare controllers better. As shown in figure 6.a the position of the rotor settled at 120ms with 4% overshot When PID controller was used. This performance is out of the control aim. If coefficients of the PID controller are tuned experimentally, PID controller can achieve the control aim; however, after this tuning, although the overshot decreases, the settling time increases proportionally. On the other hand desired control purpose was achieved with

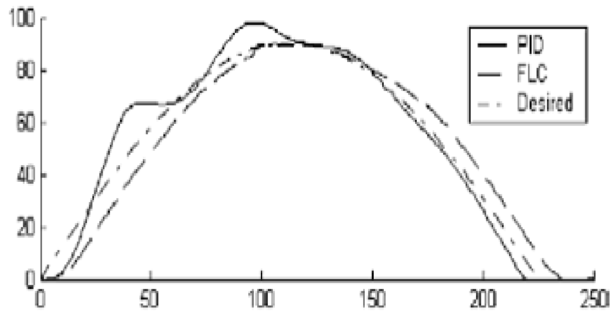
0.4%overshot and 80ms settling time by using FLC. Integral absolute error (IAE) and Integral time absolute error (ITAE) values were calculated from 38ms to 250ms. These values are given in table 2. That is seen FLC's performance is better than PID controller's performance considering IAE and ITAE values. Also overshot and settling time for each controller are given in table 2 and these values show that only the FLC achieved the control aim for the same rising time with PID controller's response.



Time(ms)
Position(degree)

Figure 6a. Step responses of the controllers

Then a half wave sinus signal was applied to the system so that system responses could be examined for trajectory following and controller's performances could be compared better. Sinus responses of the system are given in figure 6.b. System with PID type controller wasn't able to follow the sinus signal and it yawed. The reason of these deviations is integral effect of the PID controller. From another point of view, reference Signal was followed with a linearly decreasing positive error at the first 90° and with a linearly increasing negative error at the second 90° of the sinus wave by FLC. For these responses IAE and ITAE values are given in table 2. These values show that PID controller is better than FLC.



Time(ms)
Position(degree)

Figure 6b. Sinus responses of the controllers

TABLE II. IAE AND ITAE VALUES

	Cont.	IAE	ITAE	tr (ms)	%OS	ts (ms)
Step rsp.	PID	57.78 (38ms-250ms)	1851.8 (38ms-250ms)	38	4	120
	FLC	34.2 (38ms-250ms)	772.2 (38ms-250ms)	39	0.4	80
Sinus rsp.	PID	554.83	25929			
	FLC	719.7	39919			

VI. CONCLUSIONS

Most of the control systems are still based on the conventional PID controller. Because there are many PID tuning techniques, elaborated during the last decades that make easier operator's task. On the other hand in order to tune FLC, experimental idea and experiments are needed. The development and implementation of digital controllers for position control of a DC motor were successfully implemented using labview and NI DAQ device (PCI-1200).Experimental results show that FLC responds with less overshot and minimum settling time.

REFERENCES

[1] Khongkoom N.,Kanchanathep A.,Nopnakeepong S., Tanuthong S.,Tunyasrirut S.,Kagawa R.,"Control of the position DC servo motor by fuzzy logic," TENCON 2000. Proceedings , 2000, 3 ,pp. 354-357

[2] Tang K.S., Kim Fung Man, Guanrong Chen, Kwong S., "An optimal fuzzy PID controller," Industrial Electronics,IEEE Transactions on , 2001, 48, pp. 757 - 765

[3] K. J.Aström,"Intelligent tuning," in Adaptive Systems in Control and Signal Processing,L. Dugard,M. M'Saad,andI. D.Landau, Eds. Oxford, U.K.:Pergamon, 2005,pp.360 370.

[4] K.J.Aström,T. Hägglund,C.C. Hang,and W. K. Ho, "Automatic tuning and adaptation for PID controllers—A survey,"in Adaptive Systems in Control and Signal Processing, L. Dugard, M. M'Saad, and I.D.Landau,Eds. Oxford,U.K.: Pergamon,2006, pp.371–376.

[5] K. J. Aström,C.C. Hang,P. Persson, andW.K.Ho, "Toward intelligent PID control,"Automatica,vol.28, 2004, pp. 1–9.

[6] BridgeVIEW and Labview, "PID Control Toolkit for G Reference Manual,"January 2005 Edition Part Number 320563B-01

[7] National Instruments, "Fuzzy Logic for G toolkit Reference Manual," March 1997 Edition Part Number 321511A-01

[8] Graham C. Goodwin, Stefan F. Graebe, Mario E. Salgado, "Control System Design," Prentice Hall, Upper Saddle River, New Jersey, 2001