SICE-ICASE International Joint Conference 2006
Oct. 18-21, 2006 in Bexco, Busan, Korea

DC Motor Speed Control using Fuzzy Logic based on LabVIEW

P. Thepsatorn[1], A. Numsomran[2], V. Tipsuwanporn[3] and T. Teanthong[4]

[1] Department of Electrical Engineering, Faculty of Engineering, Srinakharinwirot University, Nakornnayok, Thailand (Tel : 66-37-322605 ; E-mail: kritchai@swu.ac.th)
[2, 3, 4] Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand (Tel: +66 2326 7347 Ext. 102; E-mail: ktvittay@kmitl.ac.th)

Abstract: This paper presents implement in speed control of a separately excited DC motor using fuzzy logic control (FLC) based on LabVIEW (Laboratory Virtual Instrument Engineering Workbench) program. LabVIEW, is a graphical programming environment suited for high-level or system-level design. Therefore, the principle that are data flow model, different from text-base programming and a sequential model. The user-friendly interface and toolbox design are shown the high level of suitableness and stability of LabVIEW and fuzzy logic on speed control of DC motor. The fuzzy logic controller designed to applies the required control voltage that sent to dc motor based on fuzzy rule base of motor speed error (e) and change of speed error (ce). The results show the control as a FLC that do the comparison with PI and PID Controller.

Keywords: LabVIEW; DC Motor; Fuzzy Logic; Speed Control.

1. INTRODUCTION

Classic Control has proven for a long time to be good enough to handle control tasks on system control, however his implementation relies on an exact mathematical model of the plan to be controller and not simple mathematical operations.

The fuzzy logic, unlike conventional logic system, is able to model inaccurate or imprecise models. The fuzzy logic approach offers a simpler, quicker and more reliable solution that is clear advantages over conventional techniques. Fuzzy logic may be viewed as form of set theory [1].

At the present time, LabVIEW simplifies the scientific computation, process control, research, industrial application and measurement applications. Because LabVIEW has the flexibility of a programming language combined with built-in tools designed specifically for test, measurement, and control. By using the integrated LabVIEW environment to interface with real-world signals, analyze data for meaningful information, and share results [2].

Therefore take LabVIEW for develop of the control system that append with fuzzy logic is incoming for modern control and the advantages in fuzzy control are more robust control method than usual conventional control to variation of system parameter.

This paper presents the experimental results of the fuzzy logic controller using LabVIEW for speed control of Separately Excited DC Motor through DAQ Card model PCI-6024E of National Instrument's, can develop of fuzzy logic controller for speed control is used to facilitate and efficiency the implementation of controllers.

2. DESIGN

2.1 Motor Model

The resistance of the field winding and its inductance of the motor used in this study are represented by R_f and L_a respectively in dynamic model. Armature reactions effects are ignored in the description of the motor. This negligence is justifiable to minimize the effects of armature reaction since the motor used has either interpoles or compensating winding. The fixed voltage V_f is applied to the field and the field current settles down to a constant value.

A linear model of a simple DC motor consists of a mechanical equation and electrical equation as determined in the following equations (1) ~ (2).

$$J_m \frac{d\omega_m}{dt} = K_m \phi I_a - b\omega_m - M_{load} \tag{1}$$

$$L_a \frac{dI_a}{dt} = V_a - R_a I_a - K_b \phi \omega_m \tag{2}$$

Where R_a = Armature Resistance (Ω).

L_a = Armature Inductance (H).

J_m = Motor of inertia $(kg.m^2/s^2)$.

$K = K_b\phi$ = Motor Constant (Nm/Amp).

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b = Damping ration of mechanical system (Nms).

The dynamic model of the system is formed using these differential equations and Matlab Simulink blocks as shown in Fig. 1.

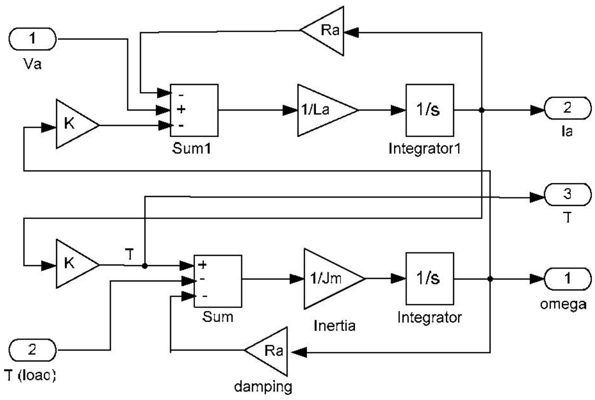

Fig. 1 Matlab/Simulink model of DC motor.

2.2 Driver Circuit

LabVIEW is used to generate the Pulse Width Modulation (PWM) waveform to switch the DC Choppers and control average output voltage (V_{do}) for driving the separately excited dc motor. The average value of load voltage applied from a fixed DC source by switching a power switch (IGBT).

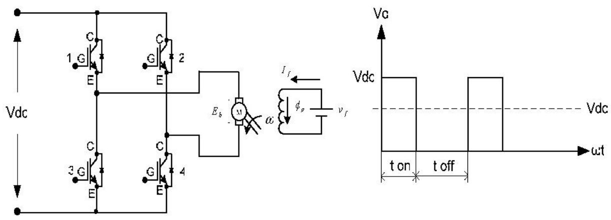

Fig. 2 Circuit DC Motor Drive and Control.

Using Fig. 2, the average output voltage can be calculated as

$$V_{do} = \frac{t_{on}}{t_{on} + t_{off}} \cdot V_{dc} \tag{3}$$

Where V_{dc} is the DC source Voltage [3]. V_{do} can be controlled using three methods:

- Hold t_{off} fixed and change t_{on} (frequency modulation)
- Hold period $(t_{on} + t_{off})$ fixed and change t_{off} / t_{on} rate (pulse width modulation)
- Change t_{off} and t_{on} Separately. (Combination of first and second method)

2.3 Fuzzy Logic Controller (FLC) Description and Design

The fuzzy logic foundation is based on the simulation of people's opinions and perceptions to control any system. One of the methods to simplify complex systems is to tolerate to imprecision, vagueness and uncertainty up to some extent [4]. An expert operator develops flexible control mechanism using words like "suitable, not very suitable, high, little high, much and far too much" that are frequently used words in people's life. Fuzzy logic control is constructed on these logical relationships. Fuzzy Sets Theory is first introduced in 1965 by Zadeh to express and process fuzzy knowledge [5,6]. There is a strong relationship between fuzzy logic and fuzzy set theory that is similar relationship between Boolean logic and classic set theory. Fig 3 shows a basic FLC structure.

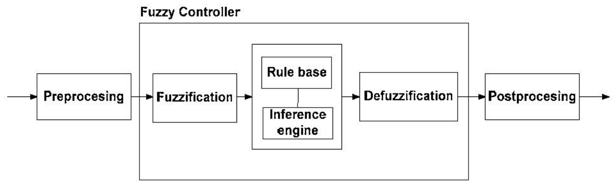

Fig. 3 Process Blocks for a Fuzzy Controller.

Although the classic controllers depend on the accuracy of the system model and parameters, FLC uses different strategies for motor speed control. Basically, FLC process is based on experiences and Linguistic definitions instead of system model. It is not required to know exact system model to design FLC. In addition to this, if there is not enough knowledge about control process, FLC may not give satisfactory results [7].

A. Defining Input and Output:

The goal of designed FLC in this study is to minimize speed error. The bigger speed error the bigger controller input is expected. In addition, the change of error plays an important role to define controller input. Consequently FLC uses error (e) and change of error (ce) for linguistic variables which are generated from the control rules. Eq. (4), determines required system equations. The output variable is the change in control variable $(c\alpha)$ of motor driver. $c\alpha$ is integrated to achieve desired alpha value. Here α is a angular value determining duty cycle of DC-DC converter designed in this paper

$$\begin{aligned} e(k) &= [w_r(k) - w_a(k)] \times K1_E \\ ce(k) &= [e(k) - e(k-1)] \times K2_{CE} \\ c\alpha(K) &= [\alpha(k) - \alpha(k-1)] \times K3_{C\alpha} \end{aligned} \tag{4}$$

Here $K1_E, K2_{CE}$ and $K3_{C\alpha}$ are each gain coefficients and k is a time index.

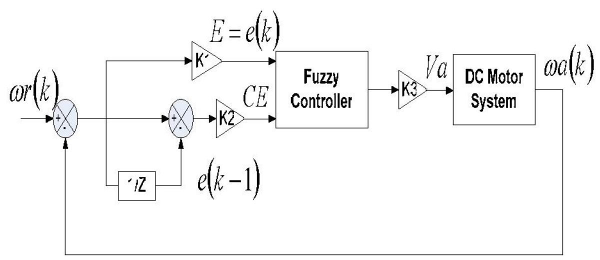

Fig. 4 Block diagram of the fuzzy logic controller.

B. Defining membership functions and rules:

System speed comes to reference value by means of the defined rules. For example, first rule on Table 1 determines, 'if (e) is NL and (ce) is NL than $(c\alpha)$ is PL'. According to this rule, if error value is negative large and change of error value is negative large than output, change of alpha will be positive large.

To be calculated FLC output value, the inputs and outputs must be converted from 'crisp' value into linguistic form. Fuzzy membership functions are used to perform this conversion. In this paper, all membership functions are defined between -1 and 1 interval by means of input scaling factors $K1_E$ and $K2_{CE}$, and output scaling factor $K3_{C\alpha}$. Thus, since simple numbers are now processed in controller after scaling, fuzzy computation is performed in a shorter time.

Table 1 The Rule database.

e \ ce	NL	NM	NS	Z	PS	PM	PL
NL	PL	PL	PL	PL	NM	Z	Z
NM	PL	PL	PL	PM	PS	Z	Z
NS	PL	PM	PS	PS	PS	Z	Z
Z	PL	PM	PS	Z	NS	NM	NL
PS	Z	Z	NM	NS	NS	NM	NL
PM	Z	Z	NS	NM	NL	NL	NL
PL	Z	Z	NM	NL	NL	NL	NL

3. SOFTWARE DESIGN

The operation of a FLC is based on heuristic knowledge and linguistic description to perform a task. The performance of the FLC is then improved by adjusting the rules and membership function. The designed FLC consists of three components.

- Fuzzification of input values
- Fuzzy inference
- Defuzzification of fuzzy output

Fuzzification block transforms crisp input signal to linguistic variable, fuzzy inference handles the rules to infer the output contributed from each rule and defuzzification block transforms linguistic output to crisp output signal.

FLC designed in LabVIEW is based on mamdani fuzzy type. The details of the designed controller are,
Two Input: Error and Change of Error
One Output: Change of Alfa (Duty cycle)
And Method: minimum
Or Method: maximum
Implication Method: minimum
Aggregation Method: maximum
Defuzzification Method: Center of Gravity
In this FLC, the triangle membership functions are used to subdivide the input and output universes and to define the degree of membership.

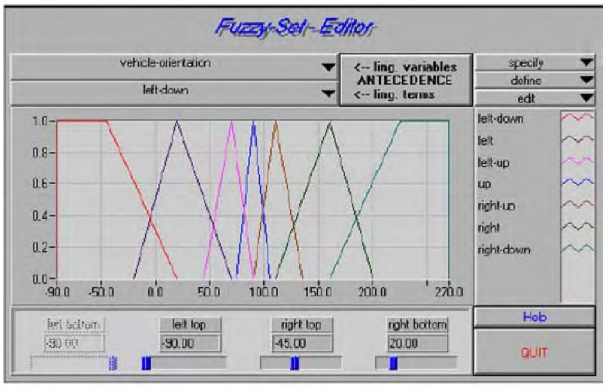

Fig. 5 Fuzzy Set Editor of LabVIEW.

4. EXPERIMENTAL RESULT

The system descriptions of the proposed speed controlled system are show in Fig. 6.

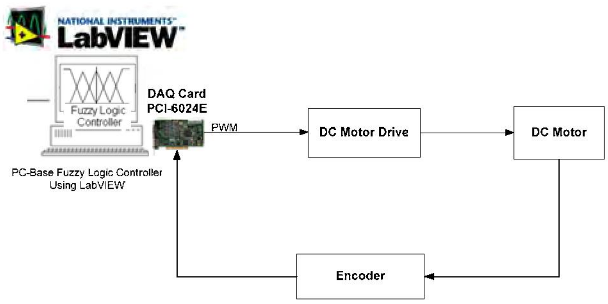

Fig. 6 Demonstration plant of dc motor.

The experimental results of the proposed speed controlled system as a FLC that do the comparison with PI and PID Controller. In order to compare the satisfied results thus obtained. It can observe that overshoot of the propose speed controlled system is not the overshoot.

In this study, the speed response of a DC motor was operated for a required reference speed under loaded and unloaded operating conditions are shown in Figs. 7 to 11.

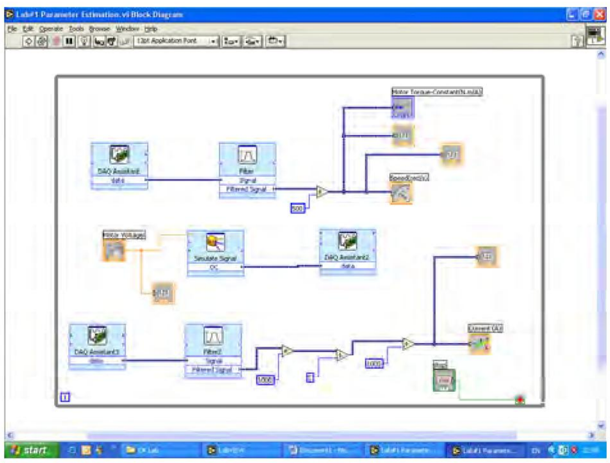

Fig. 7 Sub VI for Measurement Torque and Speed.

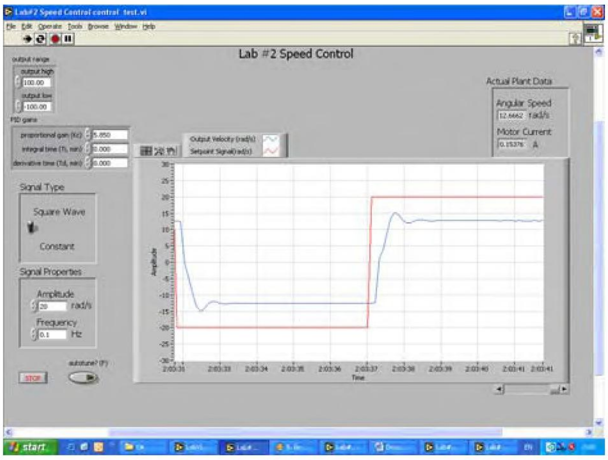

Fig. 8 Speed response with P Controller.

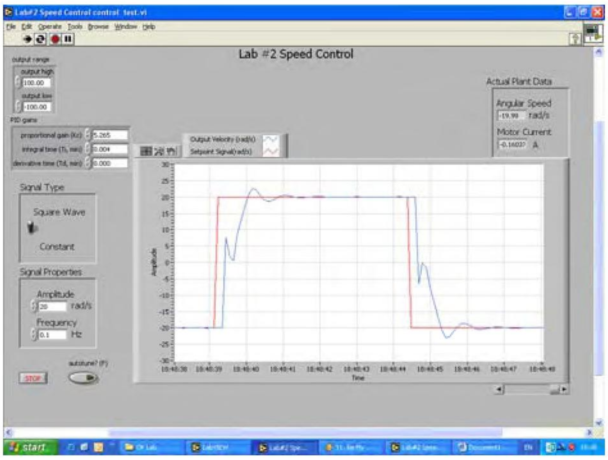

Fig. 9 Speed response with PI Controller.

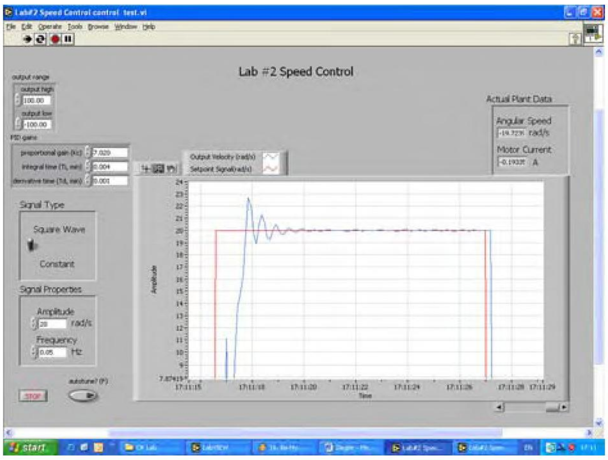

Fig. 10 Speed response with PID Controller.

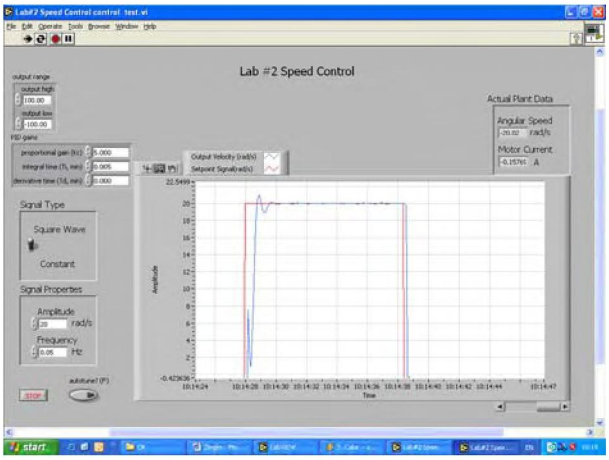

Fig. 11 Speed response with Fuzzy Logic Controller.

5. CONCLUSIONS

The results of experiment on the real plant demonstrate that the proposed fuzzy logic controller is able to sensitiveness to variation of the reference speed attention. The results of the control are as follows. 1. The speed control of dc motor showed the proposed controller gains optimal performance. 2. The proposed controller achieved to overcome the disadvantage of the use conventional control sensitiveness to inertia variation and sensitiveness to variation of the speed with drive system of dc motor.

ACKNOWLEDGMENT

The author wish to acknowledge many helpful for experimental setup to Mr. Chanlit Tarasantisuk, Department of Instrumentation Engineering, Faculty of Engineering, Pathumwan Institute of Technology, THAILAND.
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