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LabVIEW Based Multi-Input Fuzzy Logic Controller of Dc Motor Speed Control

D. Sobya

Department of Electronics and Communication Engineering, Research scholar: Sathyabama University.
e-mail: sobyadevaraj@gmail.com

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Abstract: **Multi input fuzzy logic controller for speed control of Direct Current (DC) motor based on LabVIEW environment is presented, which overcomes all the drawbacks and produces a robust control throughout the operating range of the drive. LabVIEW is a graphical programming environment combined with built-in tools designed specifically for test, measurement and control. The proposed multi input fuzzy logic controller produces Pulse Width Modulation (PWM) signal to switch the DC Choppers and control the average output voltage for driving the dc motor based on fuzzy rule base of motor speed error, change in speed error and change of change in speed error. For three inputs there are 343 rules and the accuracy of the rules fired by the Fuzzy Logic Controller (FLC) is increased, hence the control action is very accurate.**

Keywords: **LabVIEW, FLC, PID Controller, Second & Third Derivative of Error, PWM**

I. INTRODUCTION

DC motors are being extensively used in several industrial applications such as heavy load conveyors, electric vehicles, electric cranes, steel rolling mills and robotic manipulators due to precise, wide, simple and continuous control characteristics. The growth of high performance motor drives is very significant in industrial as well as other purpose applications. High performance DC motor drives are used extensively in industrial applications. The DC motor drive is a highly controllable electrical motor drive suitable for robotic manipulators, guided vehicles, steel mills and electrical traction. A DC motor as the name indicates is a motor initiated usually by direct current and is converted into mechanical energy according to the requirement. DC motors are ruling the world due to their extensive use in modern technologies and in almost every industry such as to operate steel rolling mills, electric screw drivers, sewing machines, hard disk drives, air compressors, reciprocating machine etc. [1]. Machines have successfully replaced uncountable human efforts into efficient and reliable output. Both DC and AC machines are equally important suiting to the required application. Several researches have been done on improving reliability and efficiency in machines. They have not discussed that despite of so many advantages of AC machines for why only DC motors speed should be precisely and accurately controlled and how are they better than AC machines [2-4]. Similarly, no comparison of separately excited DC motor and self-excited DC motor is shown [5-8]. All parameters of DC motors are correlated such as load dynamics, angular machines, speed of drive etc. Angular position can be affected by changes in load and speed until and unless ideal case is assumed. Research studies have been done on using different controllers to control speed of separately excited DC motor. Several mathematical models have been used to control speed of drive as discussed in [9&10]. Different types of controllers used are Proportional Integral Controller (PI), Proportional Integral Derivative (PID) Controller etc.

Publication such as [11] has not focused on how angular position will be affected with variable speed of the drive. DC motors speed can be controlled by various methods of which most commonly used is fuzzy controller based on Mamdani and Sugeno systems. [12&13] have not discussed the reason of using Mamdani system rather than preferring Sugeno system. Usually, precise, fast, effective speed references tracking with minimum overshoot/undershoot and small steady state error are essential control objectives of such a drive system [14]. There has been several conventional control techniques in DC motor drives such as P, PI, PID controller. The conventional control strategies are a fixed structure, fixed parameter design. Hence the tuning and optimization of these controllers is a challenging and difficult task, particularly, under varying load conditions, parameter changes, abnormal modes of operation, etc. In the drive field, fuzzy logic has applied to various problems, such as robust control of DC drive systems [15]. To achieve maximum productivity, every single thing of a machine should be taken into account and analyzed accordingly. In motor control systems, hundreds of problems are faced such as change in load dynamics. The most important affecting factor will be noise parameter which is too much various and unpredictable affecting the functioning of the machine [16]. In this article FLC is used instead of the PI controller to overcome the undesired undershoots coming from load impact at some abnormal conditions. A complete circuit for the system under consideration has constructed. The proposed controller is implemented using LabVIEW software in order to verify the robustness of these controllers.

II. LABVIEW AND ITS FEATURES

Presently LabVIEW simplifies the research, scientific computation, process control, industrial application and measurement applications. Because Lab VIEW has the flexibility of a programming language combined with built-in tools designed specifically for test, measurement, and control. By using the integrated Lab VIEW environment, we can interface with real world signals, analyze data for meaningful information, and share results.[17] Therefore LabVIEW is taken for developing the control system that append with fuzzy logic is incoming for modern control and the advantages in fuzzy control are more robust than usual conventional control to variation of system parameter.

III. FUZZY LOGIC CONTROLLER FOR DC MOTOR DRIVE

In current years many authors have reported that fuzzy control is a more robust control method than usual PID control to variation of system parameters. It must be so, because the fuzzy control is more flexible. As opposed to the PID-control it allows to use nonlinear relations between input and output values of the controller. That is, before the fuzzy controller design it is necessary to be clearly aware of what type of nonlinearity has to be introduced for the robust speed control of the DC drive and what parameters of the fuzzy controllers form its type of nonlinearity. As mentioned above the fuzzy approach is a convenient method to design a controller with a desired nonlinear dependence between the input and the output of the controller. So, our task is to properly choose the fuzzy controller parameters that form the desired controller. The fuzzy system needs to get such a fuzzy controller for following conditions are valid: Value of the change-of-control increment decreases when the error decreases and value of the change-of-control increment increases when the change of- error decreases.

IV. 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. 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. FL control is constructed on these logical relationships. Fuzzy sets are used to show linguistic variables. Fuzzy Sets Theory is first introduced in 1965 by Zadeh to express and process fuzzy knowledge. There is a strong relationship between fuzzy logic and fuzzy set theory that is similar relationship between Boolean logic and classic set theory. Fig. 1 shows a basic FLC structure. 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 and if there is insufficient knowledge about control process then FLC may not give satisfactory results [18].

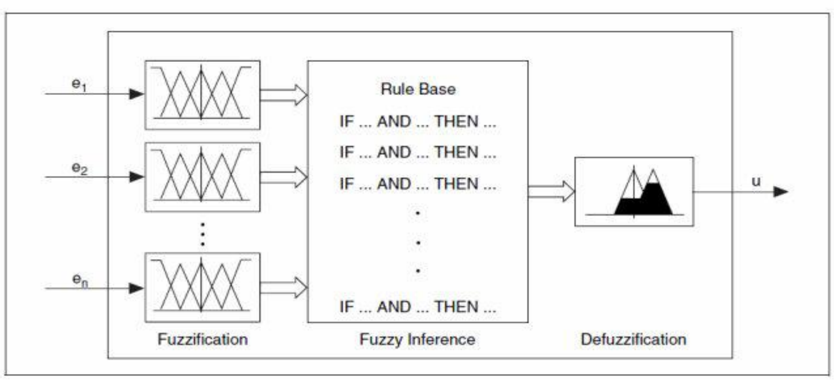


Fig. 1 Structure of FLC

A. *Fuzzification*

The first block inside the controller is fuzzification, which converts each piece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block thus matches the input data with the conditions of the rules to determine how well the condition of each rule matches that particular input instance. There is a degree of membership for each linguistic term that applies to that input variable.

B. Rule Base

The rules may use several variables both in the condition and the conclusion of the rules. The controllers can therefore be applied to both multi-input multi- output problems and single-input-single-output problems. The typical SISO problem is to regulate a control signal based on an error signal. The controller may actually need both the error the change in error, and the change in change of error as inputs, but we will call it single-loop control, because in principle all three are formed from the error measurement. Basically a linguistic controller contains rules in the if- then format.

C. Inference Engine

For each rule, the inference engine looks up the membership values in the condition of the rule. The inputs are combined logically using the AND operator to produce output response values for all expected inputs. The active conclusions are then combined into a logical sum for each membership function.

D. Defuzzification

The resulting fuzzy set must be converted to a number that can be sent to the process as a control signal. This operation is called Defuzzification. The resulting fuzzy set is thus defuzzified into a crisp control signal. Here center of gravity method is used.

E. Defining Inputs, Outputs and Universe of Discourse

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) and Change in Change of Error (cce) for linguistic variables which are generated from the control rules. The output variable is the change in control variable (cu) of motor driver, (cu) is integrated to achieve desired alpha value. Here 'u' is an angular value determining duty cycle of DC-DC converter.

F. Defining Membership Functions and Rules

The variables e(k), ce(k), cce(k) and cu(k) are the conditions monitored by the FLC. These conditions are expressed in terms of linguistic variables such as negative large (NL), negative medium (NM), negative small (NS), zero (ZE), positive small (PS), positive medium (PM) and positive large (PL).

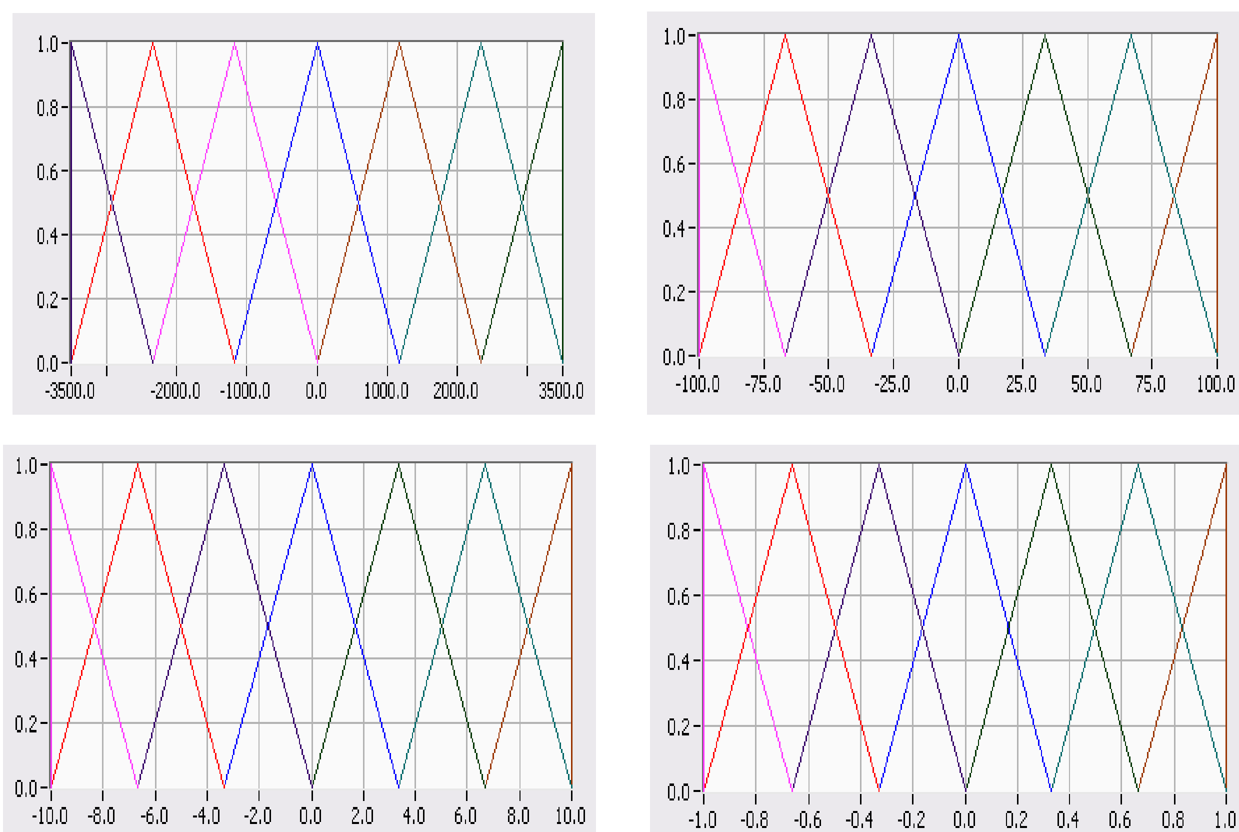


Fig. 2 Fuzzy Membership Functions for e(k), ce(k), cce(k) and cu(k)

Figure 2 shows the symmetrical triangular membership functions with 50 per cent overlap with neighboring membership functions for three-input FLC. Depending on these conditions, the rule-base is constructed in the rule-base editor. Depending upon the above conditions, a particular rule (control signal) is fired by the FLC from the rule-base editor. The control signal is in the fuzzified form. To convert this into a crisp form, defuzzification module is used.

For two-input FLC, there are 72 = 49 rules. A typical rule is as follows

ce/e	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NM	NM	NS	ZE	PS
NS	NL	NM	NS	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PS	PM	PL
PM	NS	ZE	PS	PM	PM	PL	PL
PL	ZE	PS	PM	PL	PL	PL	PL

For three-input FLC, there are 73 = 343 rules. For simplicity 64 rules are reproduced.

A controller compares the process variable (pv) with the set point (sp), determines the error and produces the control signal to minimize the error.

The equations for e(k), ce(k), and cce(k) are:

$$e(k) = \text{Set speed} - \text{Process speed} \quad (1)$$

$$ce(k) = [e(k) - e(k-1)] \quad (2)$$

$$cce(k) = [ce(k) - ce(k-1)] \quad (3)$$

Where, k is sampling instant of the process.

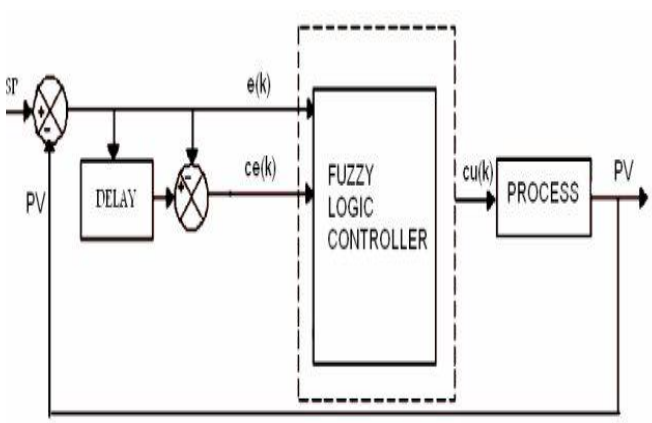


Fig. 3 Block Diagram for 2 input FLC

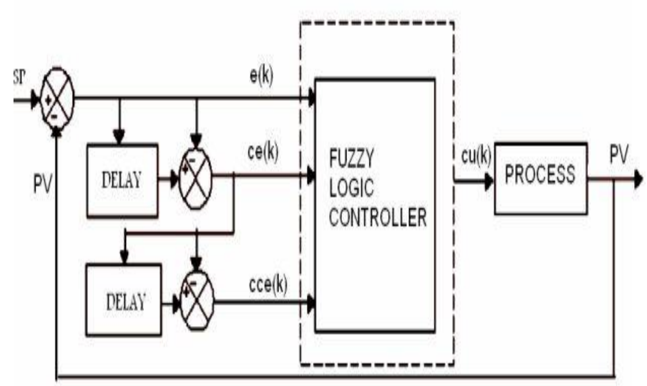


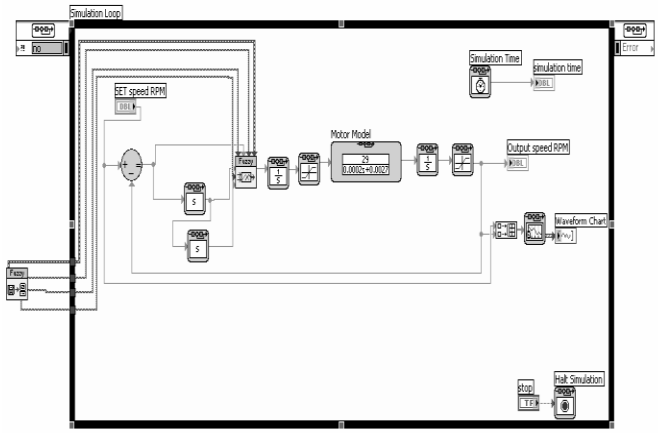
Fig. 4 Block Diagram for 3 input FLC

The FLC produces change in control variable cu(k) which is represented by control action.

$$cu(k) = u(k) - u(k-1) \quad (4)$$

Where u(k) is the is a angular value determining duty cycle of DC-DC converter.

V. SIMULATION RESULTS



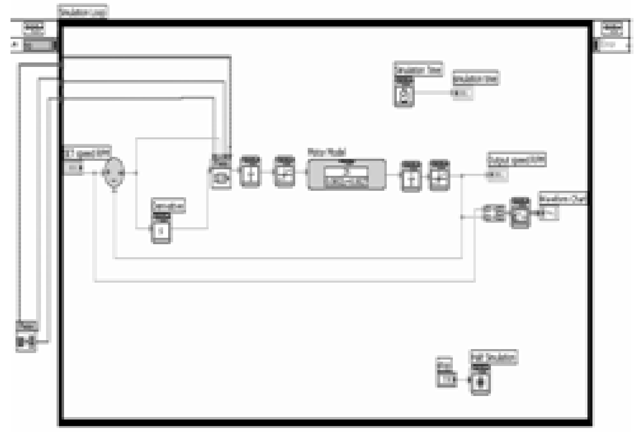
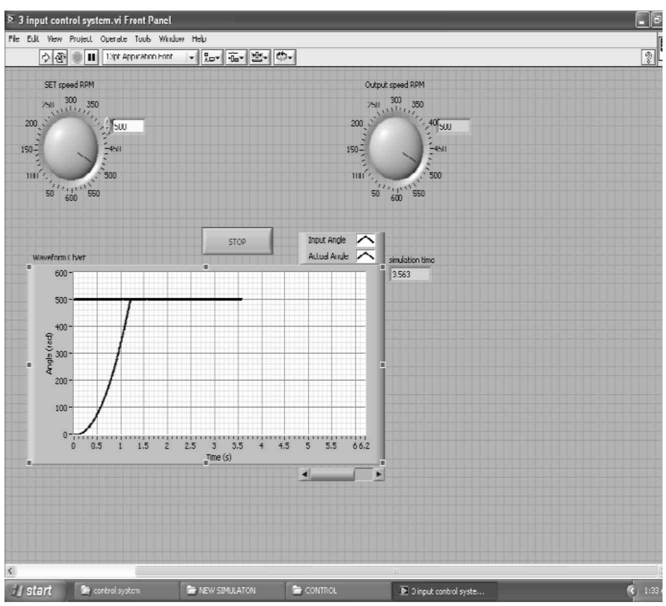


Fig. 5 VI Block Diagram for 3 input FLC Fig. 6 VI Block Diagram for 3 input FLC

FRONT PANEL



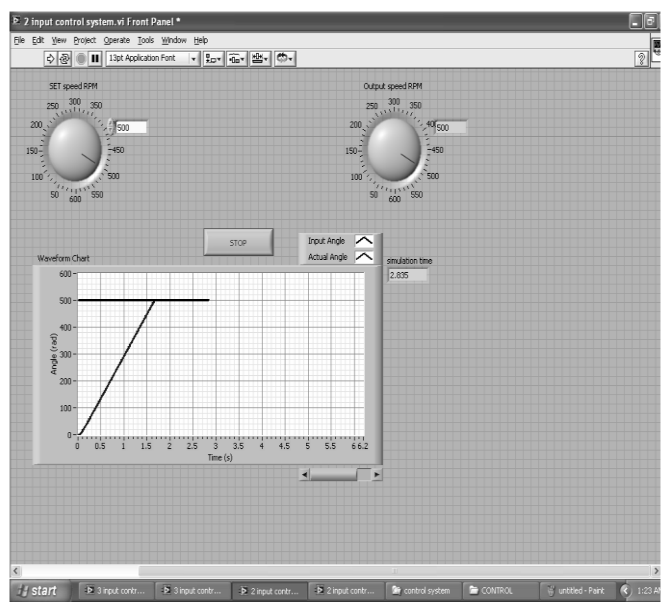


Fig. 7 VI Front Panel for 3 Input FLC Fig. 8 VI Front panel for 2 Input FLC

Figures 5 and 6 show VI block diagrams of the three input [e(k), ce(k) and cce(k)] and two input FLC for the speed control of dc motor. The process variable is obtained from the feedback. The transient response is plotted using the waveform chart represented as DBL icon. The set point is also represented by DBL icon labeled as set point. Here DBL implies double precision floating point value for the input/output variable.

FLC designed in LabVIEW is based on mamdani fuzzy type. The membership functions and the ranges are chosen using set-editor of fuzzy logic controller design VI option of fuzzy logic toolkit. The rules and the defuzzification methods are chosen using rule-base editor of fuzzy logic controller design VI option of fuzzy logic toolkit. The designed FLCs consist of 7- number symmetrical 50 per cent overlapped triangular membership functions for fuzzification and center of gravity as defuzzification method. The e(k), ce(k) and cce(k) are selected with the ranges from +3500 to – 3500, +100 to –100 and +10 to –10 (Figs 2), respectively. The range of cu(k) is from + 1 to – 1 for FLC. The rules and the fuzzification methods are verified using the I/O characteristics in the fuzzy logic controller design in the VI option of fuzzy logic toolkit. The load control icon loads the complete set of fuzzy controller parameters and information defined in the fuzzy control icon such as e(k), ce(k), and cce(k) input variables and cu(k) as control variable.

The FLC gives out change in duty cycle cu(k). All the above computations are done in the simulation loop.

VI. CONCLUSION

Two and three input fuzzy logic controller has been effectively developed using LabVIEW to produce suitable results. Even though three input FLC takes larger computational time (because of 343 rules in the rule-base) as compared to the two-input FLC (49 rules in the rule-base), the accuracy of the rules fired by the fuzzy logic controller is increased, hence the control action is very accurate. It is concluded that the proposed controller achieve less settling time and steady state errors to overcome the disadvantage of the use of conventional control technique such as PI and PID controller.

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