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Speed Control of a Separately Excited DC Motor Using Fuzzy Logic Control Based on Matlab Simulation Program

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Abstract— The paper presents speed control of a separately excited DC motor using fuzzy logic control (FLC) based on Matlab Simulation program. This method of speed control of a dc motor represents an ideal application for introducing the concepts of fuzzy logic. The paper shows how a commercially available fuzzy logic development kit can be applied to the theoretical development of a fuzzy controller for motor speed, which represents a very practical class of engineering problems.

Index Terms— DC motor control, Fuzzy Logic controller, Pulse Width Modulation, Matlab simulation program

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; Matlab Simulation simplifies the scientific computation, process control, research, and industrial application and measurement applications. Because Matlab has, the flexibility of a programming language combined with built-in tools designed specifically for test, measurement, and control. By using the integrated Matlab environment to interface with real world signals, analyze data for meaningful information, and share results [2]. Therefore take Matlab for develop of the control system that append with fuzzy logic is incoming for modem control and the advantages in fuzzy control are more robust control method than usual conventional control to variation of system parameter.

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This paper presents the experimental re sults of the fuzzy logic controller using Matlab for speed control of Separately Excited DC Motor through fuzzy logic controller for speed control is used to facilitate and efficiency the implementation of controllers.

2 System Description

2.1 Motor Model

The resistance of the field winding and its inductance of the motor used in this study are represented by R_a and L_a La 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 interlopes 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).

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

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

Where

R_a = Armature Resistance (Ω).

L_a = Armature Inductance (H).

J_m = Motor of inertia (kg.m² /S²).

$K = K_b\phi$ = 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 differentials.

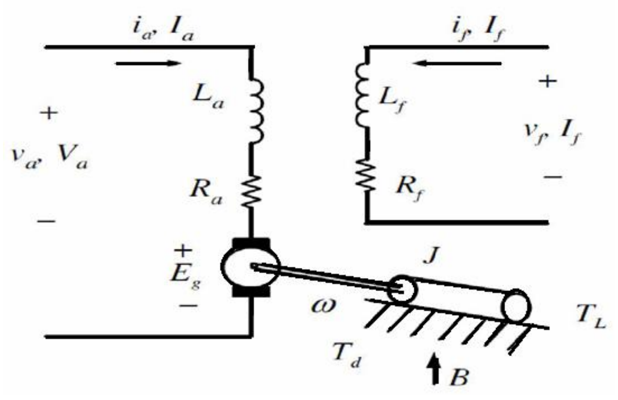


Fig. 1. Dynamic Motor Model

2.2 Driver Circuit

Matlab 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).

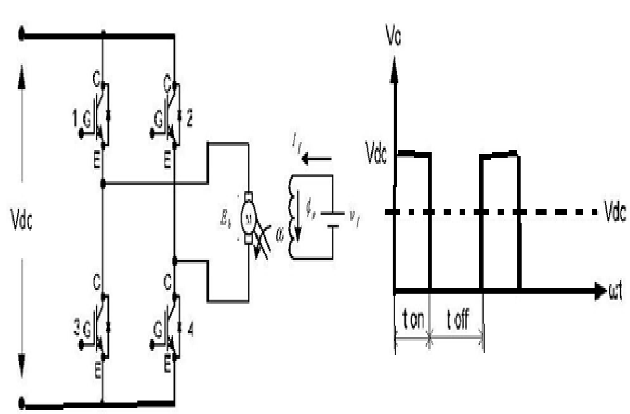


Fig. 2. DC motor drive and control

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

$$V_{do} = \frac{t_{on}}{t_{on} + t_{off}} \bullet V_{dc} \quad (3)$$

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

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

3 Fuzzy Logic Controller

3.1 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.

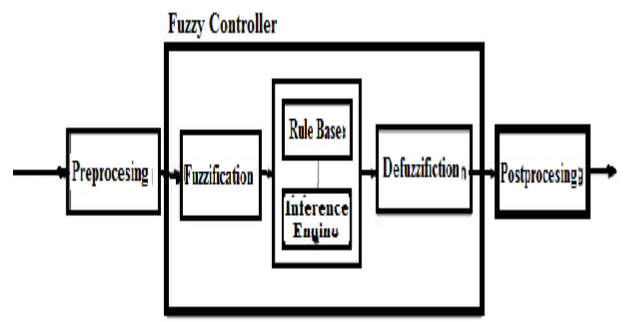
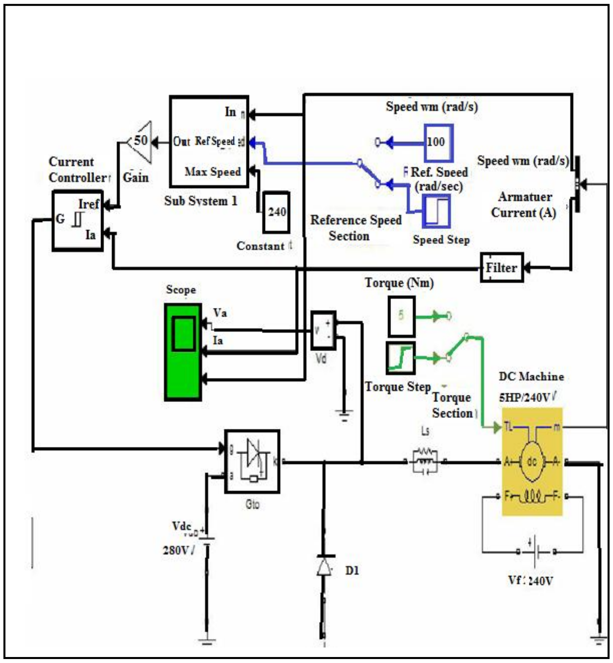


Fig. 3. Process Blocks for a Fuzzy Controller

Although the classic controllers depend on the accuracy of the system model and parameters, FLC uses different strategies for motor speed control. 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 inguistic variables which are generated from the control rules. Eq. (4), determines required system equations. The output variable is the change in control variable (ca) of motor driver. cca is integrated to achieve desired alpha value. Here a is a angular value determining duty cycle of DC-DC converter designed in this paper

$$e(K) = [W_r(K) - E_a(K)] * K_1 E$$
$$ce(K) = [e(K) - e(K-1)] * K_2 CE$$
$$caC(K) = [aC(K) - ac(K-1)] * K_3 ca \quad (4)$$

Here K_1E , K_2CE , K_3ca are each coefficients and K is a time index.



4 Defining Membership Faction And Rules

System speed comes to reference value by means of the defined rules. For example, first rule on Table 1determines, 'if (e) is NL and (ce) is NL than (ca) 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 K1E and K2CE, and output t scaling factor K3c. Thus, since simple numbers are now processed in controller after scaling, fuzzy computation is performed in short time.

TABLE 1:- The Rule Database

c,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*

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.

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