

2 Novel Approaches for Speed Control of DC Motor: Fuzzy Logic and Artificial Neural Network Techniques

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Abstract- The design of intelligent control systems has become an area of intense research interest. A promising direction in the design of intelligent systems involves the use of Fuzzy Logic Controller (FLC) and Artificial Neural controller (ANC) to discover the abilities of intelligent control systems in utilizing experience via rule-based knowledge.

This paper presents the FLC and ANC. Both controllers are designed, implemented and compared in the MATLAB/Simulink model to examine the performance of DC motor with different loads.

Index Terms- DC Motor, Fuzzy Logic Controller (FLC), ANN, Artificial Neural controller (ANC).

I. INTRODUCTION

Direct current (DC) motors have variable characteristics and are used extensively in variable-speed drives. DC motor can provide a high starting torque and it is also possible to obtain speed control over wide range. Why do we need a speed motor controller? For example, if we have a DC motor in a robot, if we just apply a constant power to each motor on a robot, then the poor robot will never be able to maintain a steady speed. It will go slower over carpet, faster over smooth flooring, slower up hill, faster downhill, etc. So, it is important to make a controller to control the speed of DC motor in desired speed.

DC motor plays a significant role in modern industrial. These are several types of applications where the load on the DC motor varies over a speed range. These applications may demand high-speed control accuracy and good dynamic responses.

DC 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_f , respectively. The resistance of the armature and its inductance are shown by R_a 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 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:

$$J_m \frac{d\omega}{dt} = K_m \cdot \phi \cdot I_a - b \cdot \omega - M_{load}$$

$$L_a \frac{dI}{dt} = V_a - R_a \cdot I_a - K_b \cdot \phi \cdot \omega$$

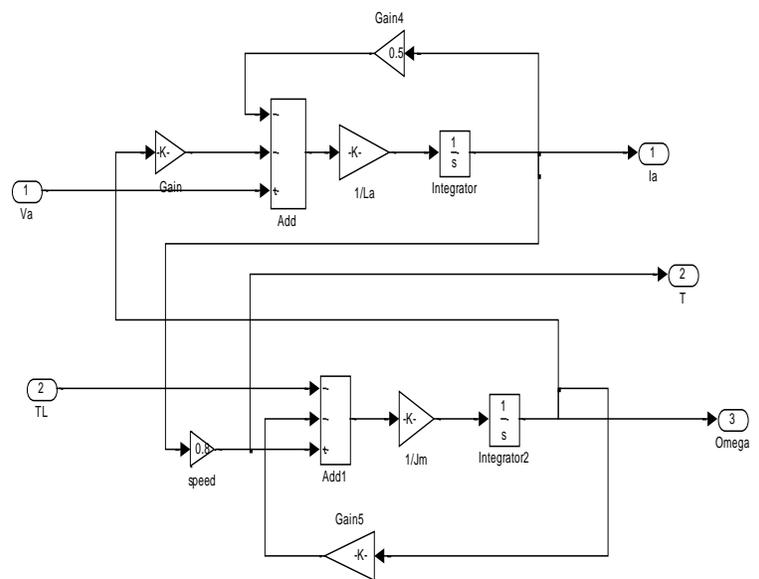


Fig 1. Simulink model of separately excited dc motor

Speed Response of DC Motor without any controller is shown below:

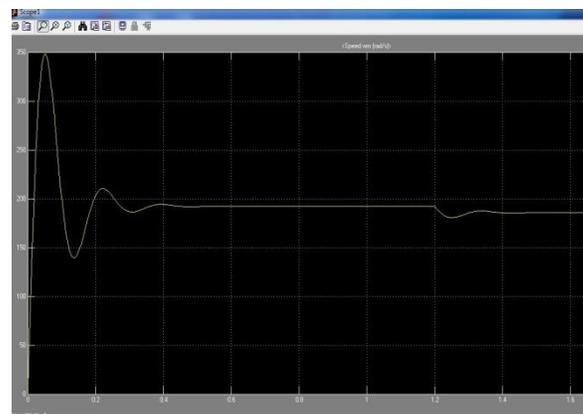


Fig 2. Speed Response of DC Motor without any controller

The Peak Overshoot and number of oscillations obtained in above curve are much more and hence undesirable. These parameters are controlled by using ANC and FLC discussed below.

II. FUZZY LOGIC CONTROLLER

Fuzzy logic has two different meanings, in a narrow sense, fuzzy logic is a logical system, which is an extension of multivolume's logic, and however, in a wider sense fuzzy logic is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with un-sharp boundaries in which membership is a matter of degree. In this perspective fuzzy logic in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multi-valued logical system. Fuzzy logic is a convenient way to map input space to an output space. Mapping input to output is the starting point for everything.

FLC have some advantages compared to other classical controller such as simplicity of control, low cost and the possibility to design without knowing the exact mathematical model of the process. Fuzzy logic incorporates an alternative way of thinking which allows modeling complex systems using higher level of abstraction originating from the knowledge and experience. Fuzzy logic can be described simply as "computing words rather than numbers" or "control with sentence rather than equations."

III. STRUCTURE OF FUZZY LOGIC

There are specific components characteristic of a fuzzy controller to support a design procedure. Figure 3 shows the controller between the preprocessing block and post processing block.

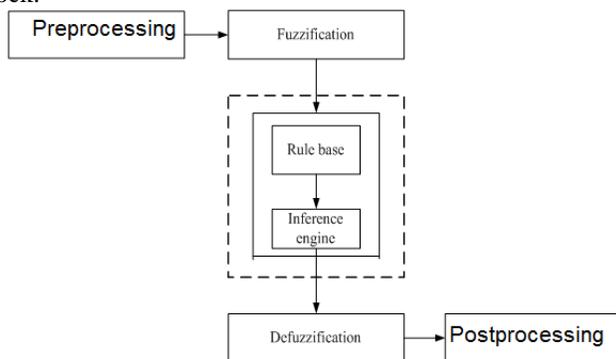


Fig. 3 Structure of fuzzy logic controller

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 matches the input data with the conditions of the rules to determine. There is degree of membership for each linguistic term that applies to the input variable. The first step in designing a fuzzy controller is to decide which state variables represent the system dynamic performance must be taken as the input signal to

the controller. Fuzzy logic uses linguistic variables instead of numerical variables. The process of converting a numerical variable (real number or crisp variables) into a linguistic variable (fuzzy number) is called Fuzzification. System variables, which are usually used as the fuzzy controller inputs includes states error, state error derivative, state error integral or etc.

The membership function is a graphical representation of the magnitude of participation of each input. There are different memberships functions associated with each input and output response. In this study, we use the trapezoidal membership function for input and output variables. The number of membership function determines the quality of control which can be achieved using fuzzy controller. As the number of membership function increases, the quality of control improves. As the number of linguistic variables increases, the computational time and required memory increases. Therefore, a compromise between the quality of control and computational time is needed to choose the number of linguistic variables. For the speed control of DC motor study, five linguistic variables for each of the input and output variables are used to describe them.

Rule Base

The collection of rules is called a rule base. The rules are in "If Then" format and formally the *If side* is called the *conditions* and the *Then side* is called the *conclusion*. The computer is able to execute the rules and compute a control signal depending on the measured inputs *error* (e) and *change in error* (dE). In a rule based controller the control strategy is stored in a more or less natural language. A rule base controller is easy to understand and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques.

Defuzzification

Defuzzification is when all the actions that have been activated are combined and converted into a single non-fuzzy output signal which is the control signal of the system. The output levels are depending on the rules that the systems have and the positions depending on the non-linearities existing to the systems. To achieve the result, develop the control curve of the system representing the I/O relation of the systems and based on the information; define the output degree of the membership function with the aim to minimize the effect of the non-linearity. The reverse of Fuzzification is called Defuzzification. The use of Fuzzy Logic Controller (FLC) produces required output in a linguistic variable (fuzzy number). According to real world requirements, the linguistic variables have to be transformed to crisp output.

It obtains the center of area occupied by the fuzzy set. It is given by the expression.

$$X = \frac{\int \mu(x)x dx}{\int \mu(x) dx}$$

Where, X=crisp value;x = support value at which the membership function reaches the maximum value; $\mu(x)$ = maximum value of membership function corresponding to the quantization level.

Post processing

The post processing block often contains an output gain that can be tuned and also become as an integrator.

IV. NEURAL NETWORK CONTROLLER

Neural networks are wonderful tools, which permit the development of quantitative expressions without compromising the known complexity of the problem. This makes them ideal in circumstances where simplification of the problem, in order to make it mathematically tractable, would lead to an unacceptable loss of information. As pointed out by Ziman, there is a fine balance between over-idealizing the initial hypothesis in order to make it amenable to mathematical analysis, and abandoning reality.

Neural networks resemble the human brain in the following two ways:

1. A neural network acquires knowledge through learning.
2. A neural network's knowledge is stored within inter-neuron connection strengths known as synaptic weights.

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well.

The true power and advantage of neural networks lies in their ability to represent both linear and non-linear relationships and in their ability to learn these relationships directly from the data being modeled. Traditional linear models are simply inadequate when it comes to modeling data that contains non-linear characteristics.

The neural network consists of junctions which are connected with LINKS, also called processing units. For each junction a number is ordered, this number is called weight. The weights are the tools for the long distance information storing in the neural network, the learning process occurring with the appropriate modification of weights. These weights are modified so that the network input/output behavior is in consonance with the environment, which provide the input data.

The calculation algorithm consists of Calculation of the output of the network, with inputs and weights and modification of weights.

A single input neuron consists of a scalar input 'p' multiplied by the scalar weight 'w' to form 'wp' which is fed to the summer along with bias 'b' multiplied by '1'.

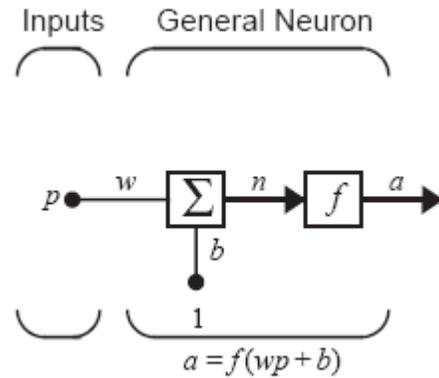


Figure 4: Basic Neural Network

The net input is $wp+b$ and the output a is;
 $a=f(WP+b)$;
 f- Transfer function
 W & b can be adjusted by learning rule.

TRANSFER FUNCTION:

- LINEAR TF:
 $a = \text{purelin}(n)$

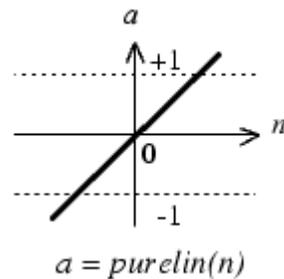


Figure 5: Linear Transfer Function

V. CONTROLLER DESIGN

DC MOTOR SPEED CONTROL USING FUZZY LOGIC CONTROLLER (FLC)

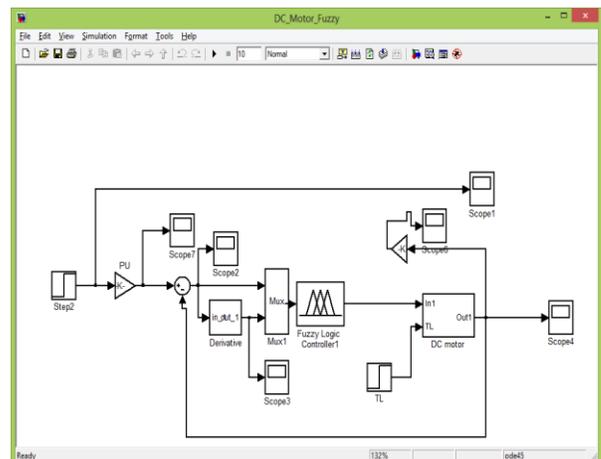


Figure 6 MatLab/Simulink model for DC motor using Fuzzy Controller.

The figure 6 gives the MatLab/Simulink model for control of speed of DC motor using fuzzy logic controller.

ARCHITECTURE OF NEURAL NETWORK CONTROLLER

The Figure 7 shows the model of Artificial Neural Network controller (ANC) for DC motor. The model is simulated with speed vs time of the DC motor with the fixed load and also with varying load.

The ANC model is shown below:

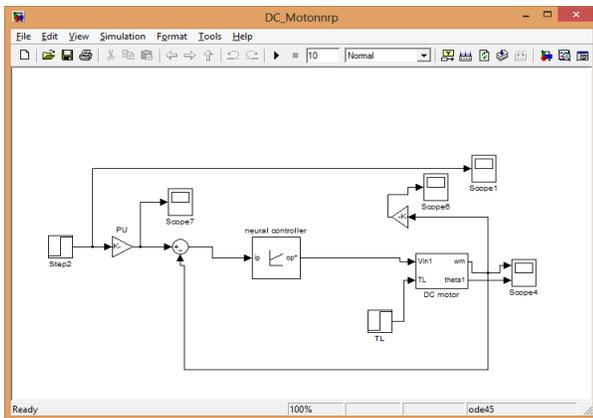


Fig 7. Simulink model of Artificial Neural Network Controller

VI. RESULT AND DISCUSSION

Simulation result of DC motor without using any controller is shown in fig 1. That fig may be compared with fig 7 for speed control.

COMPARISON OF SPEED CONTROL USING FUZZY LOGIC CONTROLLER AND ARTIFICIAL NEURAL CONTROLLER:

All the controllers are simulated on MATLAB and their *Speed Vs Time* characteristic is studied. The Characteristic is shown below:



Fig 7. Simulation results of FLC and ANC.

VII. CONCLUSION

From the simulation results it may be concluded that:

- ANC has better performance by reducing, e_{ss} (Steady state error), M_p (maximum overshoot) and T_s (settling time).
- But FLC has small rise time (T_r) as compared to Artificial Neural Network controller.
- Biggest disadvantage of ANC is its more rise time (T_r).

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