Design and Simulation of Speed Control of DC Motor by Fuzzy Logic Technique with Matlab/Simulink

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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 to discover the abilities of intelligent control systems in utilizing experience via rule-based knowledge.

The most commonly used controller in the industry field is the proportional plus- integral-plus- derivative (PID). PID controller requires a mathematical model of the system while Fuzzy logic controller (FLC) provides an alternative to PID controller, especially when data are not available or partly available for the system.

For comparison purpose, three controllers PI, PID and FLC have been designed and implemented in the MATLAB/Simulink model to examine the performance of DC motor with different loads. The results show that the FLC give better response compared to PI &PID controller.

Index Terms- PI, PID, Fuzzy logic controller, DC Motor,

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 and 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 manner.

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.

[1] 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:

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

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

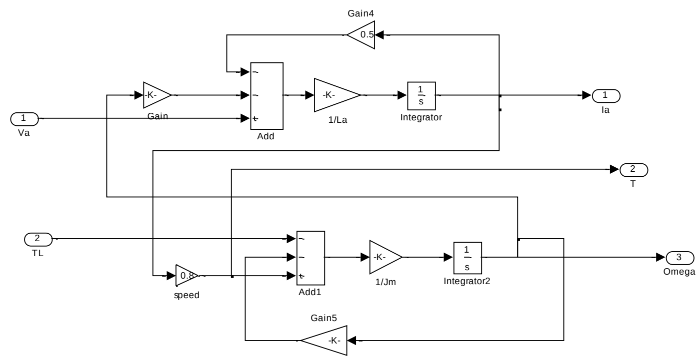

Fig 1 Simulink model of separately excited dc motor

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

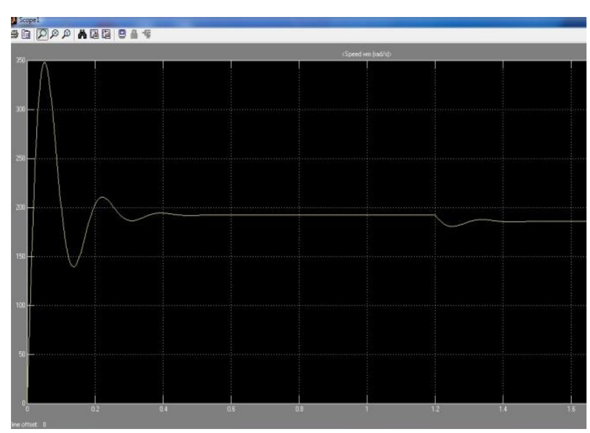

Fig 2. Speed Response of DC Motor without any controller

The Peak Overshoot and number of oscillations obtained in above curve are much more and hence undesirable. These

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parameters are controlled by using different controllers discussed below.

II. PROPORTIONAL PLUS - INTEGRAL (PI) CONTROLLER

Since most of the process cannot work with an offset, they must be controlled at their set points and in order to achieve this, extra intelligence must be added to proportional controller and this is achieved by providing an integral action to the original proportional controller. So the controller becomes proportional integral controller.

- Under PI Controller as long as error is present the controller keeps changing its output and once the error is zero or it disappears the controller does not change its output.
- Integration is the mode that removes the offset or the error but sometimes it may make transient response worse.
- In PI Controller the output of the controller is changed proportional to the integral of the error.

The mathematical expression of the PI Controller is:

$$y = Kp.e + Ki\int e\,.dt$$

Where, K_i = Integral gain of the PI controller.

PI Controller has the following disadvantages:

- The response is sluggish at the high value of the integral time.
- The control loop may oscillate at the small value of integral time.

III. PROPORTIONAL-INTEGRAL-DERIVATIVE (PID) CONTROLLER

PID Controller includes all the three control actions i.e. proportional, integral and derivative.

- A PID controller calculates and outputs a corrective action, which corrects the error between the process output and the desired set point that adjusts the process accordingly and rapidly.

The output of the controller or the manipulated variable is obtained by adding P, I and D components and their associated coefficient.

The mathematical expression of the PID Controller is:

$$y = Kp.e + Ki\int e\,.dt + K_0\frac{de}{dt}$$

IV. 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."

V. 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.

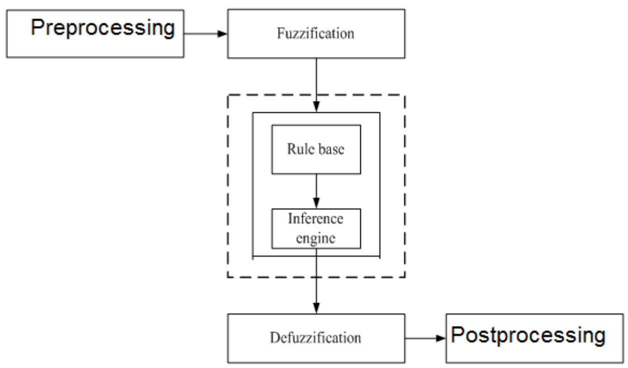

Fig. 3. Structure of fuzzy logic controller

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; μ(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.

VI. CONTROLLER DESIGN

DC MOTOR SPEED CONTROL USING PI CONTROLLER:

The Figure 4 shows the model of PI controller for DC motor. The model is simulated with speed vs time of the DC motor with the fixed load and also with varying load.

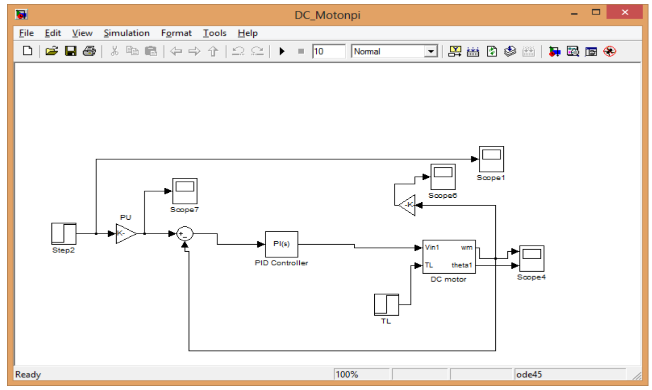

Fig 4. Mat Lab/Simulink model for DC motor using PI Controller

DC MOTOR SPEED CONTROL USING PID CONTROLLER:

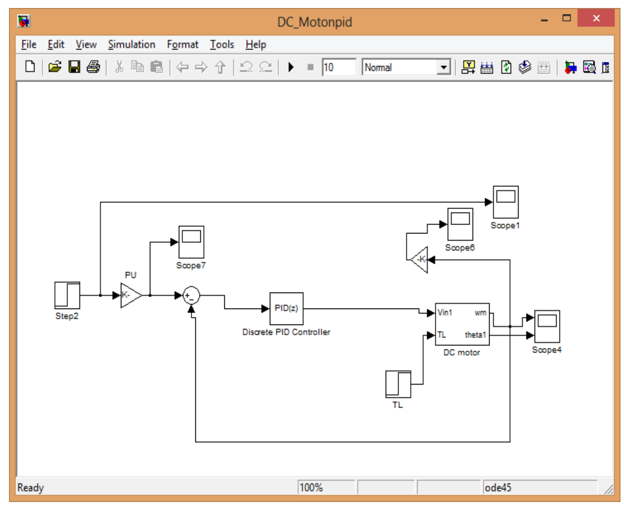

Fig 5. Mat Lab/Simulink model for DC motor using PID Controller.

The figure 5 shows the MatLab/Simulink model for 11speed control of DC motor using PID controller.

DC MOTOR SPEED CONTROL USING FUZZY LOGIC CONTROLLER (FLC)

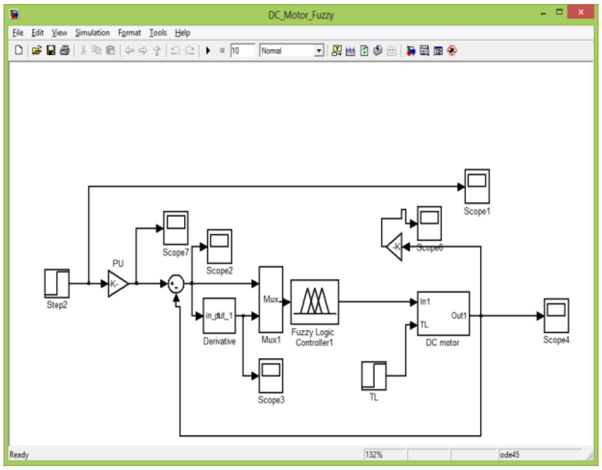

Figure 6 MatLab/Simulink model for DC motor using Fuzzy Controller.

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

VII. 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 PI, PID AND FUZZY LOGIC CONTROLLER:

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

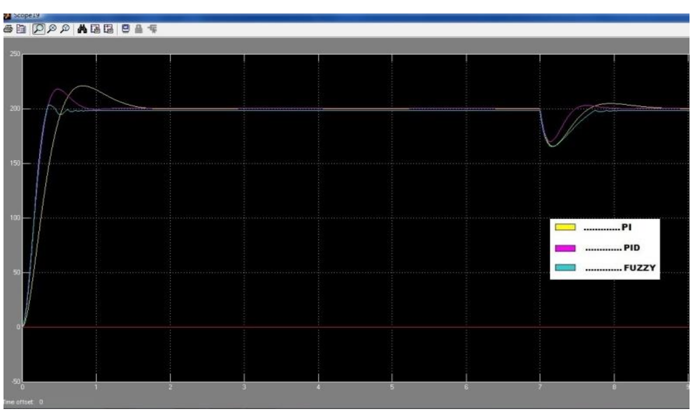

Fig 7. Simulation Result for DC motor using PI, PID and Fuzzy Logic Controller.

VIII. CONCLUSION

From Simulation results it may be concluded as:

- FLC have better performance by reducing, e_{ss} (Steady state error), M_p (maximum overshoot), T_r (rise time) and T_s (settling time).
- FLC have more sensitive responses against load disturbances to classical PI & PID controller.
- FLC is better than conventional PI & PID controller.

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