FUZZY LOGIC CONTROL OF DC MOTOR

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ABSTRACT

This research paper is about fuzzy logic control of dc motor. This is a demonstration of how to implement fuzzy logic controller. Objectives are to control the position, times response of dc motor by chose inputs and outputs variable of fuzzy logic bloc and all parameters for reliable performance.

Keyword : *error, precision, fuzzy, control, PID*

1. INTRODUCTION

For any system, precision, time response and stability are defaults proprieties. Thus, output must follow the input and time response should be as fast as possible. It is often, signal feedback from the system output is compared with a reference input signal. Then, the result being used to obtain the control or actuating system input. Such is the case of a DC motor, used in several field as drones with controller. Fuzzy logic can be used to control motor response [1].

2. DC MOTOR MODEL

For a DC motor, when the friction viscosity and the inductor of motor are negligible, the motor can be approximated by a first-order system. In this paper, first-order, transfer function M(p) of the motor system is expressed by [2] :

$$M(p) = \frac{105}{1 + 0{,}1p} \quad (1)$$

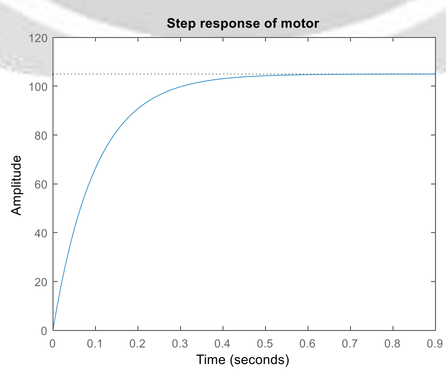

Fig -1: Step response of motor

The step response of motor, show that, it is stability but not precise because, the output response does not follow the input. Time response of system is slow.

3. CONTROL DESIGN SYSTEM

In a closed-loop system input is affected by the system output. By using output information to affect in some way the control input of the system, feedback is being applied to that system. A close loop mechanism of system is used to control output by error measurement [3].

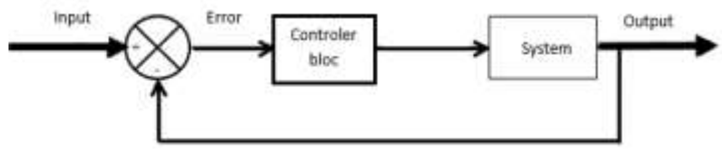

Fig -2: Close loop

The corrector introduced is used to correct the output of the system. These are more controller like as digital or analog PID controller. PID is a classical control method for Proportional (P) Integral (I) Derivative (D) control action, has been extensively used. In this paper, the goal is to minimize the error between the actual system output and the desired.

2. CONCEPT OF FUZZY LOGIC

Fuzzy logic is a mathematical theory, based on degree of truth, defined as a many-valued logic form which may have truth values of variables in any real number between true and false. Fuzzy logic process, is based in three stages: fuzzification, inference and defuzzification [4].

2.1 Fuzzification

Fuzzification consists in representing in the form of a fuzzy set the real values of an input variable. A fuzzy set is defined by its "membership function" and several fuzzy sets can be defined on the same variable.

2.2 Fuzzy inference

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. Fuzzy inference uses the concepts of fuzzy rules and fuzzy implication. The rules used in fuzzy logic is of the type "If (X is A) and (Y is B) Then (Z is C)".

2.3 Defuzzification

The input for the defuzzification process is a fuzzy set and the output is a single number [5].

3. MOTOR CONTROL PROCESS

All inputs, for position, speed, acceleration and personalized control of motor, are defined by:

$$x(t) = u(t) \quad (2)$$

$$x(t) = r(t) \quad (3)$$

$$x(t) = e^{2t} \quad (4)$$

$$x(t) = 10\sin(2\pi 0{,}2t) \quad (5)$$

Where x(t) is the input, u(t) is unit step signal and r(t) is ramp signal

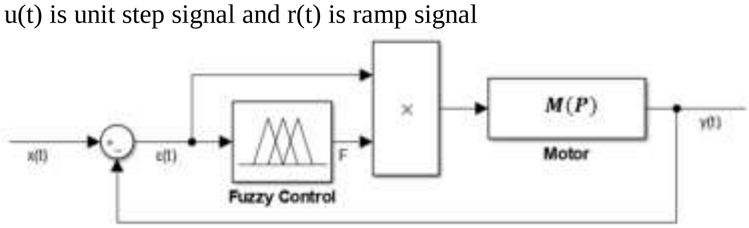

Fig -3: Fuzzy logic motor control

Where ε(t) is the error, y(t) the output of motor controller and F is the output of fuzzy controller.

3.1 Fuzzification

During fuzzification process, we suppose that error is between [-1; 1] and can take three possible values as, less, near or greater than zero. Three input sets of Fuzzy controller are ELZ or Error Less than Zero, ENZ or Error Near Zero and EGZ or Err or is Greater than Zero.

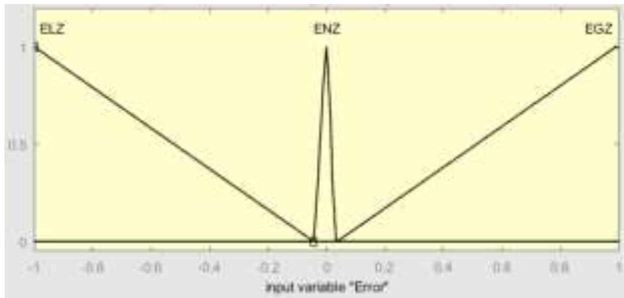

Fig -4: Fuzzy partition of input error

Steady state error is defined as:

$$\varepsilon = \lim_{t \to \infty} \varepsilon(t) = \lim_{p \to 0} p\varepsilon(p) \qquad (6)$$

With, $\varepsilon(p) = Y(p) - X(p)$

Where:

- $\varepsilon(p)$ is error transform Laplace
- $Y(p)$ is output transform Laplace
- $X(p)$ is input transform Laplace

$$Y(p) = \frac{1}{1 + FM(p)} X(p) \qquad (7)$$

Where, F is the output value of fuzzy control.
When input is step signal, Y(p) is expressed by:

$$Y(p) = \frac{1}{1 + FM(p)} \frac{1}{p} \qquad (8)$$

$$\varepsilon(p) = \lim_{p \to 0} \frac{1}{1 + FM(p)} \qquad (9)$$

$$\varepsilon = \frac{1}{1 + FM(0)} \qquad (10)$$

Where, M(0) is the steady state gain of motor

$$\varepsilon = \frac{1}{1 + 105F} \qquad (11)$$

With high value of fuzzy logic output, we have $\varepsilon = 0$.

Then, at output, there are two output sets. First, OEFZ or Output when the Error is Far from Zero. Secondly, OENZ or Output when the Error is Near Zero.
OEFZ and OENZ are expressed by:

- OENZ=550
- OEFZ=690

Control for others as ramp and acceleration use fuzzy logic controller bloc.

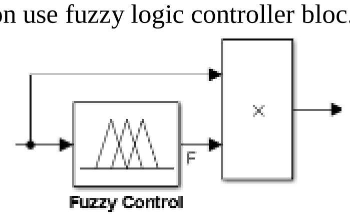

Fig -5: Fuzzy logic controller bloc

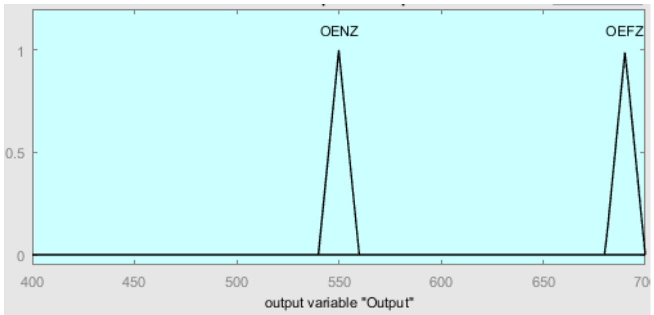

Fig -5: Fuzzy partition of output

3.2 Fuzzy inference

Rules used during inference are:

- If Error is ELZ Then Output is OEFZ
- If Error is EGZ Then Output is OEFZ
- If Error is ENZ Then Output is OENZ

The implication method used is the Mamdani method. Mamdani's fuzzy inference method is the most commonly seen in fuzzy methodology.

3.3 Defuzzification

During defuzzification which provides real outputs values, the center of gravity method is uses.

3.4 Simulation with Simulink

To appreciate, performance of fuzzy logic controller, firstly, during simulation, step, ramp and sinusoidal input are used.

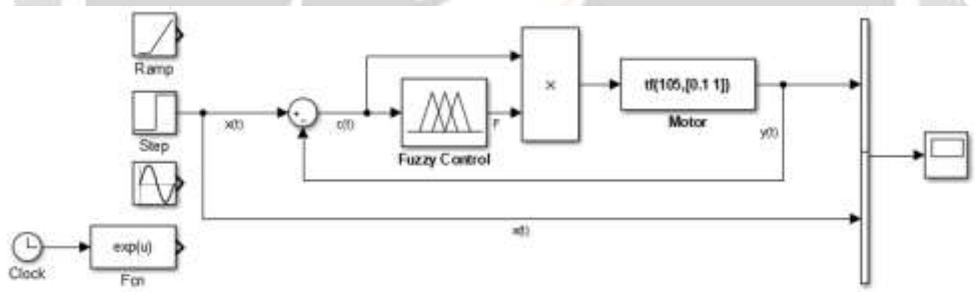

Fig -5: Simulink model of simulation

Secondly, simulation with disturbance for step input is used.

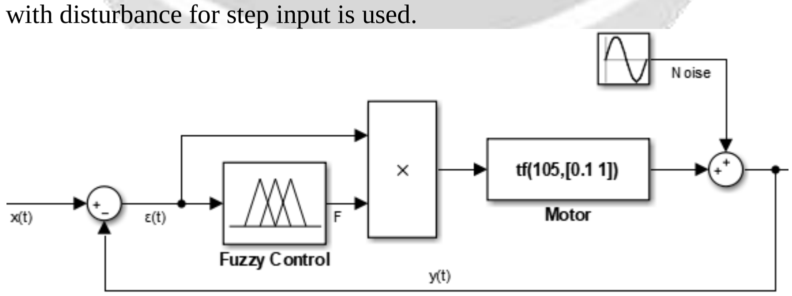

Fig -6: Fuzzy controller of motor with disturbance

4. RESULTS

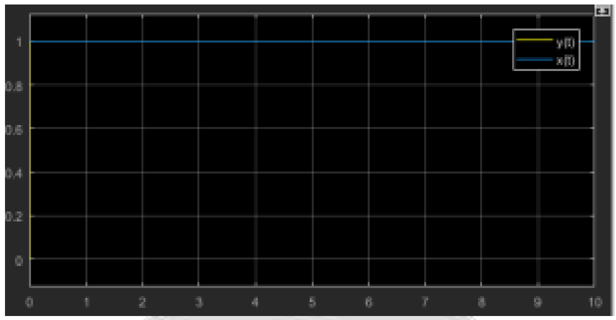

Fig -7: Position control with fuzzy logic bloc

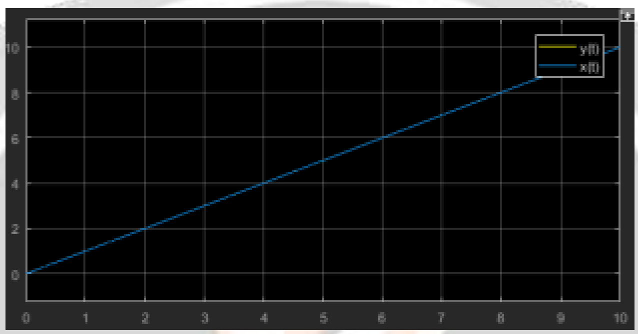

Fig -8: Speed control with fuzzy logic bloc

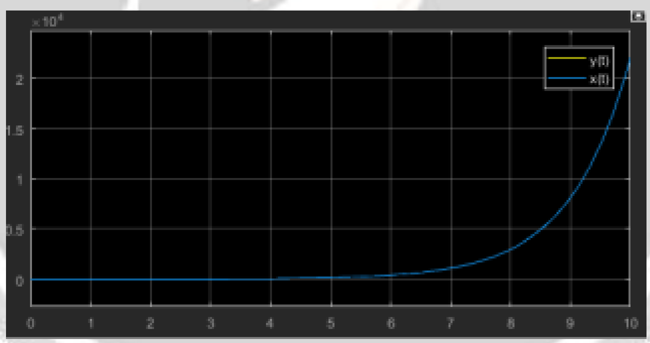

Fig -9: Response for exponential input

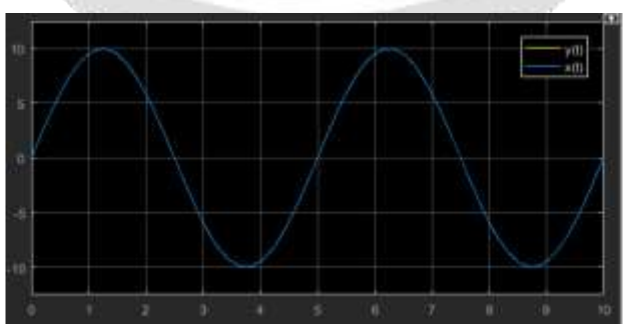

Fig -10: Response for sinusoidal input

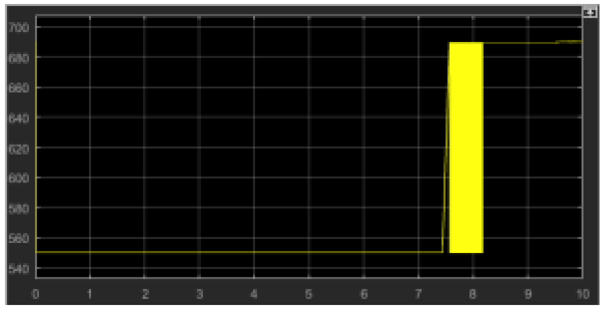

Fig -11: Output of fuzzy controller with exponential input

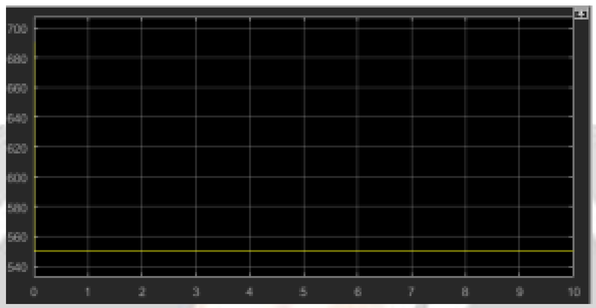

Fig -12: Output of fuzzy controller with step, ramp and sinusoidal inputs

From **Fig-7**, **Fig-8**, **Fig-9** and **Fig-10**, with fuzzy logic controller, all outputs follow inputs. From **Fig-11**, **Fig-12**, **t**he output of the fuzzy controller is equal to OENZ for step, ramp and sinusoidal inputs but maximum value as OEFZ for exponential.

Fig -13: Response for step input with disturbance signal

With sinusoidal disturbance, fuzzy logic controller is performant.

5. CONCLUSION

Fuzzy controller parameters as the range value of input and output depend on the transfert function of system. The efficiency also depends on the number of fuzzy sets used at the input and output level. For DC motor, two fuzzy set are used during control process. For all inputs, fuzzy logic controller is performant.

6. REFERENCES

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