©2016 Published in 4th International Symposium on Innovative Technologies in Engineering and Science 3-5 November 2016 (ISITES2016 Alanya/Antalya - Turkey)

Speed Control of DC Motor Using Fuzzy Logic Application

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Abstract

Direct current (DC) motors are controlled easily and have very high performance. The speed of the motors could be adjusted within a wide range. Today, classical control techniques (such as Proportional Integral Differential - PID) are very commonly used for speed control purposes. However, it is observed that the classical control techniques do not have an adequate performance in the case of nonlinear systems. Thus, instead, a modern technique is preferred: fuzzy logic. In this paper the control system is modelled using MATLAB/Simulink. Using both PID controller and fuzzy logic techniques, the results are compared for different speed values.

Keywords: Fuzzy Logic, DC Motor speed control, PID Controller.

1. Introduction

DC motors are used for fast transportation, electric trains, electric vehicles, electric winches, printers, floppy drives, paper industry, etc. where adjustable speed and precise positioning is important. In the last few years, with the improvements in technology, they are also used in home applicants and other applications demanding low power, low cost and adjustable speed, which have a broad usage [1]. Another reason they have many usages is that the control of DC motors are easier than Alternative Current (AC) motors. Compared to AC motor drivers, the circuits of DC motor drivers are much simpler and cheaper, so DC motors are more preferred for adjustable speed applications.

For the applications, the speed control system used is as important as the motor driver. Open loop systems are not used for constant speed applications. In these systems, the change in the armature voltage and the rotor speed because of the load is ignored, the rotor speed increases or decreases with the load. That is the reason why the open loop systems are not preferred instead the closed loop systems are used. Proportional-Integral (PI) controller is widely used in closed loop controllers for speed control of DC motors [2]. PID control technique is widely used for the control of dynamic systems. About 85% of dynamic control systems are PID based systems [3]. Due to the simplicity of its application, PID control technique is used for various industrial applications. The earlier usages include pneumatic systems, vacuum systems and solid state analog electronics. Later, the digital applications of microprocessors are started to be used [4].

In this study, it is thought that the construction of a MATLAB/Simulink model to better understand the system reactions is necessary for speed control of a DC motor using fuzzy logic. It would be appropriate to determine the DC motor parameters and control the speed of the DC motor with a

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classical method first. With this method, to be able to adjust the angle of the transformer (α), we have changed the α from 0 to 90 degrees with certain steps and recorded the respective rotor speed values for each angle. Based on the results of this trial, we have determined the memberships of our fuzzy control system. That is, we defined the input and output fuzzy sets. In this simulation it is aimed to control the motor current through armature voltage and the speed of the motor through the motor current.

2. Speed Control Using PI Controller

In the case of speed control with closed loop systems, the output value is rendered independent of the system variables. Using the loop shown in Figure 1, we want to keep the motor speed constant. For the closed loop system in question, the motor speed is adjusted according to the reference value. The true speed of the motor is measured using a tachometer. For different load values, primary voltage or armature voltage are changed to keep the motor speed at the reference value. As the motor voltage is regulated with the use of semi-conductors, the system is efficient and stable.

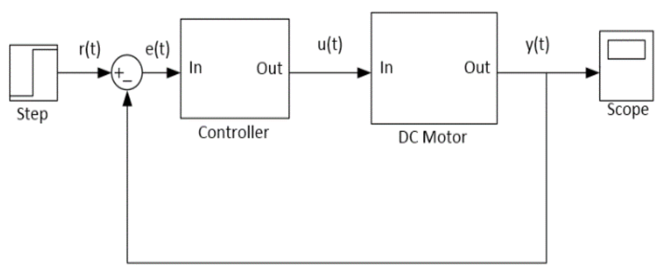

Figure 1. Block diagram of PI Controller

In Figure 1, the PI controller controls the speed of the DC motor and relays it to the output. The error signal $e(t)$ is multiplied by the proportional gain (K_p) and the integral of the error signal is multiplied by the integral gain (K_i) at the controller. PI systems are the summation of the proportional control and integral control effects. PI controller output can be defined as in Equation 1.

$$u(t)=K_p\, e(t)+K_i\int_0^t e(t)dt \qquad (1)$$

In this study, K_p and K_i values are determined using equations (2) and (3).

$w=125.6\ (rad/s)$
$E_a=115.5\ V$
$R_a= 3.5\ \Omega$
$L_a=0.024\ H$
$K=0.919$

$J=0.66\ kgm^2$
$K_c=127$
$K_i=4.4161809$
$K'_i=\frac{K_i}{25}=0.1766472$ (2)
$K'_p=\frac{K_c}{25}=5.08$ (3)

The system parameters along with equations (2) and (3) are presented above. The ratio of K_p / K_i is defined as the integral time (T_i). When the PI controller is merged with a closed loop system, it will change the effect of the control until the error becomes zero. The greatest advantages of the PI control are the absence of steady state error, the easy implementation and the fast response when the parameters are selected correctly.

3. Speed Control Using Fuzzy Logic

DC motors are commonly used for the applications that require position and speed control. There might be uncertainties regarding the load when the parameters such as resistances and inductances of the DC motors change with time. For that reason the control method should be carefully selected especially for sensitive systems.

Fuzzy logic has been introduced by the Azerbaijani scientist A. Zadeh in 1964. Instead of the zero and one in the standard logic, fuzzy logic is a control method that the inputs and outputs may have several membership functions [5].

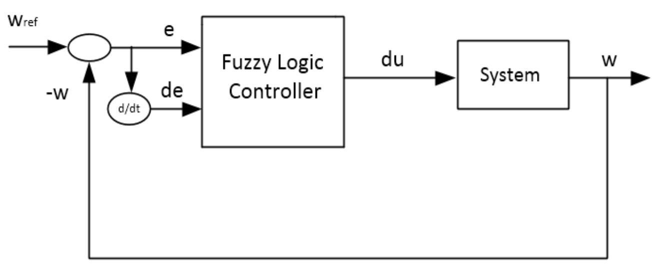

Figure 2. Block diagram of Fuzzy Logic Controller

In Figure 2, the block diagram for the fuzzy logic control system is presented. As it is seen in Figure 2, for the fuzzy logic to control the system there should be two inputs: the error signal and the change in the error. The error value is found by subtracting the instantaneous speed value of the DC motor (that is measured by the encoder connected the output of the motor) from the reference value, and the change in the error signal is found by subtracting the present error value from the previous error. These two data are fuzzed using membership functions of the controller. After the fuzzing, the truth values are extracted using the rules defined earlier and the control signal is defuzzy field. The most important stage of the fuzzy control structures that are widely used in

industry nowadays is to determine the set of rules of the systems. The reason for that is the set of rules that will provide satisfactory results can only be defined by an expert who knows the system and has experience with the system. That is only achievable if there is sufficient time to perform numerous trials. Today, because of such problems, investigative methods that will automatically learn and infer from the examples are used to form the necessary set of rules [6].
The rules for the 5 variable state of this study are presented in Table 1.

Table 1: Rules Table

e/de	NB	NK	S	PK	PB
NB	NB	NB	NB	NK	S
NK	NB	NB	NK	S	PK
S	NB	NK	S	PK	PB
PK	NK	S	PK	PB	PB
PB	S	PK	PB	PB	PB

In Table 1, "e" parameter represents the error signal, while "de" parameter represents the change in the error. The abbreviations are NB (Negative Large), NK (Negative Small), PK (Positive Small) and PB (Positive Large).

4. Simulation Results

In this section the modelling of the system that composes of DC motor, DC power source, transformer and three phase AC source is done on MATLAB/Simulink. The results for the fuzzy logic controller and PI controller for different speed values (1500 rpm, 1400 rpm, 1200 rpm, 1000 rpm, 900 rpm, 750 rpm and 500 rpm) are calculated, but the speed values are 1200 rpm and 500 rpm presented in graphical form in here. In this study, also the changes in the speed curves are analyzed while the load is decreased from 10 (N.m) to 5 (N.m) after 1 second of operation.

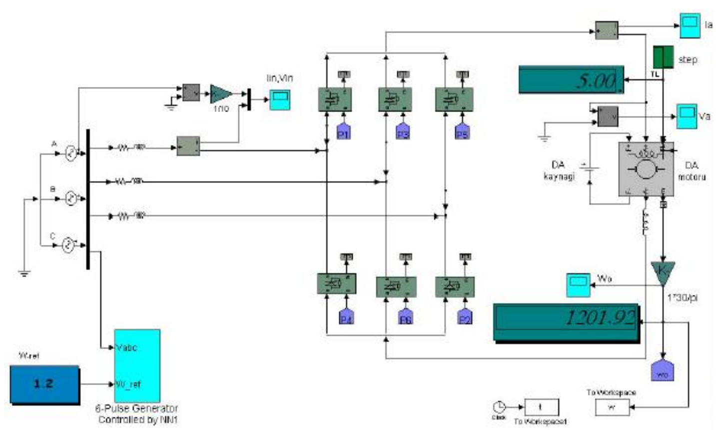

Figure 3. Simulink Model of Fuzzy Logic Controller (1200 rpm)

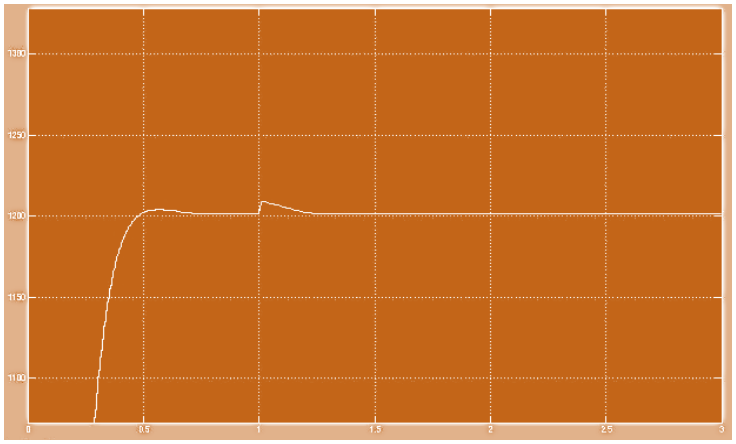

Figure 4.Time-Speed curve for Fuzzy Logic Controller (1200 rpm)

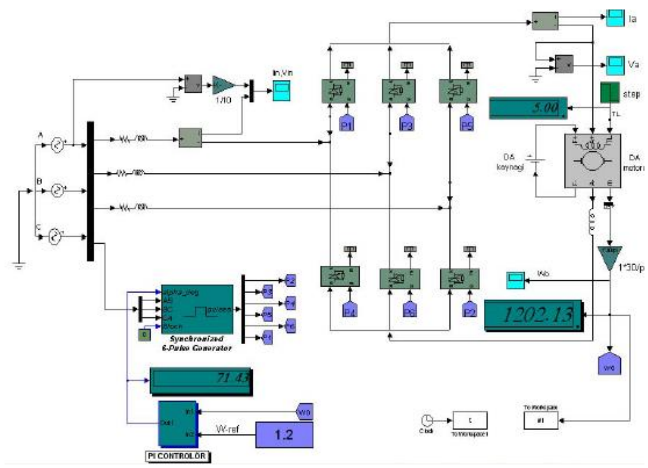

Figure 5. Simulink Model of PI Controller (1200 rpm)

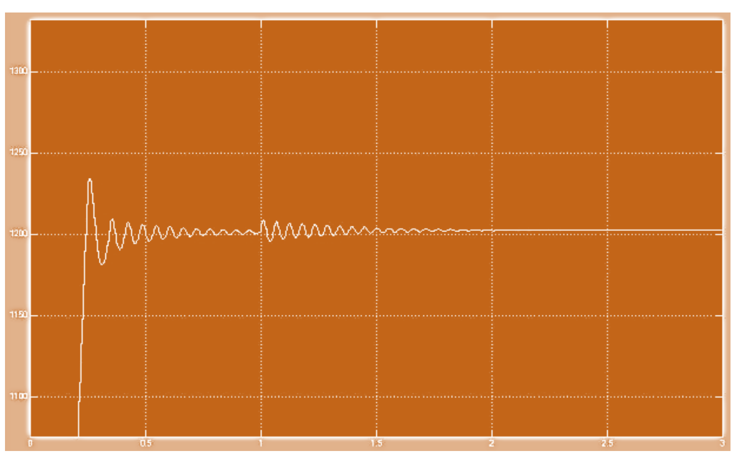

Figure 6. Time-Speed curve for PI Controller (1200 rpm)

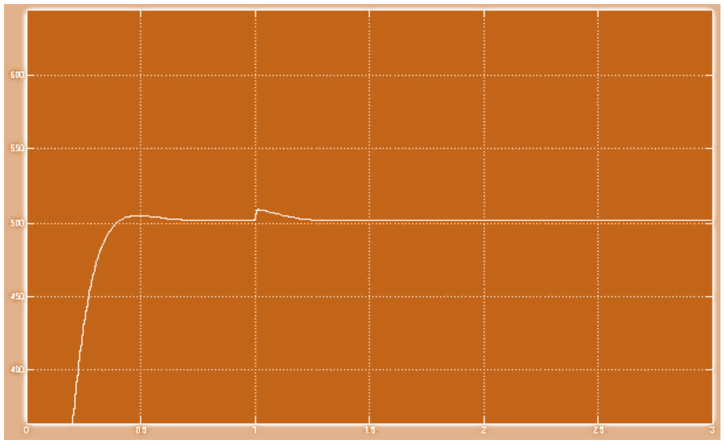

Figure 7. Time-Speed curve for Fuzzy Logic Controller (500 rpm)

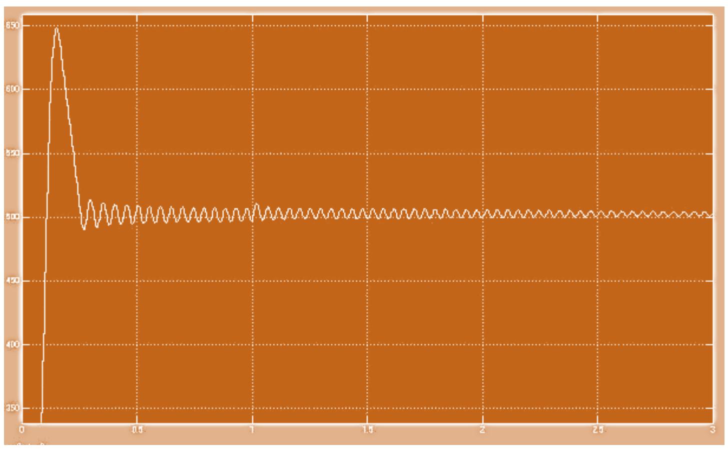

Figure 8. Time-Speed curve for PI Controller (500 rpm)

In Figures 3 and 5 the block diagrams for the PI controller and Fuzzy logic circuit constructed on MATLAB/Simulink are presented respectively. In Figures 4 and 6, the rotor speed versus time curves for the speed is equal to 1200 rpm case are given. Figure 7 and 8 shows similar results were obtained for the speed is equal to 500 rpm case are given.

V. Conclusions

In this study, where the speed control of the DC motor is performed, the classical control method and the fuzzy logic method are compared. The reaction of the system when the load is changed is investigated for both PI controller and fuzzy logic controller cases. The change in speed with time for constant torque case and the case when the torque is changed after 1 second of operation has been presented in graphical form. According to our simulation results, the fuzzy logic method is obviously superior to the classical control method.

Nomenclatures

$u(t)$: PI controller output
K'_p: Proportional gain
$e(t)$: Error
K'_i : Integral gain
E_a: EMF
R_a: Armature resistance
L_a: Armature inductance
W: Angular velocity
J: Rotor inertia (Moment of Inertia)
$r(t)$: Set point
$y(t)$: New Feedback Value

References

[1] Chan, C.C. , "Low Cost Electronic-Controlled Variable Speed Reluctance Motors", IEEE Transactions on Industrial Electronics, 1987,Vol. IE-34, No. 1, pp. 95-100.
[2] Ahmed, F.I., El-Tobshy, A.M., Mahfouz, A.A.,Ibrahim, M.M.S.," P-I and I-P Controllers in a Closed Loop for DC Motor Drives", Power Conversion Conference, 1997, Vol. 2, pp 613-618.
[3] Robert A. Paz," The Design of the PID Controller", Klipsch School of Electrical and Computer Engineering, 2001.
[4] Rahul Malhotra, Tejbeer Kaur, Gurpreet Singh Deol," DC motor control using fuzzy logic controller", international journal of advanced engineering sciences and Technologies, 2011.
[5] A. A. Sadiq, G. A. Bakare, E. C. Anene, H. B. Mamman," A Fuzzy-Based Speed Control of DC Motor Using Combined Armature Voltage and Field Current", 3 rd IFAC International Conference on Intelligent Control and Automation Science, China, 2013.
[6] Herrara, F., Lozano, M., Verdegay, J.L., "Generating Fuzy Rules from Examples Using Genetic Algorithms", Department of Computer Science and Artificial Intelligence. University of Granada, Spain, 1995.