

PMDC Motor Speed Control with Fuzzy Logic Algorithm Using PIC16F877 Micro Controller and Plotting Data on Monitor

Ahmet Işık^{1,3}, Oktay Karakaya^{1,4}, P. Alper Öner^{1,5}, Mehmet Kubilay Eker^{2,6}

¹Balıkesir University, Graduate School of Natural and Applied Science, Balıkesir, TR.

²Balıkesir University, Electrical and Electronics Engineering, Balıkesir TR.

³ahmetisik@bau.edu.tr , ⁴karakaya@balikesir.edu.tr , ⁵alper_oner@yahoo.com , ⁶kubilay@balikesir.edu.tr

Abstract

In this study, speed of permanent magnet dc (PMDC) motor is controlled with Fuzzy Logic (FL) algorithm at real time. For real time closed loop control, it has been used a PIC16F877 micro controller usage with 8 bit resolution. Only 3 membership functions which are called Negative (N), Zero (Z) and Positive (P) are used definition for FL algorithm, because of the difficulty to write the software to the micro controller via compiler program. Membership degrees of the functions are defined from 0 to 255 which is 8 bit unsigned maximum value. Integer numbers are used for programming algorithm, because compiler program using to write the software program to the micro controller is not enough sensitive for floating point number. Instantaneous values of the speed of the motor are transferred to PC with another PIC16F877 micro controller and plotting on monitor using interface program developed from DELPHI.

1. Introduction

Since fuzzy sets were introduced by Zadeh [1], FL algorithm have been used in many areas from recognition to control by researchers [2-8]. Due to the fact that performance of classical controllers is dependent to the controller parameters, FL theory exhibits a new approach for control systems. The objects are dependent to the system with membership degree changing from 0 to 1 unlike classical set theory concept. Based on this approach, systems are controlled with FL theory and compared with classical and other new control [4,5,8] theories.

DC motor is used to very common at control systems from speed control [2-8] to the robotic application. In this study, PMDC motor speed is controlled with FL theory, and an experimental set up is prepared for this aim. Speed of the motor is measured with an electronic circuit and transferred to the micro controller. A software program is written to keep the motor speed on reference value with micro controller. Difference between reference speed and measured speed is used to produce membership degrees for error. Difference between error and previous error is used to produce membership degrees for change in error. Triangle type functions are used for membership degrees, and there are 9 rules to produce the output of FL controller in this study. Center of area method is produced new duty cycle value of PWM generator.

System is modeled with mathematically and simulated at MATLAB program to compare between experimental and simulation results.

2. Designed Control System

Closed loop control system consists of a PMDC motor, a motor driving circuit, a speed measuring circuit, and two PIC16F877 micro controllers, first is for control to system, latter is for transferring data to PC which are shown in Fig 1.

To measure the speed of PMDC motor, a disc with 200 holes is designed. Produced data are transferred to the counter unit of micro controller and during 30 ms of periods, counted holes are added and speed of motor is calculated. Error value produced by comparing between reference and measured speed is transferred to the software program written for FL algorithm, and duty cycle ratio of chopper is being adjusted for the PWM pulse generator inside micro controller.

PMDC motor is supplied with 24 V at nominal condition but a DC chopper which has 36 V input voltage is used to approach to the desired output. While the speed measurement is being done 30 ms by fixed period, new duty cycle ratio is transferred to PWM pulse generator by periods of 32 ms because of the running program delaying time.

Using a second PIC16F877 controller, the speed data measured from the system is transferred to computer and displayed on the monitor with an interface program which is designed with DELPHI. Also by using the interface program, it is possible to change the reference value of motor speed. The communication between designed card and computer is made by the serial communication channel of the computer and micro controller.

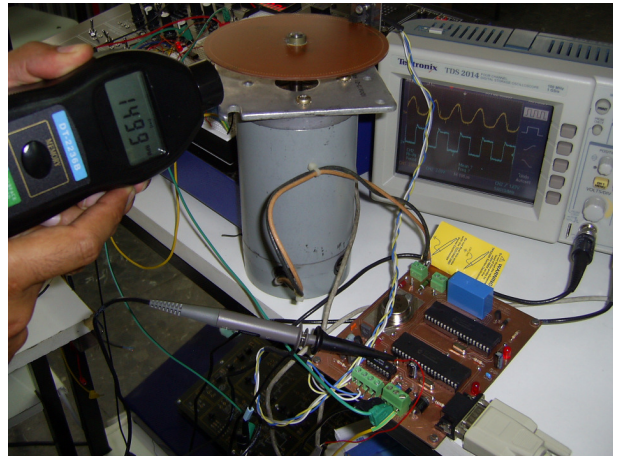


Figure 1: General appearance of designed system

2.1. The Circuit Designed for Speed Measurement

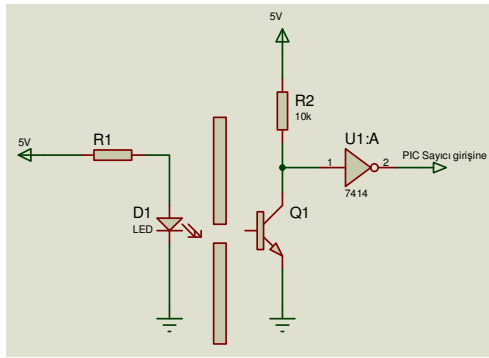


Figure 2: The circuit designed for speed measurement

The speed knowledge is produced by the optic receiver-transmitter couple which is connected to the motor shaft and designed to count the holes on the card. The general structure of the designed optic receiver-transmitter is shown in Fig 2.

The signal at the output of optic receiver-transmitter is not completely clear so that micro controller is not able to count these signals correctly. To produce regular level passage signals, schmitt inverter circuit is connected to the output of optic receiver-transmitter. An oscilloscope display is shown in Fig 3, channel 1 shows optic receiver-transmitter output and channel 2 shows the correcting signal on the schmitt inverter output. These signals are transferred to the counter unit of first micro controller and counted the holes passing during 30 ms of period. Motor angular speed is calculated as in (1).

$$\omega_r = 2\pi \times \left(\frac{C}{30 \times 10^{-3} \times 200} \right) = 1.0472 \times C \text{ [rad/sec]} \quad (1)$$

In this equation, C is number of the counted holes, and coefficient 200 is number of the total holes on the disc.

The period of the square wave signal at channel 2 is measured as 197.6 μsec for Fig 3. In this case, the speed of motor is found as 158.9 rad/sec as calculated by using (2).

$$\omega_r = 2\pi \times \left(\frac{1}{197.6 \times 10^{-6} \times 200} \right) = 158.9 \text{ [rad/sec]} \quad (2)$$

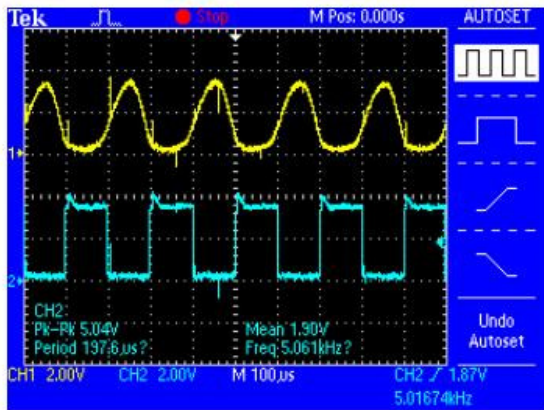


Figure 3: The oscilloscope monitor shows the correcting of speed signals

2.2. Driving circuit for PMDC motor

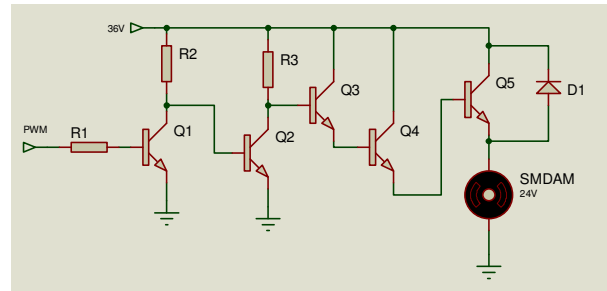


Figure 4: Driving circuit for PMDC motor

Motor driving circuit consists of the transistors to drive the power transistor of motor depending on the switching time of PWM signal generator. As shown in Fig 4, the PWM signals which are produced by first micro controller at 5 V level are raised to 36 V with Q1 and Q2 transistors, and Q3 and Q 4 darlington couple gives a sufficient current to drive Q5 power transistor.

The driving circuit is supported with snubber components to provide the continuity of the motor current at switch off time for PWM progress.

2.3. The Interface Program Plotting Data on Monitor

The second micro controller receives speed data from first micro controller and transfers to the PC via serial communication channel at 5 msec interval. Data receiving from the system are plotted on the graphic unit of visual interface program which is shown in Fig 5. As seen on the interface program which is developed from DELPHI, user can change the reference speed using "SELECT SPEED" unit and upload the reference speed value to the software program written for first micro controller with clicking "LOAD VALUE" button.

User can see real time speed data on *Graphic Unit* of interface program, and save the graphic data as a text file and graphic screen as a visual file by double clicking on *Graphic Unit* or clicking "SAVE GRAPHIC" button. By this way, speed data belonging to the experimental study can be compared with simulation result or another controller type.

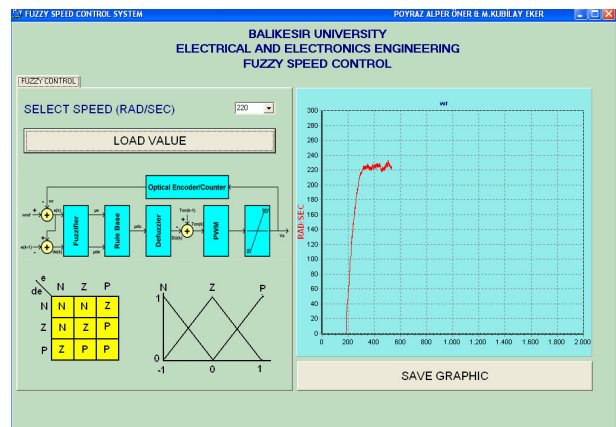


Figure 5: Designed interface program for monitoring data

3. Fuzzy Logic Controller

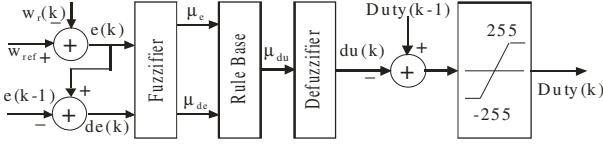


Figure 6: Block diagram of fuzzy logic controller

A fuzzy logic based controller is built up mainly by three parts, which are called fuzzifier, rule base (control rules), and defuzzifier as shown in Fig 6 [9].

Because of the 8 bit resolution working with micro controller, revolution per second knowledge is used for controller input to yield susceptibility of the study as in describe in (3).

$$n_{measured} = \left(\frac{C}{30 \times 10^{-3} \times 200} \right) \times 60 = 10 \times C \quad (3)$$

Similar to classical controllers, the error (e) signal that is defined as the difference between system output and reference set point is compensated by FLC as in (4).

$$e(k) = n_{ref} - n_{measured}(k) \quad (4)$$

However, in addition to error, change in the error (de) signal is also considered in FL based controllers in order to include the information about variation speed and direction of the error signal in determining the change in control signal as in (5).

$$de(k) = e(k) - e(k-1) \quad (5)$$

The first stage of a FL controller is called *Fuzzifier* where the crisp values of error (e) and change in the error (de) are converted to fuzzy numbers in terms of membership degrees μ_e and μ_{de} , respectively. The fuzzy numbers that are also called fuzzy sets represent the linguistic terms negative (N), zero (Z), and positive (P). The shapes of the fuzzy subsets used in this study are shown in Fig 7.

At the first stage, there are two membership values belonging to two subsets for error because of the triangle membership functions forming. There is same situation for change in error. We can call two membership degrees as μ_{e1} and μ_{e2} , and represent e_1 and e_2 for two subsets. Similarly, we can call two membership degrees for change in error as μ_{de1} and μ_{de2} , and represent de_1 and de_2 for two subsets.

The second stage of FLC is called *Rule Base* where Rule Table is used to produce the output membership subset as a du . Due to subsets of e and de , there are four combination of du . We can call these functions as du_1 , du_2 , du_3 and du_4 . The control rules representing the control actions to be taken in terms of the linguistic variables N, Z, and P are given in Table 1.

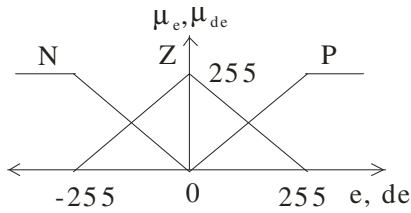


Figure 7: Fuzzy subsets

Table 1. Fuzzy control rule table

de \ e	N	Z	P
N	N	N	Z
Z	N	Z	P
P	Z	P	P

Last stage is called as *Defuzzification*, and output membership degrees are found using with some definitions. In this study, minimum function is used for this purpose. After that, the center of area (COA) method, which is defined as in (6), is used to find the mean value of these output membership degrees.

$$Du = \frac{\sum_{i=1}^n \mu_i(du) \times du_i}{\sum_{i=1}^n \mu_i(du)} \quad (6)$$

Flowing chart of FL algorithm written to micro controller is shown in Fig 8.

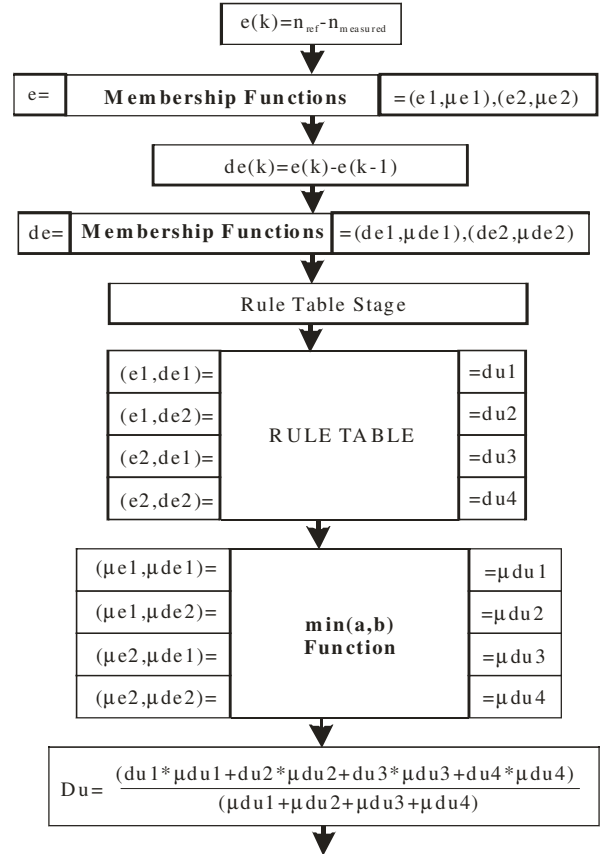


Figure 8: Flowing chart of the software program written for micro controller

New duty cycle of the PWM generator is found as in (7).

$$Duty(k) = Duty(k-1) + Du(k) \quad (7)$$

4. Experimental Results

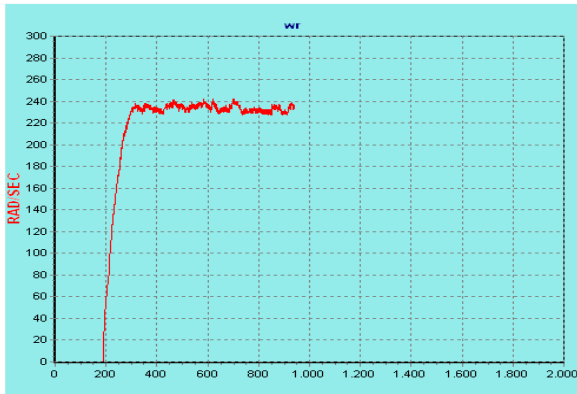


Figure 9: Plotting of speed for 230 rad/sec reference value

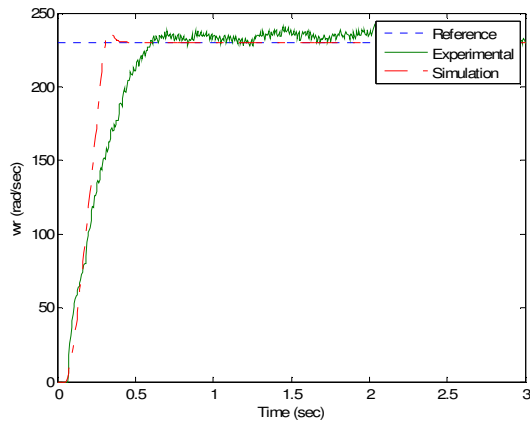


Figure 10: Simulation and experimental results for 230 rad/sec reference speed

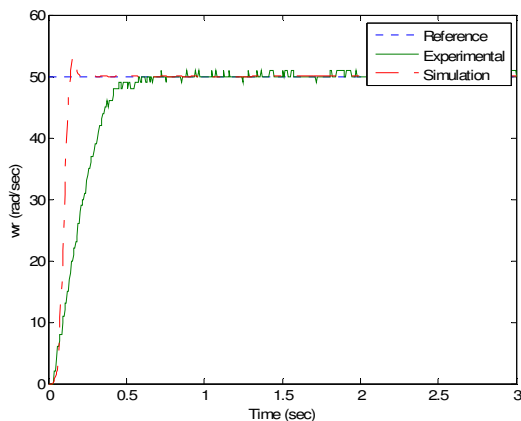


Figure 11: Simulation and experimental results for 50 rad/sec reference speed

Plotting data drawing to the monitor is shown in Fig 9, and compared results between experimental and simulation are shown in Fig 10 and Fig 11. Because of the no sensibility for floating point number at compiler program using to program PIC16F877 micro controller, there is an oscillation on the steady state condition especially effecting for 230 rad/sec reference value shown at Fig 10. Working with only integer number or changing the compiler program, this problem will be eliminated.

5. Conclusions

In this study, Fuzzy Logic Algorithm is applied to PMDC motor for speed control at real time working. Results are monitored to the PC, also can be written to the data file depending on the user selection. We can write other control algorithms for changing only software program without changing hardware using this setup. Comparing with classical and other control algorithms with this experimental setup is very easy and only with changing software program written to the micro computer. User can see real time results for Fuzzy Logic Controller on monitor and change reference value. For other control theories which can be written to micro controller, user can change some controller parameter, and compare results between different control algorithms.

6. References

- [1] Zadeh, L.A., "Fuzzy sets", *Information and Control*, 8: 338-353, 1965.
- [2] Altas, I.H., and Aydar, H., "A real-time computer controlled simulator: For control systems", *Computer Applications in Engineering Education*, 16 (2): 115-126, 2008.
- [3] Akcayol, M.A., Elmas C., Erdem, O.A., and Kurt, M., "An educational tool for fuzzy logic controller and classical controllers", *Computer Applications in Engineering Education*, 12 (2): 126-135, 2004.
- [4] Kumar, N.S., Sadasivam, V., and Sukriya H.M.A., "A comparative study of PI, fuzzy, and ANN controllers for chopper-fed DC drive with embedded systems approach", *Electric Power Components and Systems*, 36:680-695, 2008.
- [5] Rubai, A., Ricketts, D., and Kankam, M.D., "Experimental verification of a hybrid fuzzy control strategy for a high-performance brushless DC drive system", *IEEE Trans on Industrial Applications*, 37 (2):503-512, 2001.
- [6] Pravadaliloglu, S., "Single-chip fuzzy logic controller design and an application on a permanent magnet dc motor", *Engineering Applications of Artificial Intelligence*, 18:881-890, 2005.
- [7] Eker, I., and Torun, Y., "Fuzzy logic control to be conventional method", *Energy Conversion and Management*, 47:377-394, 2006.
- [8] Orlowska-Kowalska, T., Szabat, K., and Jaszczak, K., "The influence of parameters and structure of PI-type fuzzy-logic controller on DC drive system dynamics", *Fuzzy Sets and Systems*, 131:251-264, 2002.
- [9] Eker M.K., and Altas, I.H., "A fuzzy voltage regulator (FVR) for a stand-alone synchronous generator", *Electric Power Components and Systems*, 35:429-443, 2007.