



## Decreasing Starting Current for Separate Excited DC Motor using ANFIS Controller

Saber Ghadri<sup>1</sup>, Shahram Javadi<sup>2</sup>, Fardad Farokhi<sup>3</sup>

<sup>1</sup>MSc Student, Electrical Engineering Department, Islamic Azad University, Central Tehran Branch, Tehran, Iran  
saberghadri@yahoo.com

<sup>2</sup>Assistant Professor, Electrical Engineering Department, Islamic Azad University, Central Tehran Branch, Tehran, Iran  
sh.javadi@iauctb.ac.ir

<sup>3</sup>Assistant Professor, Electrical Engineering Department, Islamic Azad University, Central Tehran Branch, Tehran, Iran  
f\_farokhi@iauctb.ac.ir

### Abstract

Today, DC motors is still being used globally due to their easy speed controllability. In this article, an Adaptive Neuro-Fuzzy Inference System (ANFIS) controller is designed for DC motors. The main purpose of performing such task is to reduce the DC motor starting current and deleting the ripple current during starting time in considering control parameters such as: rise time, settling time, maximum overshoot and system steady state error. The results have been simulated in MATLAB and a comparison is made between ANFIS controller and PID controller.

**Keywords:** ANFIS, PWM, Separate Excited DC Motor, Speed Control

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### 1. Introduction

Through development of the power electronic equipment and because of a wide speed control range for separate excited DC motors, these machines are still being used [1]. The most important applications of these motors include electrical vehicles, welding industries, electrical cranes and robotics manipulators [2].

Usually, the motors draw high current from the power supply during starting. Therefore, it is required that the starting current is limited to a desirable level in the motor speed controlling process. The common speed controllers for DC motor are: PID controller and FLC (Fuzzy Logic controller)[1].

The most important reasons for using PID controller; as it was presented in [3]; are:

1) Simple designing PID controller

2) Clear relationship between the PID controller coefficients and system response parameters

3) The flexibility of this controller can be useful for technology development

However, PID controllers have some disadvantages. For instant, these controllers require a precise mathematical model of the system and identification of zero-poles location. In addition, PID controllers include three parts: proportion, integration and derivation, while these parts have linear relationships, which cause a linear control rule, while DC motors have non-linear parameters practically. On the other hand, some of the system parameters such as armature resistance vary with time, which changes the position of zeroes and poles of the system. The aforementioned factors cause that a precise transfer function and Ziegler-Nichols factors have been applied for PID controller with low efficient after a while due to changing in the motor

parameters, considerably. To overcome this problem, an experienced-knowledgeable human operator is required in industry that changes the factors of such controllers frequently [2].

In order to avoid and overcome above-mentioned problems, the Adaptive Neuro Fuzzy Inference System (ANFIS) controller can be used [4]. This controller was introduced around 1990 by Jang, in which the fuzzy and neural networks concepts were combined to form a hybrid intelligent system which automatically learn and adopt. This hybrid system has been used to model and forecast in a variety of engineering systems [1]. Unlike the common PID controllers, ANFIS controllers do not need any system mathematical model understanding such as zeros and poles location placement of transfer function [3]. Additionally, the ANFIS controllers are superior to the pure fuzzy model, as by using it there is no need for an operator to set the membership functions margins [1].

The basis for ANFIS controller learning method are adaptive neurons which can use a variety of methods for modeling and learning information based on data set, and focus on automatic calculation of membership function parameters to track this data set [1,5].

Whereas armature voltage controlling method is highly used in order to control the speed of motor for speeds below base speed [6]; in this article, the main method to control the speed of separate excited DC motor is to use ANFIS controller together with the Pulse With Modulation (PWM) method; while the output voltage of PWM procedure is applied on the motor armature. Meanwhile, in order to test the validity of controller, the ANFIS controller is compared with PID controller in the load torque and speed change test.

The main purpose in the presented paper is reducing the motor starting current and deleting of its ripples upon load torque and speed change.

**2. Problem Solving Method**

Fig.1 indicates the general scheme of the circuit that has been designed using MATLAB to control the separate excited DC motor speed. The motor input is the load torque and four signals at the motor output, which we use armature current signal as the most important output signal, because the starting current of an electric motor can be several times greater than the motor’s rated current, it becomes necessary to limit the current. The main purpose of ANFIS controller in this paper is to determine the best margin for the fuzzy membership functions to improve the system unsteady state response and reducing the starting current.

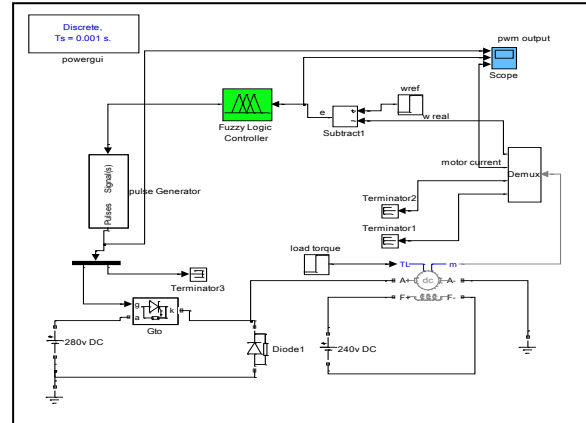


Fig.1. circuit designed to control the separately excited DC motor speed

The first output signal of the motor, indicates the rotor speed, which is named as  $\omega_{real}(\text{rad/s})$ . The difference between this signal and the reference speed ( $\omega_{ref}$ ), indicates the error signal, while such signal is the input for ANFIS controller and the controller makes output as appropriated with this signal.

The motor speed is controlled by armature voltage controlling method, while this task can be completed using PWM method (fig.2) [2]. In this method, a series of pulses is used to control the voltage, while all such pulses have fixed "T" periods, but their band width ( $t_d$ ) is variable. Therefore, they change the average applied voltage of armature. Equation (1) indicates the average voltage ( $V_{ag}$ ) value, where  $V_m$  is the value of the applied electrical signal, and "k" is the duty cycle [2].

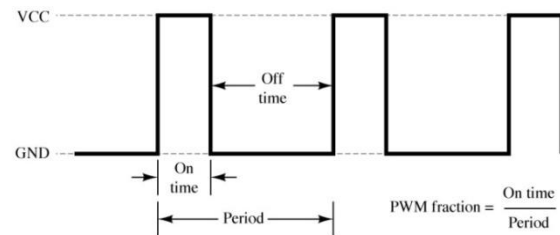


Fig.2. Pulse Width Modulation method

$$V_{ag} = \frac{1}{T} \int_0^T V(t). dt = \frac{t_d}{T} V_m = k. V_m \tag{6}$$

As the generated pulses are not able to supply current to the motor, it is used a GTO thyristor. In fact the voltage source which is connected to the thyristor anode is responsible for supplying current to the motor.

Fig.3 indicates the simulated ANFIS controller structure, which has been included of five layers, as it is shown in fig.3. The performance description of these layers has been given in the following items.

Layer 1: It is formed of some calculation nodes and activation functions with fuzzy membership (triangle, trapezoid, etc.). The output of this layer defines a fuzzy membership degree for the input vectors, or in other words, this layer is responsible to do fuzzification [2].

Layer 2: The output of each node in this layer is the fuzzy multiplication of all the signals entering into such node. In fact this layer takes the minimum among its inputs [2].

Layer 3: In this layer each input is normalized with respect to other inputs, while this action is made through dividing the input of each node with respect to other inputs [2].

Layer 4: Each adaptive node in this layer calculates the contribution of error and error derivative signals [2].

Layer 5: This layer is responsible to defuzzificate the fuzzy values, while it completes such task based on average weight method [2].

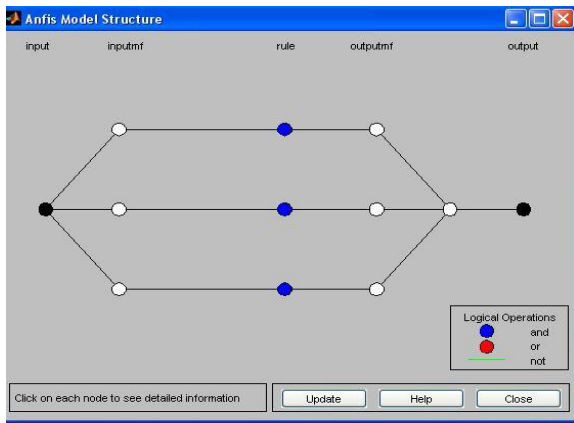


Fig.3. simulated ANFIS controller structure

**3. Results**

In this part the PID and ANFIS controllers are compared concerning the ability to control the motor starting current as well as their efficiency in improving the controlling parameters such as: rising time, settling time, maximum overshoot and steady state error, while this comparison is performed in the load torque stepped change from 0 to 5(N.m), in starting time (t=0), and also the reference speed stepped change from 0 to 140 rad/s at the same time.

The value of PID controller parameters ( $k_p$ ,  $k_i$ ,  $k_d$ ) have been obtained by using genetic algorithm [7]. It should be mentioned that the genetic algorithm is a strong optimization algorithm which works based on the natural choice method and genetics.

The initial population in this program has been produced randomly and this program has been used by population size of 30, maximum generation production of 120, and crossover probability of 0.8 and mutation probability of 0.2. Meanwhile, the

roulette wheel method has been used to choose the members and reproduction process. The lines chosen for the crossover and mutation are prepared and make the new population members. This algorithm uses average error signal as cost function. Fig.4 indicates the error signal after applying the obtained PID controller.

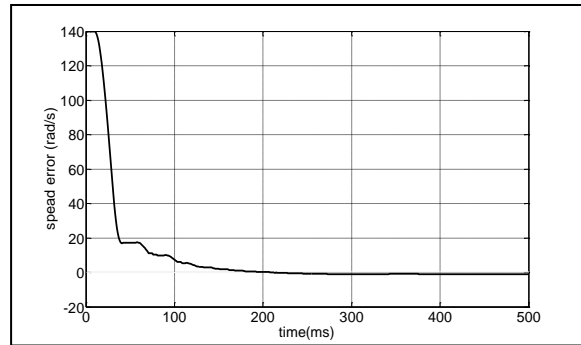


Fig.4. error signal due to the applied PID controller

Also the ANFIS controller has been trained with 50 epoch, error of 0.001, three triangular membership functions, Sugeno inference method and by using hybrid optimization method, as it is clearly shown in fig.5, and the relevant error signal has been shown in fig.6 as well.

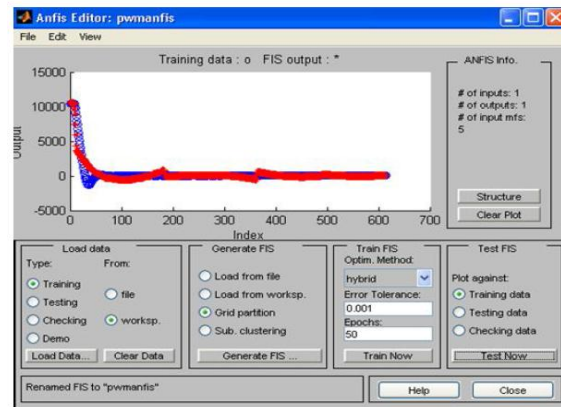


Fig.5. trained ANFIS controller

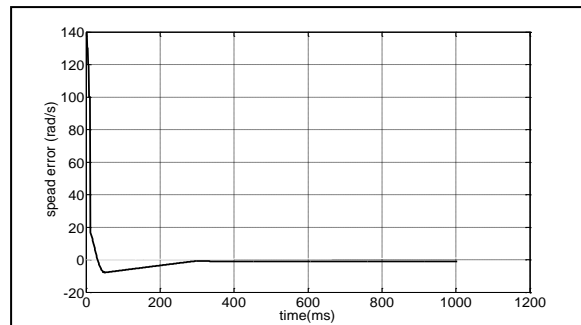


Fig.6. error signal due applying ANFIS controller

Also figures 7 and 8 show the motor current upon applying PID and ANFIS controllers respectively. In table 1 a complete comparison between PID and ANFIS controllers, is shown.

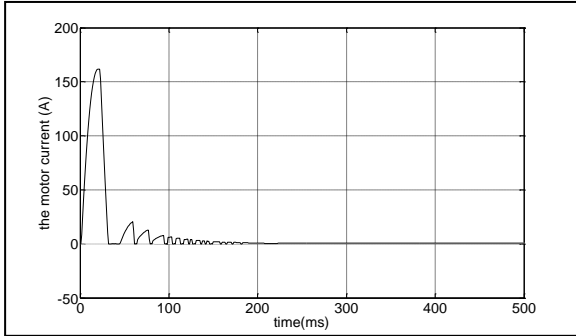


Fig.7. motor current due applying PID controller

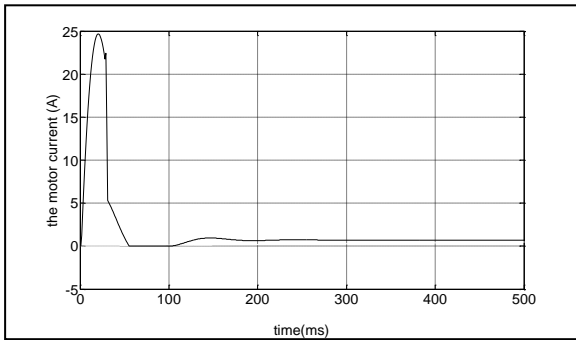


Fig.8. motor current due applying ANFIS controller

Table.1  
comparison between PID and ANFIS controllers

controller	Starting current	Rise time	Settling time	Maximum overshoot	Steady state error
PID	161.8 A	211 ms	320 ms	0 rad/s	1.7 rad/s
ANFIS	24.66 A	26 ms	288 ms	7.216 rad/s	1 rad/s

**4. Conclusion**

In this article a speed controlling system based on ANFIS controller was successfully designed and tested using MATLAB. The system efficiency with PID and ANFIS controllers was compared at load torque and reference speed change, while the ANFIS controller had better results in the field of decreasing the starting current as well as in most of the controlling parameters (rise time, settling time and steady state error). Additionally, the ANFIS controller was also successful in deleting the ripples of the current. We hope to practically implement this controller in future using the obtained results of this study.

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