Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2015, 2(1):16-21

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Speed Control of DC Motor Using Adaptive Neuro Fuzzy Controller

WISAM NAJM AL-DIN ABED

Department of Electronic engineering, University of Diyala, Iraq

Abstract The aim of this work is to design an Adaptive Neuro-Fuzzy Inference System (ANFIS) controller for speed control of Separately Excited Direct Current Motor (SEDM), and the results are compared with PID controller. The mathematical model using dynamic equations of (SEDM) is simulated using MATLAB simulink. The (SEDM) is loaded with different loads. The comparison between (ANFIS) controller performance and the PID controller is presented. The results show the proposed controller has superior feature, including adaptive characteristics which make the controller robust for wide range of loading conditions, also improving the time response of the plant which reduce the rise time, peak time, peak over shoot and settling time.

Keywords Adaptive Neuro-Fuzzy Inference System (ANFIS), Separately Excited DC Motor (SEDM), Proportional-Integral-Derivative (PID).

Introduction

Direct current (DC) motors have been widely used in many industrial applications such as electric vehicles, steel rolling mills, electric cranes, and robotic manipulators due to precise, wide, simple, and continuous control characteristics. Traditionally rheostat armature control method was widely used for the speed control of low power dc motors. However the controllability, cheapness, higher efficiency, and higher current carrying capabilities of static power converters brought a major change in the performance of electrical drives [1]. The speed of DC motor can be adjusted to a great extent as to provide controllability easy and high performance [1, 2]. The controllers of the speed that are conceived for goal to control the speed of DC motor to execute one variety of tasks, is of several conventional and numeric controller types, the controllers can be: PID Controller, Fuzzy Logic Controller; or the combination between them: Fuzzy-Neural Networks, Fuzzy-Genetic Algorithm, Fuzzy-Ants Colony, Fuzzy-Swarm [2]. The adaptive neuro-fuzzy inference system (ANFIS) is a hybrid model which combines the ANNs adaptive capability and the fuzzy logic qualitative approach [10]. ANFIS harnesses the power of the two paradigms: ANNs and fuzzy logic, and overcomes their own shortcomings simultaneously [3]. However the PID (proportional _integral _derivative) controller is still extensively used in the industry this is due to its simplicity and the ability to apply in a wide range of situations. On the other hand a PID controller is rather difficult and can be a time consuming process. The speed of DC motor can be adjusted to a great extent so as to provide easy control and high performance. There are several conventional and numeric controller types intended for controlling the DC motor speed at its executing various tasks [4].

Intelligent control systems increase the effectiveness of control strategies and overcome limits of classical and adaptive controllers. They are expected to have in-built adaptation/learning and decision-making capabilities to handle uncertainties so the desired performance can be achieved. To overcome traditional computing paradigm limits, researchers look for new computational approaches to partial modeling of neural system functionality and that can solve real-world problems effectively. Novel computational models have emerged, collectively called soft computing. Incorporating intelligence into soft computing are ANN (artificial neural network), FL (fuzzy logic), ANFIS, GA (genetic algorithm), and knowledge-based expert systems. ANFIS was developed in the early 90s by Jang. Combining the concepts of fuzzy logic and neural network, it is a hybrid intelligent system that enhances automatic learning and adaptation. Researchers have used such a system to predict and model in various engineering systems. Basic to neuro-adaptive learning techniques is a fuzzy modeling procedure that learns the data set and automatically computes the membership function parameters that best allow the associated FIS to track the given input/output data. The membership function parameters are tuned by a combination of least-squares estimation and back-propagation algorithm for membership-function parameter estimation [5].

The Integration of fuzzy logic and neural network algorithm is an adaptive neuron fuzzy inference system (ANFIS). It had been applied to control the speed of conventional DC motor drive, so it compares with PI, IP, fuzzy, ANFIS controller. The results are response of ANFIS controller that is the best [6].

Mathematical Model of Separately Excited DC Motor

In a separately excited dc motor, the field coil is supplied from a different voltage source than that of the armature coil. The field circuit normally incorporates a rheostat through which the field current, and thus the motors characteristics, can be externally controlled. This motor is mainly suitable for two types of loads; those that require constant torque for speed variations up to full-load speed, and those whose power requirements are constant for speed variations above nominal speed. The electrical armature and field circuit can model the motor [4]. Figure (1) shows the equivalent circuit with armature voltage control and the model of a general mechanical system that incorporates the mechanical parameters of the motor and the mechanism coupled to it [7].

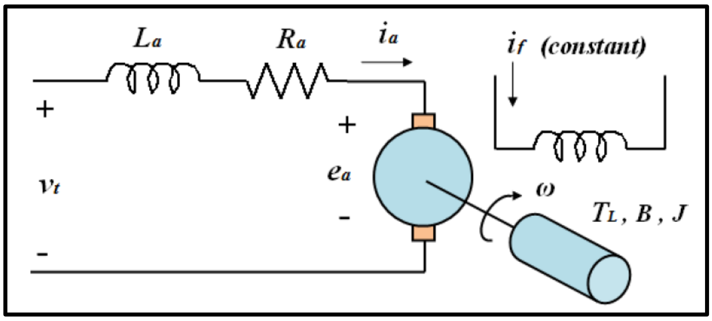


***Figure 1**: Equivalent circuit of separately excited DC motor*

The characteristic equations of the DC motor are represented as,

$$\frac{\mathrm{d}i_a}{\mathrm{d}t} = \frac{1}{L_a}(V_a - R_a i_a - E) \quad (1)$$

$$\frac{\mathrm{d}i_f}{\mathrm{d}t} = \frac{1}{L_f}(V_f - R_f i_f) \quad (2)$$

$$\frac{\mathrm{d}\omega}{\mathrm{d}t} = \frac{1}{J}(T_e - T_L - B\omega) \quad (3)$$

Where T_e is the development electrical torque, Eis the back EMF, B denotes the viscous friction coefficient, and J is the moment of inertial [8]. The armature circuit consists of an inductor La and resistor Ra in series with a counter emf which is proportional to the DC motor speed [9].

$$E = K_E \omega \quad (4)$$

K_E is the voltage constant and ω is the machine angular speed. In a separately excited DC machine model, the voltage constant K_E is proportional to the field current (I_f) as in (5).

$$K_E = L_{af} I_f \quad (5)$$

Where L_{af} is the field armature mutual inductance. The electromechanical torque (Te) developed by the DC machine is proportional to the armature current (I_a) as in (6).

$$T_e = K_T I_a \quad (6)$$

Where K_T is the torque constant. In the SI unit, the torque and voltage constants are equal as in (7).

$$K_T = K_E \tag{7}$$

Simulation and Results

The first step in analysis and designing the controllers for the SEDM is to use the mathematical model of the SEDM which is more reality to the actual plant rather than linear transfer function model in the control design and studies. The proposed SEDM model was developed from the mechanical and electrical dynamic equations of the SEDM.

Simulation of SEDM Using Matlab/Simulink

The proposed mathematical model is developed from the mechanical and electrical dynamic equations of the SEDM, equations (1-7). The SEDM are loaded for four different loads (assumed). These loads are: (no-load, (0.3 of full-load) as a light load, (0.5 of full-load) as a half full load, and finally (full-load). The simulink of the SEDM mathematical model is shown in Figure (2). The parameters values of SEDM used in the simulation is taken from MATLAB/Toolbox and shown in Table (1).

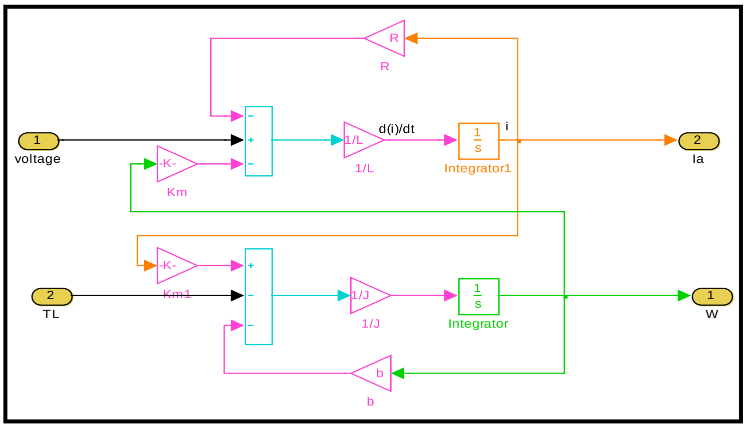
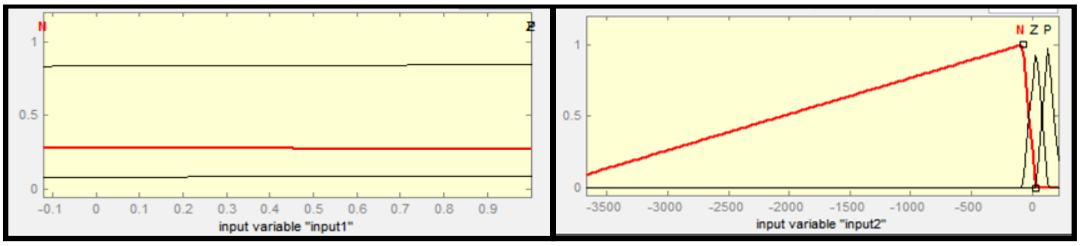


Figure 2: SEDM simulation using MATLAB/SIMULINK

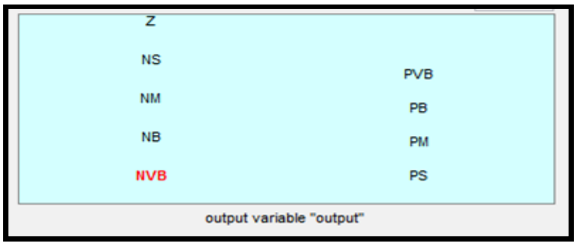
Table 1: 10 hp, 500V, 1750 R.P.M. supply SEDM parameters

Motor ratings and parameters	Values
Power	10 hp
Supply or armature voltage (Va)	500 V
Speed	1750 R.P.M.
Field voltage (Vf)	300 V
Armature resistance (Ra)	4.712Ω
Armature inductance (La)	0.05277 H
Km = Kf	2.242
Inertia of the rotor (J)	0.04251 Kg.m2
damping coefficient (B)	0.003406 N.m.s

The ANFIS controller is designed with two inputs and one output each input with three triangular membership functions while the output with nine membership functions as shown in Figure (3). Table (2) shows the ANFIS controller used rules.



(a) Input 1 membership functions (b) Input 2 membership functions



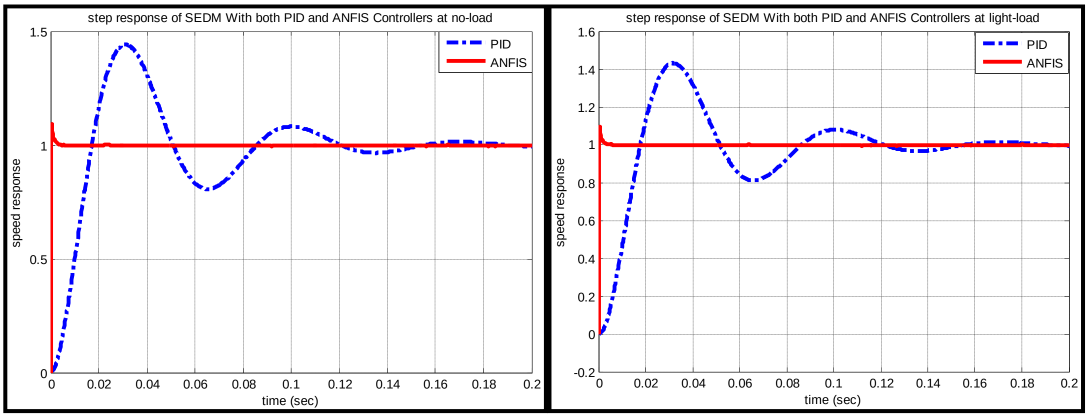
(c) Output membership functions

Figures 3(a,b,c): Membership functions for ANFIS controller

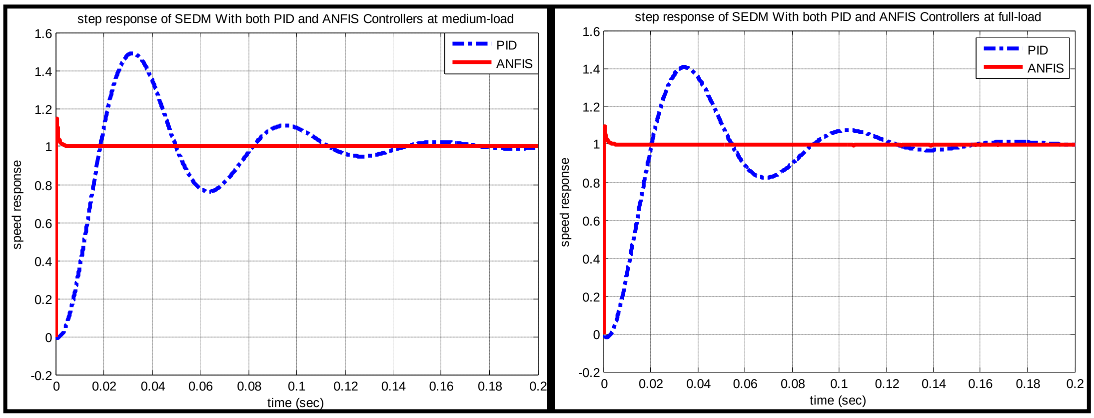
Table 2: ANFIS rules

ΔE E	N	Z	P
N	NVB	NB	NM
Z	NS	Z	PS
P	PM	PB	PVB

The speed step responses of SEDM with different loads for PID (KP=9,KI=642.8 AND KD=0.0315) and ANFIS controllers are shown in Figures (4) (a, b, c, and d).



(a) SEDM at no-load (b) SEDM at light load



(c) SEDM at half full-load (d) SEDM at full-load

Figures 4(a,b,c,d): SEDM speed responses for both controllers at different loads

The transient response specifications of SEDM speed response are listed in Table (3) for both controllers with different loading conditions.

Table 3: Transient response specifications

		Rise time(s)	Peak time(s)	%percentOvershoot	Settling time(s)
no-load	PID	0.35	0.03	48	0.18
	ANFIS	0.085	0.002	15	0.0041
light-load	PID	0.35	0.031	46	0.18
	ANFIS	0.085	0.0021	15	0.0041
half full-load	PID	0.36	0.032	46	0.18
	ANFIS	0.084	0.0021	14	0.0043
full-load	PID	0.36	0.032	42	0.18
	ANFIS	0.084	0.0022	14	0.0043

From Table (3) it is clearly that, the transient specifications are improved of SEDM with ANFIS controller versus PID controller for different loads.

Conclusions

In this work a simulation of mathematical model for SEDM based on mathematical model depending on the electrical and mechanical equations of SEDM. This work also concerned with ANFIS controller design for speed control of SEDM. The main concluding remarks can be summarized as follows:

The PID controller is normally used in the industry due to it's simple structure, and the ability to apply for a wide range of situations.

ANFIS controller give best results as compared with (PID), which improve the step response for wide range of loads.

ANFIS controller work efficient due to back propagation training algorithm which make this controller have adaptive characteristic.

Using wide rang of loads during tuning process, gave the controller robustness and superiority for controlling the speed even the load changes during the motor operation.

References

1. George, M. (2008). Speed control of separately excited DC motor. *American journal of applied sciences*, *5*(3), 227-233.
2. Allaoua, B., Laoufi, A., Gasbaoui, B., & Abderrahmani, A. (2009). Neuro-fuzzy DC motor speed control using particle swarm optimization. *Leonardo Electronic Journal of Practices and Technologies*, *15*, 1-18.
3. Lei, Y., He, Z., Zi, Y., & Hu, Q. (2007). Fault diagnosis of rotating machinery based on multiple ANFIS combination with GAs. *Mechanical Systems and Signal Processing*, *21*(5), 2280-2294.

4. Mohammed, A. J. (2013). Speed Control for Separately Excited DC Motor Drive (SEDM) Based on Adaptive Neuro-Fuzzy Logic Controller. *Eng. & Tech. Journal*, *31*(2), 277-295.
5. Yousif Al Mashhadany (2013). Hybrid ANFIS Controller for 6-DOF Manipulator with 3D Model. *International Journal of Computers & Technology* *4*(2).
6. Hidayat, H., Sasongko, P. H., Sarjiya, S., & Suharyanto, S. (2011, July). Performance analysis of adaptive neuro fuzzy inference systems (ANFIS) for speed control of brushless DC motor. In *Electrical Engineering and Informatics (ICEEI), 2011 International Conference on* (pp. 1-6). IEEE.
7. Hameed, W. I., & Mohamad, K. A. (2012). Speed Control Of Separately Excited DC Motor Using Fuzzy Neural Model Reference Controller. *International Journal of Instrumentation and Control Systems (IJICS) Vol*, *2*.
8. Liu, C. J., Li, B. X., & Yang, X. X. (2011, September). Fuzzy logic controller design based on genetic algorithm for DC motor. In *Electronics, Communications and Control (ICECC), 2011 International Conference on* (pp. 2662-2665). IEEE.
9. Tipsuwanporn, V., Numsomran, A., Klinsmitth, N., & Gulphanich, S. (2007, October). Separately excited DC motor drive with fuzzy self-organizing. In *Control, Automation and Systems, 2007. ICCAS'07. International Conference on* (pp. 1316-1321). IEEE.