Simulation model of ANN and PID controller for direct current servo motor by using Matlab/Simulink

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Article Info

Article history:

Received Feb 01, 2022
Revised Jun 15, 2022
Accepted Jun 23, 2022

Keywords:

Artificial neural networks
DCSM
Performance characteristics
PID controller

ABSTRACT

In the current era, researchers have been active in confirming and achieving their work through simulation using the computer program Matlab, in addition to the comparison between different control methods is also one of the prevailing behaviors, and the focus has been on the use of electrical machines in industry through multiple applications. Researchers in this study selected type of electric motors and two types of control systems for comparison, and to verify the possibility of improving the system's work performance through the simulation results, the process of achieving the objectives of the current research is carried out. This paper presents using conventional proportional-integral-derivative (PID) controller and artificial neural networks (ANN) with direct current servo motor (DCSM) in order to obtain good performance characteristics because of efficient and widely use of this motor in the fields of control. The motor model in addition to the controller is built using Matlab simulation software. A comparison was made between these controllers (PID and ANN), where the simulation results indicate that the neural networks being developmental in the process of simulating the operation of the servo motor type and got good performance and better results from the traditional real-time console use case.

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1. INTRODUCTION

In industries, there are many kinds of direct current (DC) servo motors using because of it has very small rotor inertia that led to very high torque/inertia because of much small time constants and relatively small power ratings therefore DC servo motors are used in computer-related equipment such as tape drives, printers, disk drives, and word processors [1], that require speed control accuracy and accurate positioning. In servo motors, the position and speed of the motor are controlled by signals sent from the feedback controller [2]. In recent years, proportional-integral-derivative (PID) controllers have been used in industrial processes because it achieve minimize error by modifying process control input [3], one of the advantages of the PID controller is the quality of its performance as a basic continuous feedback controller [4]. Alzarok and Musbah [2] refer to optimization strategy for speed control DC servo motor (DCSM) by tuning parameters of PID tuning using genetic algorithm (GA). In Mezher [5] include using laboratory virtual instrumentation engineering workbench (LabVIEW) program and PID controller to speed control of the DCSM by using a three basic processes: Proportional, integrative and derivative. In [6] this study proposed a robust control unit against load disturbance as a control scheme for a servo motor and used numerical simulation to verify the effectiveness of the scheme. In [7] optimum engine starting performance is obtained and an induction-type motor is optimized using artificial intelligence (AI), which reduces current, torque and flow. Abdullah *et al.* [8] is a comparison between two conventional and expert PID controllers and an artificial neural network for a three-phase induction motor. To determine the best value of the external resistance that can be added to the armature circuit in the motor to increase the starting torque and reduce the starting current. Artificial neural network (ANN) is used to solve problems in a different way than traditional computer techniques. A network consists of neurons that are a group of elements that process in parallel to solve a specific problem. ANN has good non-linear learning ability and is a kind of continuous time dynamic system [9]. The traditional PID control system is usually used with DC motor [10]-[13]. The conventional PID control system is easy and simple [14]-[16], but the non-linear system differs in its performance, so it is not as efficient or has lower efficiency than its use with linear systems. Other methods called expert have also appeared, including the neural network, which has had success in giving performance efficiency with the nonlinear system [17]-[19]. This research included the implementation of a continuous servo motor model using Matlab/Simulink and the use of both traditional and expert PID controllers represented by ANN in order to simulate and improve the operating characteristics of the electric motor.

2. MATHEMATICAL MODEL OF DC SERVO MOTOR

Electric motors play an important role, including servo motors, in many industrial applications such as their use in robotics [20]. In addition to being very suitable for wide range of adjustable speed drives and speed control [21]. Figure 1 and Figure 2 illustrated each of modeling and a block diagram that represented dynamic behavior of DCSM respectively, [21], [4] whereas the (1) describes transfer function of motor [22], [23].

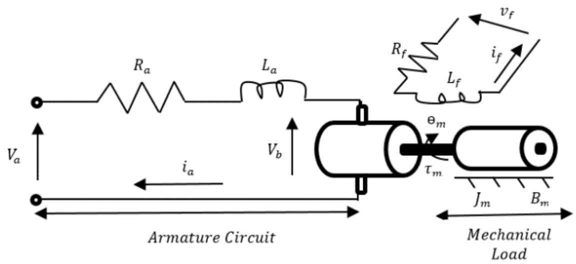

Figure 1. Model representation of DCSM

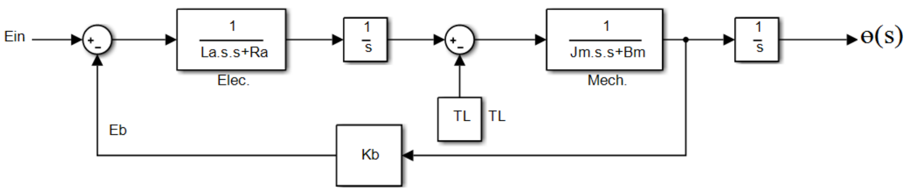

Figure 2. Dynamic behavior of DCSM

$$G(s) = \frac{\theta(s)}{Va\ (s)} = \frac{Kt}{s(Las+Ra)(Jms+Bm)+KtKbs} \tag{1}$$

Where: Jm = moment of inertia; Bm = viscous friction coefficient; ϴ = angular displacement of the motor shaft; Ra = armature resistance; La = armature inductance; Kt = torque constant; Eb = back emf constant; Ea = Electromotive voltage. In Table 1 shows the parameters of DCSM which is depended in this paper.

Table 1. Parameters of DCSM

Parameter	values
Electric resistance (Ra)	1 ohm
Electric inductance (La)	0.5 mH
Torque constant (Ka)	0.01 Nm/A
Back emf constant (Kb)	0.01 V/rad s-1
Moment of inertia (Jm)	0.01 Kg.m2
Friction coefficient (Bm)	0.1 N.ms

3. DCSM AND CONTROLLERS

The current research presents a study to develop the operation and performance characteristics of DCSM by using traditional controller (PID) and the intelligent controller (ANN). PID controller, in industrial control system. This controller includes three gains: 1) proportional (Kp), 2) derivative (Kd), and 3) integral (Ki) [24]. The objectfor tuning the PID gains is to obtain zero steady state error which refers to low values for each rising, settling and overshoot time, traditional PID block diagram is shown in Figure 3. In generally PID controller can be represented in (2) [25], [26].

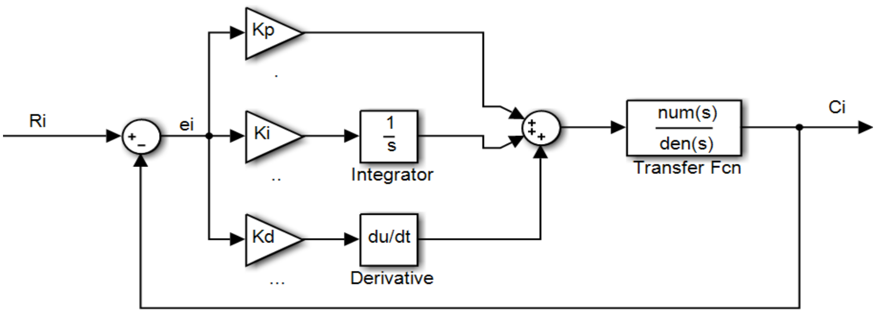

Figure 3. PID block diagram

$$Ri\ (T) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt} \tag{2}$$

Where Ri is the input of the plant $G(s)$. PID controller, it has three parameters gains (Kp , Ki ,and Kd) and the error is (ei). In Figure 4 shows the simulink model with PID controller [27]. In Figure 5 of the structure of PID controller [28], [29].

ANN, it is very effective with the learning pattern based on the train of data, and to imitate and function to introduce ANN the input and output function is trained, ANN used in identifying and control each non-linear and linear system, it is the principle feature to allow knowledge of any complex assignment to output mapping. ANN makes the construction of the sensor data causes it to react to different data, because its strong against noise compared to with conventional control and using data. Since it has so many inputs and outputs, it is adequately for multi-input and multi-output systems, and it can improve the control through learning. Figure 6 and Figure 7 show a model representing neurons signaling to construct and represent the structure of neurons.

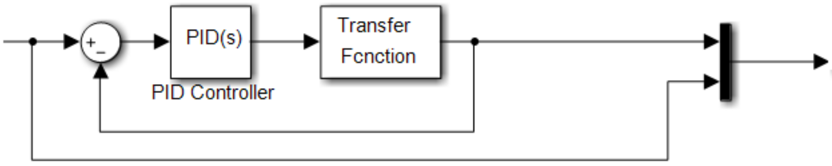

Figure 4. Simulink model with PID controller

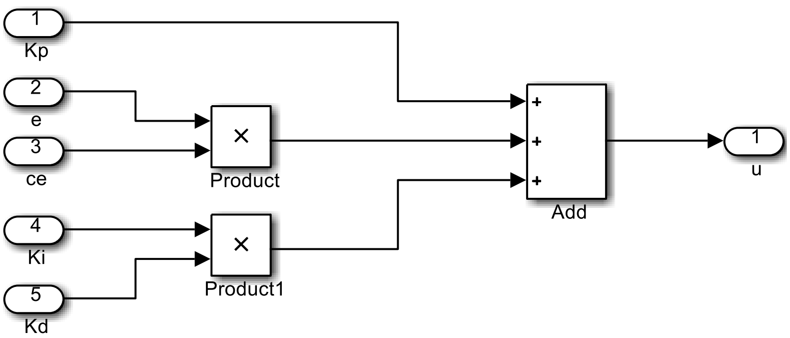

Figure 5. Simulink model of structure PID controller

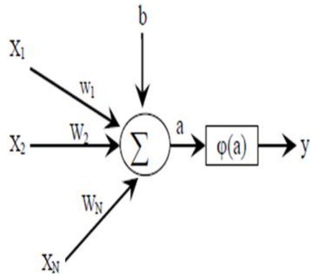

Figure 6. Building and representing neural networks

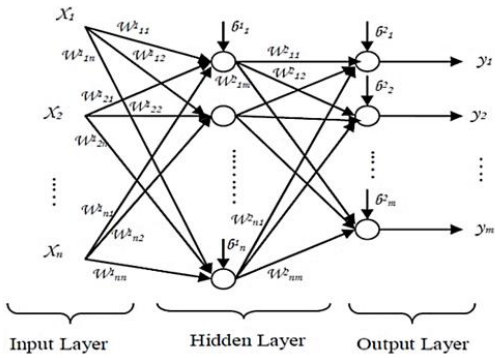

Figure 7. Model of construct and structure of neural network

4. SIMULINK MODELS

In this section, there are three simulation model. First the simulation model of servo motor without controller that show in Figure 8. Second the simulation model of DC servo motor with PID controller that show in Figure 9. Finally the simulation model of servo motor with ANN that show in Figure 10. In Figure 11 the construction of ANN, in Figure 11(a) custom neural and Figure 11(b) layer content. In Figure 12 shows a flowchart illustrating the steps.

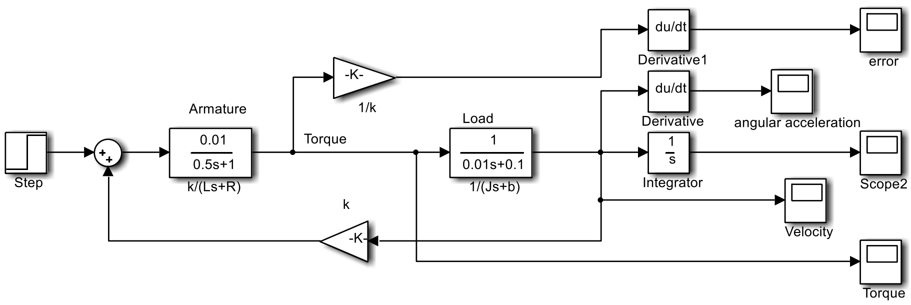

Figure 8. DC Servo motor without controller

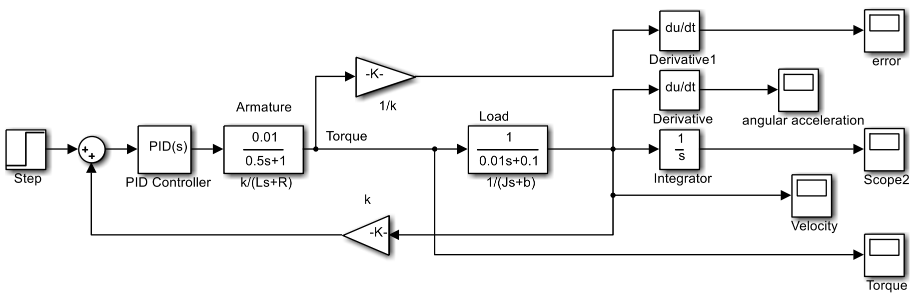

Figure 9. DC Servo motor with PID controller

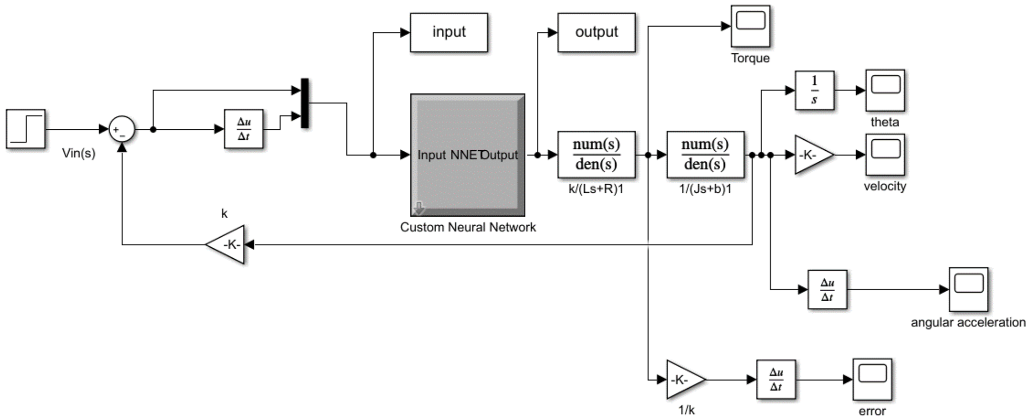

Figure 10. Simulink model of DC servo motor with ANN

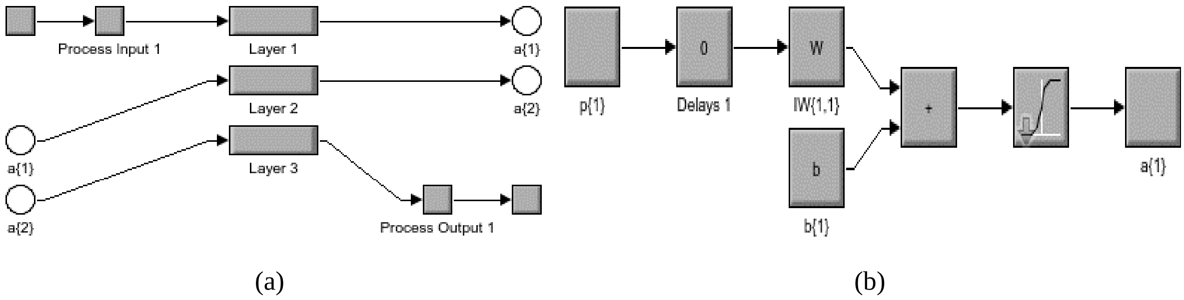

Figure 11. The construction of ANN: (a) custom neural and (b) layer content

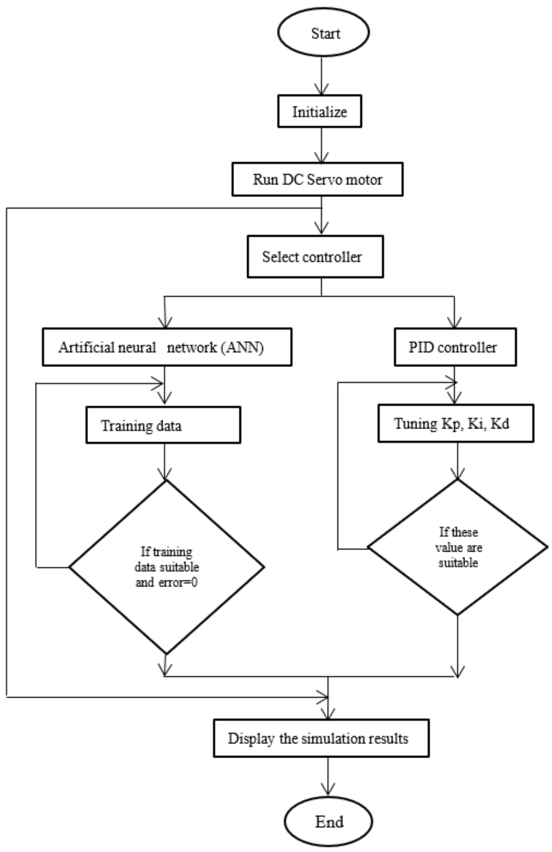

Figure 12. Flowchart illustrating the steps

5. SIMULATION RESULTS

In this section, the simulation is carried out in several steps, the first of which is to test the motor model and show the simulation results for the characteristics of the motor and include the DCSM characteristics which are error, torque, theta, velocity, and angular acceleration, respectively, which are shown in Figure 13. Second, the simulation is to compare the use and non-use of control units. That is, adding control and testing tools and testing the difference in performance, and there are three test auras in the simulation results. First the simulation result of a servo motor without control. Second, servo motor simulation result with PID controller. Finally the result of servo motor simulation with ANN. The Figure 13 shows the simulation results to determine the torque characteristics of the motor using traditional and expert control techniques, which can indicate the best performance. Other fragments can be observed showing simulation results for both angular acceleration and velocity, illustrating the difference in performance between the methods used in the simulation.

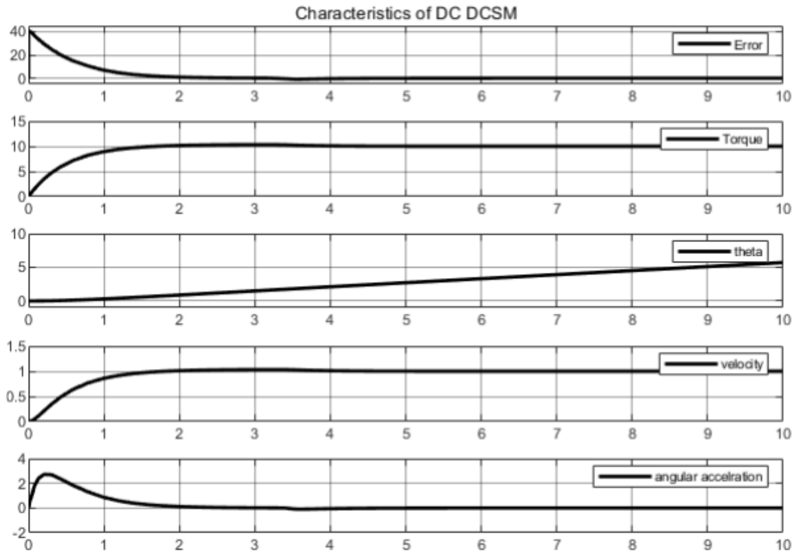

Figure 13. Characteristics of DC DCSM

First case without controller and second case with PID controller. Using PID controller led to improve performance of DCSM. The parameters of PID are represented in Table 2. PID controller is tuned to obtain better value of performance characteristics of DCSM. Also reduce value for each rise time and over shoot that show in Table 3. Therefore, the characteristics of DCSM is develop by using PID controller from the first case without controller.

Table 2. Control parameters

Control parameter	Values
P	35.2755
I	4.4005
D	19.45
N	405.4947

Table 3. Performance and robustness

Performance and robustness	Values
Rise time	0.411 sec
Settling time	6.1 sec
Overshoot	2.93%
Peak	1.03
Closed-loop stability	Stable

The torque characteristic of DCSM by using each of PID controller and ANN as show in Figure 14, we can see the comparative of these value for torque in Table 4 that refers to the best value can be obtained by using ANN. The velocity characteristic of DCSM by using each of PID controller and ANN as show in Figure 15, we can see the comparative of these value for torque in Table 5 that refers to the best value can be obtained by using ANN. also we can be shown these values of velocity develop by using controllers specially ANN which reaches to unity smoothly and overshoot equal to zero. The angular acceleration of DCSM by using each of PID controller and ANN as show in Figure 16, we can see the comparative of these value for torque in Table 6 that refers to the best value can be obtained by using ANN. The theta of DCSM by using each of PID controller and ANN as show in Figure 17, we can see the comparative of these value for torque in Table 7 that refers to the best value can be obtained by using ANN.

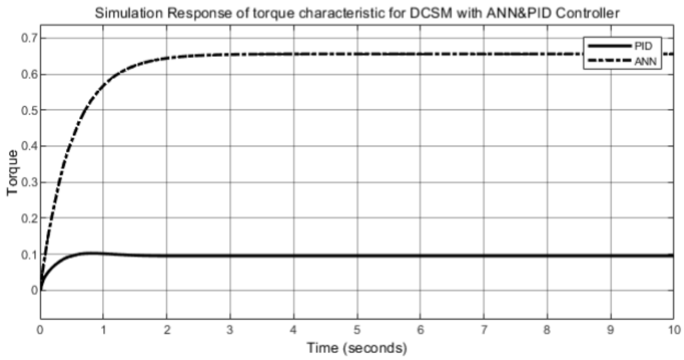

Figure 14. Torque characteristic of DCSM

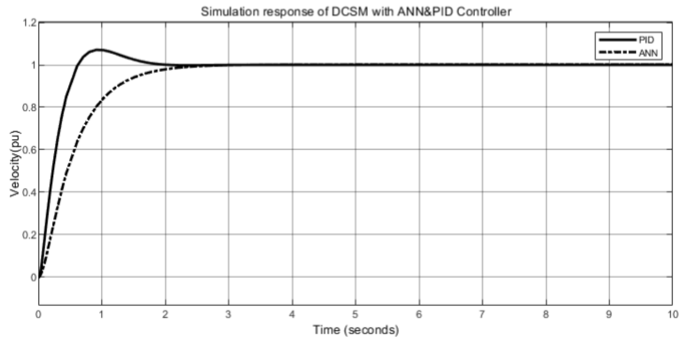

Figure 15. Velocity characteristic of DCSM

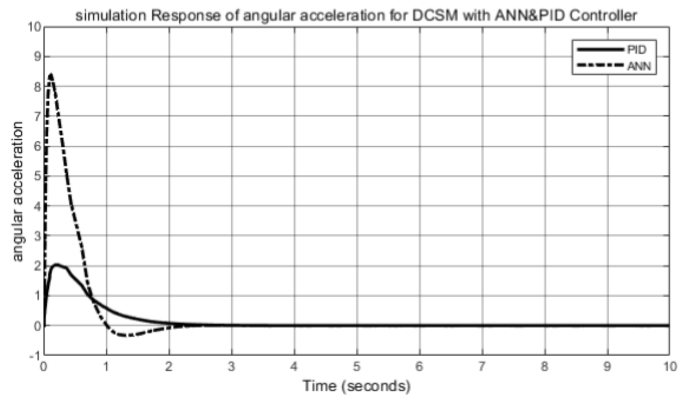

Figure 16. Angular acceleration of DCSM

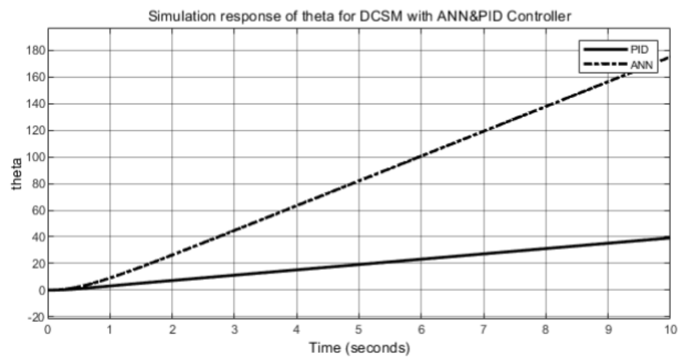

Figure 17. Theta of DCSM

Table 4. Torque characteristic

Time	PID	ANN
0	0	0
1	0.14	0.536
2	0.1	0.61
3	0.1	0.61
4	0.1	0.62

Table 5. Velocity characteristics

Time	PID	ANN
0.5	0.852	0.60
0.75	1.122	0.788
1	0.08	0.82
2	1	0.99
3	1	0.1
4	1	1

Table 6. Angular acceleration

Time	PID	ANN
0.25	8	1.25
0.5	7.5	2.35
1	2.5	0.09
2	0	0
3	0	0

Table 7. Theta of DCSM

Time	PID	ANN
1	4	6
2	9	10
3	18	17
4	30	20
5	50	28

Data of artificial neural network, the neural network training in this paper can be shown in Figure 18 to Figure 21. In Figure 18 shown the neural network training. In Figure 19 the neural network training performance. That show the best training performance with mean squared error (MSE). In Figure 20 show the neural network training state. In Figure 21 show the neural network regression data.

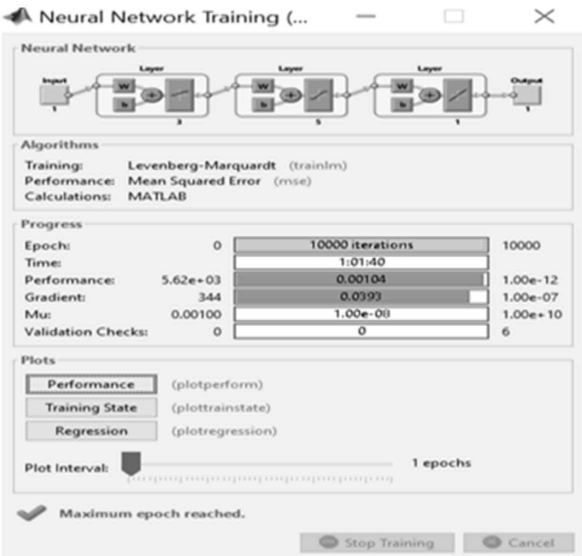

Figure 18. Neural network training

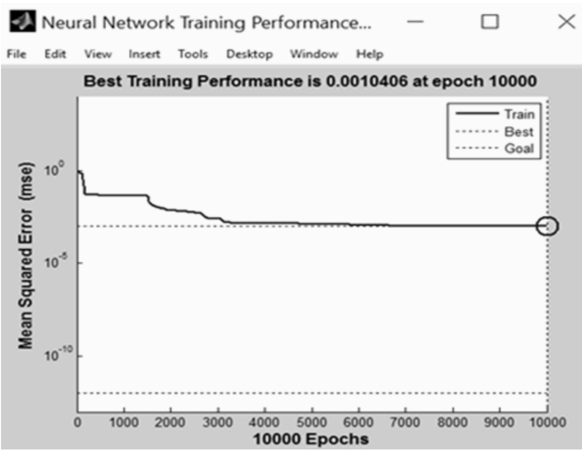

Figure 19. Neural network training performance

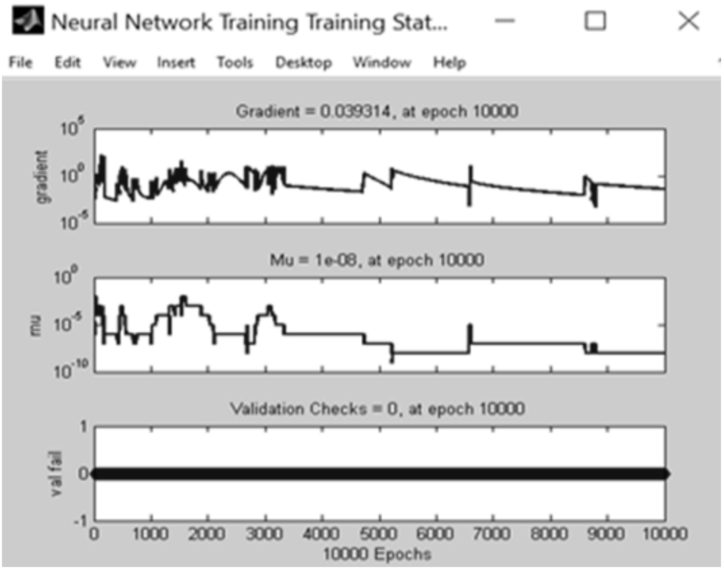

Figure 20. Neural network training state

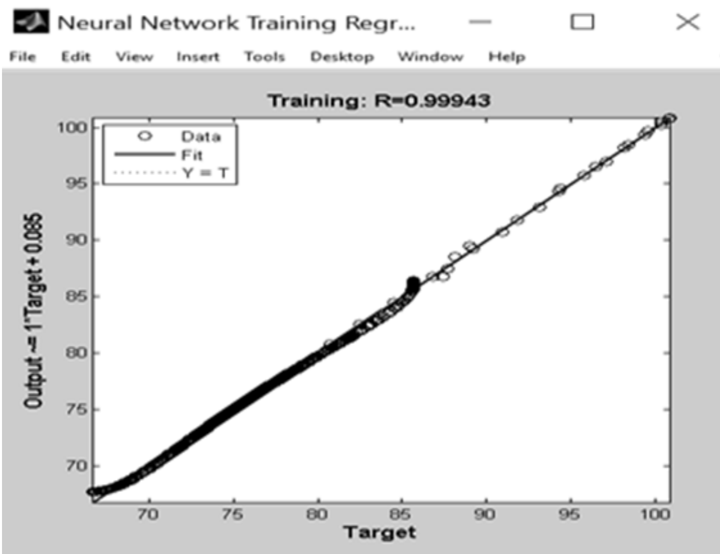

Figure 21. Neural network regression data

6. CONCLUSION

Due to the importance of the servo motor in the fields of industrial control, the current paper dealt with use of Matlab Simulink environment in order to develop and improve the characteristics of operation and performance of this motor through conventional controller (PID) and artificial neural network, as well as a comparison study has been done between these two controllers. The simulation results show the difference in performance between the operating condition without a control unit and the presence of two types of control units, including the traditional systems represented by the PID control unit and the expert systems. The improvement of performance using traditional systems showed that in the absence of a control unit and improvement of performance using expert systems, the simulation was by testing the characteristics of the motor for both torque, angular acceleration and rotational speed, and observing the response speed and the time required to obtain the steady state, the amount of overshoot, which was included in the simulation results in figures and tables. In the field of control, researchers have found that using a neural network is better than using traditional control devices, as it gives better results with high accuracy.

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