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DC Motor Speed Control using Artificial Neural Network

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Abstract: **This paper presents an insight into the speed control of DC motor using artificial neural network controller to meet the desired speed. The neural network scheme consist of two parts: one is neural estimator, which is used to estimate the motor speed and the other is the neural controller, which is used to generate a control signal for a converter. These two neural networks are trained by feed forward neural network algorithm. Simulation results are presented to demonstrate the effectiveness and advantage of control system of DC motor with ANN in comparison with conventional control scheme. For the comparison we used PID control.**

I. 1NTRODUCTION

DC motors still continued to be significant fraction in machinery purchased each year. There were several reasons for the continued popularity of DC motors. One was the DC power systems are still common in cars and trucks. Another application for DC motors was a situation in which wide variations in speed in needed. Most DC machines are like AC machines in that they have AC voltages and currents within them, DC machines have a DC output only because a mechanism exists that converts the internal AC voltages to DC voltages at their terminals. The greatest advantage of DC motors may be speed control. Since speed is directly proportional to armature voltage and inversely proportional to the magnetic flux produced by the poles, adjusting the armature voltage and/or the field current will change the rotor speed. Today, adjustable frequency drives can provide precise speed control for AC motors, but they do so at the expense of power quality, as the solid-state switching devices in the drives produce a rich harmonic spectrum. The DC motor has no adverse effects on power quality.

II. Classification of DC Motor and ANN

In Permanent Magnet motors, it falls into two categories: PM DC motors and PM AC motors .Permanent Magnet motor classification can be based on control strategy, which produces more classification of PM motors, the brushless DC (BLDC) motor and conventional permanent magnet .synchronous motor.

II.a Brushless DC (BLDC) Motor and ANN

A brushless DC motor (BLDC) is a synchronous electric motor which is power driven by direct-current electricity (DC) and which has an electronically controlled commutation system, instead of a mechanical commutation system based on brushes. In such motors, current and torque, voltage and rpm are linearly related. The new technologies are applied to these in order to design the complicated technology system. One of these new technologies is Artificial Neural Network (ANNs) which based on the operating principle of human being nerve neural. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems.

ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process.

There are a number of articles that use ANNs applications to identify the mathematical DC motor model. Then, this model is applied to control the motor speed. The inverting forward ANN with two input parameters for adaptive control of DC motor ANNs are applied broadly because all the ANN signal are transmitted in one direction, the same as in automatically control system, the ability of ANNs to learn the sample.

From the very beginning, it has been realized by systems theorists that most real world dynamical systems are nonlinear. However, linearization's of such systems around the equilibrium states yield linear models, which are mathematically obedient. In particular, based on the superposition principle, the output of the system can be computed for any arbitrary input, and alternately, in control problems, the input, which optimizes the output in some sense, can also be determined with relative ease. In most of the adaptive control problems, where the plant parameters are assumed to be unknown, the fact that the latter occur linearly makes the estimation procedure straightforward. The fact that most nonlinear systems thus far could be approximated satisfactorily by linear models in their normal ranges of operation has made them attractive in practical contexts as well. It is this combined effect of ease of analysis and practical applicability that accounts for the great success of linear models and has made them the subject of intensive study for over four decades. In recent years, a rapidly advancing technology and a competitive market have required systems to operate in many cases in regions in the state space where linear approximations are no longer satisfactory. To cope with such nonlinear problems, research has been underway on their identification and control using artificial neural networks based entirely on measured inputs and outputs.

This inherent parallel and distributed architecture of ANN can be successfully used for control of PM DC motor drive system. Some useful works on the speed control of DC motor drives using ANN based speed controllers were reported [13], [14], [2], [5], [4]. In Weerasooriya and Sharkawi [13-14] a DC motor was successfully controlled using an ANN, which has a capability of capturing the unknown, time invariant, nonlinear operating characteristics of the DC motor. However their works are primarily based on an off-line trained ANN with indirect model reference adaptive technique (MRAC). Due to the absence of on-line training of the ANN, the speed control is not totally satisfactory. This is because under unknown operating conditions, that are not considered during the off-line ANN training process, the ANN controller does not perform well.

Hoque, Zaman and, Rahman [4], [5] have reported work on a real-time implementation of an ANN based control of a PM DC motor drive. In their works a PM DC motor drive system with ANN speed controller is designed. A multi layer ANN structure with one feedback loop is adopted in order to achieve an adaptive speed control over a wide operating range with load and parameter variations. This arrangement involves both off-line and on-line weight and bias updating for the ANN using the back-propagation algorithm. Here the stability over a wide range of operating

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points was obtained by using an ANN structure with feedback loop. Although the drive system stability has been improved, the evaluated system responses have considerable amounts of speed overshooting under some operating conditions. This is because the learning rate is not adaptive during the on-line weights and biases updating.

Narendra and Mukhopadhyay [10] in their work introduced two classes of models which are approximations to the NARMA (The NARMA model is an exact representation of the input–output behaviour of finite-dimensional nonlinear discrete-time dynamical systems in a neighbourhood of the equilibrium state) model, and which are linear in the control input. Their extensive simulation studies have shown that the neural controllers designed using the proposed approximate models perform very well, and in many cases even better than an approximate controller designed using the exact NARMA model.

III. Problem Statement

When commerce with DC motor, the problem come across with it are efficiency and losses. In order for DC motor to function efficiently on a job, it must have some special controller with it. Thus, the Artificial Neural Network Controller will be used. There are too many types of controller nowadays, but ANN Controller is chosen to interface with the DC motor because in ANN, Non-adaptive control systems have fixed parameters that are used to control a system. These types of controllers have proven to be very successful in controlling linear, or almost linear, systems.

IV. Principle of operation of DC Motor

Consider a coil in a magnetic field of flux density **B** (figure 1). When the two ends of the coil are connected across a DC voltage source, current I flows through it. A force is exerted on the coil as a result of the interaction of magnetic field and electric current. The force on the two sides of the coil is such that the coil starts to move in the direction of force.

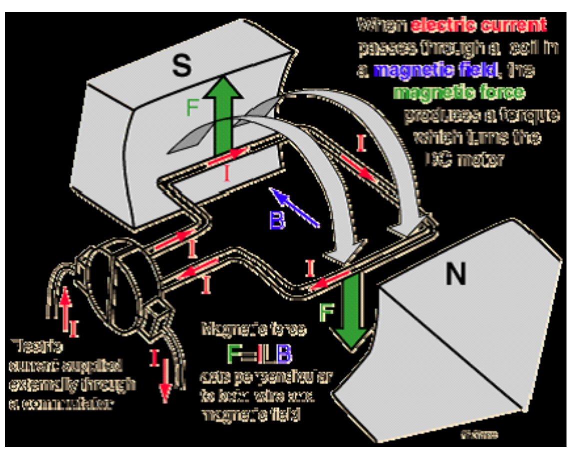

Fig.1 DC Motor

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In an actual DC motor, several such coils are wound on the rotor, all of which experience force, resulting in rotation. The greater the current in the wire, or the greater the magnetic field, the faster the wire moves because of the greater force created. At the same time this torque is being produced, the conductors are moving in a magnetic field. At different positions, the flux linked with it changes, which causes an *emf* to be induced ($e = d/dt$) as shown in figure 2. This voltage is in opposition to the voltage that causes current flow through the conductor and is referred to as a *counter-voltage* or *back emf*.

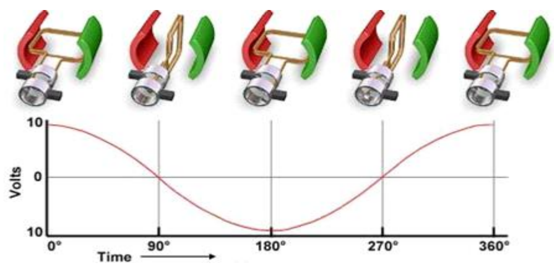

Fig..2 waveform

The value of current flowing through the armature is dependent upon the difference between the applied voltage and this counter-voltage. The current due to this counter-voltage tends to oppose the very cause for its production according to Lenz's law. It results in the rotor slowing down. Eventually, the rotor slows just enough so that the force created by the magnetic field ($F = Bil$) equals the load force applied on the shaft. Then the system moves at constant velocity.

V. Feed forward neural network structure

Recently, computational intelligence systems and among them neural networks, which in fact are model free dynamics, have been used widely for approximation functions and mappings. The main feature of neural networks is their ability to learn from samples and generalizing them and also their ability to adapt themselves to the changes in the environment. In fact, neural networks are very suitable for problems in the real world. These net-works with participation of a special kind of parallel pro-cessing are able to provide the modelling of any kind of nonlinear relations. Higher accuracy, robustness, generalized capability, parallel processing, learning static and dynamic model of MIMO systems on collected data and its simple implementation are some of the importance characteristics of the neural network that caused wide applications of this technique in different branches of sciences and industries, especially in designing of the non-linear control systems [9, 20].

VI. SIMULATION AND RESULT

VI a. Introduction

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In this section we are going to study the simulation of DC Motor in matlab . In this section, you will learn how to use the DC drive models of the Electric Drives library. First, we will specify the types of motor, converters, and controllers used in the seven DC drive models designated. These models are based on the DC brush motor in the Electric Drives library. As in any electric motor, the DC brush motor has two main parts, the stator (fixed) part and the rotor (movable) part. The DC brush motor also has two types of windings, the excitation or field winding and the armature winding. As its name implies, the field winding is used to produce a magnetic excitation field in the motor whereas the armature coils carry the induced motor current. Since the time constant (*L*/*R*) of the armature circuit is much smaller than that of the field winding, controlling speed by changing armature voltage is quicker than changing the field voltage. Therefore the excitation field is fed from a constant DC voltage source while the armature windings are fed by a variable DC source.

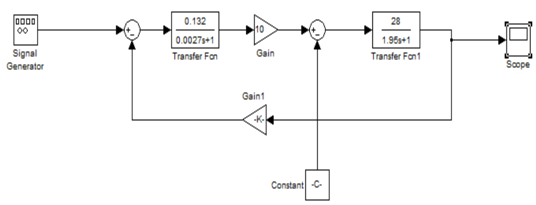

Fig.5.1 Simulink Block of separately excited DC Motor

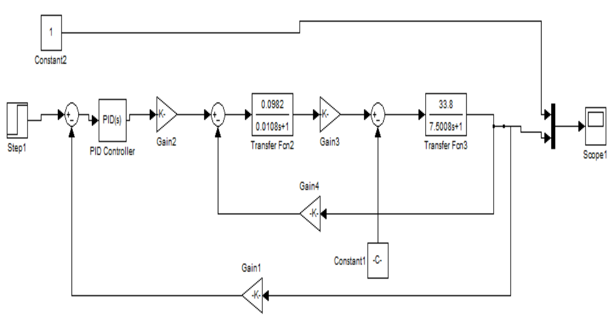

Fig.5.2 Dc Motor with PID controlle

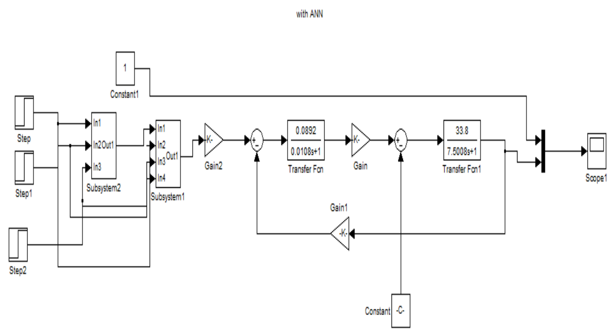

Fig.5.3 Simulation block of DC Motor With ANN Controller

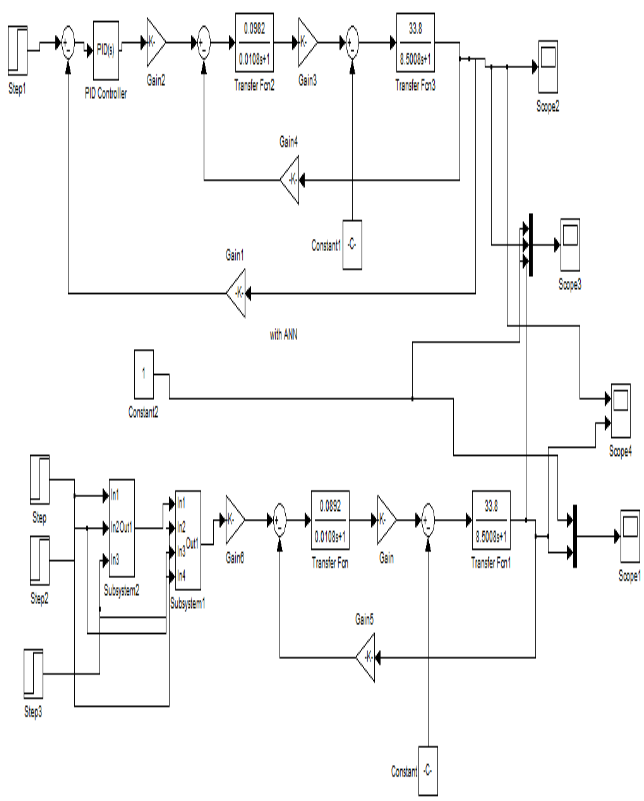

Fig.5.4 simulink block diagram of Artificial Neural Network and PID Controller

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The above diagram is show that the DC Motor simulink diagram with ANN and PID Controller. To varying the different parameter we find the response and compare to improve settling time with Adjusting gain value with respective controller, Also it can be observed that the speed overshooting of the ANN based controller is significantly lower than the other controllers. This critically damped speed response has been achieved using the adaptive leaning rate feature in the ANN based controller Also it can be observed that the speed overshooting of the ANN based controller is significantly lower than the other controllers. This critically damped speed response has been achieved using the adaptive leaning rate feature in the ANN based controller.

RESULT

SPEED

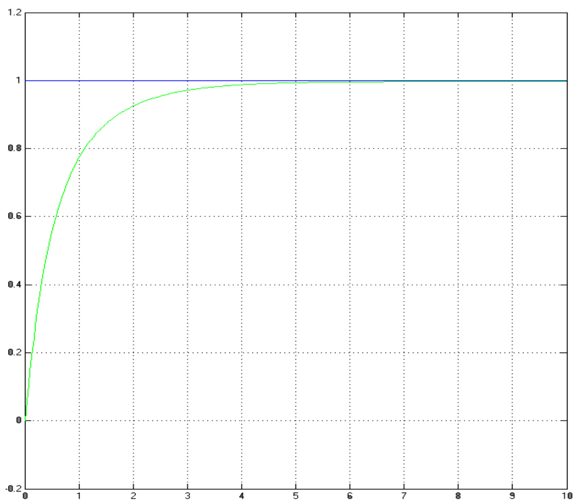
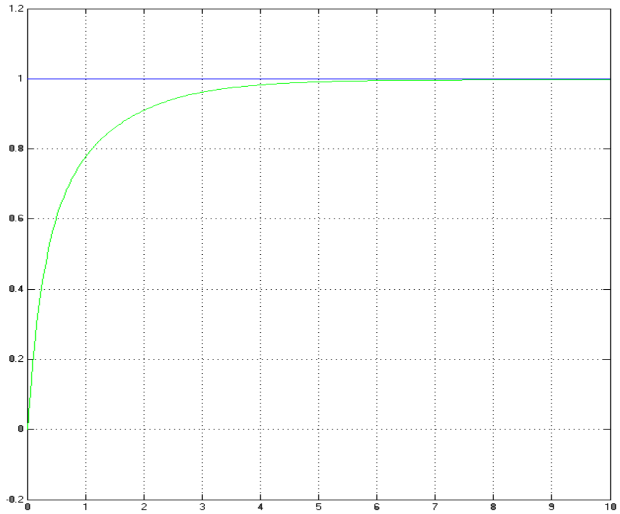


Fig.5.5 Time response of speed of DC Motor with PID Controller

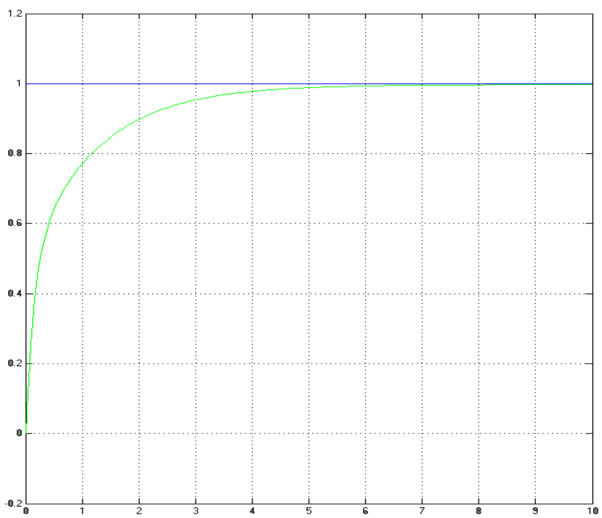
The above figure show the response of speed of DC Motor without using Artificial Neural Network . to analyze the better result we need to apply a controller as Artificial Neural Network . to design a controller we used a simple feed forward neural network with reference signal.

SPEED



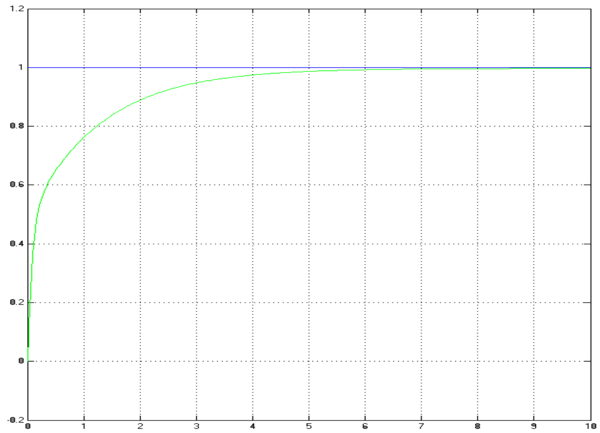
Time(s) Fig.5.6 response of speed of DC Motor with PID Controller with Tm1=75%Tm

The above figure show the response of speed of DC Motor without using Artificial Neural Network . with sully voltage to analyze the better result we need to apply a controller as Artificial Neural Network . to design a controller we used a simple feed forward neural network

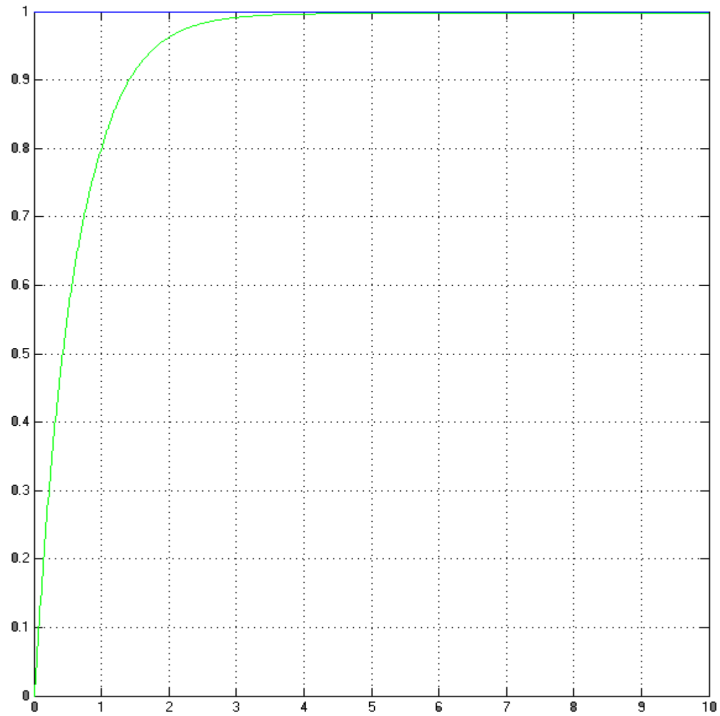


Time(s) Fig.5.7 response of speed of DC Motor using PID with Tm2=50%Tm

SPEED



Time(s) Fig.5.8 response of speed of DC Motor using PID With Tm3=30%Tm



Time(s)

Fig.5.9 response of speed of DC Motor using ANN

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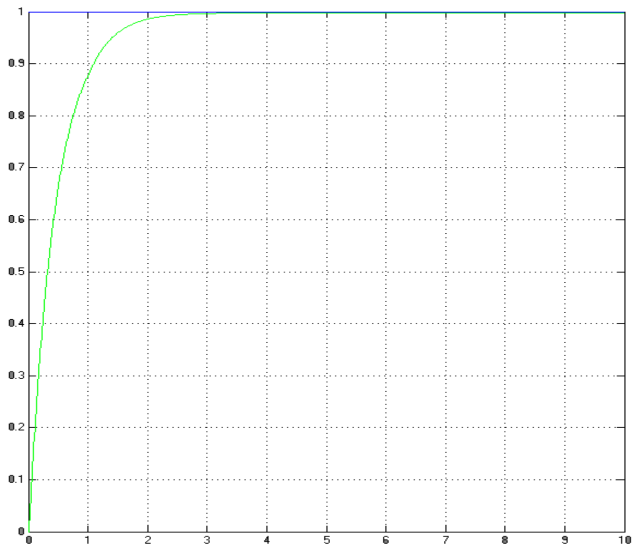


Fig.5.10 response of speed of DC Motor using ANN Controller with Tm1=75%Tm

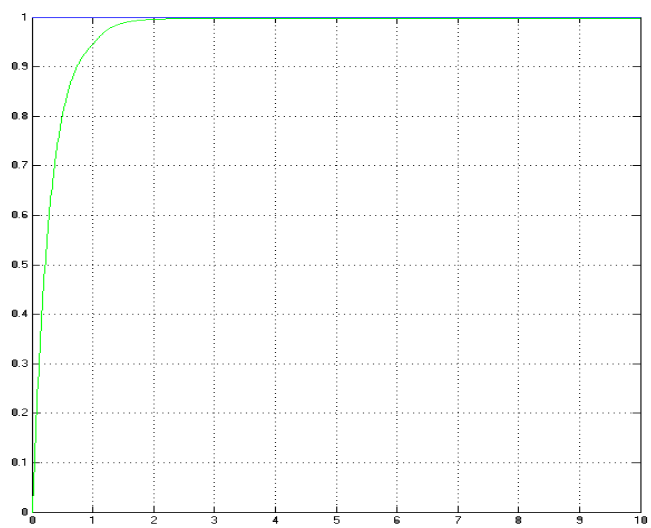


Fig.5.11 response of speed of DC Motor using ANN with Tm2=50%Tm

From the above figure we can say that the response of DC Motor speed using ANN is

SPEED

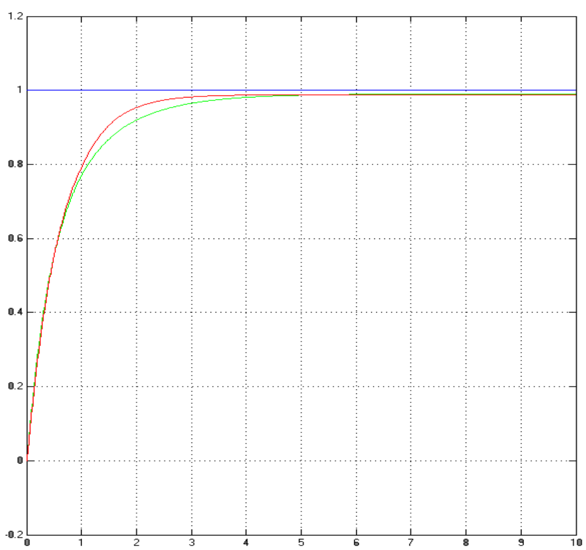
Time(s)

Fig.5.12 response of speed of DC Motor using ANN with Tm3=30%Tm

SPEED

Response with PID

Response with ANN



Time(s)

Fig.5.13 response of speed of DC Motor using ANN and PID From the above figure we can say that the response of DC Motor speed using ANN is better than PID Controller

SPEED

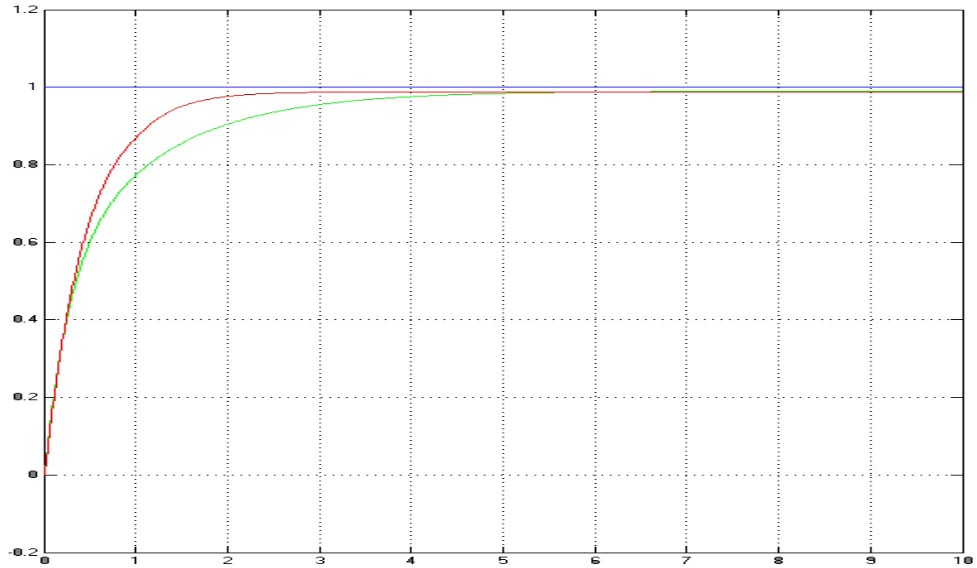


fig.5.14 DC motor and PID speed response Tm1=75%

Response with PID

Response with ANN

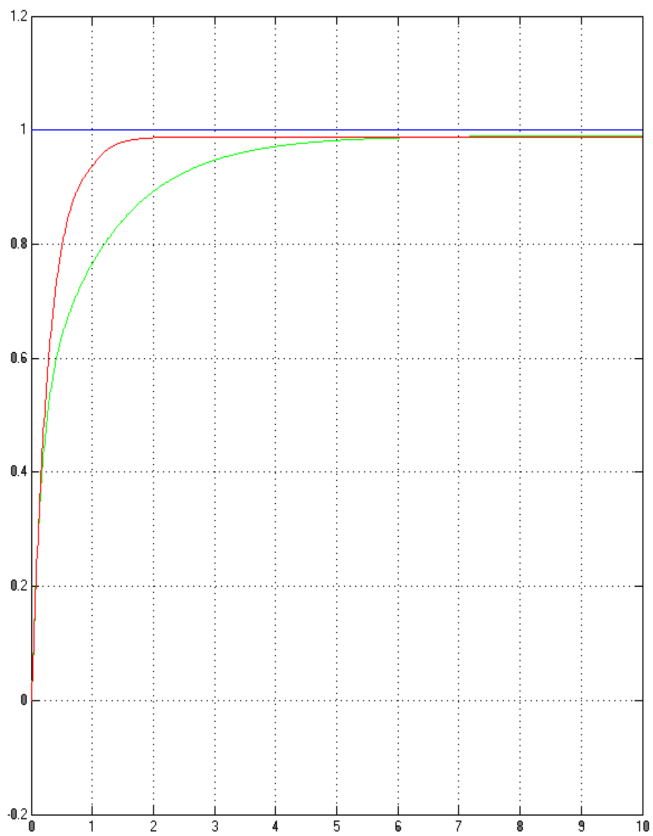


Fig.5.15 response of speed of DC Motor using ANN and PID with Tm2=50%Tm

SPEED

Response with PID

Response with ANN

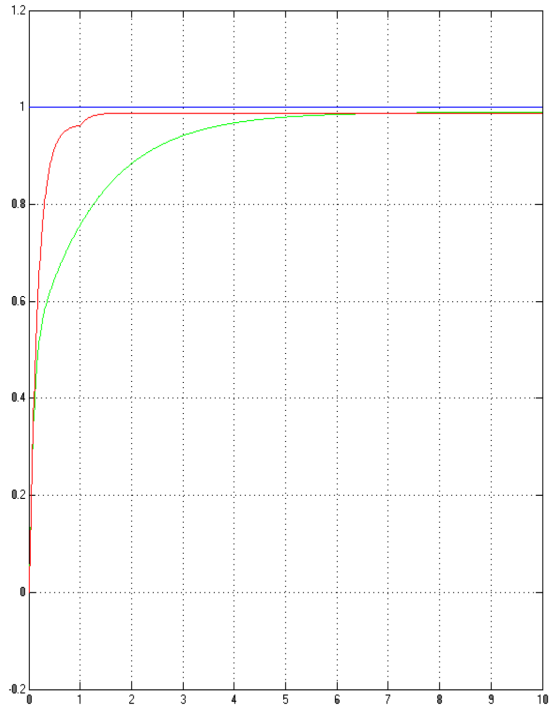


Fig.5.16 response of speed of DC Motor using ANN and PID with Tm3=30%Tm

CONCLUSION

The DC motor has been successfully controlled using an ANN. Two ANNs are trained to emulate functions: estimating the speed of DC motor and controlling the DC motor, Therefore , and so ANN can replace sensors speed in the model of the control systems. Using ANN, we don't have to calculate the parameters of the motor when designing the system control. It is shown an appreciable advantage of control system using ANNs, when parameters of the DC motor is variable during the operation of the motors. The satisfied ability of the system control with ANNs . ANN application can be used in adaptive controlling in the control system machine with complicated load. Nowadays, in order to implement the control systems using ANNs for DC motor on actual hardware, the ANN micro processor is being used.

Artificial Neural Network was used as a trainable non-linear mapping system. The speed of a self exited dc motor was controlled using the proposed ANN based adaptive controller. The details of development of the proposed controller were presented, including all analytical derivations. Programming and implementation details including hardware interfacing were given as well, for both the computer setup and the physical experimentation.

To controlled speed of DC Motor we used PID Controller for tuning the ANN to improve accuracy of speed. During the experimentation and after observing the results it has been proved that the proposed ANN based controller has a good ability to control the speed of the Separately excited dc motor, which shows the non-linearity behavior. Experimental results verify that this ANN and PID controllers both are controlled of speed of DC Motor with comparatively result.

The tracing error to less that . We can come to a conclusion that the proposed artificial neural network based adaptive controller is clearly superior, particularly in the case of non-linearities, parameter variations and load disturbances. The on-line weights and biases updating feature of the ANN can compensate for both parameter changes and disturbances during operation

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