International Journal of Recent Trends in Engineering, Vol 2, No. 6, November 2009

A Neural Network Based Speed Control for DC Motor

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***Abstract*-This paper introduces the new concept of Artificial Neural Networks (ANNs) in estimating speed and controlling the separately excited DC motor. The neural control scheme consists of two parts. One is the neural estimator, which is used to estimate the motor speed. The other is the neural controller, which is used to generate a control signal for a converter. These two networks are trained by Levenberg-Marquardt back propagation algorithm. Standard three layer feed forward neural network with sigmoid activation functions in the input and hidden layers and purelin in the output layer is used. Simulation results are presented to demonstrate the effectiveness and advantage of the control system of DC motor with ANNs in comparison with the conventional control scheme.**
***Keywords*--DC motor, artificial neural networks, control system**.

I. INTRODUCTION

Nowadays, the fields of electrical power system control in general and motor control in particular are gaining momentum. The new technologies are emerging for control scheme. One of these new technologies is Artificial Neural Networks (ANNs) which is based on the operating principle of human being nerve neural. This method is applied to control the motor speed [1]. Inverting forward ANN with two input parameters for adaptive control of DC motor [4] is used. However, these researches were not interested in the ability of forecasting and estimating the DC motor speed. ANNs are applied broadly because of the following special qualities:

1. All the ANN signals are transmitted in one direction, the same as in automatically control system.
2. The ability of ANNs to learn the sample.
3. The ability to creating the parallel signals in Analog as well as in the discrete system.
4. The adaptive ability.

With the special qualities mentioned above, ANNs can be trained to display the nonlinear relationships that the conventional tools could not implement. It also is applied to control complicated electro- mechanic system such as DC motor and synchronous machines [5]. To train ANNs, the input and output datasheets are to be determined first, and then design the ANNs net by optimizing the number of hidden layers, the number of neurals of each layer as well as the input/output number and the transfer function. The following is to find the ANNs net learning algorithm. ANNs are trained relying on two basic principles: supervisor and unsupervisor. According to supervisor, ANNs learn the input/ output data (targets) before being used in the control system. In this paper, the author would like to present the new ANN application in speed estimating and controlling separately excited DC motor. The motor speed is controlled by forecasting method and forecasting task which ANNs undertake from the terminal voltage parameter, armature current and a reference speed.

II. DC MOTOR CONTROL MODEL WITH ANNS

The DC motor is the obvious proving ground for advanced control algorithms in electric drives due to the stable and straight forward characteristics associated with it. It is also ideally suited for trajectory control applications as shown in reference [1-3]. From a control systems point of view, the DC motor can be considered as SISO plant, thereby eliminating the complications associated with a multi-input drive system.

A. Mathematical model of DC motor:

The separately excited DC motor is described by the following equations:

$$KF\omega_p(t) = -R_a i_a(t) - L_a[di_a(t)/dt] + V_t(t) \quad (1)$$

$$KFi_a(t) = J[d\omega_p(t)/dt] + B\omega_p(t) + T_L(t) \quad (2)$$

where,

$\omega_p(t)$ - rotor speed (rad/s)
V_t (t) - terminal voltage (V)
$i_a(t)$ - armature current (A)
$T_L(t)$ - load torque (Nm)
J - rotor inertia (Nm^2)
KF - torque & back emf constant (NmA^{-1})
B - viscous friction coefficient (Nms)
R_a - armature resistance (Ω)
L_a - armature inductance (H)

From these equations mathematical model of the DC motor can be created. The model is presented in Fig1.

Where,
Ta -Time constant of motor armature circuit and Ta=La/Ra (s)
Tm – Mechanical time constant of the motor Tm=J/B (s)

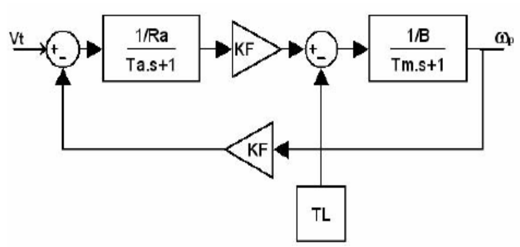
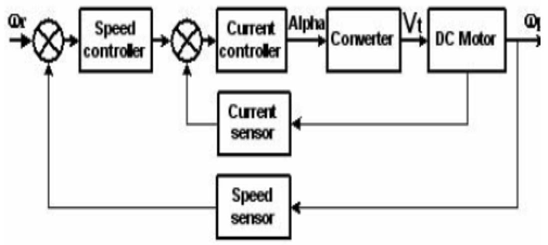


Fig1. The mathematical model of a separately DC motor

B. The conventional control systems of DC motor

There are different methods to synthesize control systems of DC motor, but for a comparison with method used ANNs authors presented a conventional control system of DC motor, where the regulator current and regulator speed are synthesized by Bietrage-optimum to reduce the over-regulation [6].



In the conventional model current and voltage sensors are very important elements and they play main role during regulation of speed alongside with regulator current and regulator speed. For the controlling of the speed of a DC machine the conventional feedback control logic approach is observed to be lower in accuracy due to direct sensor measurements. The approach is to be developed with an approach where an adaptive approach can be presented for making a decision for adaptively making a decision for selecting the speed parameters and providing and accurate controlling to the driving circuitry. For the realization of such an controlling approach in this paper an neural network based control strategy is proposed. The developed approach is briefed in the following sections.

C. The control system of DC motor using ANNs:

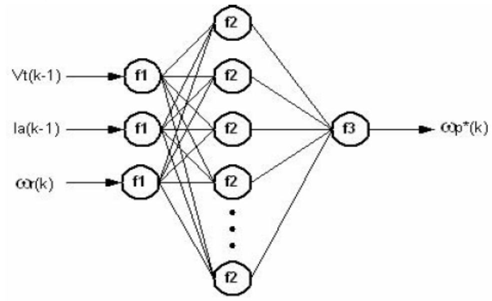
A neural network is a generalized approach of making the learning algorithm and making a decision for accurate controlling operation in various applications. The approach of neural network basically works on the provided priories information and makes a suitable decision for a given testing input based on the provided training information. This approach is analogous to the human controlling approach where all the past observations are taken as the reference information and are used as a decision variable. To obtain such estimation in current DC motor controlling approach the current DC motor drives are to be improved using such a learning approach. In this paper a dual level neural network approach is designed for DC machine speed controlling. A dual level modeling provides a faster training and converging as compared to a single level neural modeling. For the realization of a dual level neural modeling, two-neuro architecture namely ANN-control and ANN-train is proposed.

The 2 models of the control system of DC motor using ANNs is built with, ANN-train, and ANN-control unit where the network are trained to emulate a function: ANN-train to estimate the speed, ANN-control to control terminal voltage.

D. The structure and the process of learning ANNs.

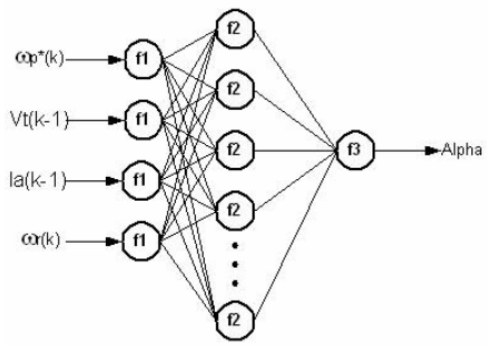
ANNs have been found to be effective systems for learning discriminates for patterns from a body of examples [5]. Activation signals of nodes in one layer are transmitted to the next layer through links which either attenuate or amplify the signal.

ANNs are trained to emulate a function by presenting it with a representative set of input/output functional patterns. The back-propagation training technique adjusts the weights in all connecting links and thresholds in the nodes so that the difference between the actual output and target output are minimized for all given training patterns [1]. In designing and training an ANN to emulate a function, the only fixed parameters are the number of inputs and outputs to the ANN, which are based on the input/output variables of the function. It is also widely accepted that maximum of two hidden layers are sufficient to learn any arbitrary nonlinearity [4]. However, the number of hidden neurons and the values of learning parameters, which are equally critical for satisfactory learning, are not supported by such well established selection criteria. The choice is usually based on experience. The ultimate objective is to find a combination of parameters which gives a total error of required tolerance a reasonable number of training sweeps [1,2,3].



f1: tansig; f2:tansig; f3: purelin
Fig 4. Structure of ANN-training

The ANN1 and ANN2 structure are shown in Fig4, and Fig5. It consists of an input layer, output layer and one hidden layer. The input and hidden layers are tansig-sigmoid activation functions, while the output layer is a linear function. Three inputs of ANN are reference speed ωr(k), terminal voltage Vt(k-1) and armature current ia(k-1). And output of ANN1 is an estimated speed ωp*(k). The ANN2 has four inputs: reference speed ωr(k), terminal voltage Vt(k-1), armature current ia(k-1) and an estimated speed ωp*(k) from ANN-1. The output of ANN is the control signal for converter Alpha.



f1: tansig; f2:tansig; f3: purelin
Fig 5. Structure of ANN model

The ANNs are trained off-line using inputs patterns of ω_r (k), V_t (k), i_a (k) - for ANN1, and of ω_r (k), V_t (k), i_a (k), ω_p*(k) for ANN2.
The training program of ANN is written in the Neural Network of Matlab program under m-file and it uses the Levenberg – Marquardt back propagation. There are no references that mention the optimal number of neural in each layer, so collecting the neural networks becomes more complicated. In order to choose the optimal number of neurals, the neural network is trained by m-file program, reducing the number of neurals in ANNs hidden layer until the learning error can be accepted.
The ANNs and the training effort are briefly described by the following statistics.

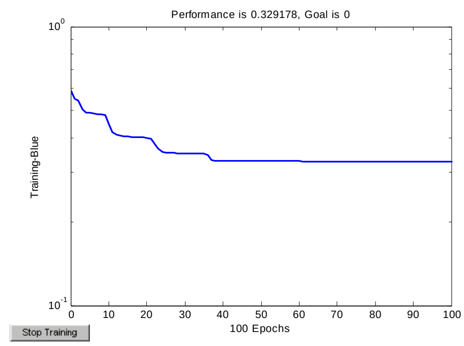
TABLE 1
THE RESULTS OF THE ANN TRAINING

Network	ANN1	ANN2
Number of input	3	4
Number of output	1	1
Number of hidden layer	1	1
Number of hidden neurons	3	4
Number of training patterns	1215	1215
Number of training sweeps	5000	5000
Learning error	1e-7	1e-8

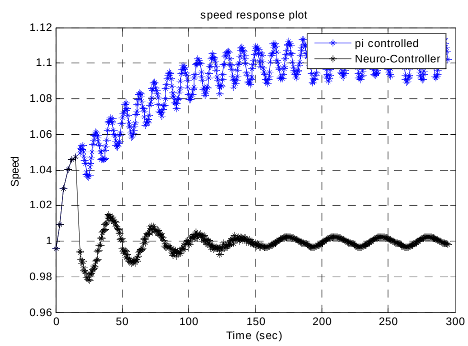
III. SIMULATION RESULTS

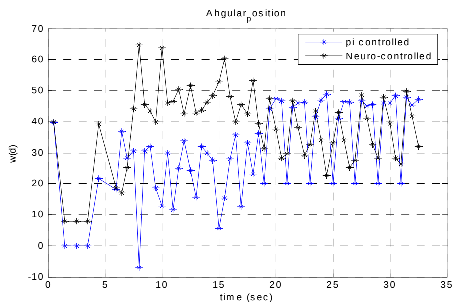
To simulate the conventional control system and control system with ANNs, a Simulink/Matlab program with the toolbox of Neural-network is used. The DC motor, which is used in models has the follows parameter 5HP, 240V, 1750 RPM, field 150V, J=0.02215 Nm2, KF=1.976 NmA-1, B=0.002953 Nms, Ra=11, La=0.1215 H. To compare the results of two control system schemes different operating modes of the DC motor are considered.

Training observation of NN designed

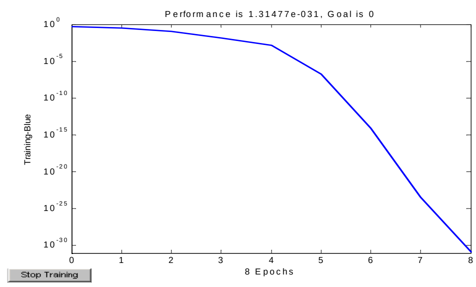


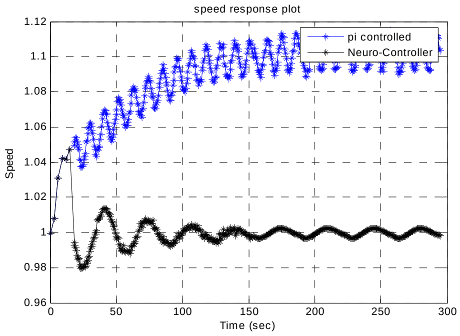
a) When reference parameters of the DC motor are same. At reference = 0.1

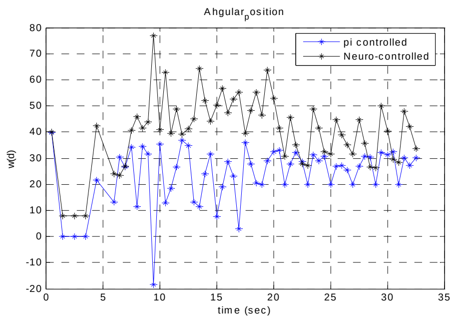




2) When reference parameters of the DC motor are different.







The observations illustrate the generated NN training error falls down to zero with the motor excitation. The speed response of the designed DC-machine is observed to shoot up in PI based control scheme to attain stability but with neural controller this speed is observed to be stable at a faster rate than the conventional method. The angular position of the field is observed to be maximum in case of DC motor with ANN as compared to PI – controller.

IV. 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, ANN can replace speed sensors in the control system models. Using ANN, there is no need to calculate the parameters of the motor when designing the system control. It has shown an appreciable advantage of control system using ANNs above the conventional one, when parameter of the DC motor is variable during the operation of the motors. The satisfied ability of the system control with ANNs is much better than the conventional controller. ANN application can be used in adaptive controls for machines with complicated loads.

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