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Comparison Between Conventional PID Controller and Neural Network PID Controller Based on DC Motor Speed Control

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Abstract— DC motor is a multivariable, strong coupling and nonlinear controlled system, and is difficult to setting up the accurate mathematical model. So, it cannot achieve good control effect using traditional PID control method. To tackle this problem ANN based PID controller is proposed in this paper. The objective here is to compare the response of DC motor controlled by two different PID controllers.

Keywords— ***ANN, DC Motor, PID Controller, Time Response, MATLAB, Control System***

Introduction

Proportional Integral Derivative Controller also known as PID controller is used to control different process variables like pressure, flow, temperature and speed in industrial applications. In this controller, a control loop feedback device is used to regulate all the variables. PID controller maintains the output such that there is zero steady state error between the variables and the desired output in closed-loop operations. Even though PID controller have been used extensively for industrial control system, it is very much inadequate for multi -variable nonlinear systems. DC Motor is one of such systems. For better control of DC motor in the past fuzzy PID controller have also been designed. In this paper, Artificial Neural Network (ANN) based PID controller is presented for the better control of DC motor.

ANN are computing systems inspired by the biological neural networks i.e. brain. A neural network is a massively parallel distributed processor made up of simple processing units (nodes), which has a natural propensity for storing experiential knowledge and making it available for use ANN consist of three-layer input layer, hidden layer, output layer and each layers have a number of nodes. Each unit or Node receives incoming signals, processes them, and can then transmit signals to other connected neurons. These signal transmissions are represented as real numbers, and the output of each neuron is determined by a non-linear function applied to the sum of its input signals. Each nodes have a weight to them. These weights play a crucial role in either strengthening or weakening the signal's impact at a given connection. Furthermore, neurons may have an associated threshold value, requiring the aggregate signal to surpass this threshold before initiating a signal transmission.

Dc Motor Speed Control

There are various types of DC motors. In this paper, Separately Excited DC (SEDC) Motor is considered to illustrate speed control using PID controller. Figure1 shows the circuit diagram of a separately excited DC motor.

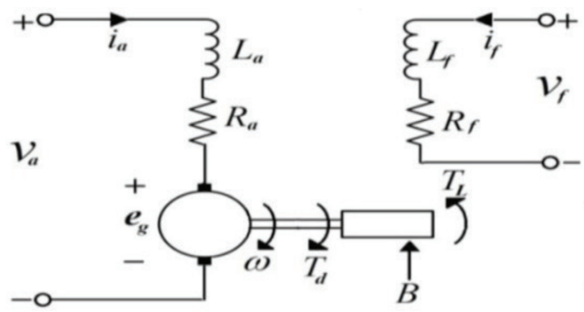

Fig 1 Circuit diagram of Separately Excited DC Motor.

The factors affecting the speed of a SEDC are described by the equation (1)

$$N \,\alpha\, \frac{V - I_a R_a}{\Phi} \tag{1}$$

Where,

V=Applied Voltage

I_a = Armature Current

R_a= Armature Winding

Φ = Magnetic flux per pole

In this paper, flux control method is considered for speed control of SEDC motor.

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DC Motor Modelling

A. Linear DC Motor Model

For modelling a Linear DC motor in MATLAB, the built in DC motor of MATLAB is used. Figure 2 shows the linear DC motor model in MATLAB Simulink.

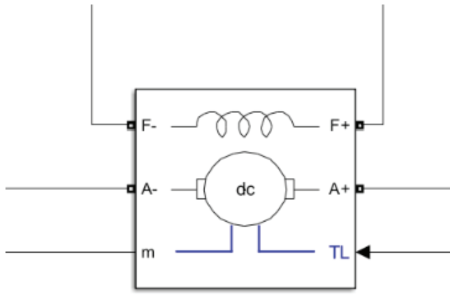


Fig 2 MATLAB Built-in DC Motor.

B. Non-Linear DC Motor Model

For non-linear modelling of DC motor, the following equations are used:

$$L_a \frac{dI_a}{dt} = V_a - I_a R_a - V_b \qquad (2)$$

$$L_f \frac{dI_f}{dt} = V_f - I_f R_f \qquad (3)$$

$$J \frac{d\omega}{dt} = T_e - B\omega - T_L - T_C \qquad (4)$$

Where,

I_a = Armature current

I_f = Field winding current

V_a =Armature voltage

R_a = Resistance of armature winding

R_f = Resistance of field winding

V_b = kΦ(If)ω = back emf

ω = Mechanical speed

L_a = Inductance of armature winding

L_f =Armature and field inductance

V_f = Field Voltage

T_e = Develop torque = kIaΦ

B = Viscous damping co-efficient

J = Moment of inertia for motor and load.

T_c = Coulomb Torque

T_L = Load Torque

Φ is magnetic flux produced by field current. The relation between the flux generated and the field current is shown in the Figure 3.

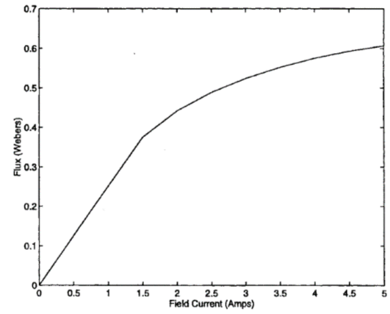


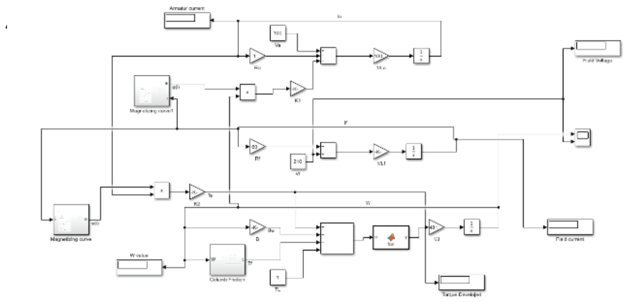
Fig 2 Magnetization Curve

For implementation of the curve in MATLAB piecewise linearization was used.

Similarly, for coulomb friction we use the equation

$$T_f = \mu * sgn(\omega) \qquad (5)$$

Where,



Using the equation (2), (3) and (4), the nonlinear model of SEDC motor is created. The armature voltage is constant for the motor. Whereas the Field voltage is controlled by the PID. Back emf is the product of motor constant, flux and angular speed. The value of angular speed is derived from eqn (4) and flux is the function of field current so by using magnetization curve the value of flux is determined for a given value of field current. Similarly, for Developed torque is calculated from product of motor constant, armature current and flux.

The parameters employed for the model is:

TABLE 1

REFERENCE PARAMETER FOR SEDC MOTOR.

Parameter	**Value**
L_f	60 H
L_a	0.01 H
R_a	1 Ω
R_f	60 Ω
K	0.1238 N m/A^2
B	0.0011 N ms/rad
j	0.00208 Kg m^2

Artifical Neural Network

In this paper, a multilayer feedforward network with three layers is employed. Figure 5 shows the visual representation of the designed ANN model with three layers. The three layers are: Input layer, Hidden layer and Output layer. The Input layers consist of input nodes through which input data for the ANN are fed. In this ANN there are four input nodes. These input nodes take the following data: Reference, Error, Actuation and Output signal of a conventional PID DC motor speed control system. The ANN consist of 6 hidden nodes. The number of nodes in Hidden layer is completely arbitrary. For the output layer we employed 3 output nodes which are Proportional constant, Integral constant and derivative constant.

In MATLAB model for PID, there is another constant called filter coefficient, so four output nodes for the output layer is employed. Thus, the ANN is designed with 4-6-4 topology. For the activation function, tan sigmoid function is employed in the hidden layer and linear function in output layer. The rest of the parameters like weights and biases were all set by MATLAB from training the ANN.

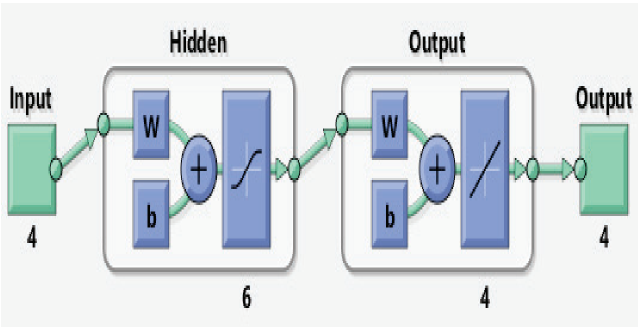


Fig 4 Visual Representation of the designed ANN

Training and Validating ANN

For training the neural network the datas were collected from the MATLAB simulation of the Linear and Non-linear DC motor speed control by conventional PID controller. 70% of the dataset were used for training the algorithm and remaining 30% were used for validating the neural network.

Testing the ANN

To test the performance of the ANN based PID control system was compared to the conventional PID control system. Both systems would have the same reference speed and load torque on them.

As for the training algorithm for the ANN all the 12 available training algorithms are employed for both the linear and Non-linear systems.

The best training algorithm i.e. the algorithm that produced the minimum error for linear system was Variable Learning Rate Gradient Descent (traingdx) and for Nonlinear system was Bayesian Regularization (trainbr).

Simulation & Result

Figure 6 & 7 shows the simulation results of speed responses with comparison between conventional PID and ANN based PID. The plot-1 represents the result with ANN based PID control response, Plot-2 represents the result with conventional PID and the plot-3 represents the reference speed for the system

Linear System:

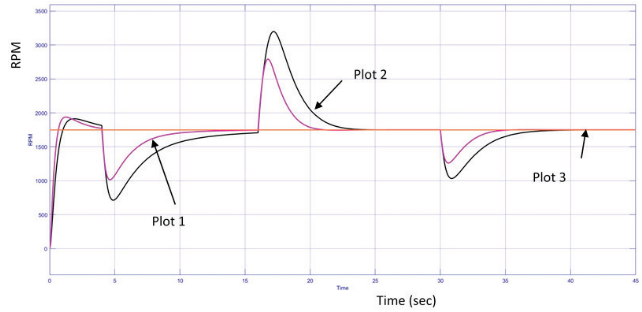


Fig 5 Comparison between speed response with conventional PID and ANN BASED PID FOR LINEAR SYSTEM.

TABLE 2

COMPARISON BETWEEN CONVENTIONAL PID AND ANN BASED PID TIME RESPONSE

S.No	Conventional	ANN
Delay Time(td)	370.79 ms	249 ms
Rise Time (tr)	1.020 s	0.667 s
Peak Time (tp)	1.635 s	1.263 s
Maximum Overshoot (Mp)	1450	1045
Setting Time (ts)	6.348 s	4.081 s
Error	0.132309716	0.001672594

Non-linear System

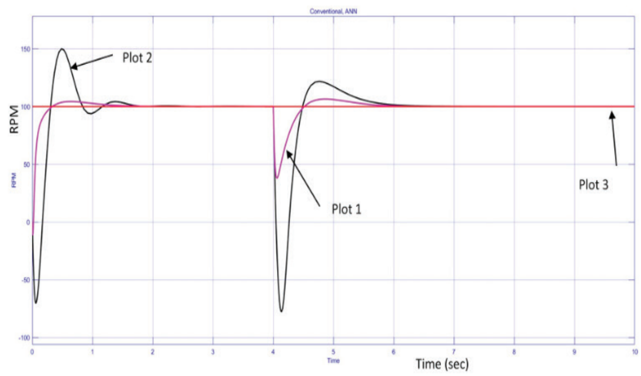


Fig 6 Comparison graph between conventional PID and ANN based PID for non-linear model

TABLE 3
COMPARISON BETWEEN CONVENTIONAL PID AND ANN BASED PID FOR NON-LINEAR MODEL TIME RESPONSE

S.No	Conventional	ANN
Delay Time(td)	232.305 ms	50.48 ms
Rise Time (tr)	305.461 s	313.280 s
Peak Time (tp)	496.711 s	571.142 s
Maximum Overshoot (Mp)	50	4.266
Setting Time (ts)	1.578 s	1.184 s
Error	0.000310193	2.49167E-05

Conclusions

Hence, ANN based PID control of DC motor can achieve better control of the system then the traditional PID controllers.

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