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Design and Simulation of Speed Control of DC Motor by Artificial Neural Network Technique

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Abstract- This paper proposes the artificial neural network based controller for speed control of a separately excited DC motor. The Artificial Neural Network controller allows controlling both type of systems i.e. linear and non-linear system by training the network. So it is a novel approach to study and a broad research area.

In this paper three controllers "PI, PID, ANC" have been designed and implemented in the MATLAB /Simulink model to examine the performance of DC motor with different loads. The results show that the ANC give better response compared to PI & PID controller.

Index Terms- PI, PID, ANN, Artificial Neural controller (ANC), DC Motor.

I. Introduction

Direct current (DC) motors have variable characteristics and are used extensively in variable-speed drives. DC motor can provide a high starting torque and it is also possible to obtain speed control over wide range. Why do we need a speed motor controller? For example, if we have a DC motor in a robot and we just apply a constant power to each motor on a robot, then the poor robot will never be able to maintain a steady speed. It will go slower over carpet, faster over smooth flooring, slower up hill, faster downhill, etc. So, it is important to make a controller to control the speed of DC motor in desired speed.

DC motor plays a significant role in modern industrial. These are several types of applications where the load on the DC motor varies over a speed range. These applications may demand high-speed control accuracy and good dynamic responses.

II. DC Motor model

The resistance of the field winding and its inductance of the motor used in this study are represented by R_f and L_f, respectively. The resistance of the armature and its inductance are shown by R_a and L_a respectively in dynamic model. Armature reactions effects are ignored in the description of the motor. This negligence is justifiable to minimize the effects of armature reaction since the motor used has either interlopes or compensating winding. The fixed voltage V_f is applied to the field and the field current settles down to a constant value. A linear model of a simple DC motor consists of a mechanical equation and electrical equation as determined in the following equations:

$$J_m \frac{d\omega}{dt} = K_m . \phi .I_a - b.\omega - M_{load}$$

$$L_a \frac{dI}{dt} = V_a - R_a .I_a - K_b . \phi . \omega$$

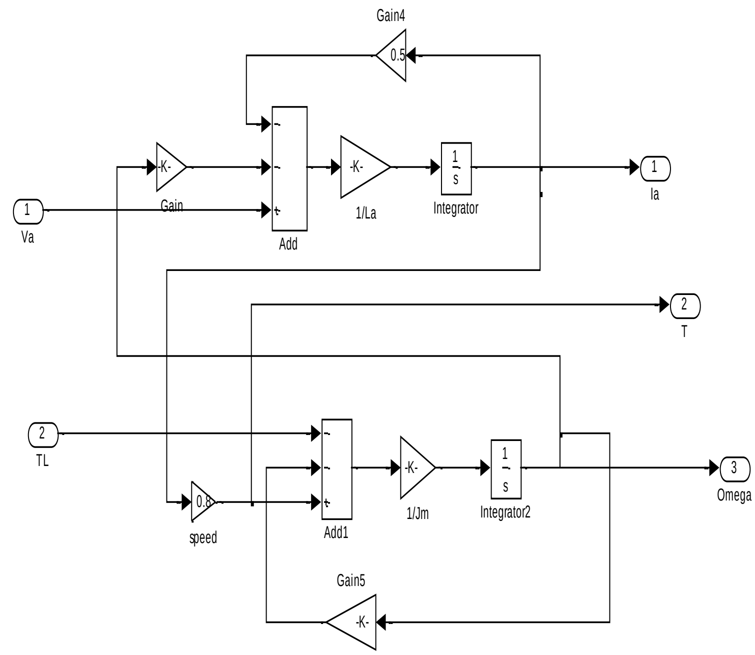

Fig 1.Simulink model of separately excited dc motor

Speed Response of DC Motor without any controller is shown below:

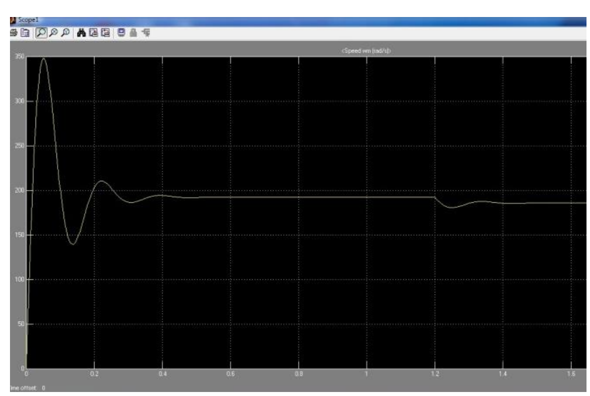

Fig 2. Speed Response of DC Motor without any controller

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The Peak Overshoot and number of oscillations obtained in above curve are much more and hence undesirable. These parameters are controlled by using different controllers discussed below.

III. PROPORTIONAL PLUS- INTEGRAL (PI) CONTROLLER

Since most of the process cannot work with an offset, they must be controlled at their set points and in order to achieve this, extra intelligence must be added to proportional controller and this is achieved by providing an integral action to the original proportional controller. So the controller becomes proportional – Integral controller.

- Under PI Controller as long as error is present the controller keeps changing its output and once the error is zero or it disappears the controller does not change its output.
- Integration is the mode that removes the offset or the error but sometimes it may make transient response worse.
- In PI Controller the output of the controller is changed proportional to the integral of the error.

The mathematical expression of the PI Controller is:

$$y = Kp.e + Ki\int e\,.dt$$

Where, Ki = Integral gain of the PI controller.

PI Controller has the following disadvantages:

- The response is sluggish at the high value of the integral time Tn.
- The control loop may oscillate at the small value of integral time Tn.

IV. PROPORTIONAL-INTEGRAL-DERIVATIVE (PID) CONTROLLER

PID Controller includes all the three control actions i.e. proportional, integral and derivative.

- A PID controller calculates and outputs a corrective action, which corrects the error between the process output and the desired set point that adjusts the process accordingly and rapidly.
- The output of the controller or the manipulated variable is obtained by adding P, I and D components and their associated coefficient.

The mathematical expression of the PID Controller is:

$$y = Kp.e + Ki\int e\,.dt + K_0\frac{de}{dt}$$

V. NEURAL NETWORK CONTROLLER

Neural networks are wonderful tools, which permit the development of quantitative expressions without compromising the known complexity of the problem. This makes them ideal in circumstances where simplification of the problem, in order to make it mathematically tractable, would lead to an unacceptable loss of information. As pointed out by Ziman, there is a fine balance between over-idealizing the initial hypothesis in order to make it amenable to mathematical analysis, and abandoning reality.

Neural networks resemble the human brain in the following two ways:

1. A neural network acquires knowledge through learning.
2. A neural network's knowledge is stored within inter-neuron connection strengths known as synaptic weights.

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. 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. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well.

The true power and advantage of neural networks lies in their ability to represent both linear and non-linear relationships and in their ability to learn these relationships directly from the data being modeled. Traditional linear models are simply inadequate when it comes to modeling data that contains non-linear characteristics.

The neural network consists of junctions which are connected with LINKS, also called processing units. For each junction a number is ordered, this number is called weight. The weights are the tools for the long distance information storing in the neural network, the learning process occurring with the appropriate modification of weights. These weights are modified so that the network input/output behavior is in consonance with the environment, which provide the input data.

The calculation algorithm consists of Calculation of the output of the network, with inputs and weights and modification of weights.

A single input neuron consists of a scalar input ‘p’ multiplied by the scalar weight ‘w’ to form ‘wp’ which is fed to the summer along with bias ‘b’ multiplied by ‘1’.

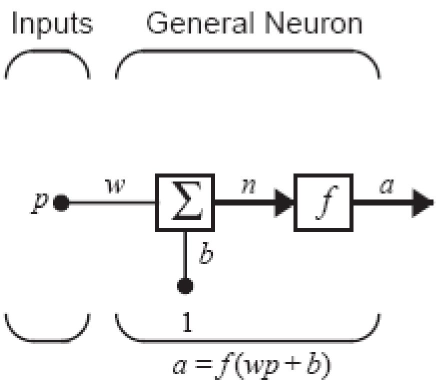

Figure 3: Basic Neural Network

The net input is wp+b and the output a is;
a=f (WP+b);
f- Transfer function
W & b can be adjusted by learning rule.

TRANSFER FUNCTION:

- LINEAR TF:

a = purelin (n)

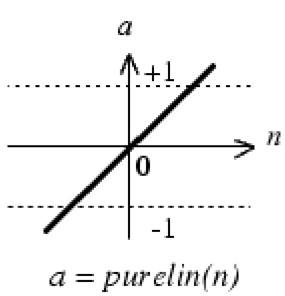

Figure 4: Linear Transfer Function

VI. CONTROLLER DESIGN

DC MOTOR SPEED CONTROL USING PI CONTROLLER:

The Figure 5 shows the model of PI controller for DC motor. The model is simulated with speed vs time of the DC motor with the fixed load and also with varying load.

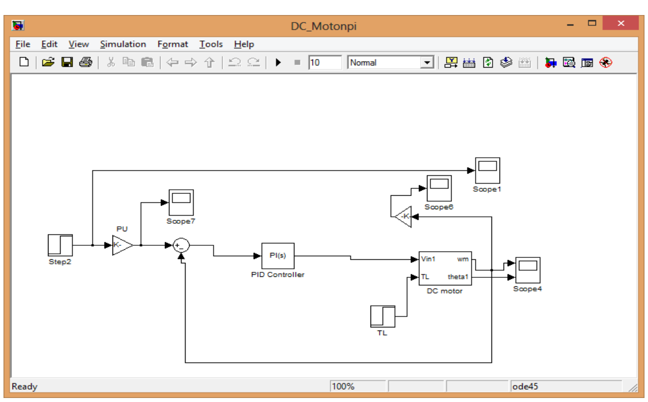

Figure 5. Mat Lab/Simulink model for DC motor using PI Controller

DC MOTOR SPEED CONTROL USING PID CONTROLLER:

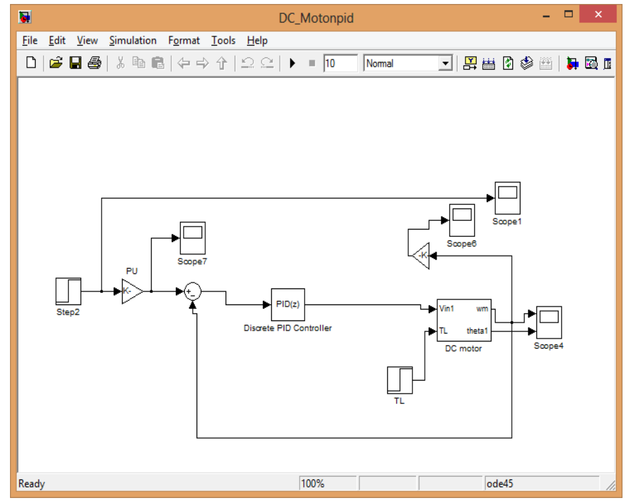

Figure 6 Mat Lab/Simulink model for DC motor using PID Controller.

The figure 6 shows the MatLab Simulink model for speed control of DC motor using PID controller.

ARCHITECTURE OF NEURAL NETWORK CONTROLLER

The Figure 7 shows the model of Artificial Neural Network controller (ANC) for DC motor. The model is simulated with speed vs time of the DC motor with the fixed load and also with varying load.

The ANC model is shown below:

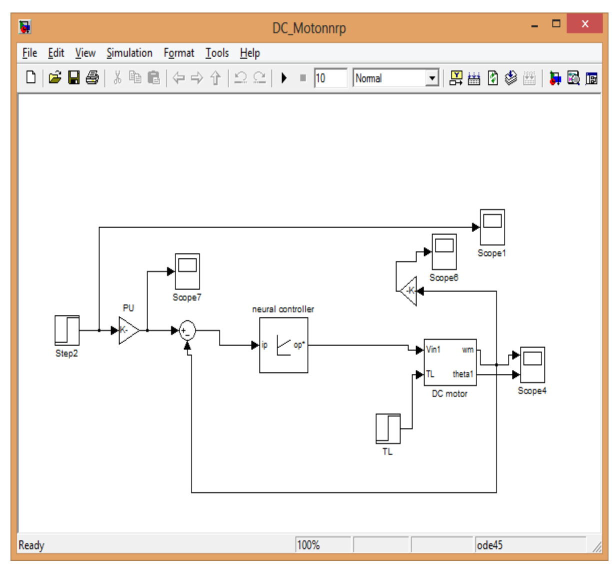

Fig 7. Simulink model of Artificial Neural Network Controller

VII. RESULT AND DISCUSSION

Simulation result of DC motor without using any controller is shown in fig 1. That fig may be compared with fig 8 for speed control.

COMPARISON OF SPEED CONTROL USING PI, PID, ARTIFICIAL NEURAL NETWORK CONTROLLER:

All the controllers are simulated on MATLAB and their ***Speed Vs Time*** characteristic is studied. The Characteristic is shown below:

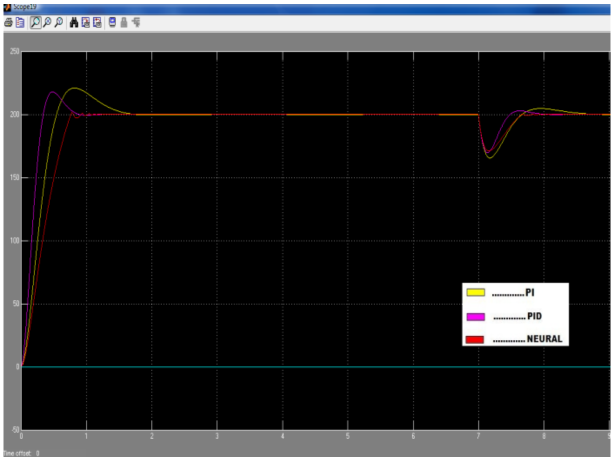

Fig 8. Simulation Result for DC motor using PI, PID and Artificial Neural Network Controller.

VIII. CONCLUSION

Simulation results show that:

- ANC have better performance by reducing, e_{ss} (Steady state error), M_p (maximum overshoot), T_r (rise time) and T_s (settling time).
- ANC have more sensitive responses against load disturbances to classical PI & PID controller.
- ANC is better than conventional PI & PID controller.

Biggest disadvantage of ANC is its more rise time.

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