Study of Performance enhancement of PID controller by Implementation of Neurofuzzy technology

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ABSTRACT

DC drive systems are often used in many industrial applications such as robotics, actuation and manipulators. In the first two, a wide range of position control is required. Tuning method for PID controller is very important for the process industries. Proportional Integral Derivative controllers have the advantage of simple structure, good stability, and high reliability. Accordingly, PID controllers are widely used to control system outputs, especially for systems with accurate mathematical models. The key issue for PID controllers is the accurate and efficient tuning of parameters. The aim of this dissertation is to study the PID tuning of a plant model using Adaptive Neuro Fuzzy Controller. In order to solve this problem a PID controller under Adaptive Neuro Fuzzy Controller with self–tuning is applied, which will perform high efficiency position control. The efficiency of Control Algorithm is presented through a MATLAB Simulink model. It is found that the proposed PID parameters adjustment by the Adaptive Neuro Fuzzy Controllergives better performance. This proposed method could be applied to the higher order system also.

Keywords:PID controller, PID tuning, DC motor, Neurofuzzy controller set of rules

1.INTRODUCTION

1.1 Overview

In most of the industrial processes like electrical, mechanical, construction, petroleum industry, iron & steel industry, power sectors, development sites, paper industry, beverages industry, etc. the need for higher productivity is placing new demands on mechanisms connected with electrical motors. They lead to different problems in work operation due to fast dynamics and instability. That is why control is needed by the system to achieve stability and to work at desired set targets. The robust speed and position control of electrical motors is of outmost importance due to various non-linear effects like load and disturbance that affected the motor to deviate from its normal operation.

The direct current (DC) motor is a gadget that utilized as a part of numerous businesses so as to change the characteristic of electrical energy into mechanical energy [8]. This is all result from the availability of speed controllers is wide range, easily and many ways. In most applications, speed control is very important. For example, if we have DC motor in radio controller car, in the event that we simply apply a staticpower to the motor, it is impossible to maintain the desired speed. It will go slower over rocky road, slower uphill, faster downhill and so on.

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In this way, it is paramount to make a controller to control the speed of DC motor in wanted velocity.

DC motor plays a significant role in modern industry. The purpose of a motor speed controller is to take a signal representing the demanded speed, and to drive a motor at that speed. There are numerous applications where control of speed is required, as in rolling mills, cranes, hoists, elevators, machine tools, transit system and locomotive drives. Usages stated above may request fast control exactness and great element reactions.

1.2Problem Identification

The position control of electrical motors is most important due to various nonlinear effects like load and disturbance that affects the motor to deviate from its normal operation. The position control of the motor is to be widely implemented in machine automation.Currently, more than half of the controllers used in industry are PID controllers. In the past, many of these controllers were analog; however, many of today's controllers use digital signals and computers. When a mathematical model of a system is available, the parameters of the controller can be explicitly determined. However, when a mathematical model is unavailable, the parameters must be determined experimentally. Controller tuning is the process of determining the controller parameters which produce the desired output. Controller tuning allows for optimization of a process and minimizes the error between the variable of the process and its set point.

Controller tuning involves the selection of the best values ofK_c, T_i andT_d. This is often a subjective procedure and iscertainly process dependent. A number of methods have been proposed inthe literature over the last 50 years. However, recent surveys indicate,

- 30 % of installed controllers operate in manual.
- 30 % of loops increase variability.
- 25 % of loops use default settings.
- 30 % of loops have equipment problems.

A possible explanation for this is lack of understanding of process dynamics,lack of understanding of the PID algorithm or lack of knowledge regardingeffective tuning procedures. This section of the notes concentrates on PIDtuning procedures. The suggestion being that if a PID can be properly tunedthere is much scope to improve the operational performance of chemicalprocess plant.When tuning a PID algorithm, generally the aim is to match somepreconceived 'ideal' response profile for the closed loop system.

Types of controller tuning methods include the trial and error method, and process reaction curve methods. The most common classical controller tuning methodis Ziegler-Nichols method. This method is often used when the mathematical model of the system is not available. It can be used for both closed and open loop systems. A closed-loop control system is a system which uses feedback control. In an open-loop system, the output is not compared to the input.

The equation below shows the PID algorithm as discussed in the previous PID Control section.

$$u(t) = K_c\left(\varepsilon(t) + \frac{1}{T_i}\int_0^t \varepsilon(t')\,dt' + T_d\frac{d\varepsilon(t)}{dt}\right) + b \qquad (1.1)$$

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u = control signal

ε= difference between the current value and the set point.

K_c = gain for a proportional controller.

T_i = parameter that scales the integral controller.

T_i = parameter that scales the derivative controller.

t = time taken for error measurement.

b = set point value of the signal, also known as bias or offset.

The Ziegler-Nichols formulation is a classical tuning method which found a wide range of applications in the controller design process. However, computing the gains does not always give best results because the tuning criteria presume a one-fourth reduction in the first two-peaks that's why system stability here is matter of unreliable stability that's why we are adopting Adaptive Neuro Fuzzy Controller.

1.3 Objective

The control of DC motor uses the digital signal processing system. Proportional Integral Derivative (PID) controller has been widely used for processes and motion control system in industry. Now more than 90% of control systems are still with PID controllers. The most critical step in the application of PID controller is parameters tuning. The main objective of the work is to design a controller of any plant model (CSTR and BLDC) by selection of PID parameters using Adaptive Neuro Fuzzy Controller.

2. BACKGROUND AND SIGNIFICANCE

2.1 DC Motor

At the most essential level, electric motors exist to change over electrical energy into mechanical energy. This is carried out by method for two communicating magnetic fields – one stationary, and an alternate connected to a part that can move. Various sorts of electric motors exist, however for the most part utilized DC motors within somestructure or an alternate. DC motors have the potential for high torque abilities (despite the fact that this is for the most part a capacity of the physical size of the motor), are not difficult to scale down, and can be "throttled" through conforming their supply voltage. DC motors are additionally the least difficult, as well as the most established electric motors.

The fundamental standards of electromagnetic induction were found in the early 1800's by Oersted, Gauss, and Faraday. By 1820, Hans Christian Oersted and Andre Marie Ampere had found that an electric current delivers an magnetic field. The following 15 years saw a whirlwind of cross-Atlantic experimentation and advancement, heading at last to a straightforward DC revolving motor. Various individuals were included in the work, so legitimate credit for the first DC motor is truly a capacity of exactly how extensively we decide to characterize the expression "motor". [15]

2.2 Continuous PID

The three controllers when combined together can be represented by the following transfer function.

$$G_C(s) = K\,(1 + 1/sT_i + sT_d) \qquad (2.1)$$

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This can be illustrated below in the following block diagram,

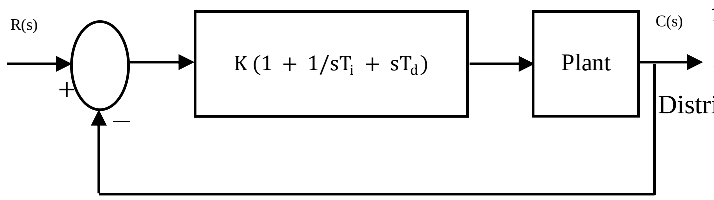

Figure 2.1: Block diagram of Continuous PID Controller

What the PID controller does is basically is to act on the variable to be manipulated through a proper combination of the three control actions that is the P control action, I- control action and D control action.The P action is the control action that is proportional to the actuating error signal which is the difference between the input and the feedback signal. The, I-action is the control action which is proportional to the integral of the actuating error signal. Finally the D action is the control action which is proportional to the derivative of the actuating error signal. With the integration of all the three actions, the continuous PID can be realized.This type of controller is widely used in industries all over the world. In fact a lot of research, studies and application have been discovered in the recent years. [10]

3. PROPOSED METHODOLOGY

3.1 PID Controller

PID controller consists of Proportional Action, Integral Action and Derivative Action. It is commonly refer to Ziegler-Nichols PID tuning parameters. It is by far the most common control algorithm. Under this heading, the basic concept of the PID controls will be explained. PID controller's algorithm are mostly used in feedback loops. PID controllers can be implemented in many forms. It can mplemented as a stand-alone controller or as part irect Digital Control (DDC) package or even Distributed Control System (DCS).

It is interesting to note that more than half of the industrial controllers in use today utilize PID or modified PID control schemes. A diagram illustrating the schematic of the PID controller is shown below. Such set up is known as non-interacting form or parallel form. [12]

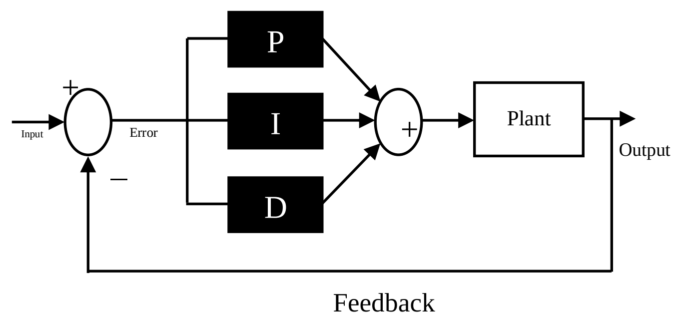

Figure 3.1: Schematic of the PID Controller- Non Interacting form

In proportional control,

$$P_{term} = K_P * Error \quad (3.1)$$

It uses proportion of the system error to control the system. In this action an offset is introduced in the system.

In Integral control,

$$I_{term} = K_I * \int Error\, dt \quad (3.2)$$

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It is proportional to the amount of error in the system. In this action, the I-action will introduce a lag in the system. This will eliminate the offset that was introduced earlier on by the P-action.

In derivative control,

$$D_{term} = K_D * \frac{d(Error)}{dt} \quad (3.3)$$

It is proportional to the rate of change of the error. In this action, the D-action will introduce a lead in the system. This will eliminate the lag in the system that was introduced by the I-action earlier on.

3.2Modeling of BLDC Motor

Brushless DC motors have the field coil in parallel (Brushless) with the armature. The current in the armature and field coil are free of each other. Therefore, these motors have fabulous speed and position control. Henceforth BLDC motors are commonly utilized that oblige five or more HPs (Horse Power). The equations depicting the vibrant performance of the BLDC motor are given as under.[16]

$$v = Ri + L\frac{di}{dt} + e_b \quad (3.4)$$

$$T_m = K_T i_a(t) \quad (3.5)$$

$$T_m = J\frac{d^2\theta(t)}{dt^2} + B\frac{d\theta(t)}{dt} \quad (3.6)$$

$$eb = e_b(t) = K_b\frac{d\theta(t)}{dt} \quad (3.7)$$

Where, R = Armature resistance in ohm.

L = Armature inductance in henry.

$i = i_a$ =Armature current in ampere.

v = Armature voltage in volts.

eb = Back EMF voltage in volts.

K_b = Back EMF constant in volt / (rad/sec).

K_T = Torque constant in N-m/Ampere,

T_m = Torque developed by the motor in N-m.

$\theta(t)$ = Angular displacement of shaft in radians.

J =Moment of inertia of motor and load in Kg-m2/rad.

B = Frictional constant of motor and load in N-m / (rad/sec).

On the basis of the equations stated above, we realized a MATLAB/SIMULINK model for the brushless DC motor as shown in Figure 4.5.

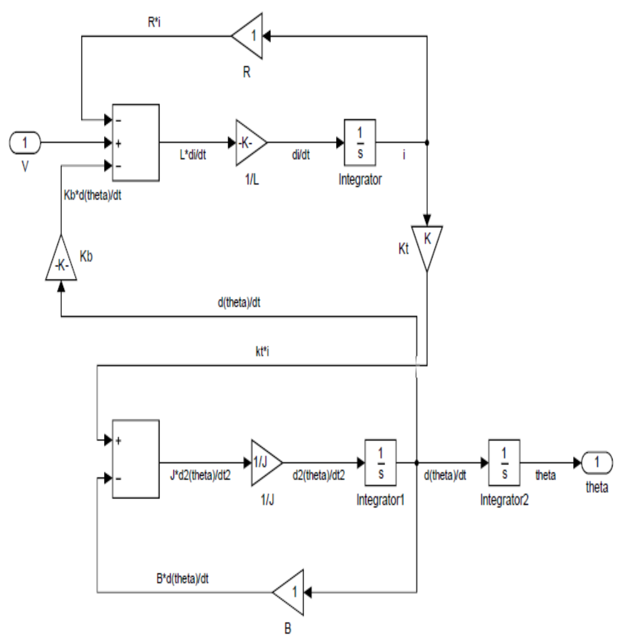

Figure 3.2: Simulink model for brushless DC motor

3.3Neuro-Fuzzy Controller

Figure 4.6 exhibits the basic block diagram for proposed Neuro fuzzy controller based PID tuning system for a plant model.

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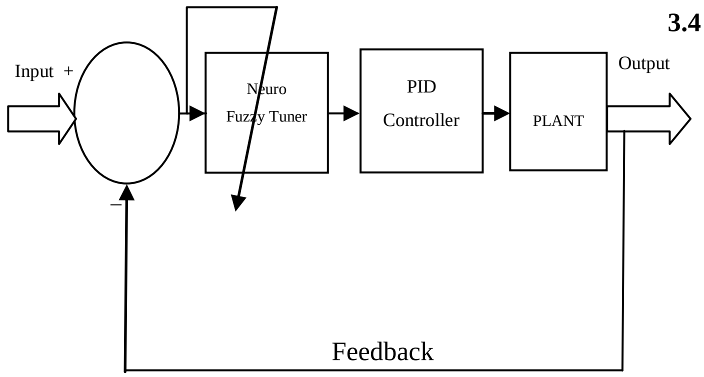

Figure 3.3: Basic block diagram for proposed Neuro fuzzy controller based PID tuning system for a plant model

To get the favorable circumstances of fuzzy and neural networks and to beat their limitations, it is wised to utilize the mixture of both, which prompts Neuro-Fuzzy Controllers (NFC). The on-line supervised learning algorithm performs exceptionally well when the training information are accessible on-line.Theerror between the reference and BLDC motor output is utilized to change the weights.This controlleris an Adaptive Network-based Fuzzy Inference System (ANFIS) [19].

3.4 Supervisory Learning in ANFIS

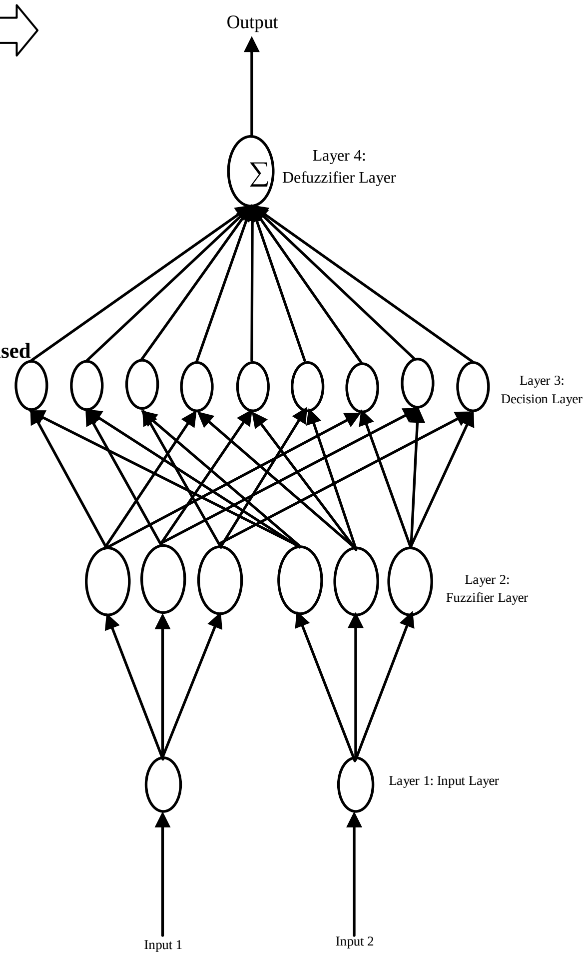

Figure 3.4: Neuro-Fuzzy network structure

In a few circumstances it might be interesting to outline an automatic controller, which emulates the activity of the human. This has been called supervised control. A Neural Network gives one opportunity to this. Training the network is comparative on a fundamental level to taking in a system forward model. For this situation, then again, the system information compares to the sensory input data got by the human. The network target outcomes utilized for training relate to the human control input

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to the framework. Figure 4.7 demonstrates the NFC as a supervisory controller.

The Error Back Propagation Through Plant (EBP-TP) method is one of the universal methodologies for neural networks training. In EBP-TP procedure, output error of the controller is passed through the BLDC motor, and redesigning law of the weights is attained. In any case, this system has a few imperfections, for example, noise affect-ability, unsettling influence and learning rate coefficient.[19]

4. SIMULATION RESULT

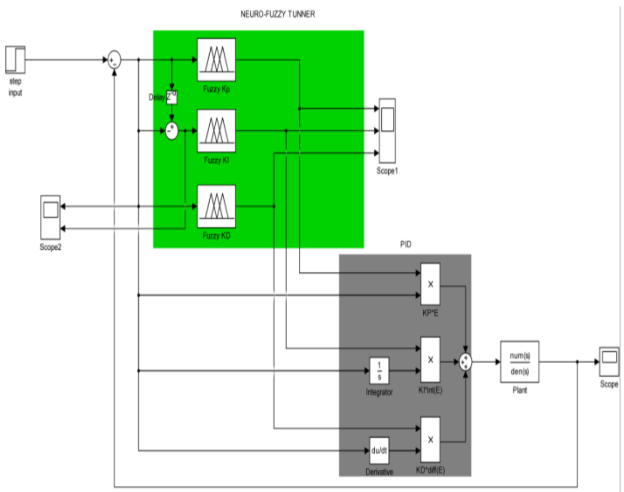

Figure 4.1: Simulink model for proposed system

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5. CONCLUSION

5.1 Conclusion

This dissertation has demonstrated the implementation of auto tuning of PID controller in MATLAB/SIMULINK. The aim of this dissertation is to introduce the technique of modeling of power components and to use computer simulation as a tool for conducting transient and control any plant model (CSTR and BLDC). The outcome of dissertation is that the designed PID with Adaptive Neuro Fuzzy Controller(ANFC) has faster response.However the ANFC designed PID with plant model is much better in terms of the rise time and the settling time. Finally the Adaptive Neuro Fuzzy Controller provides much better results compared to the conventional methods. And also the error associated with the ANFC based PID is much lesser than the error calculated in the conventional scheme. In this dissertation, implementation of the ANFC based PID controller for the DC motor position control system is covered.

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