ISSN XXXX XXXX © 2017 IJESC

Research Article Volume 7 Issue No.7

Comparison of Speed Control of DC Motor using PID Controller and Various Optimization Techniques a Review

Samikshya Tarei[1], Satish Arora[2]
M.Tech Student[1], Assistant Professor[2]
Department of Electrical Engineering
Baddi University of Emerging Sciences and Technologies H.P, India

Abstract:
This paper presents a comparative study on dc motor using different types of controllers, optimization techniques and literature review on speed control of dc motor. DC motors are widely used in industry applications, robotics and domestic appliances because of their high reliabilities, flexibilities and low costs. Dc motor can be varied below or above the rated speed by various techniques. There are basically three types of control methods are used to control the speed of dc motor which are field flux control armature control and voltage control. The conventional controller proportional integral derivative (PID) is commonly used to control the speed of dc motor in various application because it is simple, robust and highly effective. This paper represents various tuning methods of PID controller, fuzzy logic controller and optimization techniques for speed control of dc motor.

Keywords: DC motor, PID controller, tuning of PID controller, fuzzy logic controller, genetic algorithm.

I.INTRODUCTION

The field of electrical energy will be divided into three areas electronics, power and control system. Electronics basically deals with the study of semiconductor device and circuit at low power, power involves generation, transmission and distribution of electrical energy. [9]The electric motor which is high performance motor drives are very much essential for industrial application. These motor require automatic control of their main parameters such as speed, position, acceleration etc. In this paper to control the speed of dc motor separately excited dc drive system is described .So dc motor is used in many applications such as steel rolling mills, electric vehicles, electric trains, electric cranes and robotic manipulators require speed controller to perform its tasks smoothly because of their simplicity, reliability, and low cost dc drive have long been used in industrial application. Compared to ac drive dc drive are less complex. Many types of controllers such as proportional, integral, derivative, proportional integral (PI), proportional derivative (PD), proportional integral derivative (PID), fuzzy logic controller and optimization techniques have been developed for speed control of dc motor.

II.MATHEMATICALLY MODELLING OFSEDC MOTOR

In order to build the dc motor transfer function its simplified mathematical model has been used. This model consists of different equations for the electrical part, mechanical part and interconnection between them. The electrical circuit of armature and free body diagram of the motor are shown in fig.1.

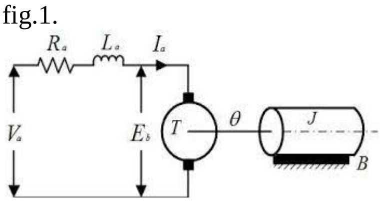

Figure.1. The electric circuit of the armature and the free body diagram of the rotor for a dc motor.

The armature equation is shown below

$$Va(t)=Ra.Ia(t)+La\frac{dIa(t)}{dt}+Eb(t) \quad (1)$$

Where
Va is the armature voltage in volts.
Eb is the motor back emf in volts.
Ia is the armature current in amperes.
Ra is the armature resistance in ohms.
La is the armature inductance in Henry.
From fig1, the following equation can be written based on Newton's law combined with Kirchhoff's Laws

$$Tm(t)=JmdW/d+BmW+TL \quad (2)$$

Where: TL is load torque in Nm.
Tm is the torque developed in Nm.
Jm is moment of inertia in kg/m².
Bm is friction coefficient of the motor in Nms/rad .
W is angular velocity in rad/sec.
θ is angular position of rotor shaft in rad.
Kt is torque constant in Nm/A.
Kb is back emf constant in Vs/rad.
Equation for back emf of motor can be written as :

$$Eb(t)=KbW(t) \quad (3)$$

Andalso,$Tm(t)=Kt.Ia(t)$ (4)
Let us combine the upper equations together

$$Va(t)=Ra.Ia(t)+L\frac{dIa(t)}{dt}+Kb.W(t) \quad (5)$$

$$Kt.Ia(t)=Jm.\frac{dW(t)}{dt}+Bm.W(t) \quad (6)$$

Taking laplace transfer function for above equations 5 an

$$Va(S)=Ra.Ia(s)+La.Ia(s)+Kb.W(s) \quad (7)$$

$$Kt.Ia(s)=Jm.W(s)+Bm.W(s) \quad (8)$$

By eliminated Ia(s) , the transfer function can be obtained ,where the rotational speed is the output and the voltage Va(t) input. When the motor is used as a component in a system. It is desired by the approximate transfer function between the motor voltage and its speed.

$$Va(S) =W(S)/Kt[LaJmS2+(RaJm+LaBm)s+(RaBm+KtKb)] \quad (9)$$

The relation between rotor shaft, speed and applied armature voltage is represented by transfer function

$$\frac{W(S)}{VA(S)} = \frac{kt}{[La.Jm.s2+(Ra.Jm+La.Bm)s+(Ra.Bm+Kb.KT)]} \quad (10)$$

The relation between position and speed is

$$\theta(s)=\frac{1}{s}W(S) \quad (11)$$

Then the transfer function between shaft position and armature current at no load is

$$\frac{\theta(s)}{Va(s)} = \frac{Kt}{[La.Jm.s3+(Ra.Jm+La.Bm)s2+(Ra.Bm+Kb.Kt)s]} \quad (12)$$

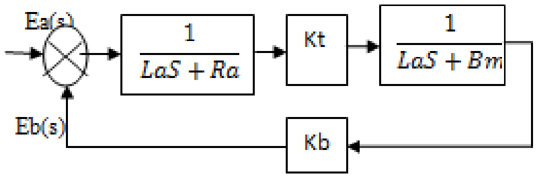

Figure.2. Block model of dc motor

III.SPEED CONTROL OF DC MOTOR

The speed control which stands for intentional speed variation, carried out manually or automatically .Natural speed change due to load ,is not included in the term speed control.[16]

The speed of dc motor is

$$Wm=Eb/Ka\phi$$
$$Eb=Va-IaRa$$
$$Wm=(Va-IaRa)/Ka\phi$$

Where Ka=armature constant=PZ/2aπ

Wm=speed of dc motor

ϕ=field flux per pole

Basically there are three methods used for speed control of dc motor

A. Armature resistance control
B. Field flux control
C. Ward Leonard voltage control

In this paper only armature resistance control method is presented

A. Armature resistance control:

In armature resistance control speed is varied up to rated speed. Speed can't be greater than rated speed in this method. This is also called constant torque mode operation of DC motor. By increasing some resistance in the armature if Rext is increased, Eb is decreases therefore speed is reduced. Before inserting external resistance

$$Ia1 =(Va-Eb)/(Ra+la)$$

But after inserting Rext current becomes

$$Ia2=(Va-Eb)/(Ra+Rext+La)$$

Due to addition of external resistance armature current decreases from Ia1 to Ia2.correspondingly torque decreases from Te1 to Te2 as torque is directly proportional to current. As torque decreases speed of motor decreases and hence back emf decreases,

and as Ia=(Vt-Eb)/(Ra+la)

So due to decrease in back emf armature current again increases till it reaches previous one. So due to constant armature current and armature flux torque develop in the motor remain constant. Hence it is called constant torque mode. It is used to control the speed below the rated speed. Due to external resistance in the armature the power loss is increased and additional cooling is required .it is also called variable power constant torque method.

IV.PID CONTROLLER

PID controller is most commonly used algorithm for controller design and it is most widely used controller in industry. The controllers used in industry are either PID controller or its improved version. The PID controllers are the most common control methodology to use in real applications and comnines advantages of three proportional, derivative and integral control action. Derivative mode which gives fast reaction on change of the controller input ,integral mode which increases the control signal to lead error towards zero and proportional mode is suitable action inside control error area to eliminate oscillations.[12] Derivative mode improves stability of the system and enables increase in gain Kd and decrease in integral time constant Ti, which increases speed of the controller response.PID controllers are the most often used controllers in the process industry.[6] The majority of control systems in the world are operated PID controllers. It has been reported that 98% of the control loops in the pulp and paper industries are controlled by single-input single output PI controllers and that in process control applications, more than 95% of the controllers are of the PID type controller.

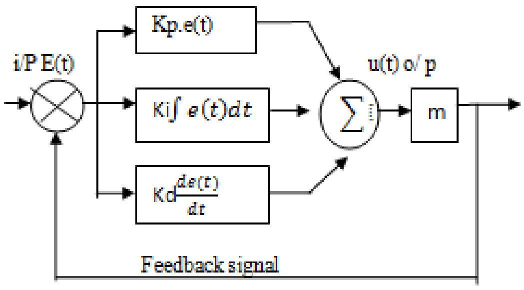

Figure.3. Block diagram of PID controller

$$U(t) =Kp.e(t)+Ki\int e(t).dt+Kd\frac{de(t)}{dt}$$

V.TUNING OF PID CONTROLLER

Tuning a control loop is the adjustment of its control parameters (proportional gain Kp, integral gain Ki and derivative gain Kd) to the optimum values for the desired control response. There are several methods for tuning a PID loop.[6] The most effective methods generally involve the development of some form of process model, then choosing P, I, and D based on the dynamic model parameters. The choice of method will depend largely on whether or not the loop can be taken "offline" for tuning, and the response time of the system. If the system can be taken offline, the best tuning method often involves subjecting the system to a step change in input, measuring the output as a function of time, and using this response to determine the control parameters. Different tuning methods are

- Manual tuning
- Ziegler-Nichols tuning
- Software tuning

In this paper Ziegler-Nichols tuning method is presented

Ziegler-Nichols tuning introduced by John G. Ziegler and Nathaniel B. Nichols in the 1940s. in the method, the Ki and Kd gains are first set to zero. The proportional gain Kp is increased until it reaches the ultimate gain, Ku, at which the output of the loop starts to oscillate. Ku and the oscillation period Pu are used to set the gains as shown.[8]

Table. 1. Ziegler–Nichols method

Control type	Kp	Ki	Kd
P	0.50Ku	-	-
PI	0.45Ku	1.2Ku/Pu	-
PID	0.60Ku	2Ku/Pu	Ku Pu/8

VI.FUZZY LOGIC CONTROLLER

Fuzzy logic control is one of the control method based on a linguistic control strategy, which is being derived from expert knowledge into an automatic control strategy. Fuzzy logic based control systems were introduced by Lotfi Zadeh to optimize the process control parameters in better way. Fuzzy logic control doesn't need any kind of difficult mathematical calculation like the others control system. fuzzy uses only simple mathematical calculation to simulate the expert knowledge and it gives good performance in a control system.

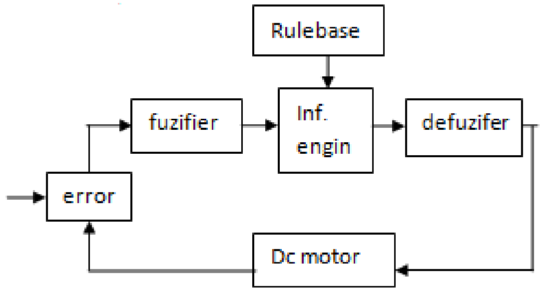

Figure.4. Block diagram of fuzzy logic controller

Advantages of Fuzzy Logic Controller

Fuzzy Logic Controller (FLC) is an attractive choice when precise mathematical formulations are not possible. Other advantages are

- Allows imprecise/contradictory inputs. i.e it uses linguistic variables.
- Rule base or fuzzy sets can be easily modified.
- Relates input to output in linguistic terms, so easily understood.
- Cheaper because they are easier to design and increased robustness than other non-linear controller Can achieve less overshoot and oscillation and doesn't require fast processors.
- It requires less data storage in the form of membership functions and rules than conventional look up table for non-linear controllers.

Principal Elements to A Fuzzy Logic Controller

A. Fuzzification
B. Rule base and Inference engine
C. Defuzzification

A.Fuzzification

This process converts the crisp input into the fuzzy linguistic values. The first step in designing a fuzzy controller is to decide which state variables represent the system dynamic performance must be taken as the input signal to the controller. Generally Fuzzy logic uses linguistic variables instead of any precise or numerical variables. The process of transforming a numerical variable (crisp variables) into a linguistic variable (fuzzy variable) is called Fuzzification.. which are generally used as the fuzzy controller inputs includes states error, state error integral, state error derivative or etc. [5]

B. Rule Base and Interface Engine

A collection of the expert control rules (knowledge) needed to achieve the control goal. This process will perform fuzzy logic operations and result the control action according to fuzzy inputs.

C. Defuzzification

The reverse of Fuzzification is called Defuzzification. It is the transformation of a fuzzy quantity into a precise quantity, just like fuzzification is the conversion of a precise quantity to a fuzzy quantity. The use of Fuzzy Logic Controller (FLC) produces required output in a linguistic variable (fuzzy number).As per the real world requirements, the linguistic variables should to be transformed to a crisp output.

VII.GENETIC ALGORITHMA.

1.Overview of Genetic Algorithm

Genetic Algorithm (GA) is a stochastic global search method that based on mechanisms of natural evolution, crossover and mutation. It is one of the methods used for optimization. John Holland formally introduced this method in the United States in 1970 at University of Michigan. GA starts with an initial population containing a number of chromosomes where each one represents a solution of the problem which performance is evaluated by a fitness function. [11]

Basically, GA consists of three main stages: Selection, Crossover and Mutation. The application of these three basic operations allows the creation of new individuals which may be better than their parents. This algorithm is repeated for many generations and finally stops when reaching individuals that represent the optimum solution to the problem[11].

2.Objective Function of the Genetic Algorithm

The most challenging part of creating a genetic algorithm is writing the objective functions. In this paper, the objective function is required to evaluate the best PID controller for the system. An objective function could be created to find a PID controller that gives the smallest overshoot, fastest rise time or quickest settling time. However in order to combine all of these objectives an objective function is designed to minimize the performance indices of the controlled system instead. [12]

3.Overview of Binary Coded G.A

GA has many types like Real coded GA, Binary coded GA, Saw tooth GA, Micro GA, Improved GA, Differential Evolution GA. This paper is based on Binary coded G.A. The binary coded genetic algorithm is a probabilistic search algorithm that iteratively transforms a set of mathematical objects into a new population of offspring objects using the Darwinian principle of natural selection and using operations that are patterned after naturally occurring genetic operations such as crossover and mutation.[12] Flow chart of genetic algorithm GA shown below.

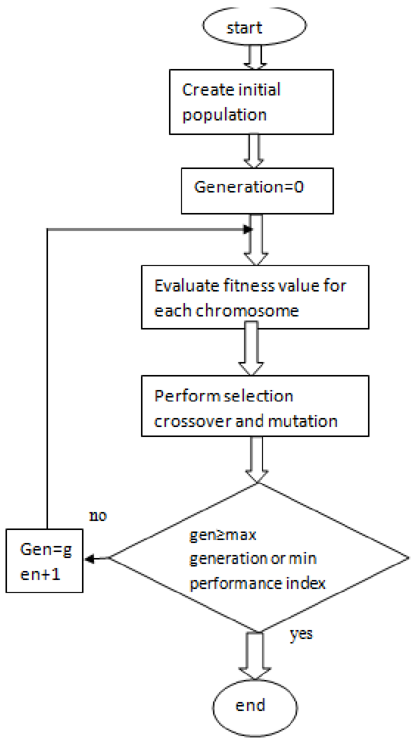

Figure.5.Flow chart of genetic algorithm

4.Encoding

In genetic Algorithm, coding is expressing the individual by the binary strings of 0"s & 1"s . In the instance one every individual has there dimension and every dimension is expressed by a 10- bit string of 0"s & 1"s.[13]

5.Selection

In this method, a few good chromosomes are used for creating new offspring in every iteration. Then some bad chromosomes are removed and the new offspring is placed in their places. The rest of population migrates to the next generation without going through selection process.

6. Crossover

The crossover/reproduction operator consists two offspring for each parent pair given from the selection operator. The crossover operator is used to create new offspring from the existing solutions available in the mating pool after applying selection operator. This operator exchanges the generation information between the solutions in the mating pool.[12]The most popular crossover selects any two solutions strings randomly from the mating pool and some portion of the strings is exchanged between the strings. The selection point is selected randomly. A probability of crossover is also introduced in order to give freedom to an individual solution string to determine whether the solution would go for crossover or not.

7.Mutation

Mutation is a genetic operation used to maintain genetic diversity from one generation of a population of genetic algorithm chromosomes to the next. A probability of mutation is again predetermined before the algorithm is started which is applied to each individual bit of each offspring chromosome to determine if it is to be inverted. Mutation changes the structure of the string by changing the value of a bit chosen at random.[12] Mutation is the occasional introduction of new features in to the solution strings of the population pool to maintain diversity in the population. Though crossover has the main responsibility to search for the optimal solution, mutation is also used for this purpose. Mutation operator changes a 1 to 0 or vise versa, with a mutation probability of .The mutation probability is generally kept low for steady convergence. A high value of mutation probability would search here and there like a random search technique.

VII.LITERATURE REVIEW

T.Venkatesh, M. Tarun kumar, B.Jayanthi, B. Ramesh, P. Chaitanya **deals** with speed control of dc motor using conventional PID controller and sliding mode control (SMC) technique. They compared PID controller and SMC techniques. The performance of the SMC is judged via MATLAB simulations using linear model of the DC motor and known disturbance. They founded that the sliding mode controller (SMCR) is superior controller than PID for the speed control of DC motor.[1] P. Mhaskar, H.Nael El-Farra and D.Christofidest deals with a two level optimization method based into account for deriving tuning guidelines for PID controllers that take explicitly presence of nonlinear behaviour The central idea behind the proposed method is the selection of PID controller tuning parameters so as to best "emulate" the control action and closed loop response under a given nonlinear controller for a broad set of initial conditions and set point changes and first level involves using classical tuning guidelines to obtain reasonable bounds on the tuning parameters in order to satisfy various design criteria such as stability and performance and robustness. These bounds are in turn incorporated as constraints on the optimization problem solved at the higher level to yield tuning parameter values that improve upon the values that improve upon the values obtained from the first level to better emulate the closed loop behaviour under the nonlinear controller. [2] Pooja.Hanchate, Priyanka.Gadag, Prithivi.H, Sapna.U, Ramya.S, Priyanka.B, Swasti.I, Raghvendra.m. shet, deals with speed control of a motor using PID controller was generated by an arduino program. Arduino is an open-source electronic prototyping platform based on flexible easy to use hardware and software. The arduino language program is dumped into the microcontroller and it is given to the analog input of microcontroller and the analog outputs are connected to PID controller. The speed of the motor will be controlled based on the PID controller and the speed sensed through Encoder would be compared with the reference value and obtained error is projected over PID controller and the process continues till we get minimum errors.[3] Pratap S Vikhe, Neelam Punjabi, Chandrakant B Kadu deals with speed control of DC motor can be controlled by using a PID controller in LabVIEW. DC Motor was interfaced with LabVIEW using an ATmega 8A Microcontroller. The speed of the dc motor was sensed by using the IR sensor. They founded PID Controller give minimize the error and bring the motor to the set point value.[4] E.J.Hepzibah and R.Korah deals with the speed control of a separately exited DC motor using fuzzy logic control (FLC) based on Lab VIEW (Laboratory Virtual Instrument Engineering Workbench) program. Lab VIEW is a graphical programming environment suited for high level or system level design. Therefore, the principle that are data flow model, different from text-base Programming and a sequential model. The user friendly interface and toolbox design are shown the high level of suitableness and stability of Lab VIEW and fuzzy logic on speed control of DC motor. The fuzzy logic controller designed to applies the required control voltage that sent to DC motor based on fuzzy rule base of motor speed error (e) and change of speed error(ce). The result show the control as a FLC that do the comparison with PI and PID controller .[5] Narayan Dutt Pandey ,Dr. Pratibha Tiwari deals with speed control of dc motor using genetic algorithm fed with PID controller and particle swarm optimization technique has been compared them. The performance was done in MATLAB. They compared two different methods of determining the PID controller parameters using PSO algorithm and Fuzzy Genetic Algorithm. they compared with both the results the PSO-PID and genetic algorithm method and shown better output as compared to simple PID controller.[6] Shatrughana Prakash Yadav, V.K. Tripathi deals with speed control analysis of DC motor using PID controller & Speed control of separately excited dc motor has done with using armature voltage control method. The control system consisting of PID controller dc motor was simulated in MATLAB. Therefore, the performance and analysis of dc the motor with PID controller was performed and calculating the various responses of the parameters such as maximum overshoot, rise time, settling time, etc. [7] Vivek shrivastva,Rameshwar singh deals with comparison of time response specification between different controllers and Linear Quadratic Regulator(LQR) for speed control of dc motor. They drawn a comparison simulation result with PID-ZN controller, PID-MZN controller and PI-PSO controller .They founded Linear Quadratic Regulator method give better performance over other controllers.[8] Dr.ch.chengaliah,K.Venkateswarlu deals with speed control of separately excited dc motor with PID and fuzzy controller. The performance was done in MATLAB .They founded fuzzy controller is better to replace conventional PID controller to improve the system characteristics.[9] Osama omer Adam Mahammed, Dr Awadalla Taifor Ali deals with speed control of separately excited dc motor using PID control and fuzzy logic control . The performance was done in MATLAB .They founded fuzzy controller is better to replace conventional PID controller to improve the system characteristics. They also founded that when torque load applied, speed reduced in PID controller but in fuzzy logic control speed is not affected and it remain constant.[10] Santosh Kumar Suman, Vinod Kumar Giri. design a speed Controller of a DC motor by selection of a PID parameters using genetic algorithm (GA). The main aim of this paper is to analyse the implementation of Evolutionary Computation (EC) techniques viz. The Genetic Algorithm (GA) for optimize PID controllers parameters for speed control of dc motor and enumerate their advantages over the conventional tuning methodologies. The genetic algorithm were implemented and analysed on a second order plant model of a DC motor with the aim of developing a speed controller. The results obtained from GA algorithms were compared with that obtained from conventional method. It was found that the evolutionary techniques outperformed traditional tuning practices of conventional PID controllers.[14] By Using Genetic Algorithm to perform the tuning of controller will result in optimum controller begin evacuated for system every time in order to solve this problem a PID controller under Genetic Algorithm with self tuning using Ziegler and Nichols applied by Nikhileshwar P. Adhikari. et.al. which will perform high efficiency position control of DC motor. The efficiency of control Algorithm is presented through a simulation and compared with quality of PID controller.[15]

VIII. CONCLIUSION

This paper presents the mathematical modelling of separately excited DC motor. This review also represents classical control method, PID-ZN controller, Fuzzy logic controller and GA optimization technique PID controller of speed control dc motor.

IX.REFERENCE

[1].T.Venkatesh, M. Tarun kumar, B.Jayanthi, B. Ramesh, P. Chaitanya "Speed Control of DC Motor and Performance is Compared with PID and SMC Controller"volume6, issue no 4. ISSN 2321 3361 © 2016 IJESC, 10.4010/2016.

[2]. P.Mhaskar, H.Nael El-Farra and D.Christofidest "A Method for PID Controller Tuning Using Nonlinear Control Techniques," in Proc. of the 2004 American Control Conf. Boston, Massachusetts June 30. July 2, 2004.

[3]. Pooja.Hanchant, PRriyanka.Gadag, Prithivi.h, Sapna.u, Ramya.s, Priyanka.b, Swathi.I, Raghvendra.m.shet "Speed control of dc motor using PID controller" Department of Instrumentation, B .V Bhoomaraddi College of Engineering and Technology, Hubli -580031.

[4]. Pratap S Vikhe, Neelam Punjabi, Chandrakant B Kadu "DC Motor Speed Control Using PID Controller In Lab View" International Journal of Innovative Science and Modern Engineering (IJISME) ISSN: 2319-6386, Volume-3 Issue-3, February 2015.

[5].E.J.Hepzibah&R.Korah, "FPGA" implementation for speed monitoring and speed control of a DC motor using fuzzy logic" in proc .IEEE Conf.Emerging Trends in Electrical Engineering and Energy Management (13-15 Dec. 2012, pp-222-228).

[6]. Narayan Dutt Pandey ,Dr. Pratibha Tiwari "Comparison between speed control dc motor using genetic algorithm and pso-pid algorithm" International Journal of Electrical Engineering & Technology (IJEET). Volume 8, Issue 1, Article ID: IJEET_08_01_003, pp. 17–25, January- February 2017Energy Management (, 13-15 Dec. 2012, pp-222-228.

[7]. Shatrughana Prakash Yadav, V.K. Tripathi "A Case Study of DC Motor Speed Control with PID Controller through MAT LAB" International Journal of Advanced Research in Computer and Communication Engineering Vol. 5, Issue 5, May 2016.

[8]. Vivek Shrivastva, Rameshwar Singh "Performance Analysis of Speed Control of Direct Current (DC) Motor using Traditional Tuning Controller" International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 5, May 2014.

[9]. Dr.Ch.Chengaiah,K.Venkateswarlu "Comparative study on dc motor speed control using various controllers" International Journal of Advanced Research in Electrical ,Electronics and Instrumentation Engineering.vol.3,Issue 1,January 2014

[10]. Osama Omer Adam Mohammed, Dr. Awadalla Taifor Ali "Comparative Study of PID and Fuzzy Contrllers for Speed Control of DC Motor" International Journal of Innovative Research in Science, Engineering and TechnologyVol. 3, Issue 9, September 2014.

[11].Neenu Thomas, Dr. P. Poongodi "Position Control of DC Motor Using Genetic Algorithm Based PID Controller" Proceedings of the World Congress on Engineering 2009 Vol II WCE 2009, July 1 - 3, 2009, London, U.K.

[12] Megha Jaiswal , Mohna Phadnis "Speed Control of DC Motor Using Genetic Algorithm Based PID Controller" International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 7, July 2013, ISSN: 2277 128X.

[13].Kalyanmoy Deb, Optimization for Engineering Design Algorithm & Examples, Indian Institute Of Technology Kanpur, Prentice Hall, 2005.

[14].Santosh Kumar Suman, Vinod Kumar Giri, "Optimization of PID controller parameters for speed control of dc motor"International Conference on Consequences of Recent Researches in Engineering & Technology-2016.

[15]. Nikhileshwar ,P. Adhikari, M. choubey, R. Singh "DC Motor Control Using Ziegler Nichols and Genetic Alogorithm Technicque" in proc.International Journal of Electrical, Electronics and computer Engineering, vol.no.1, pp33-36, 2012.

[16]. Prabha Malviya,Menka Dubey "Speed control of dc motor a review" International Journal of Engineering Science and research technology" august 2015.

[17]. Bhaskar Roy, Shilpi Sisodiya "Fuzzy Logic Controller Based Speed Analysis and Control of DC Shunt Motor"

International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 3 Issue X, November 2015.

[18]. Husain Ahmed,Dr. Gagan Singh,Vikash Bhardwaj , Saket Saurav, Shubham Agarwal "Controlling of D.C. Motor using Fuzzy Logic Controller" Conference on Advances in Communication and Control Systems 2013.

[19]. Ritu Soni, DBV Singh, Pramod Pandey and Priyanka Sharma "Simulation of Optimal Speed Control for a DC Motor Using Conventional PID Controller and Fuzzy Logic Controller" International Journal of Information and Computation Technology. ISSN 0974-2239 Volume 3, Number 3 (2013), pp. 181-188.

[20]. Vijay Singh and Vijay Kumar Garg "A Comparative Study on Speed Control of D.C. Motor using Intelligence Techniques" International Journal of Electronic and Electrical Engineering. ISSN 0974-2174, Volume 7, Number 4 (2014), pp. 431-436.

[21] Tushar Chouhan, Arkaja Agrawal "D.C. Motor Control by Genetic Algorithm" International Journal of Digital Application & Contemporary research Website: www. ijdacr. com Volume 1, Issue 1, August 2012.

[22]. Manoj Kushwah and Prof. Ashis Patra "Tuning PID Controller for Speed Control of DC Motor Using Soft Computing Techniques-A Review" Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 4, Number 2 (2014), pp. 141-148.

[23]. Shatrughana Prakash Yadav, V.K. Tripathi "A Case Study of DC Motor Speed Control with PID Controller through MAT LAB" International Journal of Advanced Research in Computer and Communication Engineering Vol. 5, Issue 5, May 2016.

[24]. Nikunj A. Bhagat , Mahesh Bhaganagare "DC Motor Speed Control using PID Controllers"EE 616 Electronic System Design Course Project, EE Dept, IIT Bombay, November 2009.

[25] Mrs.A.A Thorat, Prof.Suhas Yadav, Prof.S.S.Pati "Implementation of Fuzzy Logic System for DC Motor Speed Control using Microcontroller" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 3, Issue 2, March -April 2013, pp.950-956.

[26]. Abdul-Kareem Z. Mansoor, Ph.D. Thair A. Salih, Ph.D. Mohamed Y. Hazim "Self-tuning PID Controller using Genetic Algorithm".

[27]. Husain Ahmed, Dr. Gagan Singh,Vikash Bhardwaj , Saket Saurav, Shubham Agarwal "Controlling of D.C. Motor using Fuzzy Logic Controller" Conference on Advances in Communication and Control Systems 2013 (CAC2S 2013).

[28] .Basma A. Omar, Amira Y. Haikal, Fayz F. Areed "n Adaptive Neuro-Fuzzy Speed Controller for a Separately excited DC Motor" International Journal of Computer Applications (0975 – 8887) Volume 39– No.9, February 2012.

[29]. Umesh Kumar Bansal and Rakesh Narvey "Speed Control of DC Motor Using Fuzzy PID Controller" Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 3, Number 9 (2013), pp. 1209-1220.

[30]. Rekha kushwah, Sulochana Wadhwani "Speed Control of Separately Excited Dc Motor Using Fuzzy Logic Controller" International Journal of Engineering Trends and Technology (IJETT) - Volume4 Issue6- June 2013.