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Comparative Analysis of Speed Control of DC Motor Using AI Technique

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Abstract

This paper presents a comparative study of various controllers for the speed control of DC motor. The Proportional Integral Derivative (PID) controller is one of the most common types of feedback controllers used in dynamic systems. This controller has been widely used in many different areas such as aerospace, process control, manufacturing, robotics, automation etc. As PID controllers require exact mathematical modelling, the performance of the system is questionable if there is parameter variation. Further two more controllers are proposed namely; Fuzzy Logic Controller and FOPID Controller. The performances of the three controllers are compared. Simulation results are presented and analysed for all the controllers. It is observed that Fuzzy Logic based controller gives better response than PID and FOPID controller for the speed control of dc motor.

Keywords - *Proportional-Integral-Derivative controller, Fuzzy Logic controller, FOPID controller, DC motor speed control.*

I INTRODUCTION

DC motor is a power actuator which converts electrical energy into mechanical energy. DC motor is used in application where wide speed ranges are required. The greatest advantage of dc motors may be speed control. The term speed control stand for intentional speed variation carried out manually or automatically. DC motors are most suitable for wide range speed control and are therefore used in many adjustable speed drives. Since speed is directly proportional to armature voltage and inversely proportional to magnetic flux produced by the poles, adjusting the armature voltage and/or the field current will change the rotor speed. DC motors have been widely used in many industrial applications such as electric vehicles, steel rolling mills, electric cranes, and robotic manipulators due to precise, wide, simple, and continuous control characteristics.

Proportional-Integral-Derivative (PID) controller has been used for several decades in industries for process control applications. At the same time PID controller has some disadvantages namely; the undesirable speed overshoot, the sluggish response due to sudden change in load torque and the sensitivity to controller gains K_I and K_P. The performance of this controller depends on the accuracy of system models and parameters. Therefore there is need of a controller which can overcome disadvantages of PID controller.

Emerging intelligent techniques have been developed and extensively used to improve or to replace conventional control techniques because these techniques do not require a precise model. Fuzzy logic has rapidly become one of the most successful technologies for developing sophisticated control systems. The reason for which is very simple. Fuzzy logic addresses such applications perfectly as it resembles human decision making with an ability to generate precise solutions from certain or approximate information. It fills an important gap in engineering design methods left vacant by purely mathematical approaches (e.g. linear control design), and purely logic-based approaches (e.g. expert systems) in system design.

DC motor can also be controlled by a non-conventional control technique known as fractional-order PID (FOPID) control, a generalised version of integer order control. Dynamic systems based on fractional order calculus have been a subject of extensive research in recent years. In fractional order proportional-integral derivative (FOPID) controller, I and D operations are usually of fractional order; therefore, besides setting the proportional, derivative and integral constants K_P, K_I, K_D, we have two more parameters; the order of fractional integration $\boldsymbol{\lambda}$ and that of fractional derivative $\boldsymbol{\mu}$. Determining an optimal set of value for a given process plant. This has been solved by using N-integer tool box. The values of K_P, K_I, K_D, $\boldsymbol{\lambda}$ and $\boldsymbol{\mu}$ are selected by hit and trial method.

II MODEL OF DC MOTOR

DC motors are most suitable for wide range speed control and are therefore used in many adjustable speed drives. Fig 1 shows a separately excited DC Motor. R_a is the armature resistance and L_a is the armature inductance of separately excited dc motor. R_f is the field resistance and L_f is the inductance of the field winding.

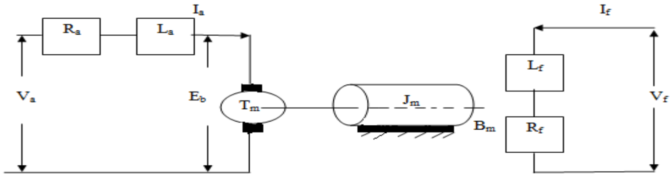


Fig. 1 Separately Excited DC Motor Model

A linear model of a simple DC motor consists of an electrical equation and mechanical equation as determined in the following equations (1) and (2).

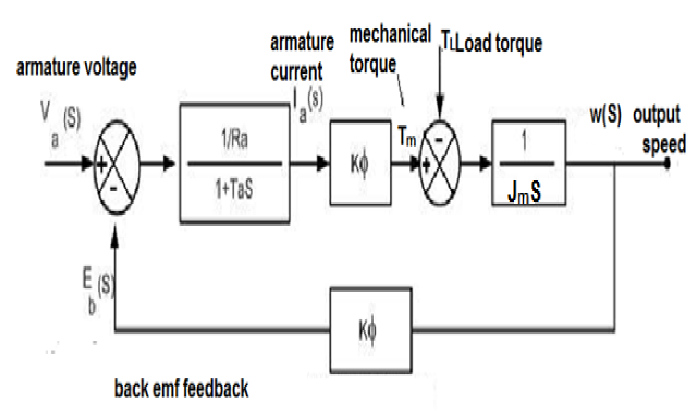
$$V_a = E_b + I_a R_a + L_a (dI_a/dt) \tag{1}$$

$$T_m = J_m \, {}^{d\omega}/_{dt} + B_m \omega + T_L \tag{2}$$

where

- V_a is the armature voltage (in volt)
- E_b is back emf the motor (in volt)
- I_a is the armature current (in ampere)
- R_a is the armature resistance (in ohm)
- L_a is the armature inductance (in Henry)
- T_m is the mechanical torque developed (in Nm)
- J_m is moment of inertia (in kg/m²)
- B_m is friction coefficient of the motor (in Nm/ (rad/sec))
- ω is angular velocity (in rad/sec)
- T_a = Armature Time Constant , $T_a = L_a/R_a$

After simplifying the above equations, the overall transfer function is obtained as shown in Fig. 2.



The following specifications of DC motor are used:

TABLE1

SPECIFICATIONS OF DC MOTOR

Symbol	**Magnitude**
$\mathbf{R_a}$	0.5Ω
$\mathbf{L_a}$	0.02H
$\mathbf{V_a}$	200V
$\mathbf{J_m}$	0.1 Kg.m^2
$\mathbf{B_m}$	0.008 N.m/rad/sec
k	1.25 V/rad/sec

By making use of the above motor constants the SIMULINK block diagram of dc motor obtained is as shown in Fig.3.

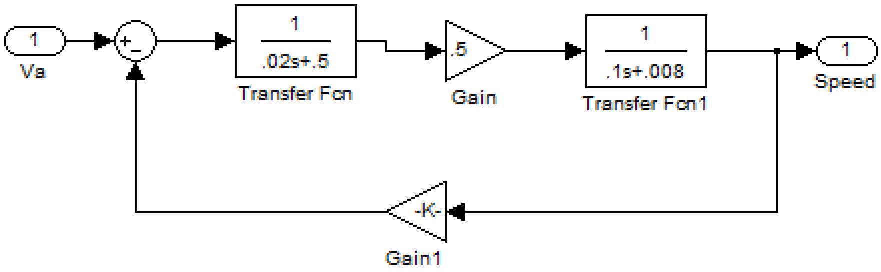


Fig. 3 SIMULINK Block Diagram of DC Motor

III. PROPORTIONAL-INTEGRAL-DERIVATIVE CONTROLLER

Fig.4. shows the SIMULINK block diagram of speed control of dc motor using PID controller. Step input is given to the controller. The error signal is given to the PID controller. Subsystem signifies the motor model as shown in Fig.3 and output is obtained at scope3.

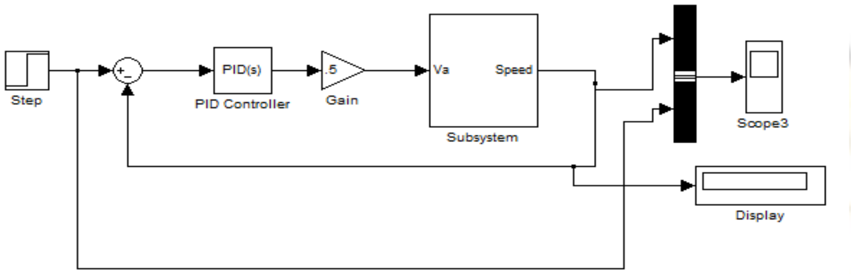


Fig.4 SIMULINK Block Diagram of Speed Control of Dc Motor Using PID Controller

Before going into the procedure of controller tuning, it is important to look at what is the aim of the controller tuning. If possible, we would like to obtain both of the following for the control system:

- Fast responses, and
- Good stability

Unfortunately, for most practical processes being controlled with a PID controller, these two cannot be achieved simultaneously. In other words:

- The faster responses, the worse stability, and
- The better stability, the slower responses.

For a control system, it is more important that it has good stability than being fast. A PID controller is design for separately excited DC Motor using MATLAB. The system as shown in Fig.4 is tuned for the following parameters for the PID controller to get desired speed:

$K_P = 315.42$, $K_I = 770.27$, $K_D = -0.7927$

Major problems in applying a conventional control algorithm in a speed controller are the effects of nonlinearity in a dc motor. The nonlinear characteristics of a dc motor such as saturation and friction could degrade the performance of conventional controller. Therefore there is need of a controller which can overcome disadvantages of PID controller.

IV FUZZY LOGIC CONTROLLER (FLC)

A Fuzzy Logic Controller (FLC) was proved analytically to be equivalent to a nonlinear PI controller when a nonlinear defuzzification method was used. The foundations of fuzzy logic have become firmer and its impact within the basic sciences - and especially in mathematical and physical sciences - has become more visible. Fuzzy controllers have been proposed for physical systems which do not lend themselves too easy and accurate mathematical modelling and crisp variables, and therefore, cannot be tackled by traditional strict analytic control design techniques. Instead, control variables are represented by fuzzy variables which let the level of uncertainty of the variables to be modelled in a systematic way. In addition, the expert knowledge of a typical operator of such a process is embodied in a set of linguistic or rule-based engines which constitutes the core of a fuzzy controller.

The objective is to implement FLC for controlling the speed of a dc motor. The goal of designed FLC in this study is to minimize speed error. The bigger speed error the bigger controller input is expected .In addition, the change of speed of error plays important role to define controller input. Consequently FLC uses error (e) and change in error (ce) for linguistic variables which are generated from control rules. The output variable is the change in control variable of the motor drive. The output variable from FLC is given to the plant i.e DC motor. A fuzzy logic controller has four main components:

a) Fuzzification
b) Inference Engine

c) Rule Base
d) Defuzzification

Fig.5. shows SIMULINK block diagram of speed control of dc motor using FLC. Speed shows the controlled speed. A Fuzzy PID controller is incorporated in the block diagram as a subsystem. Error (e) and change in error (ce) are the two inputs of the FLC and the output is u, which is fed to the motor.

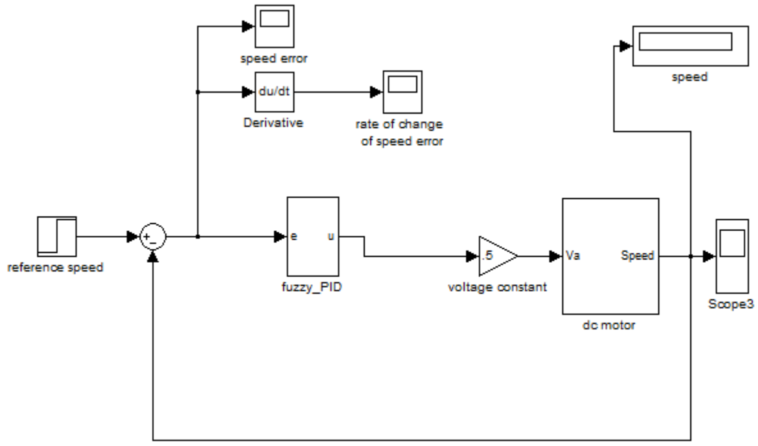


Fig. 5 SIMULINK Model for Speed Control of DC Motor Using Self Tuned Fuzzy PID Controller

To perform computations, inputs and outputs must be converted from numerical or “crisp” value into linguistic forms. The terms such as “Small” and “Big” are used to quantize the input and output values to linguistic values. In this paper, the linguistic terms used to represent the input and output values are defined by seven fuzzy variables as shown in Table 2 and Table 3.

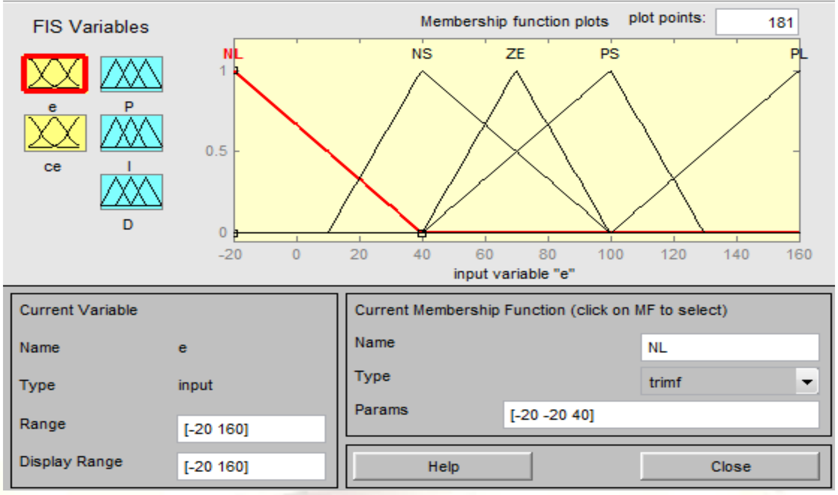
TABLE 2
FUZZY LINGUISTIC TERMS USED FOR INPUT VARIABLES

Term	**Definition**
NL	Negative Large
NS	Negative Small
ZE	Zero
PS	Positive Small
PL	Positive Large

TABLE 3
FUZZY LINGUISTIC TERMS USED FOR OUTPUT VARIABLES

Terms	**Definitions**
PVS	Positive Very Small
PS	Positive Small
PMS	Positive Medium Small
PM	Positive Medium
PML	Positive Medium Large
PL	Positive Large
PVL	Positive Very Large

Fuzzy membership functions are used as tools to convert crisp values to linguistic terms. A fuzzy membership function can contain several fuzzy sets depending on how many linguistic terms are used. Each fuzzy set represents one linguistic term. In this paper, five fuzzy sets are obtained by applying the five linguistic terms. The number for indicating how much a crisp value can be a member in each fuzzy set is called a degree of membership .One crisp value can be converted to be “partly” in many fuzzy sets, but the membership degree in each fuzzy set may be different. In order to define fuzzy membership function, designers can choose different shapes based on their preference or experience. The popular shapes are triangular and trapezoidal because these shapes are easy to represent designer’s idea and require low computations time. Fig.6. Membership Function Editor Window for the Error in Speed



plot points: 181

Current Variable

Name: e

Type: input

Range: [-20 160]

Display Range: [-20 160]

Current Membership Function (click on MF to select)

Name: NL

Type: trimf

Params: [-20 -20 40]

Fig. 6 Membership Function Editor Window for the Error in Speed

Similarly memership function for change in error (ce) and output variables can be obtainrd.

Instead of using mathematical formulas, a FLC uses fuzzy rules to make a decision and generate the control effort. The rules are in the form of IF-THEN statements.For example, IF the error(e) is equal to negative low (NL) and change in error is negative low (NL) Then the change in speed is positive very small (PVS). The solutions are based on experiences of a designer or the previous knowledge of the system.The efficiency can be improved by adjusting the membership functions and rules.Table 4, Table 5 and Table 6 shows the rule base for K_P, K_I and K_D.

Table 4
Fuzzy Rule Table for K_P

ce/e	**NL**	**NS**	**ZE**	**PS**	**PL**
NL	PVS	PMS	PM	PL	PVL
NS	PMS	PML	PL	PVL	PVL
ZE	PM	PL	PL	PVL	PVL
PS	PML	PVL	PVL	PVL	PVL
PL	PVL	PVL	PVL	PVL	PVL

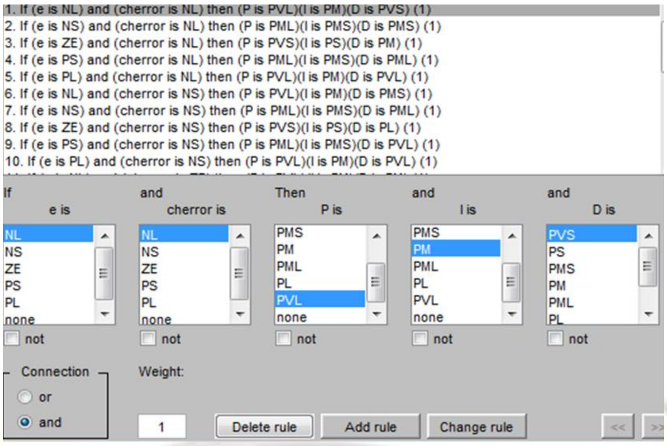
Table 5
Fuzzy Rule Table for K_I

ce/e	**NL**	**NS**	**ZE**	**PS**	**PL**
NL	PVL	PVL	PVL	PVL	PVL
NS	PML	PML	PML	PL	PVL
ZE	PVS	PVS	PS	PMS	PMS
PS	PML	PML	PML	PL	PVL
PL	PVL	PVL	PVL	PVL	PVL

Table 6
Fuzzy Rule Table for K_D

ce/e	**NL**	**NS**	**ZE**	**PS**	**PL**
NL	PM	PM	PM	PM	PM
NS	PMS	PMS	PMS	PMS	PMS
ZE	PS	PS	PVS	PS	PS
PS	PMS	PMS	PMS	PMS	PMS
PL	PM	PM	PM	PM	PM

The rule editor window for the Fuzzy Controller for DC Motor is as shown in Fig.7.There are 25 rules in total combining all the above rules



1. If (e is NL) and (cherror is NL) then (P is PVL)(I is PM)(D is PVS) (1)
2. If (e is NS) and (cherror is NL) then (P is PML)(I is PMS)(D is PMS) (1)
3. If (e is ZE) and (cherror is NL) then (P is PVS)(I is PS)(D is PM) (1)
4. If (e is PS) and (cherror is NL) then (P is PML)(I is PMS)(D is PML) (1)
5. If (e is PL) and (cherror is NL) then (P is PVL)(I is PM)(D is PVL) (1)
6. If (e is NL) and (cherror is NS) then (P is PVL)(I is PM)(D is PMS) (1)
7. If (e is NS) and (cherror is NS) then (P is PML)(I is PMS)(D is PML) (1)
8. If (e is ZE) and (cherror is NS) then (P is PVS)(I is PS)(D is PL) (1)
9. If (e is PS) and (cherror is NS) then (P is PML)(I is PMS)(D is PVL) (1)
10. If (e is PL) and (cherror is NS) then (P is PVL)(I is PM)(D is PVL) (1)

Fig. 7 Rule Editor Window for Fuzzy Controller of DC Motor

V FRACTIONAL ORDER PID CONTROLLER

A. Fractional Calculus

To study the fractional order controllers, the starting point is of course the fractional order differential equations using fractional calculus. Fractional calculus extends the classic concepts of differential and integral calculus to an arbitrary order. For the definition of the generalized operator aD_t (where a and t are the limits and _ is the order of the operation), the Riemann-Liouville (RL) and the Gr ¨unwald-Letnikov (GL) definitions are generally applied. The RL definition is given by (_ > 0): aD_

$$aD_t^{\propto} f(t) = \frac{1}{\Gamma(n-1)} \frac{d^n}{dt^n} \int_a^t \frac{f(\Gamma)}{(t-\Gamma)^{\alpha-n+1}} d\Gamma$$

where $\Gamma(x)$ is the gamma function of f(x)
The GL definition is ($\alpha \in \mathbb{R}$) u
And [x] represents the integer part of x.
The classical PID controller can be generalized into a fractional order PID controller, the so called $PI^{\lambda}D^{\mu}$, whose integro-differential equation can be expressed as:

$$u(t) = K_p e(t) + \frac{1}{T_I} D^{-\lambda} e(t) + T_D D^{\mu} e(t) \qquad (3)$$

where K_P is the proportional gain, T_I is the integral time constant, T_D is the derivative time constant, $\boldsymbol{\lambda}$ is the (non-integer) order of the integrator and μ is the (non-integer) order of the derivative action. The corresponding transfer function is expressed as

$$C(S) = \frac{U(S)}{E(S)} = K_P\left(1 + \frac{1}{T_I S^{\lambda}} + T_A S^{\lambda}\right) \qquad (4)$$

$K_I = K_P / T_I$ and $K_D = K_P \cdot T_D$, we obtain

$$C(s) = K_P + \frac{K_I}{S^{\lambda}} + K_d s^{\lambda} \qquad (4.27)$$

It turns out in any case that in the $PI^{\lambda}D^{\mu}$ controller, there are five parameters to tune and, most of all, the physical meaning of the two additional parameters is not clear. Indeed, the effect of changing these two parameters on the obtained performance is not well understood.

B. Controller Scheme

The control scheme considered is shown in Fig.8 where C and P are the controller and the process transfer functions respectively, x is the process output, y is the measured output, u is the control variable, r is the reference signal and e = r−y is the control error. Then, d denotes the load disturbance signal and n denotes the measurement noise signal. It is worth stressing that the performance of the control system in general is evaluated by considering all the input-output relationships between the three inputs r, d and n, and the three outputs y, x and u.

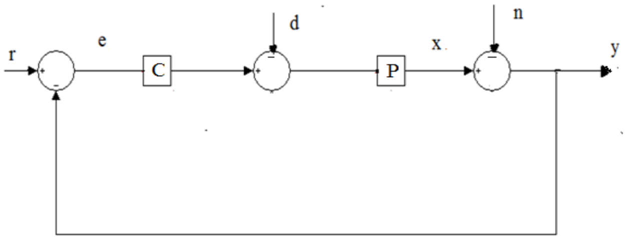


Fig. 8 Control scheme of FO PID

For the purpose of the description made in the following sections, denote as S the sensitivity function

$$S(s) = \frac{1}{1+C(S)P(S)} \qquad (5)$$

as T the complementary sensitivity function

$$T(s) = \frac{C(s)P(s)}{1+C(s)P(s)} \qquad (6)$$

and as L the open-loop transfer function

$L(s) = C(s)\, P(s)$

C. Design of FOPID Controller for Speed Control of Dc Motor

Fig.9 shows the SIMULINK model for speed control of separately excited dc motor using FOPID Controller. Subsystem shows the model of separately excited DC Motor as shown in Fig.1.

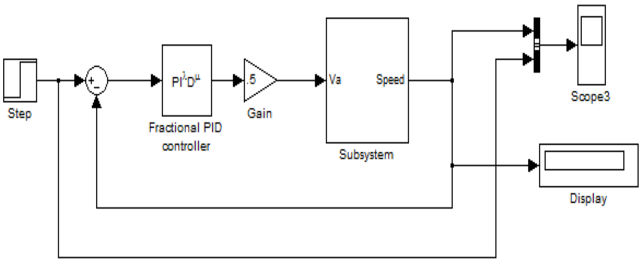


Fig. 9 SIMULINK Model of Speed Control of Motor using FOPID

To design a fractional controller, there are two approaches possible. The first one is placements of pole and second is by experimental results. The method of experimental results is used for design of controllers. The method involves studying the closed loop response of system by varying a tuning parameter. An appropriate value of tuning parameter is chosen depending on the closed loop performance requirements of the system i.e. overshoot, settling time, rise time, etc. Fractional PID controller design involves following steps:

A. Determination of proportional gain K_P:

The value of proportional gain K_P is adjusted to get minimum steady state error possible. With increase in K_P, the settling time decreases but the steady state value remains unchanged. A value of K_P is chosen as:

$K_P = 221.59$

B. Determination of K_I and λ:

When integral time T_I is increased keeping $K_P = 221.59$, it is observed that the controlled response become more and more oscillatory in nature. Now K_I is kept constant at 2.2375×10^3 and integral order λ is changed. The peak value and oscillatory nature of the response increases with increasing value of λ.. The integral order λ is chosen so as to have less oscillation in the controlled response, less settling time and K_I is selected to have low possible peak value.

The values chosen are:

$\lambda = 0.87$, $K_I = 2.2375 \times 10^3$

C. Determination of K_D and μ:

The increase in derivative time K_D causes the initial response to set point change becomes faster and also the peak value decreases. The value of derivative order **μ** is varied, which affects the peak value and also speed of the response. **μ** is chosen to have faster response but to avoid any peak overshoot. The values chosen for the derivative gain and derivative order are:

$K_D = 2.4785$, $\mu = 0.42$

VI SIMULATION RESULTS

The speed vs time response of DC motor using PID controller is shown in Fig.10.This output response shows that there are initial oscillations in speed and after a settling time of 4 seconds,the motor attains the rated speed.

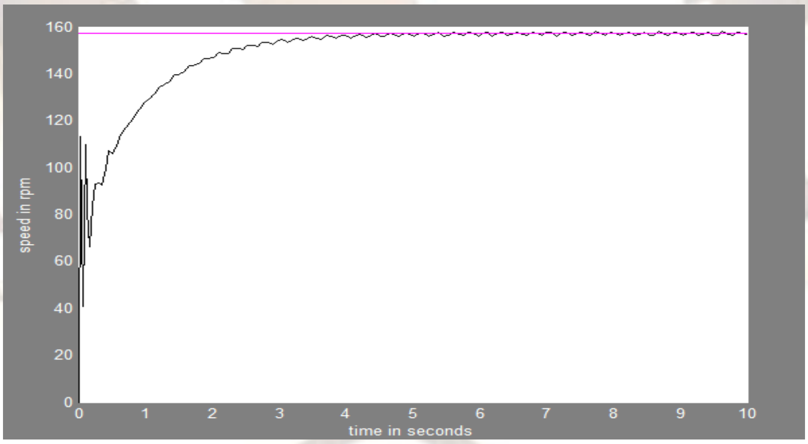


Fig. 10 SPEED VS TIME RESPONSE OF SPEED CONTROL OF DC MOTOR USING PID CONTROLLER

The speed vs time response of DC motor usingFuzzy- PID controller is shown in Fig.11. The model can be simulated to visualize and analyse the result. This output response shows that after 2.7 seconds the motor attains the rated speed of 157.07rad/s.

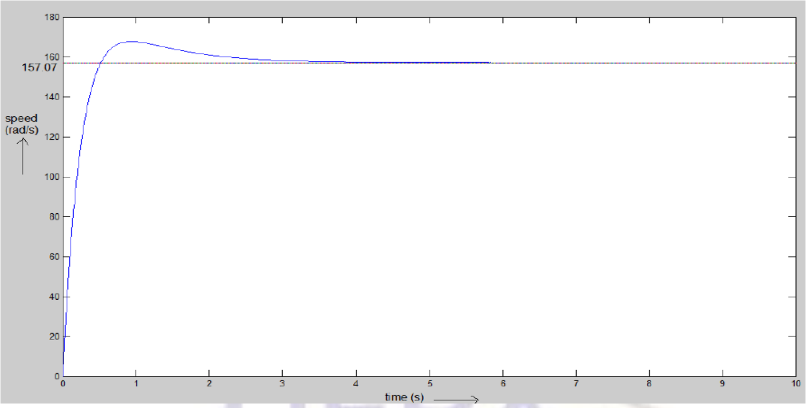


Fig. 11 Speed VS Time Response of Fuzzy Tuned PID Controlled DC Motor

The speed vs time response of DC motor using FOPID controller is shown in Fig.12

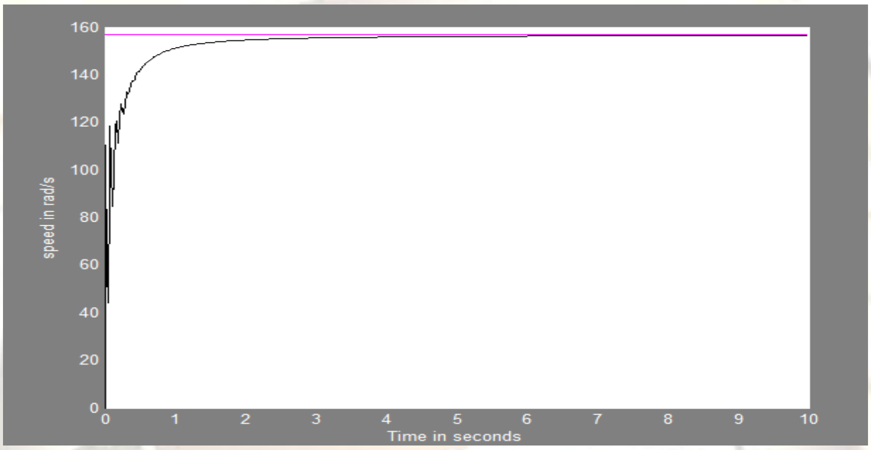


Fig. 12 Simulation Results of Separately Excited DC Motor Using FOPID Controller

After analysing the above three graphs, the comparative table is made and results are analysed and discussed. Table 7 shows the comparative analysis of the three controllers.

Table 7
The Comparative Analysis of the Controllers

Specifications	**PID**	**FOPID**	**FLC**
Rise time	3sec	1sec	0.7sec
Settling time	4 sec	3sec	2.7sec
Steady state value	156.3	156.5	157.07

The performance specifications of the controlled system using the fractional controller are better than that of the controlled system using classical PID controller. In general, the system with the integer order PID controllers takes more time to settle than with fractional order PID controller. Oscillations in FOPID are less as compared to conventional PID. Settling time is less in FOPID as compared to PID controller. When these two controllers are compared with FLC, it is observed that FLC is more efficient among the three controllers.FLC parameter controller has less rising and settling time as compared to other two controllers. Steady state error is also less in Fuzzy Logic Controller. FLC has better dynamic response properties and steady-state properties.

VI CONCLUSION

In present work, performance comparison of PID controller with that of fractional order PID controller and Fuzzy Logic controller is presented. Performance comparison are simulated and studied. The time response characteristics of the three systems are analysed. The effectiveness of the fractional order PID controller and PID controller and Fuzzy Logic controller is evaluated in terms of:

- **i.** Rise-time
- **ii.** Settling-time
- **iii.** Steady state value

Comparing the step responses with the ones obtained (in simulation) with the three controller, the better performance of the system with the Fuzzy Logic controller was observed. Fractional order PID controller for integer order plants offer better flexibility in adjusting gain characteristics than the PID controllers, owing to the two extra tuning parameters i.e. order of integration and order of derivative in addition to proportional gain, integral time and derivative time. Fine-tuned Fuzzy controller presents smaller overshoot and settling time than conventional PID controller and FOPID controller. The three parameters "K_P", "K_I", "K_D" of conventional PID control need to be constantly adjusted in order to achieve better control performance. In case of fractional PID five parameters needs to be tuned to achieve better performance. Fuzzy self-tuning PID parameters controller can automatically adjust PID parameters in accordance with the speed error and the rate of speed error-change, so it has better self-adaptive capacity. The reason for getting a smooth controller output in the PID-like FLC case is because of the fact that PID-like FLC updates the controller output by making comparison of the error and the change in error in angular displacement of the motor shaft.

REFRENCES

[1] Zhang G and Funji Furusho Fungi, “Speed Control of Two-Inertia System by PI/PID Control”, IEEE Transaction on Industrial Electronics, Vo1. 47, pp. 603-609, June, 2000.

[2] I-Hai Lin P and Ellsworth Chris, “Design and Implementation of a PC-Based Universal Fuzzy Logic Controller System”, Proceedings of International IEEE/IAS Conference on Industrial Automation and control, pp. 399-408, 06 August, 2002.

[3] Zadeh L.A., “Fuzzy Logic: Issues, Contentions and Perspectives”, IEEE International Conference on Acoustics, Speech, and Signal Processing, VI, pp. VI/183, Vol. 6, 19 April, 1994.

[4] Prommeuan S., Boonpiyathud S and Suksri T, “Fuzzy Logic Based on LabVIEW for Speed Control of Two-Inertia System”, Proceedings of International Joint Conference by the Institute of Control, Robotics and Systems (ICROS) and the Society of Instrument and Control Engineers (SICE) on Industrial Electronics, pp. 2867-2870, August, 2009.

[5] Tipsuwan Y., Mo-Yuen Chow, “Fuzzy logic Microcontroller Implementation for DC Motor Speed Control”, Proceedings of International IEEE Conference on Industrial Electronic Society, Vol. 3, pp. 1271-1276, 29 November, 1999.

[6] Sousa G.C.D and Bose B.K, “A Fuzzy Set Theory Based Control of a Phase-Controlled Converter DC Machine Drive” IEEE Transaction on Industrial Applications, Vol. 30, pp. 34-44, January, 1994.

[7] Katbab A., “Fuzzy Logic and Controller Design-a Review”, Proceedings of IEEE Conference on Visualize the Future, pp. 443-449, March, 1995.

[8] Wen J. Sheng Wang C. Hsu; Chang Y. De; Teng C. Cheng., “Intelligent Control of High-speed Sensorless Brushless DC Motor for Intelligent Automobiles”, Proceedings of IEEE Conference on System, Man and Cybernetic, pp. 3394-3398, October, 2008.

[9] N. Barakat., “Speed Control of a DC Motor using a Feedforward Computed Torque Control Scheme”, Proceedings of IEEE Conference on Intelligent Control, pp. 432-437, September, 1996.

[10] Khoei A., Hadidi Kh. and Yuvarajan S., “Fuzzy-Logic DC-Motor Controller with Improved Performance”, Proceedings of IEEE Conference on Industry Applications, Vol. 3, pp. 1652-1656, October, 1998.

[11] Altayef J. A. and Zhu Qun-xiong, “Real – Time DC Motor Position Control by (FPID) Controllers and Design (FLC) Using LabVIEW Software Simulation”, Proceedings of International Conference on Computer and Automation Engineering held in Singapur, Vol. 2, pp. 417-420, 26 February, 2010.

[12] Mrad F., DandachS H., Azar S.and Deeb G., “Operator-Friendly Common Sense Controller with Experimental Verification using LabVIEW”, Proceedings of IEEE International Symposium on Control and Automation, pp. 1051-1055, June, 2005.

[13] Huibin Z., Jianxun Jin and Jun Cheng, “Virtual Instrument Based Fuzzy Control, System form PMLSM Drive” Proceedings of IEEE International Conference on Applied Superconductivity and Electromagnetic Devices, pp. 299-303, 25 September, 2009.

[14] Khuntia S.R., Mohanty K.B., Panda S and Ardil C, “A Comparative Study of P-I, I-P, Fuzzy and Neuro-Fuzzy Controllers for Speed Control of DC Motor Drive”, Proceedings of International Journal on Electrical and Computer Engineering, Vol. 5, pp. 287-291, 2010.

[15] Natsheh E and K. A Buragga A.K., “Comparison between Conventional and Fuzzy Logic PID Controllers for Controlling DC Motors”, Proceedings of International Journal on Computer Science Issues, Vol.7, pp. 1694-0814, September, 2010.

[16] Zhao Chunna., Xue Dingy U and Chen Y.Q., “A Fractional Order PID Tuning Algorithm for A Class of Fractional Order Plants” Proceedings of American Control Conference, Minneapolis, pp. 3182-3187, June, 2006.

[17] Kaur K., Chowdhury S. and Domijan A., “Fuzzy Logic Based Control of Variable Speed Induction Machine Wind Generation System", Proceedings of IEEE Conference on Conversion and Delivery of Electrical Energy, pp. 1-11, July, 2008.

[18] Ponce P., Ramirez F. and Medina V., “A Novel Neuro-Fuzzy Controller Genetically Enhanced Using LabVIEW”, Proceedings of IEEE Annual Conference on Industrial Electronics, pp. 1559-1565, 2008.

[19] Ismail A and Sharaf A.M., “An Efficient Neuro Fuzzy Speed Controller for Large Industrial DC Motor Drive”, Proceedings of IEEE International Conference on Control Application, Vol.2, pp. 1027-1031, 10 December, 2002.

[20] Bimal B.K., “Expert System, Fuzzy Logic, and Neural Network Applications in Power Electronics and Motion Control”, Proceedings of International journals, Vol. 82, pp. 1303-1323, August, 1994.

[21] Mountain J.R., “Fuzzy Logic Motor Speed Control with Real-time Interface using an 8-bit Embedded Processor”, Proceedings of IEEE Symposium on System Theory (SSST), pp. 307-312, 7 March, 2010.

[22] Aceves Lopez A and Aguilar-Martin J, “A Simplified Version of Mamdani's Fuzzy Controller: the natural logic controller”, Proceedings of IEEE International Conference on Computational Intelligence Society, Vol.14, pp. 16-30, 13 February, 2006.

[23] Pisoni E., Visioli. A and Dormido. S, “An Interactive Tool for Fractional Order PID Controllers”, Proceedings of IEEE Annual Conference on Industrial Electronics, held in Italy, pp. 1470-1475, 2009.

[24] Bingul. Z and Karahan. O, “Tuning of Fractional PID Controllers using PSO Algorithm for Robot Trajectory Control” IEEE International Conference on Mechatronics (ICM), pp. 955-960, 13 April, 2011.

[25] Yang Ding, Bin Sun, Yongmei Huang, Weiwei Lin and Fei Qian, “Hybrid MATLAB and LabVIEW to Implement an Intelligent Foundation Field bus Control System”, Proceedings on Intelligent Control and Automation, pp. 4539-4543, 7 July, 2010.

[26] Sundaravadivu. K., B. Arun and Saravanan K., “Design of Fractional Order PID Controller for Liquid Level Control of Spherical Tank”, Proceedings of IEEE International Conference on Control System, Computing and Engineering (ICCSCE), pp. 291-295, 25 November, 2011.

[27] Hamamci S.E., “An Algorithm for Stabilization of Fractional-Order Time Delay Systems Using Fractional-Order PID Controllers”, IEEE Transactions on Automatic Control, Vol.52, pp. 1964–1969, October, 2007.

[28] Wang. Z., Cao. G and Zhu. X., “Digital Implementation of Fractional Order PID Controller, and its Application” Proceedings of Journal on Systems Engineering and Electronics, Vol.16, Issue.1, pp. 116-122, March, 2005.

[29] Zang. Y. “Fractional-order PID Controller Tuning Based on Genetic Algorithm” Proceedings of International Conference on Business Management and Electronic Information (BMEI), Vol.3, pp. 764-767, 13 May, 2011.