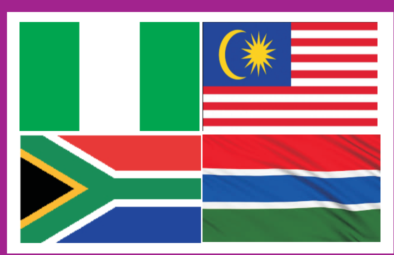
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

SCHOOL OF ELECTRICAL ENGINEERING AND TECHNOLOGY &
SCHOOL OF INFRASTRUCTURE, PROCESS ENGINEERING AND TECHNOLOGY

3rd INTERNATIONAL ENGINEERING CONFERENCE IEC 2019

THEME THE ROLE OF ENGINEERING AND TECHNOLOGY IN SUSTAINABLE DEVELOPMENT

BOOK of PROCEEDINGS



DATE:
24TH - 26TH SEPTEMBER 2019

VENUE:
CHEMICAL ENGINEERING LECTURE THEATER, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

EDITED BY

ENGR. DR. S.M. DAUDA, ENGR. DR. A.U. USMAN, ENGR. DR. U.S. DAUDA, ENGR. M. ABUBAKAR, ENGR. DR. E.A. AFOLABI, ENGR. DR. I.M. ABDULLAHI, ENGR. DR. (MRS) I.H. MUSTAPHA, ENGR. A.S. AHMAD, ENGR. J.G. AMBAFI, ENGR. T.A. FOLORUNSO, ENGR. U.U. BUHARI, ENGR. DR. OPE OSANAIYE, ENGR. A. YUSUF

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

SCHOOL OF ELECTRICAL ENGINEERING AND TECHNOLOGY &
SCHOOL OF INFRASTRUCTURE, PROCESS ENGINEERING AND TECHNOLOGY

3rd INTERNATIONAL ENGINEERING CONFERENCE IEC 2019

DATE: 24TH - 26TH SEPTEMBER 2019

THEME THE ROLE OF ENGINEERING AND TECHNOLOGY IN SUSTAINABLE DEVELOPMENT

MEMBERS OF THE CONFERENCE ORGANISING COMMITTEE

Engr. Dr. S.M. Dauda	Chairman	Engr. Dr. U.S. Dauda	Member
Engr. Dr. A.U. Usman	Co-Chairman	Engr. Dr. M.D. Yahya	Member
Engr. Prof. R.A. Muriana	Member	Engr. Dr. B.A. Orhevba	Member
Engr. Dr. T.W.E. Adejumo	Member	Engr. Dr. Michael David	Secretary

TECHNICAL COMMITTEE

Engr. Dr. U.S. Dauda	Chairman
Engr. Dr. Eyitayo Afolabi	Member
Engr. Dr. A.I. Mohammed	Member
Engr. Dr. (Mrs) H.I. Mustapha	Member
Engr. A.S. Ahmad	Member
Engr. J.G. Ambafi	Member
Engr. T.A. Folorunso	Member
Engr. Buhari U. Umar	Member
Engr. Dr. Ope Osanaiye	Member
Engr. A. Yusuf	Member
Engr. M. Abubakar	Secretary

WELFARE COMMITTEE

Engr. Dr. M.D. Yahya	Chairman
Engr. Prof. R.A. Muriana	Member
Engr. Dr. A.J. Otaru	Member
Engr. Dr. E.A. Afolabi	Member
Engr. A. Yusuf	Member
Engr. Dr. B.A. Orhevba	Secretary

LOGISTIC COMMITTEE

Engr. Prof. R.A. Muriana	Chairman
Engr. D.N. Kolo	Member
Engr. Essien Akpan	Member
Mr. Idris Akintunde	Member
Mr. Mohammed Shehu	Member
Engr. Dr. T.W.E. Adejumo	Secretary

FINANCE COMMITTEE

Engr. Dr. B.A. Orhevba	Chairman
Engr. Prof. O.A. Olugboji	Member
Engr. Dr. M.D. Yahya	Member
Engr. Dr. H.I. Mustapha	Member
Engr. Bello Abdulkadir	Member
Engr. Buhari Umar	Member
Engr. Dr. M. Alhassan	Secretary

ICT COMMITTEE

Engr. Dr. Bala A. Salihu	Chairman
Mr Emmanuel Abba	Member
Mr Alenoghena Benjamin	Member

CONTENTS

Content **Page**

FORWARD

The School of Engineering and Engineering Technology, Federal University of Technology, Minna, organized the 1st and 2nd International Engineering Conference in 2015 and 2017 respectively. With the emergence of the new School of Electrical Engineering and Technology and the School of Infrastructure, Process Engineering and Technology, the two schools came together to organize this 3rd International Engineering Conference (IEC 2019) with the theme: “The Role of Engineering and Technology in Sustainable Development” considering the remarkable attendance and successes recorded at the previous conferences. The conference is aimed at offering opportunities for researchers, engineers, captains of industries, scientists, academics, security personnel and others who are interested in sustainable solutions to socio-economic challenges in developing countries; to participate and brainstorm on ideas and come out with a communiqué, that will give the way forward. In this regard, the following sub-themes were carefully selected to guide the authors’ submissions to come up with this communiqué.

1. Engineering Entrepreneurship for Rapid Economic Growth.
2. Regulation, Standardization and Quality Assurance in Engineering Education and Practice for Sustainable Development.
3. Solutions to the Challenges in Emerging Renewable Energy Technologies for Sustainable Development.
4. Electrical Power System and Electronic as a Panacea for Rapid Sustainable Development
5. Promoting Green Engineering in Information and Communication Technology
6. Reducing Carbon Emission with Green and Sustainable Built Environment
7. Artificial Intelligence and Robotics as a Panacea for Rapid Sustainable Development in Biomedical Engineering
8. Petrochemicals, Petroleum Refining and Biochemical Technology for Sustainable Economic Development.
9. Advances and Emerging Applications in Embedded Computing.
10. Traditional and Additive Manufacturing for Sustainable Industrial Development.
11. Emerging and Smart Materials for Sustainable Development.
12. Big Data Analytics and Opportunity for Development.
13. Building Information Modeling (BIM) for Sustainable Development in Engineering Infrastructure and Highway Engineering.
14. Autonomous Systems for Agricultural and Bioresources Technology.

The conference editorial and Technical Board have members from the United Kingdom, Saudi Arabia, South Africa, Malaysia, Australia and Nigeria. The conference received submissions from 4 countries namely: Malaysia, South Africa, the Gambia and Nigeria. It is with great joy to mention that 123 papers were received in total, with 0.9 acceptable rate as a result of the high quality of articles received. Each of the paper was reviewed by two personalities who have in-depth knowledge of the subject discussed on the paper. At the end of the review process, the accepted papers were recommended for presentation and publication in the conference proceedings. The conference proceedings will be indexed in Scopus.

On behalf of the conference organizing committee, we would like to seize this opportunity to thank you all for participating in the conference. To our dedicated reviewers, we sincerely appreciate you for finding time to do a thorough review. Thank you all and we hope to see you in the 4th International Engineering Conference (IEC 2021).

Engr. Dr. S. M. Dauda
Chairman, Conference Organizing Committee

ACKNOWLEGEMENT

The Chairman and members of the Conference Organizing Committee (COC) of the 3rd International Engineering Conference (IEC 2019) wish to express our gratitude to the Vice Chancellor and the management of the Federal University of Technology, Minna, the Deans and all staff of the School of Electrical Engineering and Technology (SEET) and the School of Infrastructure, Process Engineering and Technology (SIPET) for the support towards the successful hosting of this conference. We also thank the entire staff of the university who contributed in one way or the other. We are sincerely grateful to you all.

3rd International Engineering Conference (IEC 2019)
Federal University of Technology, Minna, Nigeria

Modelling and Simulation of Adaptive Fuzzy-PID Controller for Speed Control of DC Motor

*Timothy Onyechokwa, Adegboye B. A. & A.S. Mohammed
[1]Electrical Electronic Engineering Department, Federal University of Technology, PMB 65 Minna Niger State, Nigeria
*Corresponding author email: chekwason@yahoo.com, +2348033035354

ABSTRACT

DC motors have long been use as a primary means of electrical traction. It has find wide area of applications ranging from industrial applications to basic home appliances. In most recent DC motor applications, there is need for precise speed control to give the desired performance. Thus, this paper presents a method for speed control of DC motor using adaptive fuzzy-PID controller algorithm. An adaptive fuzzy-PID controller was modelled and simulated using MATLAB control toolbox. The performance of the proposed model was measured using parameters such as rise time, peak overshoot, and settling time. Obtained results show the advantage of a combined fuzzy-PID over classical PI, PD, and PID controller.

Keywords: *DC Motor; Fuzzy-PID; Fuzzy Logic Controller (FLC); PID Controller.*

1 INTRODUCTION

DC motors have long been the primary means of electrical traction. Direct current (DC) motors have been widely used in many industrial applications such as electric vehicles, electric cranes and steel rolling mills due to precise, wide, simple and continuous control characteristics. The development of high-performance motor drives is very important in industrial as well as in other application.

The development of high-performance motor drives is very important in industrial as well as other general purpose applications such as steel rolling mills, electric trains and robotics. Generally, a high-performance motor drive system must have good dynamic speed command tracking and load regulating response to perform task. DC drives, because of their simplicity, ease of application, high reliabilities, flexibilities and favourable cost have long been a backbone of industrial applications, robot manipulators and home appliances where speed and position control of motor are required (Bansal Umesh Kumar, 2013).

There are mainly two types of dc motors used in industry. The first one is the conventional dc motor where the flux is produced by the current through the field coil of the stationary pole structure. The second type is the brushless dc motor where the permanent magnet provides the necessary air gap flux instead of the wire-wound field poles. BLDC motor is conventionally defined as a permanent magnet synchronous motor with a trapezoidal Back EMF waveform shape. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. Recently, high performance BLDC motor drives are widely used for variable speed drive systems of the industrial applications and electric vehicles (Kandiban & Arulmozhiyal, 2012).

DC drives are less complex with a single power conversion from AC to DC. Again, the speed torque characteristics of DC motors are much more superior to that of AC motors. A DC motors provide excellent control of speed for acceleration and deceleration. DC drives are normally less expensive for most horsepower ratings. They have long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose. In these applications, the motor should be precisely controlled to give the desired performance. The controllers of the speed that are conceived for goal to control the speed of DC motor to execute one variety of tasks, is of several conventional and numeric controller types, the controllers can be: proportional integral (PI), proportional integral derivative (PID) Fuzzy Logic Controller (FLC) or the combination between them: Fuzzy-Neural Networks, Fuzzy Genetic Algorithm, Fuzzy-Ants Colony, Fuzzy-Swarm. The proportional – integral – derivative (PID) controller operates the majority of the control system in the world. It has been reported that more than 95% of the controllers in the industrial process control applications are of PID type as no other controller match the simplicity, clear functionality, applicability and ease of use offered by the PID controller. PID controllers provide robust and reliable performance for most systems if the PID parameters are tuned properly (Bansal Umesh Kumar, 2013).

The major problems in applying a conventional control algorithm (PI, PD, PID) in a speed controller are the effects of non-linearity in a DC motor. The nonlinear characteristics of a DC motor such as saturation and fiction could degrade the performance of conventional controllers (Chalmers, 1992; Johnson & Lorenz, 1992). Generally, an accurate nonlinear model of an actual DC motor is difficult to find and parameter obtained from systems identification may be only approximated values. The field of Fuzzy control has been making rapid progress in recent years.

Fuzzy logic control (FLC) is one of the most successful applications of fuzzy set theory, introduced by L.A Zadeh in 1973 and applied (Mamdani 1974) in an attempt to control system that are structurally difficult to model. Since then, FLC has been an extremely active and fruitful research area with many industrial applications reported (Li & Tso, 2000). In the last three decades, FLC has evolved as an alternative or complementary to the conventional control strategies in various engineering areas. Fuzzy control theory usually provides non-linear controllers that are capable of performing different complex non-linear control action, even for uncertain nonlinear Systems. Unlike conventional control, designing a FLC does not require precise knowledge of the system model such as the poles and zeroes of the system

It is well known that the mathematical model is very crucial for a control system design. For a DC motor, there are many models to represent the machine behaviour with a good accuracy. However, the parameters of the model are also important because the mathematical model cannot provide a correct behaviour without correct parameters in the model. Fuzzy rule-based models are easy to comprehend because it uses linguistic terms and the structure of if-then rules. In this study, the characteristics of PID controllers and fuzzy logic controllers and their application to an industrial DC motor at steps including structure, characteristics and the mathematical model and simulation of stability response for speed control of DC motor will be discussed. The study involves the modelling and simulation studies used to demonstrate the basic theoretical feasibility of the system used by fuzzy and PID control to achieve better response by less noise and less overshoot.

Various researchers have explored this area. The study by Al-Maliki & Iqbal, (2018) addressed a PID controller tuning for sensor-less speed control of DC motor based on FLC. A Proportional-Integral-Derivative (PID) type speed controller with Kalman Filter (KF) estimator was used and Integral of Absolute Error (IAE), peak overshoot and settling time were chosen as performance indices. The work examined the sensor-less speed control of a DC motor in a noisy environment simulating actual working conditions. The Kalman Filter used in the work can only be used in linear state transitions. Aside the noise that was reduced by KF, the PID controller gains tuned via MATLAB resulted in large peak overshoot and IAE with a relatively long settling time. When compared, a Fuzzy Logic Controller (FLC) based PID (FLC-PID) tuned using genetic algorithms (GA), reduced the settling times by 75.98%, the IAE and the maximum overshoot by 56.2% and 97.89% respectively. Compared to the conventional PID without KF, the FLC-PID radically improved the reference command speed tracking and sudden load changes disturbance rejection for the dc motor model. Therefore, this work has a great application in a linear transition.

A comparative study of fuzzy and PID controllers as regards to the DC Motor's speed control was done by Mohammed & Ali, (2014). PID and Fuzzy controllers were tested and compared using MATLAB/SIMULINK program for speed under load and no-load conditions. The work is an extensive study that revealed the differences between the fuzzy logic controller and the PID controller. Nonetheless, the mathematical model of DC motor used was based on trial and error method. The results showed that the overshoot, settling time and control performance had been improved greatly by using Fuzzy Logic controller making it to have a better performance than the PID controller.

Rajkumar, Ranjhitha, Pradeep, Mohammad Fasil, & Kumar, (2017) proposed a fuzzy logic controller (FLC) for speed control of a BLDC motor. The fuzzy logic technique used was to estimate the speed of the brushless DC motor (BLDC) motor under variable and fixed condition of the back-EMF. More so, the speed was controlled using Proportional-Integral (PID) Controller with the help of fuzzy based estimation of the speed and rotor position. The DC-AC conversion with current resonance was achieved with a resonant inverter. The inverter was used to regulate voltage and fed into the BLDC motor through a motor driver circuit. This was then simulated on MATLAB/Simulink. Even though, fuzzy based system is always associated with tuning issues, the work provided a system for the speed control of a BLDC fed inverter with the electric vehicle. It has better noise rejection capabilities and is more robust. The simulation results showed variation of different parameters of BLDC motor including total output electrical torque, rotor speed, rotor angle, three phase stator currents, and three phase back EMF's with respect to time.

Sahputro, Fadilah, Wicaksono, & Yusivar, (2017) described the design and implementation of adaptive PID control strategy for controlling the angular velocity of DC motor. The adaptive PID controller is designed to calculate the control parameters which are timed adaptively to give control performances even if the parameters of DC motors are changed. To achieve effective performance in matching the output speed with the input speed, proportional, integral and derivative (PID) controller is commonly used for DC motor speed control. The determination of PID constants depends on the characteristics of the DC motor that are being used, which is different in each motor and sometimes change throughout the time. To find the optimal PID constants, most people use trial and error which requires a lot of time. The paper furthered shows how the PID constants can be achieved even when parameters changes. In the simulation result, controller constants can be adjusted automatically while the parameters of DC motor changed and send control signal to the DC motor. The experiment also proves the same result as in simulation. The algorithm can adjust DC motor parameters and update the controller constants.

Achanta, (2017), emphasized on the speed of DC motor which plays a major role in control industries. Traditional tuning techniques for classical PID controller suffer from many disadvantages like non-customized performance measure and insufficient process information. In this paper, the author used the Jaya optimization algorithm (JOA) for better performance in speed control and time response of the system. Experimental results are presented to study the performance of JOA based PID controller in comparison with particle swarm optimization (PSO) based PID controller. The performance of the PID controller is based on the tuning of parameters, which are proportional gain (k_p), integral gain (k_i), derivative gain (k_d). The proportional gain (k_p) will reduce the rise time and also reduce the steady state error. An integral gain (k_i) will reduce or eliminate the steady state error but it makes transient response worse. A derivative gain (k_d) will have the effect of increasing stability of system.

Sharma & Palwalia, (2018) presented simulation of a complete system of adaptive fuzzy PID controller along with DC motor model using MATLAB/SIMULINK. The writer showed comparison of conventional PID with adaptive fuzzy PID controller; hence, the results shows adaptive fuzzy tuned PID controller provides better dynamic behaviour of DC motor with low rise time, low settling time, minimum overshoot and low steady state error in speed. PID controllers are commonly exploited in conventional speed control loops. Some of the shortcomings of conventional PID controllers are undesirable overshoot and stagnant response due to sudden change in load torque and sensitivity to controller gains. To achieve better results an adaptive fuzzy logic based PID controller designed is thus proposed herewith.

2 METHODOLOGY

The methodology to be adopted in the proposed study involves the modelling and simulation of fuzzy PID controller for DC motor speed control.

2.1 Modelling of DC Motor

For modelling, the DC motor analysis becomes essential. DC motors are most suitable for wide range speed control and are there for many adjustable speed drives. Intentional speed variation carried out manually or automatically to control the speed of DC motors.

$$\frac{\alpha(V_a - I_a R_a)}{\Phi} = \frac{(V_a - I_a R_a)}{K_a \Phi} \tag{1}$$

Where Φ = Field flux per pole

$$K_a = \frac{PZ}{2\pi a} \tag{2}$$

Where P = Number of poles, Z = Total number of armature conductor, α = Number of parallel path.

From equation (1), it is clear that DC motors have basically three methods of speed control. They are: variation of resistance in armature circuit, variation of field flux, and variation of armature terminal voltage. The armature voltage equation is given by:

$$V_a = E_b + I_a R_a + L_a\left(\frac{dI_a}{dt}\right) \tag{3}$$

The torque balance equation which varies with the armature current is given by

$$T_m = KI_a \tag{4}$$

K is the torque Constant, where back emf of the motor is given as

$$E_b = K_b \omega \tag{5}$$

K_b is the back emf constant, thus, taking the Laplace transform of (3) gives

$$V_a(s) = (R_a + L_a s)I_a(s) + E_b(s) \tag{6}$$

$$V_a(s) = (R_a + L_a s)I_a(s) + K_b s \tag{7}$$

Now, taking equation (4) into consideration, the equation of torque can also be written as:

$$T_m = J\frac{d\omega}{dt} + B\omega \tag{8}$$

And taking the Laplace transform of (8) gives

$$T_m(s) = sJ\omega(s) + B\omega(s) \tag{9}$$

$$\frac{\omega(s)}{T_m(s)} = \frac{1}{Js + B} \tag{10}$$

Using (7) and (10), the transfer function of the model is obtained as:

$$\frac{\omega(s)}{V_a(s)} = \frac{K}{L_a J s^2 + (BL_a + R_a J)s + R_a B + KK_b} \tag{20}$$

The parameters of the DC motor under consideration are given in Table 1. A 3hp, 2400V, 1500 rpm separately excited DC motor will be considered in this study.

TABLE 1: PARAMETERS OF THE DESIGN

Description of the Parameter	**Parameter Value**
Armature resistance, R_a	0.5 Ω
Armature inductance, L_a	0.02H
Armature voltage, V_a	200V
Mechanical inertia, J	0.1 Kg.m2
Friction coefficient, B	0.008 N.m/rad/sec
Back emf constant, K_b	1.25 V/rad/sec
Rated speed	1500 r.p.m
Motor torque constant, K	1 N.m/A

From the parameters in Table 1, the model for the speed control of the DC motor is obtained as:

$$\frac{\omega(s)}{V_a(s)} = \frac{1}{0.002s^2 + 0.0502s + 1.254} \quad (21)$$

2.2 PID Controller Design

In a PID system, the best features of each of PI and PD are utilized. The system function of a PID system is given as in (22).

$$G_c(s) = K_p + K_D s + \frac{K_i}{s} \quad (22)$$

PID controllers have advantage of simple structure, robust performance, and easy to understand. The model in (22) can be represented in cascaded format as:

$$G_c(s) = (1 + K_{D1})(K_{P2} + \frac{K_{I2}}{s}) \quad (23)$$

Equations (22) and (23) are related by:

$$K_p = K_{p2} + K_{D1}K_{I2}$$
$$K_D = K_{D1}K_{p2} \quad (24)$$
$$K_I = K_{I2}$$

Where K_P, K_D, K_I are the proportional, differential and integral gain respectively. The cascade approach allows modular design and tuning of the PID system. Taking the Laplace transform of the armature voltage V_a, and applying the PID model of (23) on the speed control model of (21), the speed control model becomes:

$$\omega(s) = \frac{200\lfloor (K_{p2} + K_{D1}K_{p2})s + K_{I2} + K_{D1}K_{I2} \rfloor}{0.002s^4 + 0.0502s^3 + 1.254s^2} \quad (25)$$

2.3 ADAPTIVE FUZZY PID CONTROLLER

The heart of a fuzzy system is a knowledge base consisting of the so- called If-Then rules. A fuzzy If-Then statement is may have some words characterized by continuous membership functions. After defining the fuzzy sets and assigning their membership functions, rules must be written to describe the action to be taken for each combination of control variables. These rules will relate the input variables to the output variable using If-Then statements which allow decisions to be made. In this paper, the simulation of motor speed control with adaptive fuzzy PID controller was carried out using MATLAB/SIMULINK. Parallel structure of fuzzy PI and PD controllers will be used as speed control circuit. The switching action takes place according to the error signal. The output of the controller was fed to a controlled voltage source which feeds the inverter. Fuzzy logic and control toolboxes in MATLAB were used for the simulation.

Fuzzy logic involves fuzzification and defuzzification; The success of a fuzzy logic system depends on how good this stage is conducted. The first step in designing a fuzzy controller is to decide which state variables represent the system dynamic performance and this must be taken as an input signal to the controller. Fuzzy logic uses linguistic variables instead of numerical variables. The process of converting a numerical variable (real number or crisp variables) into linguistic variables (fuzzy number) is called fuzzification. Defuzzification is the reverse process. This is achieved with different types of fuzzifiers. There are generally three types of fuzzifiers which are used for the fuzzification process; they are singleton fuzzifier, Gaussian fuzzifier and trapezoidal or triangular fuzzifier. Fuzzification converts input data to degree of membership function. In this process, data is matched with condition of rules. Thus a degree of membership function is developed.

The speed error *e* and the change in speed error *ce* serve as input to the fuzzy logic system. The membership functions associated to the control variables have been chosen with Gaussian shapes. The universe of discourse of all the input and output variables were established and a suitable scaling factors will be chosen to bring the input and output variables to this universe of discourse. Each universe of discourse is divided into seven overlapping fuzzy sets: NL (Negative Large), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (positive Medium), and PL (Positive Large).

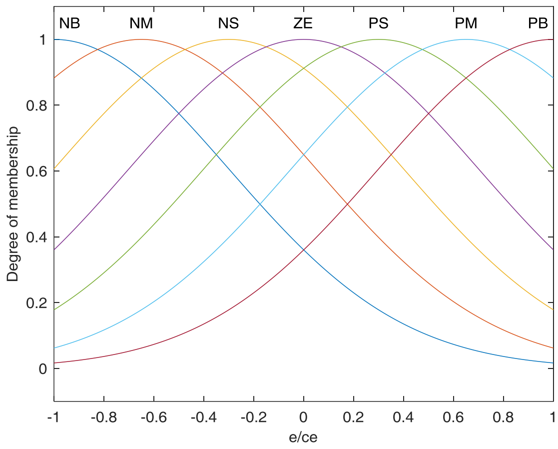


Figure 1: Gaussian membership function for inputs *ce* and *e*

Each fuzzy variable is a member of the subsets with a degree of membership μ varying between 0 (non-member) and 1 (full-member). All the membership functions have asymmetrical shape with more crowding near the origin (steady state). This permits higher precision at steady state. The reverse of fuzzification is called defuzzification. It converts resulting fuzzy set into a number that is sent to the system and this number is actually the control signal. There are many defuzzification methods but the most commonly methods are as follow; centre of gravity (COG), bisector of area (BOA) and means of maximum (MOM).

In adaptive fuzzy PID, the initial PID gains are continuously updated according to the output of the fuzzy logic controller which takes the speed error and the change in speed error as input. The final tuned parameter is obtained by multiplying the initial gain with the output from the fuzzy logic controller. The block diagram of the Fuzzy-PID is as shown in Figure 2.

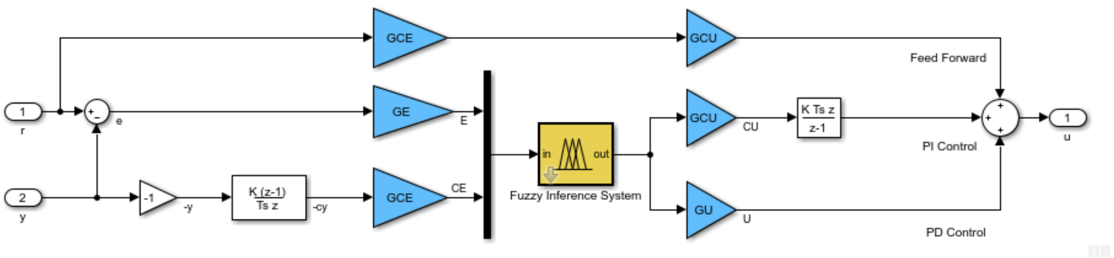


Figure 2: Block diagram of the Fuzzy-PID system

3 RESULTS AND DISCUSSION

The proposed model was simulated using MATLAB control and fuzzy logic toolbox. Obtained results are thus presented in this section. Results presented in this paper include that of traditional PID controller and fuzzy PID controller. Our future work will compare the performance of adaptive fuzzy-PID to the two aforementioned model. The obtained response for traditional PID is as shown in Figure 3, while the response of the fuzzy-PID is as shown in Figure 4.

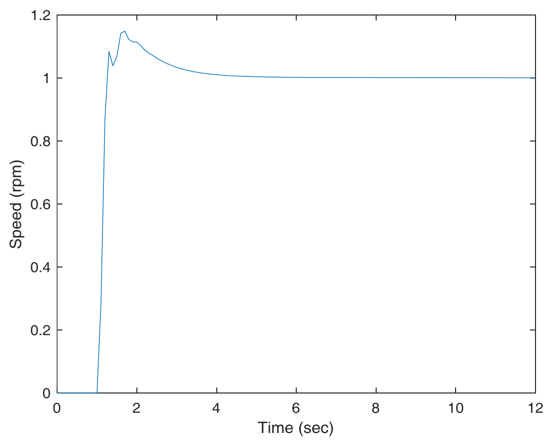


Figure 3: output response of traditional PID

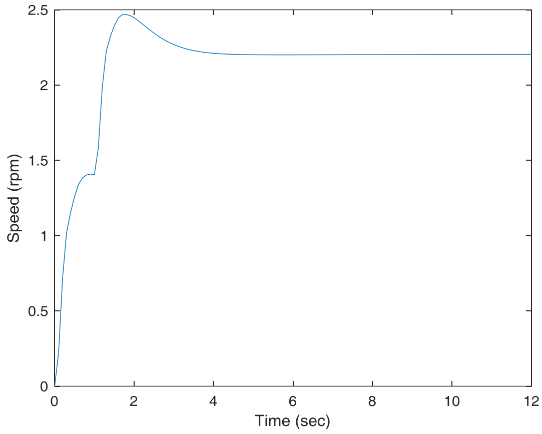


Figure 4: Output response of the fuzzy-PID controller

Though the Fuzzy-PID approach has a longer rise time, it however outperforms the other approaches in terms of settling time and percentage overshoot. Obtained results are summarized in Table 2.

TABLE 2: SUMMARY OF SYSTEM PERFROMANCE

Evaluation Metrics	PI	PD	PID	Fuzzy-PID
Rise time (s)	0.46	0.21	0.28	1.10
Settling time (s)	5.29	3.38	3.49	3.20
Overshoot (%)	29.9	14.8	16.4	12.0

4 CONCLUSION

In this paper, an adaptive fuzzy-PID controller for DC motor speed control was presented. The model was simulated using MATLAB/Simulink. Adaptive fuzzy PID provides a continuous change in the PID gains according to speed error and change in speed error. Obtained results showed that the fuzzy-PID has a faster settling time than the traditional PID though with higher overshoot. Future work will explore means of reducing the rise time while maintaining faster settling time and reduced percentage overshoot.

ACKNOWLEDGEMENTS

The authors will like to acknowledge the department of Electrical Electronics Engineering, Federal University of Technology, Minna. Nigeria

REFERENCES

Achanta, R. K. (2017). DC Motor Speed Control using PID Controller Tuned by Jaya Optimization Algorithm University College of Engineering Kakinada. *2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI)*, 983–987.

Al-Maliki, A. Y., & Iqbal, K. (2018). FLC-based PID controller tuning for sensorless speed control of DC motor. *Proceedings of the IEEE International Conference on Industrial Technology*, *2018–Febru*, 169–174. https://doi.org/10.1109/ICIT.2018.8352171

Bansal Umesh Kumar, N. R. (2013). Speed Control of DC Motor Using Fuzzy PID Control. *Advance in Electronic and Electric Engineering*, 1209–1220.

Chalmers, B. (1992). Influence of saturation in brushless permanent magnet drives. In *IEE proc. B, Elect. Power Appl*.

Johnson, C. T., & Lorenz, R. D. (1992). Experimental identification of friction and its compensation in precise, position controlled mechanism. *IEEE Trans. Ind. Applicant* , *28*(6).

Kandiban, R., & Arulmozhiyal, R. (2012). Design ofAdaptive Fuzzy PID Controller for Speed control of BLDC Motor. *International Journal of Soft Computing and Engineering (IJSCE)*, *2*(1), 2231–2307.

Li, H. X., & Tso, S. K. (2000). Quantitative design and analysis of Fuzzy ProportionalIntegral-Derivative Control- aStep towards Auto tuning. *International Journal of System Science*, *31*(5), 545–553.

Mohammed, O. O. A., & Ali, A. T. (2014). Comparative Study of PID and Fuzzy Controllers for Speed Control of DC Motor. *International Journal of Innovative Research in Science, Engineering and Technology*, *3*(9), 16104–16110.

Rajkumar, M. V., Ranjhitha, G., Pradeep, M., Mohammad Fasil, P., & Kumar, R. S. (2017). Fuzzy based Speed Control of Brushless DC Motor fed Electric Vehicle. *International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET)*, *3*(3), 12–17.

Sahputro, S. D., Fadilah, F., Wicaksono, N. A., & Yusivar, F. (2017). Design and Implementation of Adaptive PID Controller for Speed Control of DC Motor, (1), 179–183.

Sharma, K., & Palwalia, D. K. (2017). A modified PID control with adaptive fuzzy controller applied to DC motor. In *IEEE, International conference on Information, Communication, Instrumentation and Control (ICICIC-2017)* (pp. 1–6). IEEE.