China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 657-665

PSO-TUNED PID CONTROLLER OPTIMIZATION FOR DC MOTOR SPEED CONTROL

Payal Bansal
Associate Professor. Department of Electronics & Communication Engineering, Poornima College of Engineering, Rajasthan, India, payaljindalpayal@gmail.com.

Devendra Kumar Somwanshi
Associate Professor. Department of Electronics & Communication Engineering, Poornima College of Engineering, Rajasthan, India, imdev.som@gmail.com

Pravin Sonwane
Professor, Department of Electrical Engineering, Poornima College of Engineering Jaipur, Pravin.sonwane@poornima.org

Vaishali Sonwane
Associate Professor, Faculty of Computer Science and Engineering, Poornima University, vaishups2k@gmail.com

Abstract:
The design of a PID controller for its robust performance in controlling DC motor speed, even under parameter variations and load disturbance effect. Various tuning techniques such as ANT algorithm, swarm optimization method, genetic algorithm, and gravitational search algorithm are used for PID controller parameter tuning. In Fuzzy PID controller membership functions are tuned with the hit and trial methods. but genetic algorithms can automatically design the PID controller or fuzzy based PID controller with predefined membership functions. The research paper aimed to optimize the PID controller for the purpose of DC motor speed control using PSO algorithm. A comparison of the obtained results was also made with previous researches in this area.
Keyword: PSO, PID, Speed Control, DC Motor

Introduction:

DC motors are widely used in various industries due to their exceptional speed control characteristics. Several techniques have been developed for speed control of DC motors, such as PID controllers, fuzzy controllers, and fuzzy-PID controllers, using methods like genetic algorithms, fractional order fuzzy tuning, and artificial intelligence. The main goal of speed control is to prevent machine damage and avoid slow rise time and high overshoot. Among these techniques, PID controllers based on fuzzy controllers are the most commonly used method for controlling DC motor speed.

Tuning of the controller parameters is performed to obtain optimal settings from the process information. Additionally, other devices such as buck converters and microcontrollers can be combined with the PID controller to control DC motor speed, with parameters being tuned using

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 657-665

floating-point format and DSP processors. Furthermore, nature-inspired algorithms such as Particle Swarm Optimization and Gravitational search algorithm are also being explored for tuning PID controllers.

Literature Review in Speed control of dc motor

A review of more than 25 research papers was conducted in the field of controller design and parameter tuning using fuzzy logic. The purpose was to identify current challenges and potential areas for future work. The review found that the main issue addressed in the papers was speed control of DC motors. The common findings of the literature review is as follows:

- Speed control of DC motor was done by reducing three main parameters i.e. settling time, rise time and Maximum overshoot.
- Controlling of speed was done by using conventional PID controller, Fuzzy PID controller, Genetic algorithm, ANFIS and Particle Swarm Optimization. Some researchers also used Neuro Fuzzy technique.
- DC motors of range (12V – 240 V) and 1500 – 4000Rpm was used by the researchers but some of them also used Separately Excited DC Motor.
- Hardware and Software both implementations were done. In hardware 16 bit microcontroller, Buck converters and Special chip DSPIC30f4011 were used by the researchers. For software, Simulink was developed in MATLAB and LABVIEW.
- Maximum overshoot in the case of conventional PID controller was 4.47% which was reduced to 0% by using the different techniques.
- Maximum Settling time in the case of conventional PID was 2.27s which was reduced to the range of (0.25 s – 0.04 s) by using the different techniques.
- Approximately (30 – 40) % of the rise time is reduced.
- Some researchers have considered noise to be a main problem and they had controlled noise with the help of the algorithms used.
- Researchers compared their results with ZN method results or by the conventional PID controller results.

PSO based PID Controller

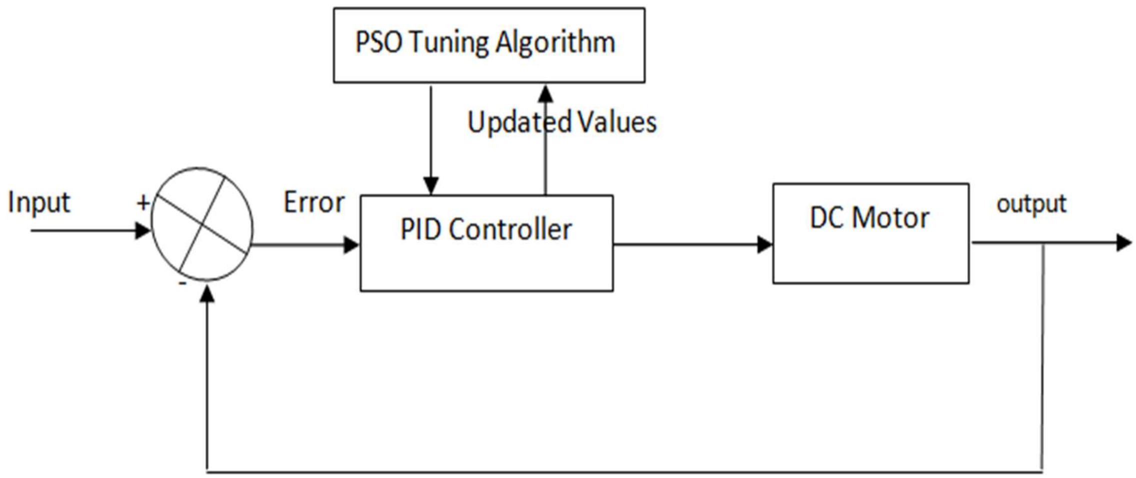


Fig: Block diagram for proposed work

The figure illustrates the implementation of a PSO-tuned PID controller for DC motor speed control. By optimizing the control parameters, this approach can effectively tune the controller and produce optimal results.

Selection of PSO Factors

The PSO algorithm requires predefining numerical coefficients such as acceleration constants, random functions, maximum and minimum velocities, inertia weight, swarm size, and communication topology. In this study, the acceleration constants were set to C1 = 0.7 and C2 = 2. These coefficients play an important role in optimizing the control parameters of the PSO-tuned PID controller for DC motor speed control.

Table 4.2 Parameters of PSO

Parameters	**Value**
No. of particles in swarm	50
Maximum iteration	80
Initial position	5
Social rate C1	0.7
Cognitive rate C2	2
Fitness Function	ISE (current) + c*(max (current)/max (speed)) ^2 *ISE (speed)

Fitness Function

In order to achieve optimal results, all three parameters of the proposed work were optimized. The search space was explored to find the best combination of [Kp, Ki, Kd] for which a particular

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 657-665

response was obtained. Each point in the search space represented a unique combination of these parameters, allowing for a comprehensive exploration of the parameter space.

Fitness = ISE (current) + c*(max (current)/max (speed)) ^2 *ISE (speed)

Where, ISE is Integral Square Error.

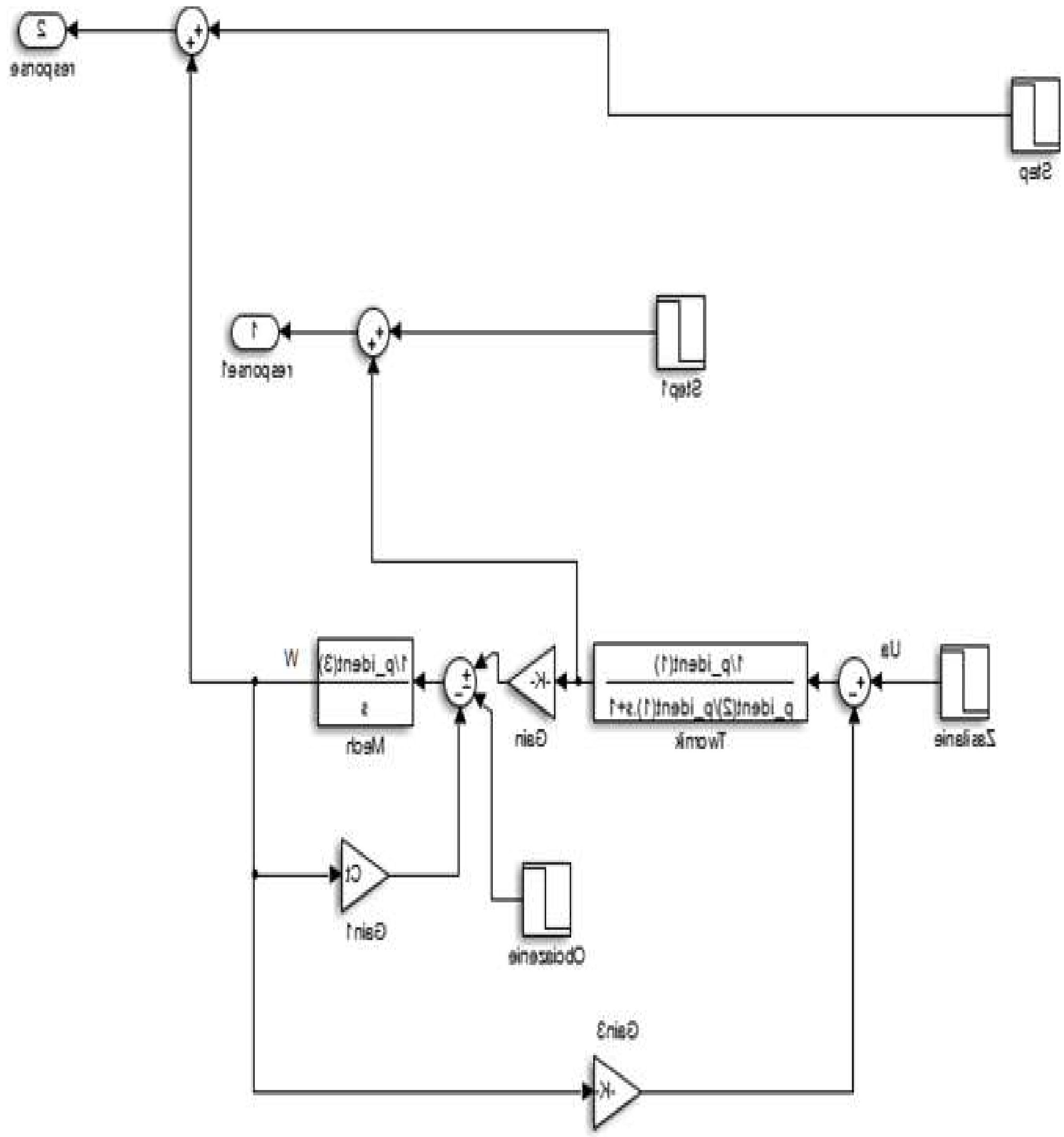
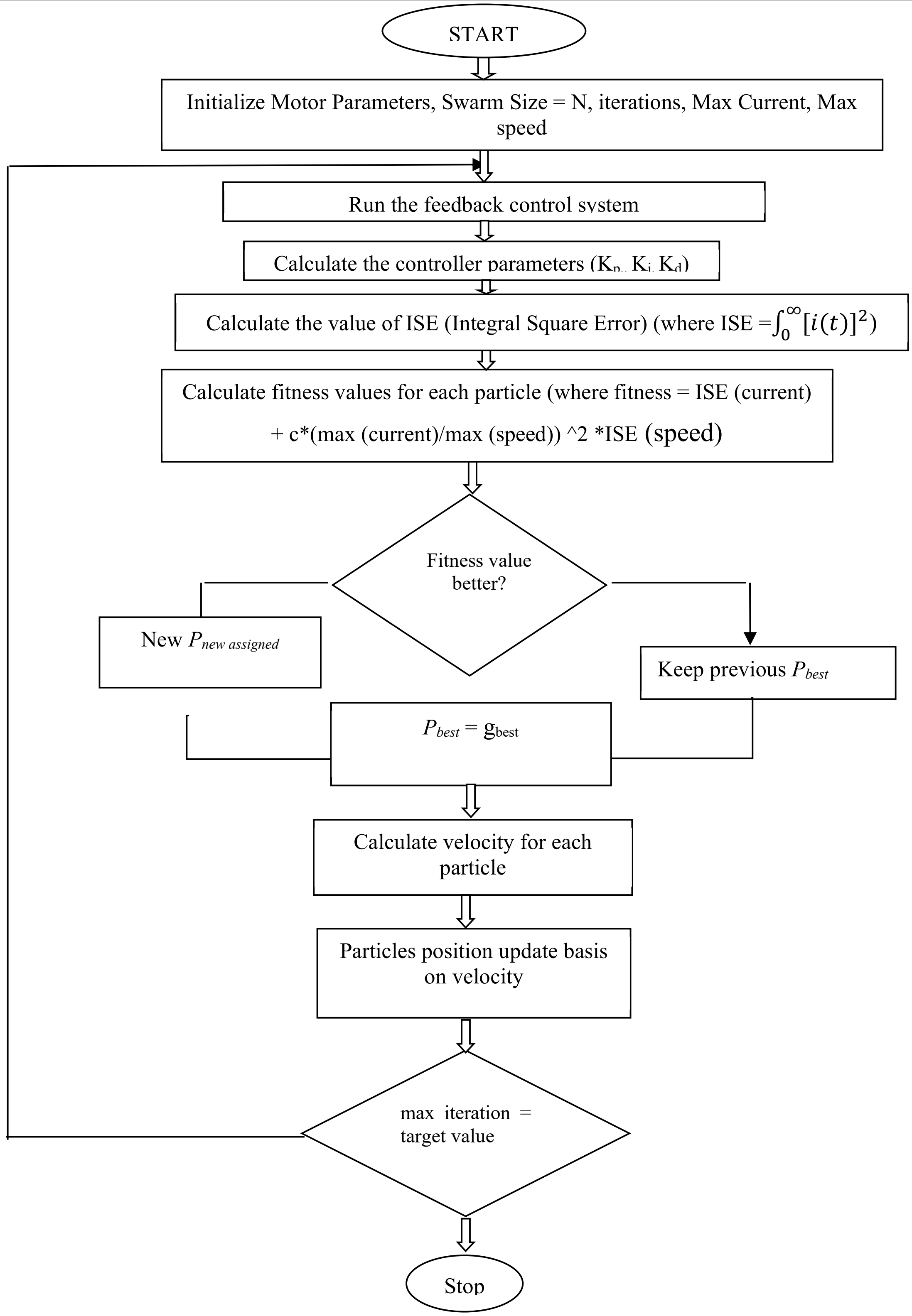


Fig: MATLAB simulink based on PSO

Particle Swarm Optimization Algorithm



According to the algorithm used the flowchart is as follows:

Yes No

No Yes

China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 657-665

Fig: Flowchart of PSO

Step 1 – input the necessary motor parameters for designing the transfer function.
Step 2 – Initialize the PSO parameters i.e. armature resistance, armature inductance, moment of inertia and the psi (flux).
Step 3 – Initialize the swarm position and velocity by taking a constant C as 0.7
Step 4 – Swarm is turned on and P_{best} value is calculated by calculating the fitness value by using equation (4.15). If estimated error crosses the threshold value the response is recognized as totally incorrect.
Step 5 – Update the position using $P_i^{k+1} = P_i^k + V_i^{K+1}$.
Step 6 the fitness value of the personal best (Pbest) of all particles is compared to determine the best. The coordinates of the best particle are stored as Gbest.
Step 7 –After , the Gbest value is obtained. The solution is determined by the particle that generated the most recent Gbest.

Table 5.9 Comparison between Previous Work and Proposed Work

	Settling time(s)	**Maximum overshoot**	**Rise time (s)**
GA (previous work) [18]	0.116	0%	0.063
PID	0.9	0.93%	0.935
PSO	0.09	0%	0.03

Rise time is reduced 0.63s to 0.03 s whereas settling time is also reduced to 0.09s from 0.116 s. This chapter describes the significant contribution of work in achieving the main objective. Next chapter deals with the conclusion of work

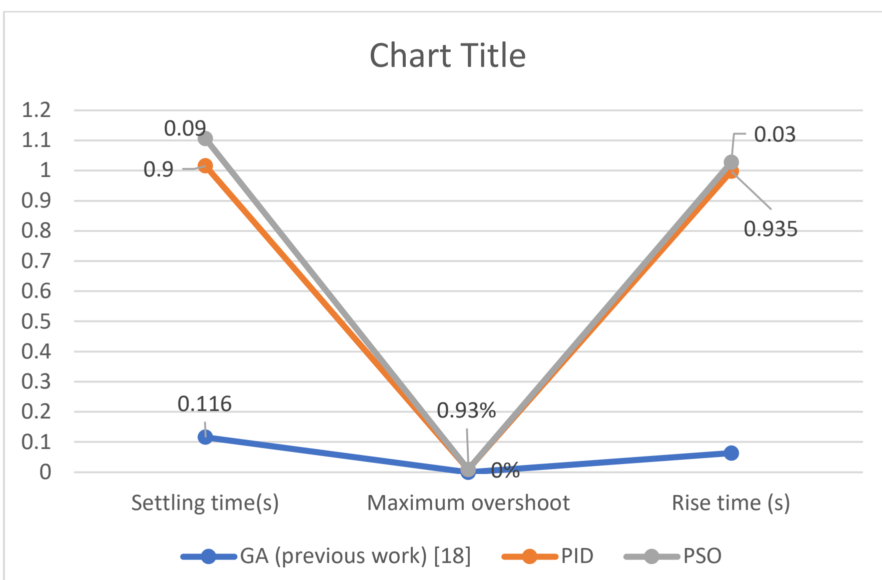


Fig:

Conclusion:

PSO was found to be a more efficient and less time-consuming technique, with a fitness function value close to 0.012 in the PSO-PID algorithm. GA was used for designing the controller and did not require a rule base table. Classical PSO was found to converge prematurely, but adaptive PSO showed better performance by changing control parameters. The use of non-linear weights in PSO proved to be more effective for the dynamic economic dispatch problem due to the changing environment over time.

References

Abou Omar, M.S.; Khedr, T.Y.; Abou Zalam, B.A., "Particle swarm optimization of fuzzy supervisory controller for nonlinear position control system," Computer Engineering & Systems (ICCES), 2013 8th International Conference on , vol., no., pp.138,145, 26-28 Nov. 2013

Changhua Lu and Jing Zhang, "Design and simulation of a fuzzy-PID composite parameters' controller with MATLAB," *2010 International Conference On Computer Design and Applications*, Qinhuangdao, 2010, pp. V4-308-V4-311.

Jong-Hwan Kim, Kwang-Choon Kim and E. K. P. Chong, "Fuzzy precompensated PID controllers," in *IEEE Transactions on Control Systems Technology*, vol. 2, no. 4, pp. 406-411,Dec1994.

H. Chaudhary, S. Khatoon and R. Singh, "ANFIS based speed control of DC motor," *2016 Second International Innovative Applications of Computational Intelligence on Power, Energy and Controls with their Impact on Humanity (CIPECH)*, Ghaziabad, 2016, pp. 63-67.

Kim Chwee Ng; Yun Li, "Design of sophisticated fuzzy logic controllers using genetic algorithms," Fuzzy Systems, 1994. IEEE World Congress on Computational Intelligence., Proceedings of the Third IEEE Conference on , vol., no., pp.1708,1712 vol.3, 26-29 Jun 1994

K. S. Devi, R. Dhanasekaran and S. Muthulakshmi, "Improvement of speed control performance in BLDC motor using fuzzy PID controller," *2016 International Conference on Advanced Communication Control and Computing Technologies (ICACCCT)*, Ramanathapuram, 2016, pp. 380-384.

M. M. Kamal, L. Mathew and S. Chatterji, "Speed control of brushless DC motor using intelligent controllers," *2014 Students Conference on Engineering and Systems*, Allahabad, 2014, pp. 1-5.

P. Ananthababu, B. A. Reddy and K. R. Charan, "Design of Fuzzy PI+D and Fuzzy PID Controllers Using Gaussian Input Fuzzy Sets," *2009 Second International Conference on Emerging Trends in Engineering & Technology*, Nagpur, 2009, pp. 957-961.

P. Payakkawan, K. Klomkarn and P. Sooraksa, "Dual-line PID controller based on PSO for speed control of DC motors," *2009 9th International Symposium on Communications and Information Technology*, Icheon, 2009, pp. 134-139.

Qingdong Zeng; Guanzheng Tan, "Optimal Design of PID Controller Using Modified Ant Colony System Algorithm," Natural Computation, 2007. ICNC 2007. Third International Conference on , vol.5, no., pp.436,440, 24-27 Aug. 2007

R. Arulmozhiyal, "Design and Implementation of Fuzzy PID controller for BLDC motor using FPGA," *2012 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES)*, Bengaluru, 2012, pp. 1-6.

R. G. Kanojiya and P. M. Meshram, "Optimal tuning of PI controller for speed control of DC motor drive using particle swarm optimization," *2012 International Conference on Advances in Power Conversion and Energy Technologies (APCET)*, Mylavaram, Andhra Pradesh, 2012, pp. 1-6.

R. Rahmani, M. S. Mahmodian, S. Mekhilef and A. A. Shojaei, "Fuzzy logic controller optimized by particle swarm optimization for DC motor speed control," *2012 IEEE Student Conference on Research and Development (SCOReD)*, Pulau Pinang, 2012, pp. 109-113.

P. M. Meshram and R. G. Kanojiya, "Tuning of PID controller using Ziegler-Nichols method for speed control of DC motor," *IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM -2012)*, Nagapattinam, Tamil Nadu, 2012, pp. 117-122.

Pai-Yi Huang; Yung-Yaw Chen, "Design of PID controller for precision positioning table using genetic algorithms," Decision and Control, 1997., Proceedings of the 36th IEEE Conference on , vol.3, no., pp.2513,2514 vol.3, 10-12 Dec 1997

R. V. Jain, M. V. Aware and A. S. Junghare, "Tuning of Fractional Order PID controller using particle swarm optimization technique for DC motor speed control," *2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES)*, Delhi, 2016, pp. 1-4.

Rey, J.P.; Lamego, M.M.; Dalvi, C.; Vescovi, M.R.; Ferreira, E.P., "A numerical-based fuzzy PID controller applied to a DC drive," Industrial Electronics, 1994. Symposium Proceedings, ISIE '94., 1994 IEEE International Symposium on , vol., no., pp.429,434, 25-27 May 1994

S. Kumar, V.Kumar, "Speed control DC motor using optimization techniques based PID controller," *2016 IEEE International Conference on Engineering and Technology (ICETECH))*, Coimbatore, 2016, pp. 1-6.

Salami, M.J.E.; Bulale, Y.I., "Design and implementation of fuzzy-based PID controller," Industrial Technology, 2002. IEEE ICIT '02. 2002 IEEE International Conference on ,vol.1,no.,pp.220,225vol.1,2002

W. M. Elsrogy, M. A. Fkirin and M. A. M. Hassan, "Speed control of DC motor using PID controller based on artificial intelligence techniques," *2013 International Conference on Control, Decision and Information Technologies (CoDIT)*, Hammamet, 2013, pp. 196-201.

W. Xiao-kan, S. Zhong-liang, Wanglei and F. Dong-qing, "Design and Research Based on Fuzzy PID-Parameters Self-Tuning Controller with MATLAB," *2008 International Conference on Advanced Computer Theory and Engineering*, Phuket, 2008, pp. 996-999.

Wang Xiao-kan; Sun Zhong-liang; Wanglei; Feng Dong-qing, "Design and Research Based on Fuzzy PID-Parameters Self-Tuning Controller with MATLAB," Advanced Computer Theory and Engineering, 2008. ICACTE '08. International Conference on , vol., no., pp.996,999, 20-22 Dec. 2008

Ying-Tung Hsiao, Cheng-Long Chuang and Cheng-Chih Chien, "Ant colony optimization for designing of PID controllers," *2004 IEEE International Conference on Robotics and Automation (IEEE Cat. No.04CH37508)*, Taipei, 2004, pp. 321-326.

Y. A. Almatheel and A. Abdelrahman, "Speed control of DC motor using Fuzzy Logic Controller," *2017 International Conference on Communication, Control, Computing and Electronics Engineering (ICCCCEE)*, Khartoum, 2017, pp. 1-8.

Zhao Yongjuan; Pan Yutitan, "The Design and Simulation of Fuzzy PID Controller," Information Technology and Applications (IFITA), 2010 International Forum on , vol.3, no., pp.95,98, 16-18 July 2010

Somwanshi, Devendra, Mahesh Bundele, Gaurav Kumar, and Gajal Parashar. "Comparison of fuzzy-PID and PID controller for speed control of DC motor using LabVIEW." *Procedia Computer Science* 152 (2019): 252-260.

Parashar G, Somwanshi D. Speed control of Dc motor using PID controller:-A review. SSRG International Journal of Electrical and Electronics Engineering. 2016 May;2(2).

Parashar, Gajal, and Devendra Somwanshi. "Response Analysis of DC Motor Using PI, PC, PD, and PID Controller." *International Journal of Automatic Control System* 2, no. 2 (2016).