Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

Optimized PID Controller for Low Power Applications using Particle Swarm Optimization

S. R. Santhiya*
School of ECE
Mar Ephraem College of Engineering and Technology Marthandam, India

S.V. Femi
School of ECE
Mar Ephraem College of Engineering and Technology Marthandam, India

S. S. Shyla Mol
School of ECE
Mar Ephraem College of Engineering and Technology Marthandam, India

V. Suresh
School of ECE
Mar Ephraem College of Engineering and Technology Marthandam, India

***Abstract*—Controllers are used to modify the behaviour of a system so it behaves in a specific desirable way. Proportional-Integral-Derivative controller has high effectiveness, simplicity in implementation so that, it is the most widely used controller in industries for many applications. Conventional method of tuning PID controller creates big overshoot. This is an acceptable result for some purpose but not optimal for all applications. The Artificial Intelligence (AI) method of Particle Swarm Optimization algorithm is employed in tuning of PID controller. The main aim of this particular work is to compare the conventional method and PSO method of tuning the PID controller and to prove that PSO method is more efficient than the conventional method in tuning the control parameters. Such type of optimized controllers may be used for low power applications with high efficiency.**

Keywords—PID controller, Ziegler Nichols method, CHR method, particle swarm optimization, simulation, comparison

I. INTRODUCTION

Control system theory evolved as an engineering discipline and due to universality of the principles involved, it is extended to various fields like economy, sociology, biology, medicine, etc. Control theory has played a vital role in the advance of engineering and science. The automatic control has become an integral part of modern manufacturing and industrial process.

The optimization techniques efficient in improving the step response than computational methods in the recent times [1-2]. In [3], a system can be optimized by using Evolutionary algorithm like Particle Swarm Optimization. A stable, robust and controlled system by tuning the PID controller using Particle Swarm Optimization [4]. PID controllers are used in industrial plants to control the armature controlled DC motor using conventional methods such as Continuous cycling method and ZN method have been compared with Genetic Algorithm by improving the performance indices [5]. The comparison between PSO based PID performance and the ZN based PID performance. The results show the advantage of the PID tuning using PSO based optimization approach [6].PID controller is tuned based on different objective functions [7]. To develop an artificial intelligence automatic PID tuning scheme using PSO algorithm that can automatically acquire the PID parameters during plant operation in a routine way [8]. To control the speed of the DC motor by PID controller using Ziegler Nichols method tuning algorithm which produces high peak overshoot [9].

This work proposes to develop a optimized PID tuning method using PSO algorithm for low power applications with high efficiency. Section II describes the PID controller, section III gives an overview of the conventional methods section IV describe an overview of the PSO algorithm and finally, section V we discuss the simulation result and conclusion is drawn in section VI

II. PID CONTROLLERS

A Proportional-integral-derivative (PID) controller is a control loop feedback controller commonly used in industrial control systems. Figure 1 depicts the block diagram of PID controller
In this model,

- **P** is proportional to the present value of the set point. P controller produce the large gain such that reduces the steady state error.
- **I** is proportional to the past value of the set point. I is integral term that eliminates the residual steady state error.
- **D** proportional to the future value of the set point. D mode is used to improve the stability of the system or predict the error.

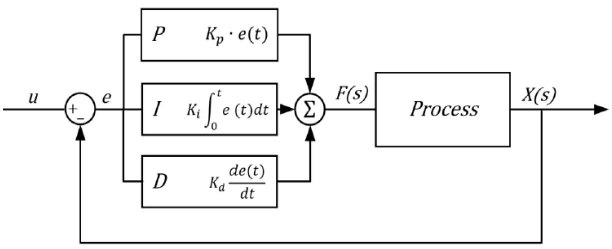

Fig 1: Block diagram of PID controller

The transfer function of the PID controller is,

$$G(s) = K_p + \frac{K_i}{s} + K_d .s$$

The output of the PID controller can be written as,

$$u(t) = K_p.e(t) + K_i \int_0^t e(\tau).d\tau + K_d \frac{de(t)}{dt}$$

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

where, K_p, K_i, K_d are the proportional, integral, derivative gains of the PID controllers respectively.

A PID controller determines the error valve as the difference between required set point and a measured process variable. The controller attempts to minimize the error over time by adjustment of a control variable to a new valve determined by a weighted sum.

III. TUNNING OF PID USING COVENTIONAL METHODS

A. Ziegler Nichols(ZN) Method

ZN tuning is based on the open-loop step response of the system. The process time parameters are used to determine the controller's tuning parameters. ZN tuning is based on the closed-loop tuning method that requires the determination of the ultimate gain and ultimate period. This method can be interpreted as a technique of positioning one point on the Nyquist curve. This can be achieved by adjusting the controller gain till the system undergoes sustained oscillations, while maintaining the integral time constant at infinity and the derivative time constant at zero.

The PID controller has four performances indices such as ISE, IAE, ITSE, ITAE. In this paper we are taking two indices ISE, IAE.

1) Integral Square Error

ISE integrates the square over time. ISE will penalize large errors more than smaller ones. control system specified to minimize ISE will tend to eliminate large errors quickly, but will tolerate small errors persisting for a long period of time often this leads to fast responses ,but with considerable, low amplitude, oscillation.

$$ISE = \int_{0}^{\infty} e^2\,(t)dt$$

2) Integral Absolute Error

IAE integrates the absolute error over time .it does not add weight to any of the errors in a system response. It tends to produce reduced speed than ISE optimal systems, but usually with less sustained oscillation.

$$IAE = \int_{0}^{\infty} |e(t)|dt$$

For some applications it might result in aggressive gain and overshoot.

B. Chien Hrones Reswich(CHR) Method

This method that has proposed by "Chien, Hrones and Reswich" is a modification of open loop Ziegler and Nichols method. They proposed to use "quickest response without overshoot" or "quickest response with 20% overshoot" as design criteria to achieve desired performance. They also made the important observation that tuning for set point responses and load disturbance responses are different. To tune the controller according to the CH-R method the parameters are determined in the same manner of the Z-N method. The tuning rules based on the 20% overshoot design criterion are quite similar to the Z-N method, while 0% overshoot criteria is used, the gain and the derivative time are smaller and the integral time is larger. This defines that the proportional action and the integral action, as well as the derivative action, are smaller.

This method is used for basic PID controller. It is not suitable for all the practical controller.

IV. TUNNING OF PID USING PSO

A. Overview of PSO Algorithm

Particle swarms was first developed by Eberhart and Kennedy in 1995. PSO algorithm, which is derived for optimizing difficult numerical functions and based on metaphor of human social interaction, is capable of mimicking the ability of human societies to process knowledge. It has two main component methodologies: artificial life (such as bird flocking, fish schooling and swarming) and, evolutionary computation. Its concept is that potential solutions are flown through hyperspace and are accelerated towards better or more optimum solutions. As in evolutionary computation paradigms, the concept of fitness is employed and candidate solutions to the problem are termed particles or sometimes individuals, each of which adjusts its flying based on the flying experiences of both itself and its companion. It keeps track of its coordinates in hyperspace which are associated with its previous best fitness solution and also of its counterpart corresponding to the overall best value acquired thus far by any other particle in the population. The basic operational principle of the particle swarm is applicable for the flock of birds or fish or for a group of people. While searching for food, the birds are either scattered or go together before they locate the place where they can find the food.

B. Implementation of PSO Based PID Tuning

PSO is implemented to tune the PID gain parameters for the required system. Optimized PID controller parameters can yield a good system response and result in minimization of performance index. The fitness function is fixed and find the suitable parameters to achieve the desired output. PSO algorithm is further improved via using a time decreasing inertia weight, which leads to a reduction in the number of iterations.

The fitness function is given by,

$$Fitness\ function = \{(100 *\ T_s + 5 * M_p^2) + (T_s + T_r)\}$$

where, T_s is settling time, M_p is maximum peak overshoot, T_r is rise time.

V. SIMULATION RESULTS

The work focused to compare the conventional methods, ZN and CHR with PSO algorithm. Particle Swarm Optimization (PSO) algorithm is used to get the optimized parameter value of PID controller. Initially Ziegler Nichols method is compared with Chien- Hrones –Reswick (CHR) method and to get the response of the transfer function. The ZN method is defined with different indices like ISE and IAE using Simulink and their response is analyzed. The

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

results of ZN, ZN-ISE, ZN-IAE and CHR are compared with the response of PSO.

Comparative results for the PID controllers are given below in Table I where the step response performance is evaluated based on the peak value, peak time and settling time. Optimized gain values are given in the table II based on the fitness function.

TABLE I: COMPARISION OF PID TUNING METHODS

Tuning methods	**Peak Value(v)**	**Peak Time(s)**	**Settling Time(s)**
ZN	1.55	1.2	6.1
ZN-ISE	1.455	0.8	3.8
ZN-IAE	1.02	0.5	3.2
CHR	1.33	0.2	2.5
PSO	1.325	0.009	0.055

TABLE II: FITNESS AND OPTIMIZED GAIN VALUES

Fitness Value	83.4507		
Optimized K_p, K_i, K_d values	K_p - 3.6000	K_i - 3.7995	K_d - 0.8527

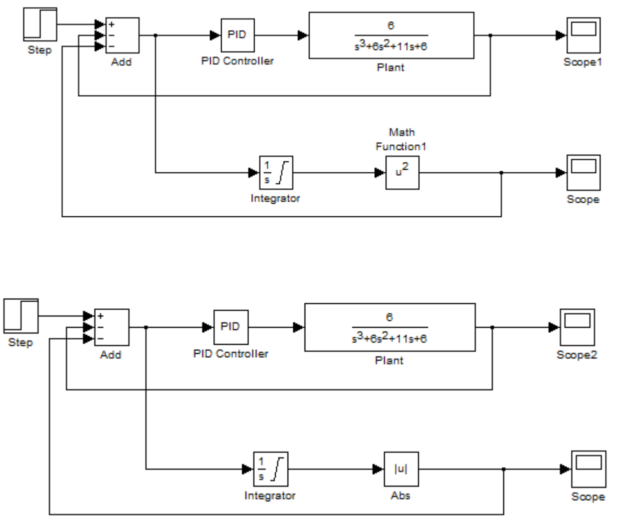

Fig 2.Simulink models

Figure 2 shows the Simulink models of different indices like ISE and IAE using MATLAB Simulink. The system transfer function is different for different applications.

Figure 3 depicts the simulation results of the comparisons of the conventional methods and PSO.

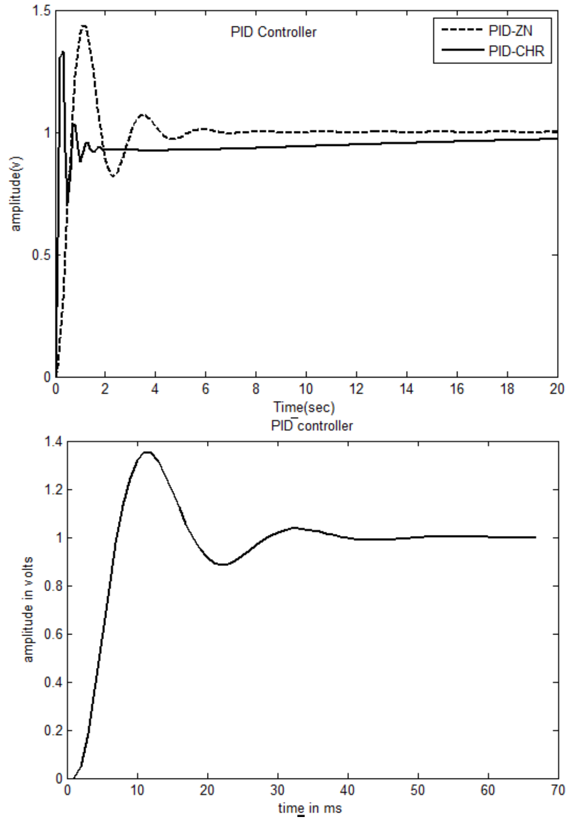

Fig 3.Simulation outputs

VI. CONCLUSION

Implementation of PID Controller Using Particle Swarm Optimization has been successfully simulated and verified with MATLAB / Simulink model. It is in tuning the controllers that the greatest gains in performance may be found. A wide variety of tuning methods exist, although of the two discussed in this article, the PSO algorithm method provides the most effective approach in tuning a controller. It was shown, by comparison of their responses that the PSO algorithm has outperformed the Ziegler Nichols method in terms of the system overshoot, settling time and rise time. Also the performance index value obtained using the proposed PSO algorithm is less than of the Ziegler-Nichols method. The performance of the PSO algorithm of tuning a PID controller has been proved to be better than the heuristic Ziegler-Nichols method.

From the results, the implemented PID controller using PSO algorithm shows superior performance over the traditional method of Ziegler-Nichols, in terms of the system overshoot, settling time. However, the traditional method provides us with the initial PID gain parameters for optimal tuning. Therefore the benefit of using a modern artificial intelligence optimization approach is observed as a complement solution to improve the performance of the PID

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

controller designed by conventional method. Of course there are many techniques that can be used as the optimization tools and PSO is one of the recent and efficient optimization tools.

REFERENCES

[1] Gaing, Z.L. (2004). A particle swarm optimization approach for optimum design of PID controller in AVR system. IEEE Transaction on Energy Conversion, Vol.19(2), pp.384-391.

[2] Zhao, J., Li, T. and Qian, J. (2005). Application of particle swarm optimization algorithm on robust PID controller tuning. Advances in Natural Computation: Book Chapter. Springer Berlin / Heidelberg, pp. 948-957.

[3] Ou, C. and Lin, W. (2006). Comparison between PSO and GA for parameters optimization of PID controller. Proc. IEEE international Conference on Mechatronics and Automation. Luoyang, China.

[4] Tae-Hyoung Kim, Ichiro Maruta and Toshiharu Sugie(2007), “Particle Swarm Optimization based robust PID Controller Tuning Scheme” ,Proc.IEEE Conference on Decision and Control.

[5] B.Nagaraj , S.Subha ,B.Rampriya. Tuning Algorithms for PID Controller Using Soft Computing Techniques, IJCSNS International Journal of Computer Science and Network Security , VOL.8 NO.4 ,April 2008.

[6] Mahmud Iwan Solihin ,Lee Fook Tack and Moey Leap Kean.Tuning . PID Controller Using Particle Swarm Optimization (PSO).Proceeding of the International Conference on Advanced Science, Engineering and Information Technology 2011.

[7] Mahmud Iwan Solihin et al, “PID Controller Using Particle Swarm Optimization(PSO)”, 2011.

[8] S.J.Bassi et al,Automatic Tuning of Proportional-Integral-Derivative(PID) Cotroller Using Particle Swarm Optimization(PSO) Algorithm, International Journal of Artificial Intelligence & Application (JIAIA),vol.2, No.4, 2011.

[9] Bhaskar Lodh , Simulink Based Model for Analysing the Ziegler – Nichols Tuning Algorithm as applied on Speed Control of DC Motor(IJAREEIE), Vol. 3, Issue 1, January 2014.