Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

OPTIMUM PID PARAMETER SELECTION BY PARTICLE SWARM OPTIMIZATION IN AUTOMATIC VOLTAGE REGULATOR SYSTEM

[1]G.MADASAMY, [2]C.S.RAVICHANDRAN
[1] Lecturer, Department of EEE, P.A.C. Ramasamy Raja Polytechnic College
Tamilnadu, India-626 108
[2] Dean, Department of EEE, Sri Ramakrishna Engineering College
Tamilnadu, India-641 022
E-mail: [1]sgmsamy@yahoo.com, [2]sravichandrran@gmail.com

ABSTRACT

This Paper presents a tuning method based on evolutionary computing approach to determine the Proportional-Integral-Derivative (PID) controller parameters in Automatic Voltage Regulator (AVR) system. The main objective is to increase the step response characteristics and reduce the transient response of AVR systems. This paper described in details how to employ Particle Swarm Optimization Technique (PSO) method to determine the optimal PID controller parameters of an AVR system. The proposed algorithm can improve the dynamic performance of AVR system. Compared with Ziegler Nichols (Z-N) tuning method, the proposed PSO method has better control system performance.

Keywords: *AVR System, PID Controller, Particle Swarm Optimization (PSO), Ziegler-Nichols Tuning*

1. INTRODUCTION

The main function of an AVR system is to hold the magnitude of terminal voltage of a synchronous generator at a specified level. Thus, the stability of the AVR system would seriously affected the security of the power system. The Proportional integral Derivative (PID) [1] controller is chosen compared to other controllers because of its uncomplicated and robust behaviour. A simple AVR consist of amplifier, exciter, generator and sensor. The block diagram of AVR with PID controller is shown in Figure 1[14].The step response of this system without control has oscillation which will reduce the performance of the regulation. Thus, a control technique must be applied to the AVR system. For this reason, the PID block is connected in series with amplifier. Several tuning methods have been proposed for the tuning of control loop. The most familiar tuning methods are: Ziegler-Nichols [2], Cohen-Coon [3], and Astra-Hagglund.

To maintain the stability and performance of the system tuning of PID controllers [4] is imperative. Due to, large range of tuning techniques, the optimum performance cannot be achieved. Several new intelligent optimization techniques have been arisen in the past two decades: Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Simulated Annealing (SA) and bacterial Foraging (BF). PSO [5-6] is a population based stochastic optimization algorithm. Swarm intelligence based optimization [7] is also applied to find optimized values. There are many literatures to find the optimum tuning of PID controllers [8-9]. PSO is one of the modern experimental algorithms; it was developed through simulation of a simplified social system. It has been found to robust in solving continuous non-linear optimization problems. It is computationally efficient compared to other optimization techniques. In the PID controller design, the PSO algorithm is applied to search a best PID control parameters. In this paper, PSO based approach to optimal designing of PID controller to AVR is presented.

2. A MODEL OF AVR SYSTEM

The role of Automatic voltage regulator (AVR) of the synchronous generator is to provide stable electrical power service with high efficiency and good dynamic response [15]. Previously, the analog PID controller is generally used for the AVR. Because, of its simplicity and economic. However, the tuning of PID parameter is not easy. This paper proposed a method to search these

Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

parameter by using a Particle Swarm Optimization (PSO) algorithm. The AVR system model is controlled by PID controller can be expressed in Fig.1 [14].

Where,

V_t is the output voltage of the system,

V_e is the error voltage between the V_s and reference input voltage $V_{ref(s)}$,

V_r is an amplify voltage by amplifier model,

V_F is the output voltage by exciter model, and

Vt is the output voltage of synchronous generator.

There are five components: (a) PID controller model, (b) Amplifier model, (c) Exciter model, (d) Generator model, and (e) Sensor model. The transfer functions are described as follows:

(a) PID Controller Model

The transfer function of PID controller is [11]

$$G_s(s) = k_p + k_d s + \frac{k_i}{s} \quad (1)$$

Where k_p, k_d, and k_i are the proportional coefficient, derivative coefficient and integral coefficient respectively.

(b) Amplifier Model

The transfer function of amplifier model is

$$\frac{V_g(s)}{V_e(s)} = \frac{K_a}{1+\tau_a s} \quad (2)$$

Where K_a is a gain and τ_a is a time constant.

(c) Exciter Model

The transfer function of exciter model is

$$\frac{V_F(s)}{V_g(s)} = \frac{K_e}{1+\tau_e s} \quad (3)$$

Where K_e is a gain and τ_e is a time constant

(d) Generator Model

The transfer function of generator model is

$$\frac{V_t(s)}{V_F(s)} = \frac{K_g}{1+\tau_g s} \quad (4)$$

Where K_g is a gain and τ_g is a time constant

(e) Sensor Model

The transfer function of sensor model is

$$\frac{V_s(s)}{V_t(s)} = \frac{K_s}{1+\tau_s s} \quad (5)$$

Where K_s is a gain and τ_s is a time constant

The range of parameters limit and used parameter in this paper is shown in Table I

Table I: Range of AVR Parameters

	Parameters Range	Used Parameter
Amplifier	$10 \le K_a \le 40$	$K_a = 10$
Exciter	$1 \le K_e \le 10$ $0.4 \le \tau_e \le 1$	$K_e = 1$ $\tau_e = 0.4$
Generator	K_g depend on load (0.7-1) $1 \le \tau_g \le 2$	$K_g = 1$ $\tau_g = 1$
Sensor	$0.001 \le \tau_s \le 0.01$	$K_s = 1$ $\tau_s = 0.05$

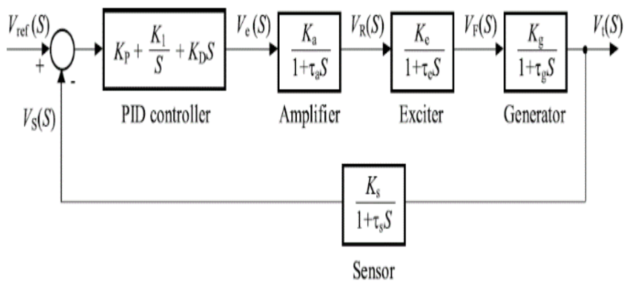


Fig.1 Block Diagram of AVR System with PID Controller [14]

In this paper, PSO algorithm is applied to search a best PID parameters so that the controlled system has good dynamic control performance. Fig.2 Shows the PSO based PID controller with AVR system.

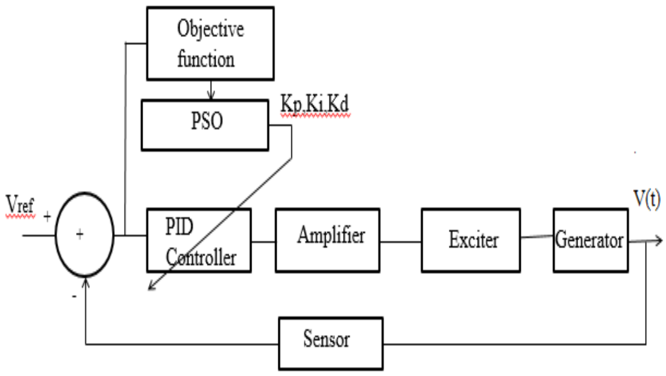


Fig.2The Block Diagram of PSO -PID Controller [6]

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

3. THEORY OF PARTICLE SWARM OPTIMIZATION

Optimization algorithms are another area that has been receiving increased attention in the past few years by research community [12]. An optimization algorithm is a numerical method or algorithms for finding the maxima or the minim of a function operating with certain constraints. Computational intelligence is a successor of artificial intelligence relying on evolutionary computation, which is a famous optimization technique.

Computational intelligence finds it fundamental application in the area of fitness function design, methods for parameter control, and techniques for multimodal optimization. Particle Swarm Optimization (PSO) is a computational algorithm technique based on swarm intelligence. This method is motivated by the observation of social interaction and animal behaviours such as fish schooling and bird flocking [4].

It mimics the way they find food by the cooperation and competition among the entire population. A swarm consists of individuals called particle, each of which represents a different possible set of the unknown parameters to be optimized. In PSO system, particle fly around in a multi-dimensional search space adjusting its position according to its own experience and the experience of its neighbouring particle. The goal is to effectively search the solution space by swarming the particles towards the best fitting solution encountered in previous iterations with inertia of encountering better solution through the course of process and eventually converging on a single minimum or maximum solution. The performance of each particle is a measured accounting to a pre-defined fitness function, which is reported to the process being solved.

The objective of this work is to use the PSO algorithm in order to obtain optimal PID controller settings for AVR, which is non-linear in nature. Every possible controller setting represents a particle in the research space which changes its parameters proportional constant K_p, integral constant K_i, and derivative constant K_d in order to minimise the objective function. The objective function used in this paper is,

$$F(k) = \left(1 - e^{-\beta}\right)\left(M_p + e_{ss}\right) + e^{-\beta}\left(t_s - t_r\right) \quad \text{---(6)}$$

Where,

M_p = Peak overshoot
t_s =Settling time
t_r =Rising time
β = Scaling factor
e_{ss} = Steady state error

3.1 Algorithm For PSO[5]:

The i^{th} particle in the swarm is represented as in the d-dimensional space.

$$X_i = \left(X_{i,1}, X_{i,2}, X_{i,3} ------- - X_{i,d}\right)$$

The best previous position of the i^{th} particle is represented as

$$P_{best} = \left(P_{best\,i,1}, P_{best\,i,2}, P_{best\,i,3}, -- ---- - P_{best\,i,d}\right)$$

The index of the best particle among the group is G_{bestd}

Velocity of the i^{th} particle is represented as

$$V_i = \left(V_{i,1}, V_{i,2}, V_{i,3}, --------- V_{i,d}\right)$$

The updated velocity and the distance from $P_{besti,d}$ to $G_{besti,d}$ is given as

$$V_{i,m}^{(t+1)} = W * V_{i,m}^{t} + C_1 * rand() * \left(P_{best\,i,m} - X_{i,m}^{t}\right) + C_2 * rand() * \left(G_{best\,i,m} - X_{i,m}^{t}\right) \quad (7)$$

And

$$X_{(i,m)}^{(t+1)} = X_{i,m}^{(t)} - V_{i,m}^{(t+1)}$$

For i=1,2,3,………n, m=1,2,3,…………d (8)

Where,

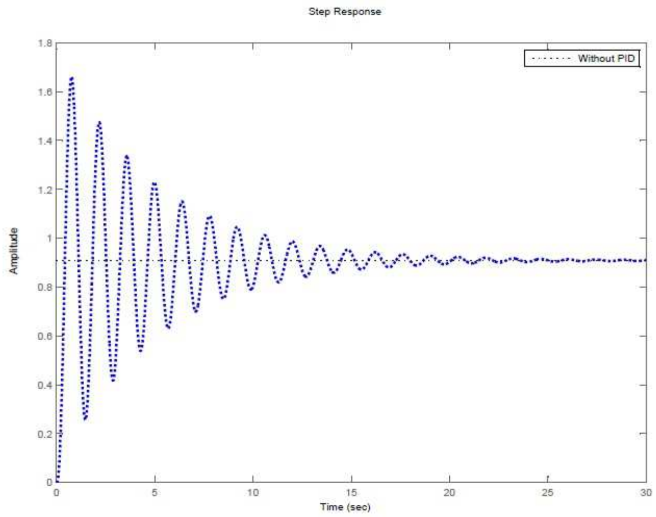
n = Number of particle in the group
d = dimension index
t = point of iteration
$V_{i,m}^{(t)}$ = velocity of particle at iteration i
W =Inertia weight factor
C_1,C_2 = Acceleration Constant
rand() = Random number between 0 and 1
$X_{i,d}^{(t)}$ = Current position of the particle 'i' at iteration
$P_{best,i}$ = Best previous position of the ith particle
G_{best} = Best particle among all the particles in the swarming population

4. SIMULATION RESULTS

The closed loop transfer function of AVR system without PID controller is given in Equation (9) and step response of system is shown in Figure 3.

Journal of Theoretical and Applied Information Technology
10th August 2014. Vol. 66 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195



$$G(s) = \frac{0.5s+10}{0.002s^4+0.067s^3+.615s^2+1.55s+11} \quad (9)$$

Fig.3 Step Response of AVR System Without PID Controller

The transfer function of AVR system with PID using Ziegler-Nichols (Z-N) tuning method is shown in Equation (10) and step response of AVR system using Ziegler-Nichols tuning is shown in Figure.4.

$$G(s) = \frac{5s^2+8s+8.66}{0.002s^5+0.067s^4+0.615s^3+6.55s^2+9s+8.66} \quad (10)$$

The transfer function of AVR system with PID - PSO method is shown in Equation (11) and step response of AVR system using PID-PSO in compare with Z-N tuning method is shown in Figure.5

$$G(s) = \frac{1.154s^2+4.538s+2.552}{0.002s^5+0.067s^4+0.615s^3+2.704s^2+5.5538s+2.552} \quad (11)$$

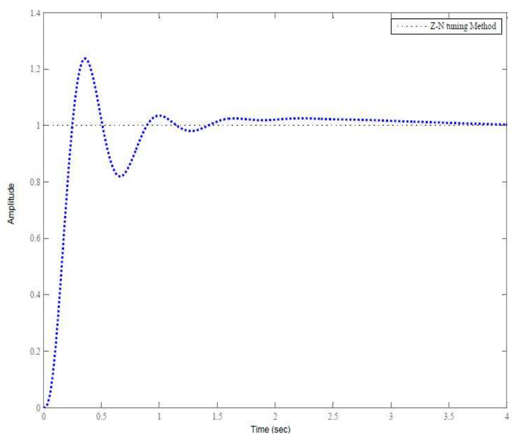


Fig.4 Step Response of AVR System With PID Controller Using Ziegler-Nichols Tuning Method

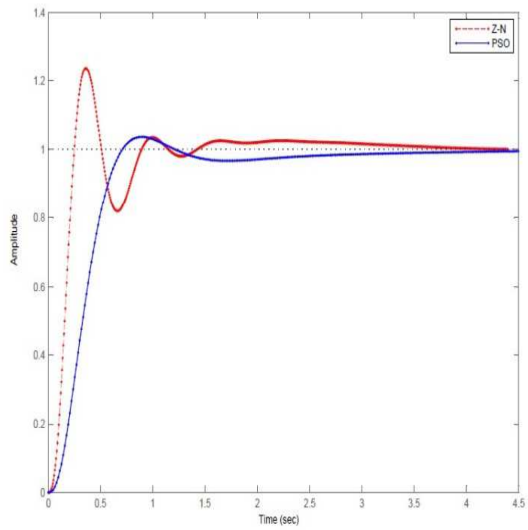


Fig.5 Step Response Of AVR System With PID Controller Using PSO And Ziegler-Nichols Tuning Method

Simulation results and PID parameters obtained using Z-N and PSO methods are shown in Table II.

Table II :PID Parameters And Results Obtained From Different Tuning Methods

Method	Z-N Tuning based PID	PSO based PID
Kp	0.80	0.4548
Kd	0.5	0.1154
Ki	0.866	0.2552
Mp(%)	23.70%@0.358 sec	3.62@0.89 sec
Ts(sec)	2.73	2.43
Tr(sec)	0.153	0.435

From the above results, it shows that the tuning PID parameter using PSO techniques gives good results.

5. CONCLUSION

There are several methods such as Z-N, and PSO algorithms for designing the parameters of the PID controller. The aim of this paper is to find the optimum parameters of PID controller using the PSO algorithm. The PID parameters searched by this method results in better optimal parameters and accuracy compared to other methods. The proposed algorithm is compared with Z-N tuning method, the simulation results of AVR system validates that the PSO algorithm is more superior compared to other optimization techniques and has better performance also requires less time to be performed.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

REFERENCES:

[1] Antonio Visioli, "Research Trends for PID Controllers," *ACTA POLYTECHNICA*, Vol.52, No.5, 2012, pp. 144-150.

[2] K.J.Astrom,T.Hagglund, " The future of PID Control", *Control Engineering Practice*, April6,2001, pp.1163-1175

[3] Dr.Satyasheel, Omhari Gupta, " New Techniques of PID Controller Tunning of DC Motor-Development of a Tool Box", *MIT International Journal of Electrical and Instrumentation Engineering*, Vol.2, No. 2, August 2012, pp.65-69.

[4] Manoj Kushwar, Prof.AshifPatra, " Tuning PID Controller for speed control of DC motor using soft computing Techniques-A Review", *Advance in Electronic and Electric Engineering*, Vol.4, No.2, 2014, pp.141-148.

[5] Nehakundariya, JyotiOhri, "Design of Intelligent PID Controller using particle swarm optimization with different performance indices," *International Journal of Scientific and Engineering Research*, Vol.4, Issue 7, July-2013,pp.1191-1194.

[6] J.Kennedy, R.C. Eberhart, " ParticleSwarm Optimization", in *Proceedings of the IEEE International Conference on Neural Network*", Vol.4, Dec.1995, pp.1942-1948.

[7] M.H.T.Omar, W.M.Ali, M.Z.Mostafa, " Auto Tuning of PID Controller Using Swarm Intelligence", *International Review of Automatic Controls (I.RE.A.CO)*, Vol.4,No.3, May 2011, pp.319-327.

[8] M.H.Moradi, "New Techniques for PID Controller Design," *IEEE Conference on Control Applications*,Vol.2, 2003, pp.903-908.

[9] J.G.Ziegler, N.B. Nichols, "Optimization settings for Automatic Controllers", *Trans.ASME*, Vol.64, pp.756-769.

[10] Benjamin C .Kuo, FaridGolnaraghi, 2009, "*Automatic Control System*", 9thed.John Willey & Sons

[11] I.J.Nagrath, M.Gopal, "*Control System Engineering*", New Age International Publishers, 2007

[12] S.M.Girirajkumar, Deepak Jayan, Anoop R .Kishan, " PSO Based Tuning of a PID Controller for High Performance Drilling Machines", *International Journal of Computer Applications*, Vol.1, No.19, pp.12-18

[13] Astrom K.J, T.Hagglund, " PID Controller: Theory, Design and Tuning", *ISA Research Triangle*, Par, Nc, 1995.

[14] HadiSaadat, " Power System Analysis", Tata McGraw-Hill Edition, New- Delhi, pp.527-565

[15] O.I. Elgard, " Electric Energy Systems Theory", McGraw-Hill, New York, pp.299-362,1982.