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Tuning Of PID Controller Using PSO Algorithm And Compare Results Of Integral Errors For AVR System

Anil Kumar
PG (M.TECH) Student of UCE, Rajasthan Technical University, KOTA , India

Dr. Rajeev Gupta
HOD & Prof. of EC Deptt. UCE, Rajasthan Technical University, KOTA, India

Abstract:

The paper Present to design PID controller parameters for an unstable Automatic Voltage Regulator system using Particle swarm optimization (PSO).The design goal is to minimize the integral errors and reduce transient response by minimizing overshoot, settling time and rise time of step response. First an objective function is defined, and then by minimizing the objective functions using real-coded PSO, the optimal controller parameters can be assigned. The avr system taken for case study is inherently unstable, highly nonlinear and after tuning of PID using PSO, results stable system.

Key words*: *AVR system, Feedback System, Optimization, PID controller, PSO

1.Introduction

The task of an AVR system is to hold the terminal voltage magnitude of a synchronous generator at a specified level. Thus, the stability of the AVR system would seriously affect the security of the power system. A simpler AVR system contains five basic components such as amplifier, exciter, generator, sensor and comparator. The real model of such a system is shown in fig1. A unit step response of this system without control has some oscillations which reduce the performance of the regulation (1). Thus, a control technique must be applied to the AVR system. For this reason, the PID block is connected to amplifier seriously. The A small signal model of this system including PID controller which is constituted through the transfer functions of these components is depicted in Fig, and the limits of the parameters used in these transfer functions are presented(2) .

PID controllers have been widely used for speed and position control of various To enhance the capabilities of traditional PID parameter tuning techniques, several intelligent approaches have been suggested to improve the PID tuning, such as those using genetic algorithms (GA) and the particle swarm optimization (PSO) (3). GA is an iterative search algorithm based on natural selection and genetic mechanism. However, GA is very fussy; it contains selection, copy, crossover and mutation scenarios and so on. Furthermore, the process of coding and decoding not only impacts precision, but also increases the complexity of the genetic algorithm. This project attempts to develop a PID tuning method using GA algorithm. For example, ants foraging, birds flocking, fish schooling, bacterial chemo taxis are some of the well-known examples in category (4).

There are five models:

- PID Controller Model,
- Amplifier Model,
- Exciter Model,
- Generator Model, and
- Sensor Model

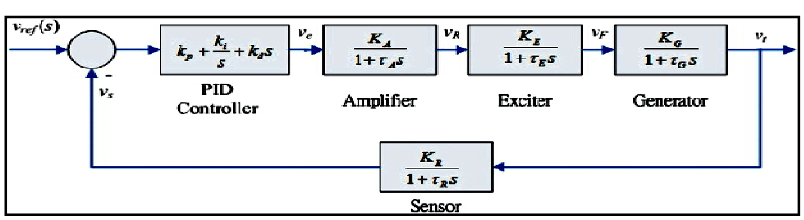


Figure 1: Block diagram of an AVR system with a PID controller

Transfer Function For AVR system is

$$\frac{1.44\ s + 160}{0.0004608\ s^4 + 0.06358\ s^3 + 1.398\ s^2 + 2.449\ s + 17}$$

2.Particle Swarm Optimization

Particle swarm optimization (PSO) is an algorithm modeled on swarm intelligence, that finds a solution to an optimization problem in a search space, or model and predict social behavior in the presence of objectives. The PSO is a stochastic, population-based computer algorithm modeled on swarm intelligence. Swarm intelligence is based on social-psychological principles and provides insights into social behavior, as well as contributing to engineering applications. James Kennedy an American Social Psychologist along with Russell C. Beernaert innovated a new evolutionary computational technique termed as Particle Swarm Optimization in 1995.The approach is suitable for solving nonlinear problem. The approach is based on the swarm behavior such as birds finding food by flocking. A basic variant of the PSO algorithm works by having a population (called a swarm) of candidate solution (called particles). These particles are moved around in the search-space according to a few simple formulae. The movements of the particles are guided by their own best known position in the search-space as well as the entire swarm's best known position. When improved positions are being discovered these will then come to guide the movements of the swarm. The particle swarm simulates this kind of social optimization. A problem is given, and some way to evaluate a proposed solution to it exists in the form of a fitness function. A communication structure or social network is also defined, assigning neighbors for each individual to interact with. Then a population of individuals defined as random guesses at the problem solutions is initialized. These individuals are candidate solutions. An iterative process to improve these candidate solutions is set in motion. The particles iteratively evaluate the fitness of the candidate solutions and remember the location where they had their best success. The individual's best solution is called the particle best or the local best.

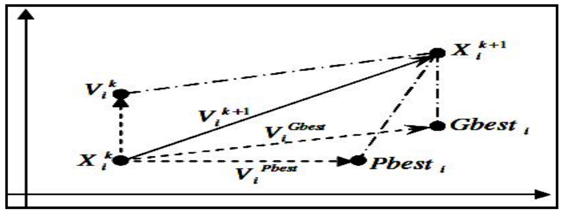


Figure 2: Concept of modification of a searching point by PSO

3. Pid Controller

PID controller consists of Proportional, Integral and Derivative gains. The feedback control system is illustrated in Fig. where r, e, y are respectively the reference, error and controlled variables.

In the diagram of Fig.1, G(s) is the plant transfer function and C(s) is the PID controller transfer function that is given as:

$C(s) = Kp + \frac{K_i}{s} + Kd$

Where Kp ,Ki, Kd are respectively the proportional ,integral, derivative gains/parameters of the PID controllers that are going to be tuned. The plant is written as:

G(s) 1.44 s + 160

=---

0.0004608 s^4 + 0.06358 s^3 + 1.398 s^2 + 2.449 s + 17

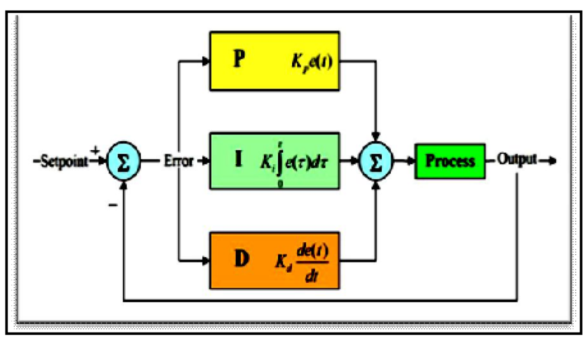


Figure 3: A common feedback PID control system

4.Performance Evaluation Criteria

Quantification of system performance is achieved through a performance index. The performance selected depends on the process under consideration and is chosen such that emphasis is placed on specific aspects of system performance. Furthermore, performance index is defined as a quantitative measure to depict the system performance of the designed PID controller. Using this technique an ‘optimum system’ can often be designed and a set of PID parameters in the system can be adjusted to meet the required specification. For a PID- controlled system, there are often four indices to depict the system performance: ISE, IAE, ITAE and ITSE. They are defined as follows:

ITAE Index:

ITAE $=\int_0^\infty t|e(t)|\,dt$

IAE Index:

IAE $= \int_0^\infty |e(t)|\,dt$

ISE Index:

ISE $= \int_0^\infty e^2(t)\,dt$

ITSE Index:

ITSE $= \int_0^\infty te^2(t)\,dt$

Therefore, for the GA -based PID tuning, these performance indexes will be used as the objective function. In other word, the objective in the GA -based optimization is to seek a set of PID parameters such that the feedback control system has minimum performance index.

5.Tuning Of Pid Using Pso-Based Optimization

5.1.Implementation Of PSO-Based PID Tuning

Stochastic Algorithm can be applied to the tuning of PID controller gains to ensure optimal control performance at nominal operating conditions. GA is employed to tune PID gains/parameters (Kp, Ki, Kd) in offline using the model in Eq. GA firstly produces initial swarm of particles in search space represented by matrix. Each GA represents a candidate solution for PID parameters where their values are set in the range of 0 to 100. For this 3-dimentional problem, position and velocity are represented by matrices with dimension of 3xSwarm size. The swarm size is the number of particle where 50 are considered a lot enough. A good set of PID controller parameters can yield a good system response and result in minimization of performance index

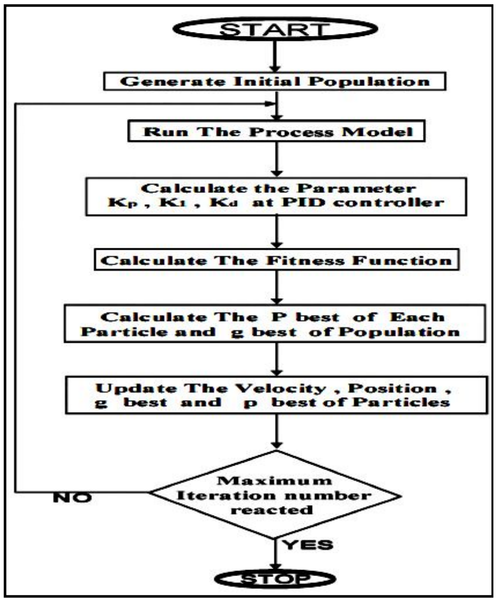
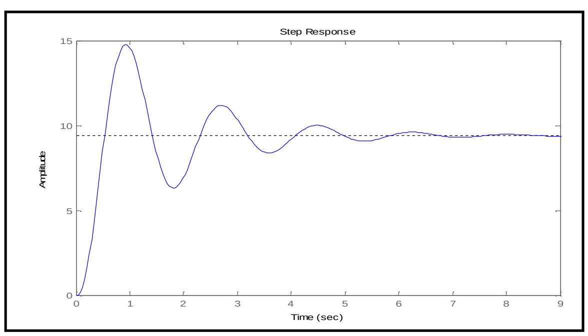


Figure 5: PSO Flowchart

6.Simulation And Results

Transfer function of an AVR system without PID

$$G(s) = \frac{1.44\,s + 160}{0.0004608\,s^4 + 0.06358\,s^3 + 1.398\,s^2 + 2.449\,s + 17}$$



Figiure 6: Step Response of an AVR system without PID

Transfer function of an AVR system with PID using PSO algorithm

1.398 s^3 + 156.5 s^2 + 126.1 s + 110.6

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0.0004608 s^5 + 0.06358 s^4 + 1.398 s^3 + 17.99 s^2 + 13.51 s + 11.06

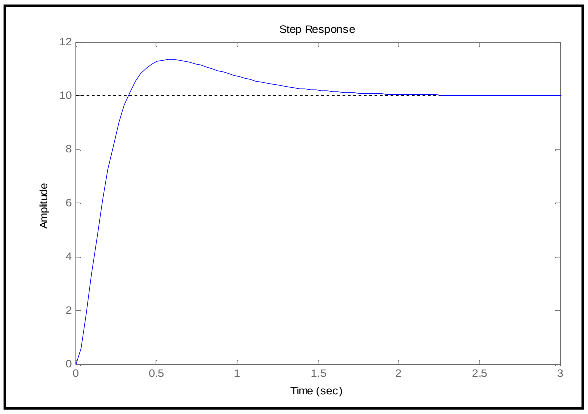

Figure 7: Step Response of of an AVR system with PID

We obtain the following parameter by tuning PID

Controller for AVR system

Kp = 0.4208

ki = 1.3150

kd = 0.9961

Comparison the results parameter without and with using GA algorithm.

parameter	Without PSO	With PSO
Rise-Time	0.3327	0.2260
Settling-Time	6.3268	1.4848
Settling-Min	6.3185	9.6336
Settling-Max	14.7694	11.3455
Overshoot	56.9245	13.4555
Undershoot	0	0
Peak	14.7694	11.3455
Peak-Time	0.9084	0.5758

Table 1: Compare results of integral errors with PID using PSO

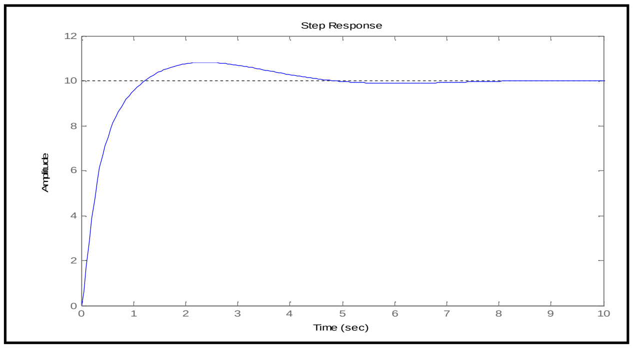

Figure 8: Step Response of PSO tune PID control system with IATE

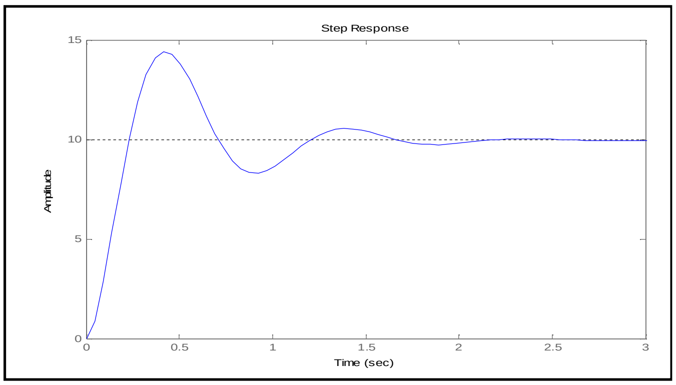

Figure 9: Step Response of PSO tune PID control system with IAE

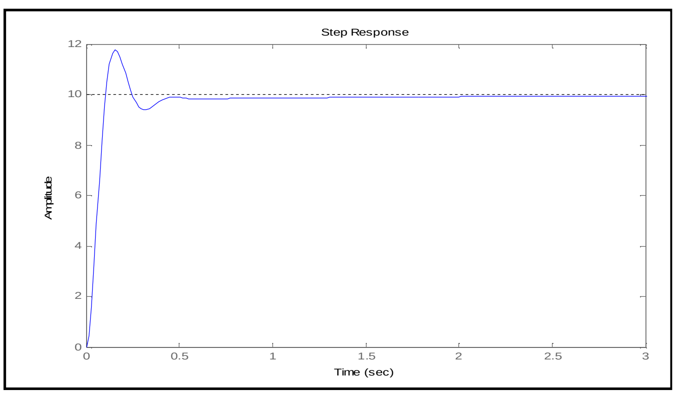

Figure 10: Step Response of PSO tune PID control system with ISE

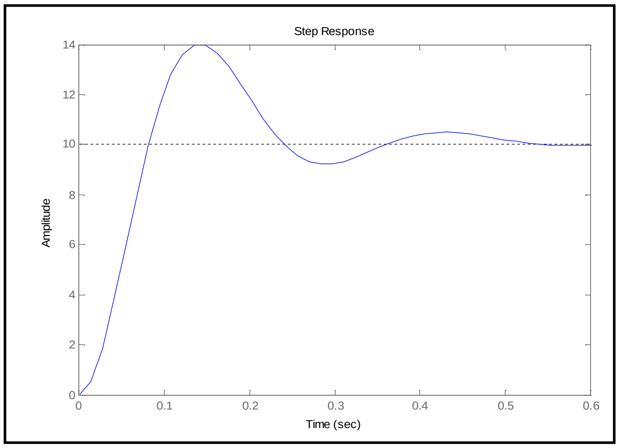

Figure 11: Step Response of PSO tune PID control system with MSE

	IATE	IAE	ISE	MSE
Rise-Time	0.3167	0.1608	0.0723	0.0561
Settling-Time	1.3337	2.0050	0.4162	0.4988
Settling-Min	9.5573	8.2945	9.3868	9.2157
Settling-Max	11.3306	14.4242	11.7657	13.9733
Over- shoot	13.3060	44.2423	17.6573	39.7325
Under- shoot	0	0	0	0
Peak	11.3306	14.4242	11.7657	13.9733
Peak-Time	0.7243	0.4153	0.1546	0.1350

Table 2

Error	Kp	Ki	Kd
IATE	0.2679	1.0032	0.3834
IAE	0.3358	3.2674	0.9235
ISE	1.6350	2.2337	0.6287
MSE	1.9978	8.2636	2.8294

Table 3

7.Conclusion

In design of PID controllers, it is very important to tune the PID parameters. If the tuning is not good, not only the control performances become worse but also the control system becomes inefficient. In this paper a systematic way for tuning PID type controllers for an AVR system has been analyzed. This tuning method uses closed loop data to determine the parameters settings for a PID controller.

The tunable results obtained are compared with the un-tunable results obtained from particle swarm optimization (PSO). This comparison shows that there is an acceptable agreement between these results.

From the above table we observe that

Rise-Time is 0.0561 by MSE

Over-shoot is 13.3060 by IATE

Peak-Time is 0.1350 by MSE

Settling-Time is 0.4162 by ISE

Hence the Over-shoot is the minimum by the IATE performance indices.

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