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PSO – ACO PID TECHNIQUES FOR STABILITY ENHANCEMENT

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Abstract—This paper Present to design method for determining the optimal proportional-integral-derivative (PID) controller parameters of an Automatic Voltage Regulator (AVR) system using the particle swarm optimization (PSO) algorithm and Ant Colony Optimization(ACO). The design goal is to minimize transient response by minimizing overshoot, settling time and rise time of step response. The proposed approach had superior features, including easy implementation, stable convergence characteristic, and good computational efficiency. Fast tuning of optimum PID controller parameters yields high-quality solution. First an objective function is defined, and then by minimizing the objective functions using real-coded ACO and PSO, the optimal controller parameters can be assigned. Compare the result of step response of AVR system by using Particle Swarm Optimization (PSO) and Ant Colony Optimization(ACO). The obtained result of the closed loop PSO-PID and ACO-PID controller response to the unit step input signal shows excellent performance of the PID controller.

Keywords— AVR system, Feedback System, Optimization, PID controller, PSO and ACO.

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 system.

Several tuning methods have been proposed for the tuning of process control loop. The most popular tuning methods are: Ziegler- Nichols, Cohen-Coon, and Astra-Hagglund. Unfortunately, in spite of this large range of tuning Several new intelligent optimization techniques have been emerged in the past two decades like: Ant Colony Optimization(ACO), Particle Swarm Optimization (PSO), Simulated Annealing (SA), and bacterial Foraging (BF) [2]. Due to its high potential for global optimization, ACO has received great attention in control system such as the search of optimal PID controller parameters. The natural genetic operations would still result in enormous computational efforts. PSO is one of themodern Heuristics algorithms it was developed through simulation of a simplified social system, and has been found to be robust in solving continuous non-linear optimization problems [2]. In this paper, a tradition method for tuning PID controller of non-linear synchronous generator AVR system control is represented. Then the ACO and PSO based methods for tuning the PID controller parameters are proposed as a modern intelligent optimization algorithm. The PSO technique can generate a high-quality solution within shorter calculation time and stable convergence characteristic than other stochastic methods. The integral performance criteria in frequency domain were often used to evaluate the controller performance, but these criteria have their own advantages and disadvantages.

In this paper, a simple performance criterion in time domain is proposed for evaluating the performance of a PSO-PID controller that was applied to the complex control system. ACO is an iterative search algorithm based on natural selection and genetic mechanism. However, ACO 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 ACO algorithm. For example, ants foraging, birds flocking, fish schooling, bacterial chemo taxis are some of the well-known examples.

2. Linearized Model of an AVR System

There are five models: (a) PID Controller Model, The transfer function of PID controller is

$K_p + K_d s + K_i/s$ ……………………… (2.1)

Where kp, kd, and ki are the proportion coefficient, differential coefficient, and integral coefficient, respectively. The derivative controller adds a finite zero to the open-loop plant transfer function and improves the transient response. The integral controller adds a pole at the origin, thus increasing system type by one and reducing the steady-state error due to a step function to zero.

3. Implementation of a pso-pid controller

In this paper, a PID controller using the PSO algorithm was developed to improve the step transient response of AVR of a generator. It was also called the PSO-PID controller. The PSO algorithm was mainly utilized to determine three optimal controller parameters Kp, Ki and Kd, such that the controlled system could obtain a good step response output. A. Individual String Definition To apply the PSO method for searching the controller parameters, we use the ―individual‖ to replace the ―particle‖ and the ―population‖ to replace the ―group‖ in this paper. We defined three controller parameters kp, ki and kd , to compose an individual by ; hence, there are three members in an individual. These members are assigned as real values. If there are n individuals in a population, then the dimension of a population is nx3. B. Evaluation Function Definition In the meantime, we defined the evaluation function given in (3.2) as the evaluation value of each individual in population. The evaluation function is a reciprocal of the performance criterion as in (3.1)

FF= (1-e-β)(Mp+Ess)+e-β(Ts-Tr) ……..(3.1)

It implies the smaller the value of individual, the higher its evaluation value

F=1/W (k) ………(3.2)

In order to limit the evaluation value of each individual of the population within a reasonable range, the Routh–Hurwitz criterion must be employed to test the closed-loop system stability before evaluating the evaluation value of an individual. If the individual satisfies the Routh–Hurwitz stability test applied to the characteristic equation of the system, then it is a feasible individual and the value of is small. In the opposite case, the value of the individual is penalized with a very large positive constant.

4. PARTICLE SWARM OPTIMIZATION

PSO is one of the optimization techniques first proposed by Eberhart and Colleagues [5, 6]. This method has been found to be robust in solving problems featuring non-linearity and non-differentiability, which is derived from the social-psychological theory. The technique is derived from research on swarm such as fish schooling and bird flocking. In the PSO algorithm, instead of using evolutionary operators such as mutation and crossover to manipulate algorithms, the population dynamics simulates a "bird flocks" behavior, where social sharing of information takes place and individuals can profit from the discoveries and previous experience of all the other companions during the search for food. Thus, each companion, called particle, in the population, which is called swarm, is assumed to ―fly ―in many directions over the search space in order to meet the demand fitness function.

Assumptions for PID tuning

pi,best and gi,best - is the position with the ‗best' objective value found so far by particle i and the entire population respectively; w - is a parameter controlling the dynamics of flying; R1 and R2 - are random variables in the range [0,1]; c1 and c2 - are factors controlling the related weighting of corresponding terms. The random variables help the PSO with the ability of stochastic searching. 4.1 PSO-PID Controller PSO-PID controller for searching the optimal or near optimal controller parameters kp, ki, and kd, with the PSO algorithm. Each individual K contains three members kp, ki, and kd. The searching procedures of the proposed PSO-PID controller were shown as below. Step 1) Specify the lower and upper bounds of the three controller parameters and initialize randomly the individuals of the population including searching points, velocities, Pbests, and gbest. Step 2) For each initial individual of the population, employ the Routh-Hurwitz criterion to test the closed-loop system stability and calculate the values of the four performance criteria in the time domain, namely Mp, Ess, tr , and ts . Step 3) Calculate the evaluation value of each individual in the population using the evaluation function. Step 4) Compare each individual's evaluation value with its Pbest. The best evaluation value among the Pbest is denoted as gbest.

Step 5) Modify the velocity factor

Step 6) Its best way for approaching that particular path.

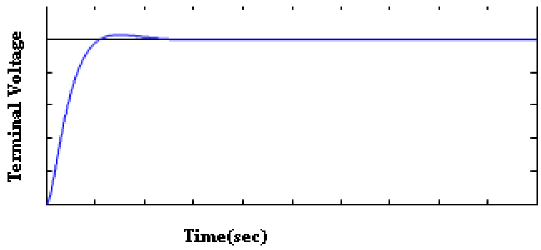
Step 7) Each member compare its position with the neighboring members.

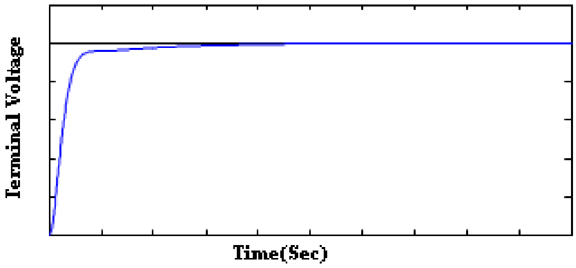
Step 8) If the number of iterations reaches the maximum, then go to Step 9. Otherwise, go to Step 2.

Step 9) The individual that generates the latest gbest is an optimal controller parameter.

PSO parameters are used for verifying the performance of the PSO-PID controller in searching the PID controller parameters: The member of each individual is Kp, Ki and Kd; Population size = 100, Inertia weight factor is set Acceleration constant C1=1.8 and C2=1.8 We have to use the value of beta is 0.5 and 1.0 Through about 150 iterations (150 generations), the PSO method can prompt convergence and obtain good evaluation value. These results show that the PSO-PID controller can search optimal PID controller parameters quickly and efficiently.

Results after simulation





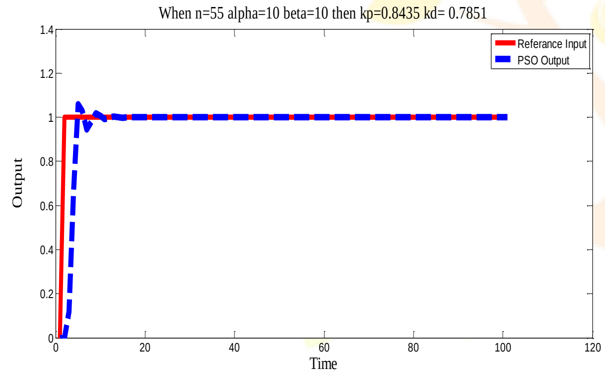
6. Ant Colony OptimizationOptimization

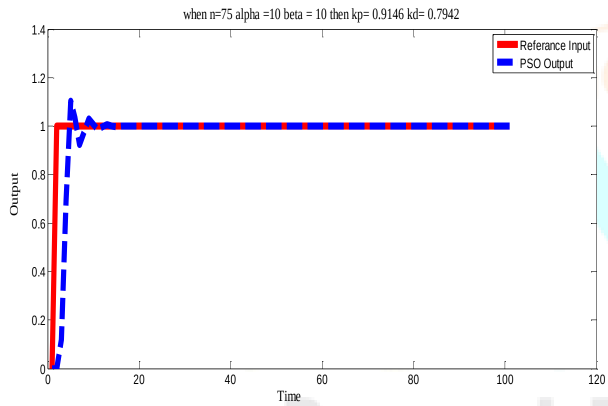
Artificial intelligent techniques have come to be the most widely used tool for solving many optimization problems. Ant Colony Optimization(ACO) is a relatively new approach of optimum searching, becoming increasing popular in science and engineering disciplines [7]. The basic principles of ACO were first proposed by Holland, it is inspired by the mechanism of natural selection where stronger individuals would likely be the winners in a competing environment [8]. In this approach, the variables are represented as genes on a chromosome. ACOs features a group of candidate solutions (population) on the response surface. Through natural selection and genetic operators, mutation and crossover, chromosomes with better fitness are found. Natural selection guarantees the recombination operator, the ACO combines genes from two parent chromosomes to form two chromosomes (children) that have a high probability of having better fitness that their parents [7, 9]. Mutation allows new area of the response surface to be explored. In this paper, a ACO process is used to find the optimum tuning of the PID controller, by forming random of population of 50 real numbers double precision chromosomes is created representing the solution space for the PID controller parameters (KP, KI and KD), which represent the genes of chromosomes. The ACO proceeds to find the optimal solution through several generations, the mutation function is the adaptive feasible, and the crossover function is the scattered. 6.1 Fitness Function In PID controller design methods, the most common performance criteria are Integrated Absolute Error (IAE), Integrated of Time weight Square Error (ITSE) and Integrated of Square Error (ISE) that can be evaluated analytically in frequency domain [2]. Each criterion has its own advantage and disadvantage. For example, disadvantage of IAE and ISE criteria is that its minimization can result in a response with relatively small overshot but a long settling time, because the ISE performance criteria weights all errors equally independent of time. Although, ITSE performance criterion can overcome this is the disadvantage of ISE criterion.

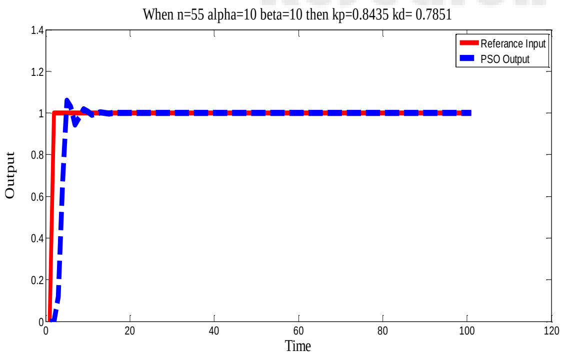
To illustrate the working process of genetic algorithm, the steps to realize a basic ACO are listed:

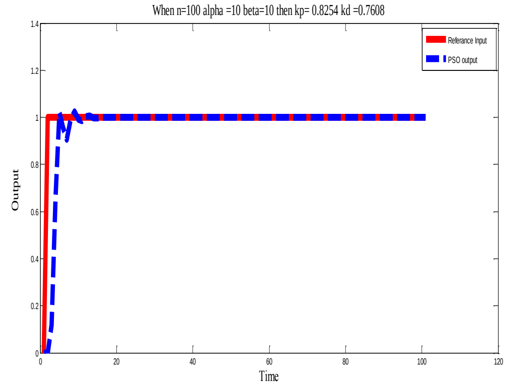
Step 1: Represent the problem variable domain as a chromosome of fixed length; choose the size of the chromosome population N, the crossover probability Pc and the mutation probability Pm.

Step 2: Define a fitness function to measure the performance of an individual chromosome in the problem domain. The fitness function establishes the basis for selecting chromosomes that will be mated during reproduction.
Step 3: Randomly generate an initial population of size N: X1 , X2 , X3 , …………., XN
Step 4: Calculate the fitness of each individual chromosome: f(X1), f(X2),……………...., f(XN).
Step 5: Select a pair of chromosomes for mating from the current population. Parent chromosomes are selected with a probability related to their fitness. High fit chromosomes have a higher probability of being selected for mating than less fit chromosomes.
Step 6: Create a pair of offspring chromosomes by applying the genetic operators.
Step 7: Place the created offspring chromosomes in the new population.
Step 8: Repeat Step 5 until the size of the new population equals that of initial population, N.
Step 9: Replace the initial (parent) chromosome population with the new (offspring) population. Step 10: Go to Step 4, and repeat the process until the termination criterion is satisfied.
To illustrate the working process of genetic algorithm, the steps to realize a basic ACO are listed:









9. DISCUSSION AND CONCLUSION
From this table it represents the better performance of PSO-PID as compared to ACO-PID technique. The no. of generation is increased the performance is increased in both methods. It is clear from the results that the proposed PSO method can avoid the shortcoming of premature convergence of ACO method and can obtain higher quality solution with better computation efficiency. The proposed method integrates the PSO algorithm with the new time-domain performance criterion into a PSO-PID controller. Through the simulation of a practical AVR system, the results show that the proposed controller can perform an efficient search for the optimal PID controller parameters. In addition, in order to verify it being superior to the ACO method, many performance estimation schemes are performed, such as multiple simulation examples for their terminal voltage step responses; convergence characteristic of the best evaluation value; dynamic convergence behavior of all individuals in population during the evolutionary processing; Computation efficiency. The amount of overshoot for the output response was successfully decreased using the above two techniques. Ant Colony Optimizationand Particle Swarm Optimization enabled the PID controller to get an output which is robust and has faster response. As the number of iterations (generations) in PSO Algorithm and also the no. of generations in ACO went on increasing the performance of the system also went on improving. The performance characteristics of the PID controller by using PSO Algorithm give the better results as compared to Genetic Algorithm.

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