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Implementation of Real-Time Temperature Pursuance Using ZN-PID Controller, ACO and PSO Tuning Technique

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Abstract

Level process. The increased complexity of modern control systems has emphasized upon the need for designing new approaches in order to meet requirements of different control engineering applications. The controller parameters have great impact on the performance and stability of controlled systems; as such estimation of optimal Proportional-Integral-Derivative (PID) parameters continues to be an area of research. An attempt has been made to improve different process systems' performance using non-traditional optimization techniques, like Particle Swarm Optimization and Simulated Annealing for searching the optimal PI/PID controller parameters. Various error criteria are used as objective functions to enable the search process.For the obtained models the controllers are first tuned using a few traditional techniques like the Zeigler – Nichols method, Internal Model Control (Skogestad), Tavakoli method, Suyama and unification methods.The time domain specifications areobserved and tabulated for various controller parameters. The performance index of the system is evaluated using the various error criteria.

Keywords: PID controller, Z-N method, ACO, PSO, Real-Time Temperature Process.

1. Introduction

Proportional Integral Derivative Controller has been using in Industrial control applications for a long time. The reasons for their wide popularity lies in the simplicity of design and good performance which includes low percent over shoot and small settling timeIntegral depends on past error, where it can overcome the offset but it overshoots value is more. Derivative depends upon the future error but it can overcome both offset and overshoot, but it cannot be used separately. For a fair comparison of different PID settings, both time domain performance. And frequency domain robustness should be considered. Numerous methods have been projected for tuning these controllers, but every method has some constraint. As a result, the design of PID controller still remains a challenge before researchers and engineers.

2. Real-Time Temperature Process

Figure 1. Temperature Process Station

The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by Rota meter. Temperature sensor (RTD) is used for temperature sensing.

1. Control Unit: Digital indicating controller with RS 485 communication
2. Communication: USB port using RS 485-USB converter
3. Temperature Sensor: Type RTD, PT 100
4. Heating Control: Proportional power controller (SSR), input 4-20mA D.C., Capacity 20 A
5. Rota meter: 6-60 LPH
6. Process Tank: SS304, Capacity 0.5 lit, insulated
7. Overall dimensions: 400w*400D*330H mm

This explores the system schematic arrangement of UT_321. A step input is applied to solid state relay (SSR) and temperature of RTD (PT 100) is recorded in excel format. Stored data is used to plot open loop step response in MATLAB. The procedure followed is

1. Connect the sensor before the delay line.
2. Start the set up and select the open loop control.
3. Set the controller output as 40% and allow the process to reach the steady state.

4. Then apply step change by increasing the controller output to 60% and allow the process to reach the steady state.

The Process Transfer Function has been determined by the Experimental Process mentioned above. The Experiment is carried out and the response is taken until the steady state is reached without the use of the controller. The response of that process without controller will be a curve with some dead time and steady state time. By that, Gain of the process can be determined which is the ratio of output to the input, Time Constant can be calculated which is the time difference from dead time to steady state and Dead time (i.e.) the time period for which the output is not responding to the input is also determined.

3. **Controller Design**

3.1 Z-N Method

The Ziegler-Nichols design methods are the most popular methods used in process control to determine the parameters of a PID controller [2]. Ziegler Nichols tuning methods (ZN tuning methods) are the principal methodsused in PID controller tuning. This method is also called to be online-tuning method. Given the magnitude and phase, we can determine gain parameter of the model, frequency f through pi-radians, plant gain K and gain margin Ku.The measure of proportional response is called “sensitivity" or "throttling range", the former being valve movement per pen movement, the latter is reciprocal or the pen movement necessary to give full valve movement. Sensitivity adjustment is necessary if optimum control stability is to be attained. It is common knowledge that control with infinitely high proportional response is always unstable, oscillating continuously. The obtained values of controller is,**Kp=1.464, Ki=0.0062, Kd=86.37.**

3.2 ACO Utilization and appliance

ACO [1, 24] is a class of algorithms, whose first member, called Ant System, was initially proposed by Colorni, Dorigo and Maniezzo [13, 21, 18]. The main underlying idea, loosely inspired by the behavior of real ants, is that of a parallel search over several constructive computational threads based on local problem data and on a dynamic memory structure containing information on the quality of previously obtained result. The collective behavior emerging from the interaction of the different search threads has proved effective in solving combinatorial optimization (CO) problems. They move by applying a stochastic local decision policy based on two parameters, called trails and attractiveness. By moving, each ant incrementally constructs a solution to the problem. When an ant completes a solution, or during the construction phase, the ant evaluates the solution and modifies the trail value on the components used in its solution. This pheromone information will direct the search of the future ants. Trails are updated usually when all ants have completed their solution, increasing or decreasing the level of trails corresponding to moves that were part of "good" or "bad" solutions, respectively.

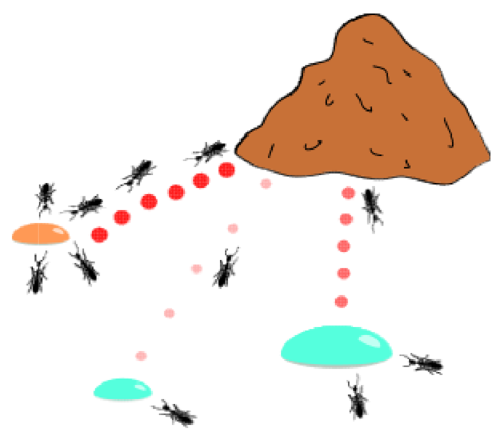


Figure 2. ACO Process Base

The first ACO algorithm was called the Ant system and it was aimed to solve the travelling salesman problem, in which the goal is to find the shortest round-trip to link a series of cities. The general algorithm is relatively simple and based on a set of ants, each making one of the possible round-trips along the cities. At each stage, the ant chooses to move from one city to another according to some rules:

1. It must visit each city exactly once;
2. A distant city has less chance of being chosen (the visibility);
3. The more intense the pheromone trail laid out on an edge between two cities, the greater the probability that that edge will be chosen;
4. Having completed its journey, the ant deposits more pheromones on all edges it traversed, if the journey is short;
5. After each iteration, trails of pheromones evaporate.

From the distribution ranges of ACO, the values obtained are,

Kp=1.6810, Ki=0.0084, Kd=45.8268.

3.3 PSO-Admittance

PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms.PSO applies the concept of social interaction to problem solving.It was developed in 1995 by James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer). It uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution.Each particle is treated as a point in a N-dimensional space which adjusts its “flying” according to its own flying experience as well as the flying experience of other particles.Each particle keeps track of its coordinates in the problem space which are associated with thebest solution (fitness) it has achieved so far. (The fitness value is also stored.) This value is called *pbest.* Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the neighbors of the particle. This location is called*lbest*. When a particle takes all the population as its topological neighbors, the best value is a global best and is called *gbest.*Unlike in genetic algorithms, evolutionary programming and evolutionary strategies, in PSO, there is no selection operation.All particles in PSO are kept as members of the population through the course of the run. PSO is the only algorithm that does not implement the survival of thefittest. No crossover operation in PSO.

The position and velocity of a particle i are D-dimensional vectors, expressed as:

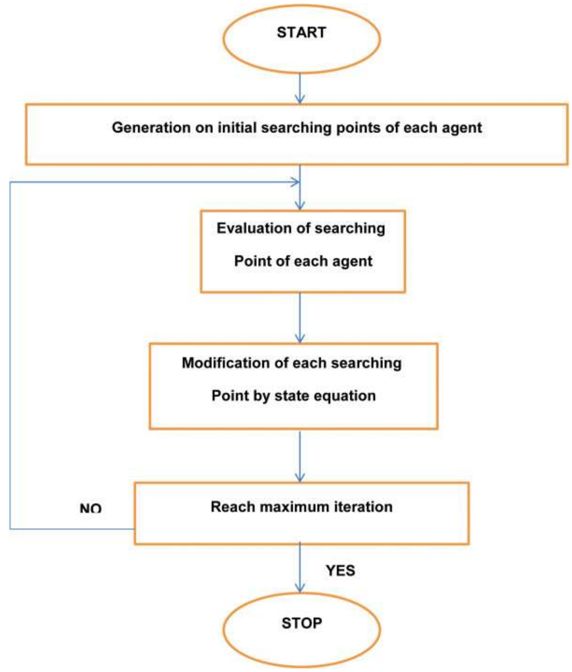
$$X_i = (x_{i1}, x_{i2}, \ldots, x_{iD})^T,\ V_i = (v_{i1}, v_{i2}, \ldots, v_{iD})^T$$

and other vectors are also D dimensions. Iterative equation is as follows:

$$V_{id}(k+1) = v_{id}(k)+c_1 rand_1(k)(pbest_{id}(k)-x_{id}(k))+c_2 rand_2(k)(gbest_d(k)-x_{id}(k))$$

$$X_{id}(k+1) = X_{id}(k)+V_{id}(k+1)$$

3.5 PROGRESSION OF PSO-ALGORITHM:



Fiugre 3. Flow Chart

A). Implementation of PSO algorithm:

The optimal values of the conventional PID controller parameter values are particles whose values are particles and whose values are attuned so as to minimize the objective function, here in this case is the error criterion. For the PID controller design, it is ensured the controller settings predictable results in a stable closed loop system.

B). Selection of PSO parameters:

To start up with PSO, certain parameters are requirement. Choice of these criterion selects to a great extent the ability of global minimization. The maximum velocity transform the ability of escaping from local optimization and refining global optimization. The size of swarm balances the requirement of global optimization and computational cost. Digitizing the values of the parameters is as per the represented table below:

Table 1. PSO Selection Parameters

Population Size	100
Number of Iterations	100
Velocity constant, c1	2
Velocity constant, c2	2

C). Performance Index for the PSO Algorithm:

The objective function measured is based on the error principle. The performance of a controller is best evaluated in terms of error principle. A number of such criteria are available and in proposed book, controller's performance is evaluated in terms of Integral Absolute Errors(IAE) principle that is given by,

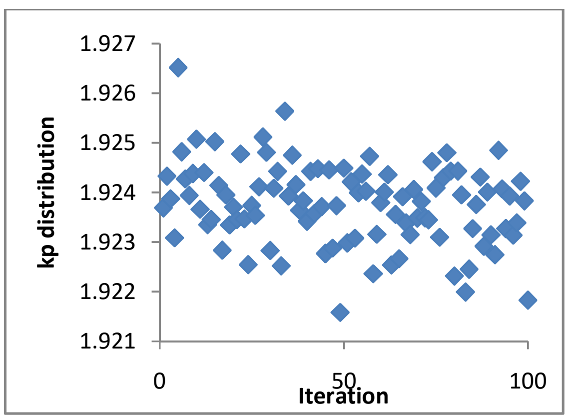
$$\text{IAE} = \int_0^T |e(t)|\, dt$$

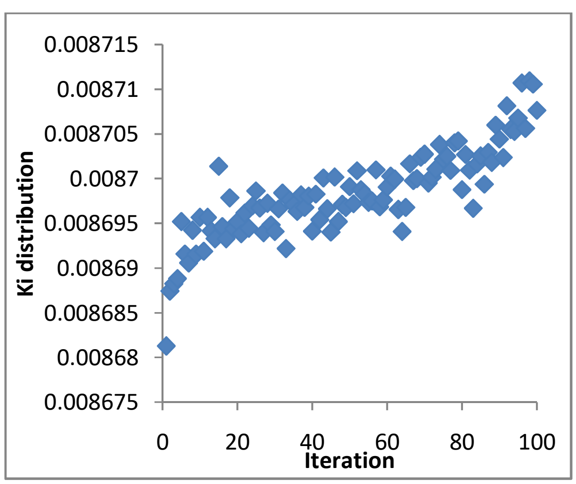
The IAE weights the error with time and hence emphasizes the error values over a range of o to T, where T is the settling time.

D). Termination Criteria:

Termination of optimization algorithm can take place either when the maximal number of iterations gets over or with the procurement of satisfactory fitness value. Fitness value is nothing but the reciprocal of the error, since we consider for a minimization of objective function. In this work the termination criteria is examined to be the maximum number of iterations. The adaption of the values for the first iteration for Kp, Ki and Kd are given below:

Kp=1.9218, Ki=0.0087, Kd=40.7960.





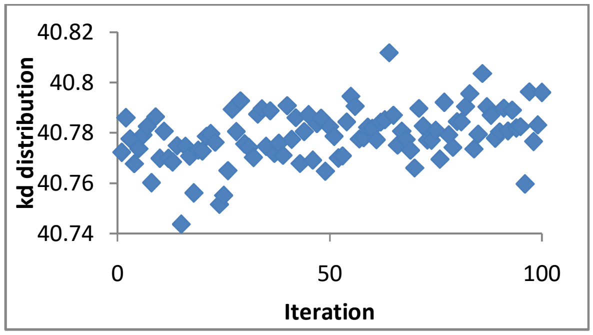


Figure 4. Kp, Ki, Kd distribution

4 Results and Discussions

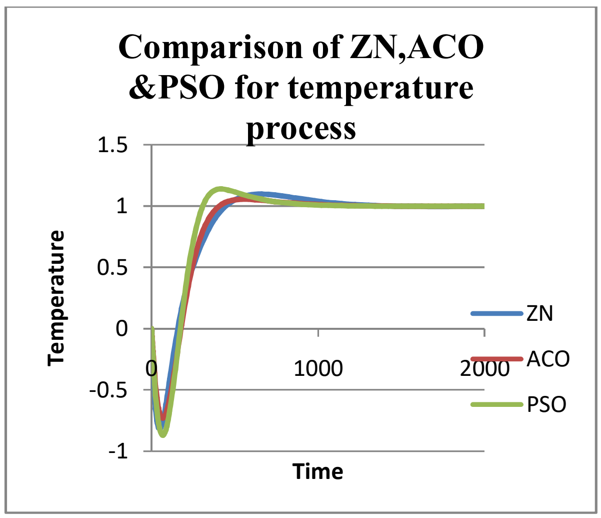


Figure 5. Closed Loop Response

Table 2. Time Domain Specifications:

Controllers	Settling time	Rise Time	Peak Time	Peak Overshoot
Ziegler-Nichols	1500	278	600	10
Ant Colony Optimization	1320	215	0	0

Particle Swarm Optimization	1000	126	0	0

Table .3. Performance Index:

Controllers	ISE	IAE	ITAE	MSE
Ziegler-Nichols	4.3094e+003	3.2625e+003	4.9048e+005	0.2878
Ant Colony Optimization	4.1063e+003	3.1474e+003	3.5207e+005	0.2552
Particle Swarm Optimization	4.3788e+003	3.0845e+003	3.3164e+005	0.2742

5 Servo Regulator Regimentation

A servo control loop is one which responds to a change in set point. The set point may be changed as a function of time and therefore the controlled variable must follow the set point.

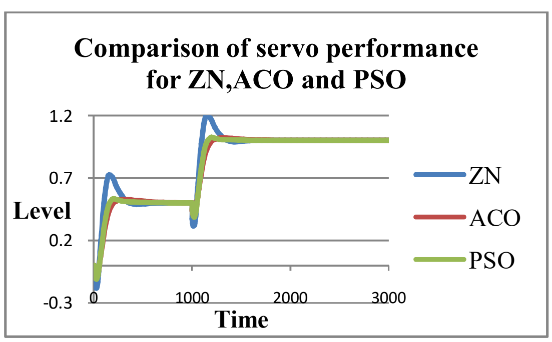
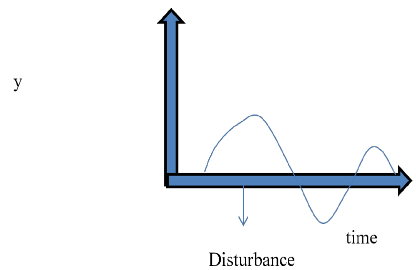


Figure 6. Servo Response

A regulatory control loop is one which responds to a change in some input value, bringing the system back to steady state. Regulatory control is by far more common than servo control in the process industries.



Regulatory control is by distant more common than servo control in the process industries. The above is the general description of the servo-regulatory responses. The following responses are produced for all the three methods. And it proves that PSO hold on best compared with the other two.

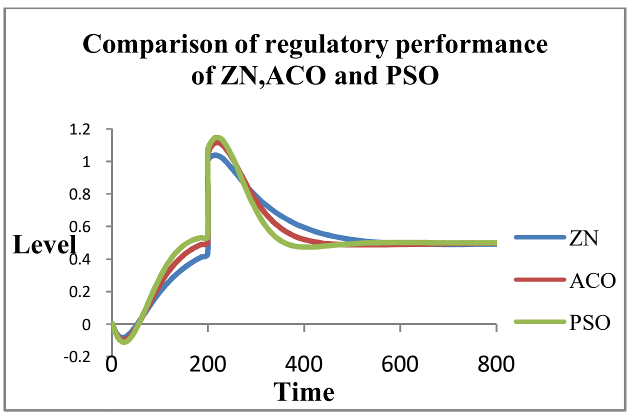


Figure 7. Regulatory Response

6 Conclusion

The PID and tuning method have been implemented on real-time temperature control performance using these methods has been completed. For the PID controller the set point tracking performance is characterized by lack of smooth transition as well is has more oscillations. Also it takes much time to reach set point but the PID-PSO based controller tracks the set point faster and maintains steady state.Simulation results have been given to show the

Performance of the method. The proposed tuning method is superlative and show good performance in apply with real time implementation.

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