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DESIGN OF PSO, BFO, ACO BASED PID CONTROLLER FOR TWO TANK SPHERICAL INTERACTING SYSTEM

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ABSTRACT— Interacting Spherical Two Tank System (ISTTS) is considered as benchmark setup in this paper. ISTTS is highly nonlinear system, design of controller for liquid level controller for this system is considered difficult due to its non linearities. The Bacterial Foraging Optimization Technique, Particle Swarm Optimization Technique and Ant Colony Optimization techniques are used to design the PID Controller. The error values are calculated and are compared using Anova test. The comparative performance of these controllers is done and result is produced. From the Anova test it is inferred that PSO based PID Controller gives less error value when compared to other optimization based PID controller.

INDEX TERMS— Nonlinear system, Bacterial Foraging Optimization, Particle Swarm Optimization, Ant Colony Optimization, PID Controller.

INTRODUCTION

Generally, nonlinear problems are problematic to solve and are not easily understandable than that of linear problems. The control of liquid level in the tanks and the flow between the tanks are the two basic problems in the process industries**.** In process industries the liquids are pumped and stored in tanks and thereafter pumped to next tank [1]. Always the liquid level in the tanks must be examined. A basic control problem in many process industries is the control of liquid levels in tanks they are stored and reaction vessels. The cross section and non-linearity of the spherical tank changes constantly so the controlling of the level is a challenging issue. Hence, control level of the liquid in tank is very important task in process industries [2]. The advantages of Spherical Tank are inexpensive and efficient washing, intensified production and reduced product loss. The spherical Tank is widely used in various industries like petrochemical industries, paper making industry, water treatment industries.

PROCESS DESCRIPTION

The setup considered contains pair of spherical Tanks. Tank 1 and Tank 2 are two similar Spherical Tanks [3]. The height is of the tank is considered as H and its value is 50 cm and the radius R is 25 cm. Restriction is R_1 which interconnects the two Spherical Tanks. The input streams $F1_{in}$ and $F2_{in}$ for the Tank 1 and Tank 2 respectively. Similarly the output stream of the Tank 2 is F_{out} which flows through restriction R_2 to the sump. The height of tanks is considered as h_1, h_2 of the Tank 1 and Tank 2 respectively [4][5]. These fluid heights are measured by differential Pressure transmitters and they are transmitted in the form of 4 – 20 mA current signals to the interfacing unit of the

Personal Computer. Here liquid level h2 in Tank 2 has to be controlled. Similarly the input flows $F1_{in}$ and $F2_{in}$ are measured by Magnetic Flow transmitters they are transmitted in the form of 4 – 20 mA current signals to the interfacing unit. The schematic of TTSIS is shown in Fig.1.

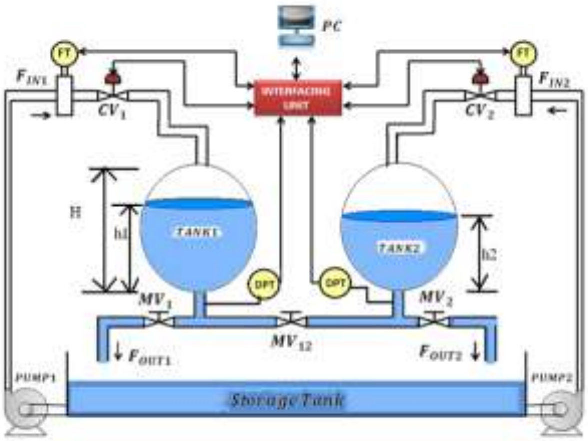

Figure 1 Schematic of TTSIS

The model of Tank 1 can be represented as,

$$A_1(h_1)\frac{dh_1}{dt} = Fin1 - \beta_{12}\sqrt{h1-h2} \qquad (7)$$

Taking Linearization above equation becomes

$$A_1(h_1)\frac{d(\partial h_1)}{dt} = f_1(Fin1) - f_1(h_1 - h_2) \qquad (8)$$

Applying partial differentiation to above equation,

$$A_1(h_1)\frac{d(\partial h_1)}{dt} = \left(\frac{\partial f_1}{\partial Fin1}\right)\cdot\partial Fin1 - \left(\frac{\partial f_2}{\partial h_2}\right)\cdot\partial h_1 - \left(\frac{\partial f_2}{\partial h_2}\right)\cdot\partial h_2 \qquad (9)$$

On rearranging above equation,

$$A_1(h_1)\frac{d(\partial h_1)}{dt} = \partial Fin1 - \frac{\beta_{12}}{2\sqrt{h_1-h_2}}\partial h_1 + \frac{\beta_{12}}{2\sqrt{h_1-h_2}}\partial h_2$$

Applying Laplace transformations to above equation,

$$\partial h_1 = \frac{\partial Fin1 + \dfrac{\beta_{12}}{2\sqrt{h_1-h_2}}\partial h_2}{A_1(h_1)s + \dfrac{\beta_{12}}{2\sqrt{h_1-h_2}}} \qquad (10)$$

The model Tank 2 can be represented as,

$$A_1(h_1)\frac{dh_2}{dt} = \beta_{12}\sqrt{h_1-h_2} - \beta_2\sqrt{h_2} \qquad (11)$$

Taking linearization,

$$A_2(h_2)\frac{d(\partial h_2)}{dt} = f_1(h_1,h_2) - f_2(h_2) \qquad (12)$$

Applying partial differentiation to above equation,

$$A_2(h_2)\frac{d(\partial h_2)}{dt} = \left(\frac{\partial f_1}{\partial h_1}\right)\cdot\partial h_1 - \left(\frac{\partial f_1}{\partial h_2}\right)\cdot\partial h_2 - \left(\frac{\partial f_2}{\partial h_2}\right)\cdot\partial h_2$$

$$A_2(h_2)\frac{d(\partial h_2)}{dt} = \frac{\beta_{12}}{2\sqrt{h_1-h_2}}\partial h_1 - \frac{\beta_{12}}{2\sqrt{h_1-h_2}}\partial h_2 - \frac{\beta_2}{2\sqrt{h_2}}\partial h_2 \qquad (13)$$

Applying Laplace transformation ,

$$\left[A_2(h_2)s + \frac{\beta_{12}}{2\sqrt{h_1-h_2}} + \frac{\beta_2}{2\sqrt{h_2}}\right]\partial h_2 - \frac{\beta_{12}}{2\sqrt{h_1-h_2}}\partial h_1 \qquad (14)$$

Substituting (4.4) in (4.8) we get,

$$\left[A_2(h_2)s + \frac{\beta_{12}}{2\sqrt{h_1-h_2}} + \frac{\beta_2}{2\sqrt{h_2}}\right]\partial h_2 = \frac{\beta_{12}}{2\sqrt{h_1-h_2}}\left[\frac{\partial Fin1 + \dfrac{\beta_{12}}{2\sqrt{h_1-h_2}}\partial h_2}{A_1(h_1)s + \dfrac{\beta_{12}}{2\sqrt{h_1-h_2}}}\right] \qquad (15)$$

Let us assume,

$$C_1 = \frac{1}{2\sqrt{h_1-h_2}} \qquad C_2 = \frac{1}{2\sqrt{h_2}}$$

$$R_1 = \frac{1}{\beta_{12}C_1} \qquad R_2 = \frac{1}{\beta_2 C_2}$$

$$\tau_1 = A(h_1)R_1 \qquad \tau_2 = A(h_2)R_2$$

Substituting the above variables in (15), we get transfer function of TTSIS relating h_2 and Fin1

$$\frac{\partial h_2}{\partial Fin1} = \frac{R_2}{\tau_1\tau_2 s^2 + \left[\tau_1 + \tau_2 + A(h_1)R_2\right]s + 1} \qquad (16)$$

Table 1 represent the parameters of the spherical tank.

TABLE I. PARAMETERS OF SPHERICAL TANK

Parameters	***Values***
Fin	107.25
β_1	78.28
β_2	19.69
h_1	31.9
h_2	30
θ	0.2
C_1	0.3627
R_1	0.03522
C_2	0.09128
R_2	0.5564
τ_1	63.85
τ_2	1048.2575

Substituting the values from Table 1 in equation (16), we get transfer function

$$\frac{\partial h_2}{\partial Fin1} = \frac{0.5564}{66931.25s^2 + 2120.87s + 1}$$

BFO ALGORITHM

Bacteria Foraging Optimization (BFO) algorithmic program is a new way of biologically impressed search technique which is supported on the behavior of *E. Coli* bacteria [6][7]. The fundamental operations of BFO Algorithm are as follows:

The Chemotaxis is an operation which associates in nursing the *E. coli* bacterium which moves towards in search of food by swimming and tumbling of flagella. Swarming is a process in which the bacterium that have an information on concerning the optimum path to the food supply can communicate with different bacteria with help of attraction signal. Reproduction is a stage in which the bacteria that are not healthy can expire and the bacterium that are healthy can divide into two and breed to increase population. Elimination- Dispersal is last stage where a bunch of the bacterium is eliminated or a bunch are scattered within the dimensional search space [8][9][10][11]. With the help of this algorithm PID controller is tuned. The mean value of 15 iterations is used to tune the controller.

PSO ALGORITHM

Particle Swarm Optimization (PSO) technique is an organic type optimization technique [12][13]. In PSO algorithm, the smaller amount of parameters is assigned [14]. Here, a group of artificial birds are initialized with arbitrary positions and velocities. Every bird within the swarm is scattered. With the steering of the Objective Function (OF), every particle within the swarm attempt to change their speed and position. Throughout the search, every particle notes its best position and also obtains the global best position [15][16][17].

PSO algorithm has a population of particles. These particles move around within the search space supported with few easy formulae. With the help of this algorithm the parameters of PID Controller is found. The mean value of 15 iterations is taken as parameters to tune PID controller [18][19].

ACO ALGORITHM

Ant Colony Optimization is a population based technique to find approximate solutions [20][21]. It is a population based technique. It is designed based on the movement of ants in search of food. Ants find the shortest path to reach the food. While moving the ants deposits phermone on the ground [22]. And they folow these solution to reach to their nest while returning. Based on this technique Ant Colony Optimization Algorithm is designed. This technique is used to find shortest path algorithm. At each iteration, a group of artificial ants are considered. They build a solution by moving vertex to vertex. With the help of this technique PID controller is designed. The mean value of 15 iterations is taken to tune the controller.

RESULTS AND DISCUSSIONS

The simulation is done for the mean value of the 15 iterations. The servo and regulatory response of the controllers are shown in the Fig.2 and Fig.3. respectively.

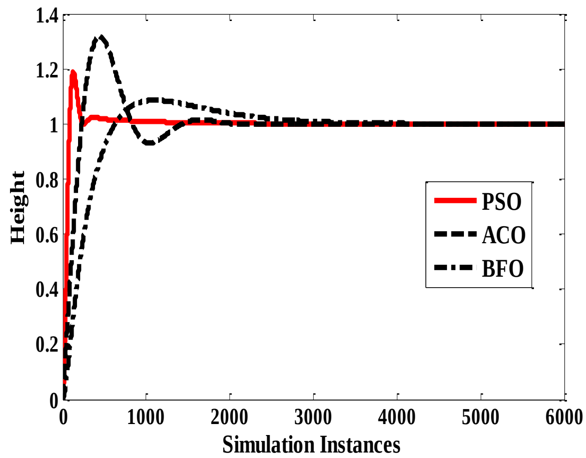

Figure 2 Servo Response of the Controller

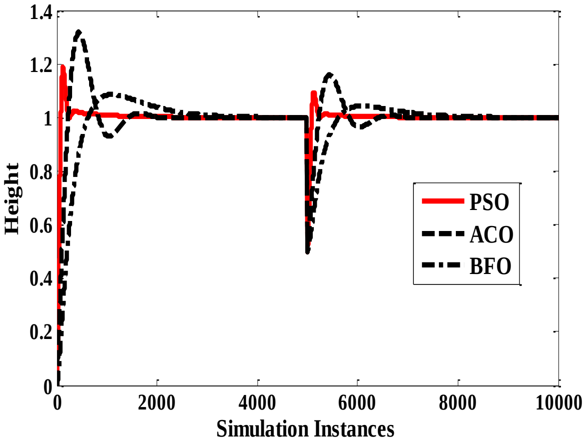

Figure 3 Regulatory Response of the controller

The error values for the PID parametrs obtained in 15 iterations are tabulated and the comparison is done with the help of Anova (Analysis of Variance) test. It is a statistical method. The result of Anova test is shown in Fig.4.

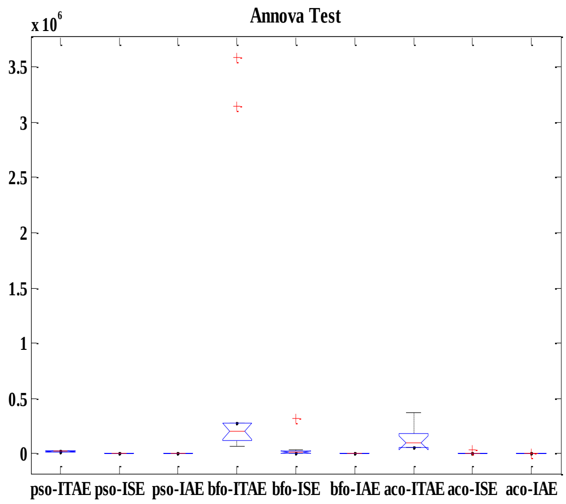

Figure 4 Result of Anova test

Multi comparison is also done to clearly show the difference between the mean values of error. It is shown in Fig.5.

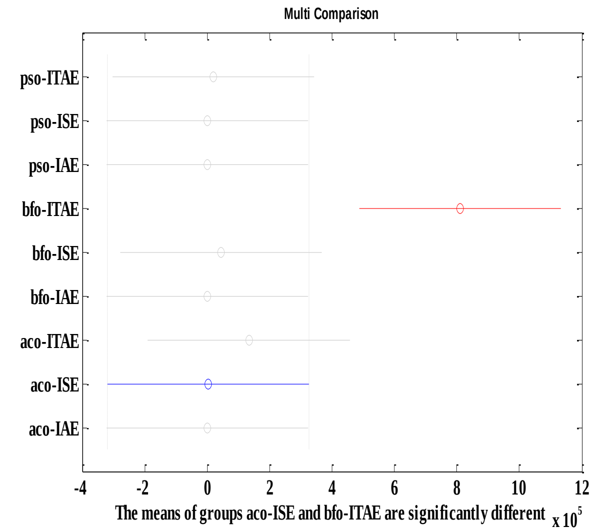

Figure 5 Multi Comparison of errors

CONCLUSION

PSO, BFO, ACO based PID controllers are designed for interacting spherical two tank system. Error analysis has been done using Anova test. Comparitive analysis of the Integral Timed Absolute Error (ITAE), Integral Square Error (ISE) and Integral Absolute Error (IAE) of the controllers using Anova test and Multi comparison is done. From the result it is inferred that the ITAE error of BFO based PID controller is large. On the other side comparative test represents that PSO based PID controller has less error value.

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