Designing and Comparison of Controllers based on Optimization Techniques for pH Neutralization Process

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Abstract- **The objective is to design controllers using different optimization techniques for pH Neutralization process. Controlling of pH in neutral region is an important process as small change in input gives the huge change in the output. The controller is designed using the Optimization techniques like BFO and PSO Algorithm. Comparison between BFO and PSO based PID controller and PSO based I-PD controller. The performance analysis is done for PID controllers in Acid, Neutral and Base region by keeping set point in 5, 7 and 12. From the simulation result it is found that BFO based PID controller gives better result when compared to other two techniques for pH neutralization process considered.**

Key words: *Nonlinear process, pH Neutralization process, BFO Algorithm, PSO Algorithm.*

I. INTRODUCTION

Waste comes from the textile industries is rarely neutral. This waste water has to be neutralized before discharge or reuse [1]. Acid is a substance which ionizes in water in order to give hydroxide ion, while base is the substance which ionize in water and give hydroxyl ion. Here strong acid (HCl) made to react with the strong base (NaOH) for maintaining of pH value at neutral, acid and base region. Controlling of pH in neutral region is an important process as small change in input gives the huge change in the output. In the areas like waste water treatment, chemical and biological reaction and production of pharmaceuticals, precipitation and electrochemistry plants, fermentation and food production control of pH neutralization process is very important part [2].

II. pH NEUTRALIZATION PROCESS

The pH process system is developed which is adequate in terms of the supposed application that is to design an improved form of the controller. A general method of getting a dynamic equation for pH neutralization process in Continuous Stirred Tank Reactors was done by McAvoy in 1972. Some points are emerged in developing a pH neutralization process that describes the nonlinearity of the process. They are

1. Material balance in terms of hydrogen and hydroxyl ion concentrations would be difficult to record. They are as a result of dissociation of water and alteration in water concentration has got to be noted.
2. The material balance is performed on all atomic species and all exta equilibrium relationships. To modify the equations the electro neutrality principle is employed [3] [4].

The reactor vessel that is used here has a volume of 5L and it can be emptied by a draining pipe. The temperature is maintained constant. And 350-bar pressure-rated reactor vessel is selected. The simulation model of the system used is shown in Fig. 1.

The technique called pneumatic pressure building technique is used to keep pressure which is inside the vessel in an elevated value in the environmental CSTR system by a solenoid valve [5].

In order to maintain the pressure, the CSTR is kept closed. The Acid and base solutions are mixed well using a stirrer. Special type of pH probe is used to measure the pH inside the setup. In this experiment, strong acid (HCl) and strong base (NaOH) of 1 molarity is prepared and used to conduct real-time experiments.

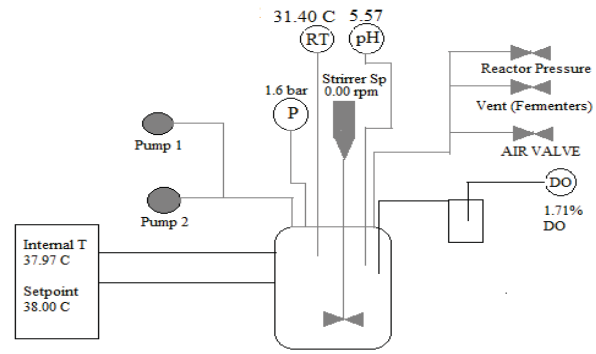

Fig. 1. Diagram of simulation model for the system

Considering the delay factors, system is modeled as FOPDT system, whose general transfer function model is given below,

$$G(s) = \frac{Ke^{-\tau_d s}}{\tau s + 1}$$

The transfer function model of the system obtained from the open-loop response is

$$G(s) = \frac{0.276e^{-5.005s}}{3.2s + 1}$$

III. BFO ALGORITHM

Bacteria Foraging Optimization (BFO) algorithmic program may be a new kind of biologically impressed international search technique supported on behavior of *E. Coli* bacteria[6]. The fundamental operations of BFO Algorithm are:

Chemotaxis: Throughout foraging operation associate in nursing an *E. coli* bacterium can move towards the food by swimming and tumbling by victimisation flagella.

Swarming: In this process, the bacterium that is having the information concerning the optimum path to the food supply can communicate to different bacteria by using an attraction signal.

Reproduction: In this stage the bacteria which are unhealthy can decay and therefore bacterium that are healthy can split into two and breed so as to take care of a continuing population.

Elimination- Dispersal: Throughout this stage, a bunch of the bacterium in a local optima are eliminated or a bunch could also be scattered into a new food location within the dimensional search space[7][9].

PID controller gives a quick response and stability, it has the ability to eliminate the offset and it has the ability to reduce peak error and provide faster recovery.

PID controller based on BFO Algorithm is designed to control pH Neutralization Process whose gain and time constant are functions of process variable is considered for testing.

The Block diagram of BFO based PID Controller is shown in Fig. 2.

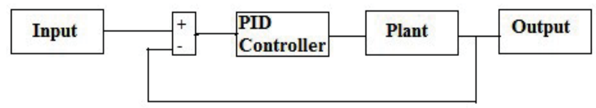

Fig. 2. Block diagram of PID controller

With the help of BFO algorithm the Proportional gain, Integral gain and Derivative gain values are calculated. With the help of these values the Controller is designed. The parameters of PID controller found using BFO algorithm is tabulated in TABLE I

TABLE I PARAMETERS OF BFO BASED PID CONTROLLER

K_p	K_i	K_d
0.7432	0.2546	0.2213

IV. PSO ALGORITHM

Kennedy and Eberhart are the scientists who prjected Particle Swarm Optimization (PSO) technique that is an organic type international optimization technique. It is attributable to the inspiration of social activities in flock of birds and school of fish [8].

In PSO algorithm, the amount of parameters that are assigned is smaller amount. In this, a group of artificial birds are initialized with arbitrary positions X_i and velocities V_i. At beginning searching stage, every bird within the swarm is scattered indiscriminately. With the steering of the Objective Function (OF), every particle within the swarm dynamically attempt to change their flying position and speed. Throughout the optimization search, every particle notes its best position earned to this point and also obtains the global best position achieved by any particle within the population [10][11].

PSO algorithm works by having a population of particles. These particles are created to move around within the search space supported on few easy formulae. The movements of those particles are target-hunting by their own best known position further because the entire swarm's best known position. Once improved positions are found these will then facilitate in guiding the movements of the swarm.

The steps to implement PSO are

Step i (initialization of swarm): For a population size *N*, the particles are going to be indiscriminately generated between their limits of parameter values.

Step ii (evaluation of objective function): The Objective function values of particles are being evaluated supported by the performance criteria for the algorithm.

Step iii (initialization of *pbest* and *gbest*): The target values obtained for the initial particles of swarm are used because the initial *pbest* values of particles. The most effective value found from all the *pbest* values obtained and it is identified as *gbest.*

Step iv (evaluation of velocity): For every particle new velocity is ready.

Step v (update the swarm): The particle position is updated. For these updated positions of particles the values of the objective function are being calculated. If the new value is best compared to the *pbest* value obtained antecedently the new value is set as *pbest*. Likewise, *gbest* value is additionally updated as the better *pbest*.

Step vi (stopping criteria): Once the stopping criteria are met, positions of particles that are represented by *pbest* are set as optimum values. Else, repeat from Step vi until the desired iteration is reached.

I-PD controller is similar to PID controller. The basic block diagram of PSO based I-PD controller is shown in Figure 2.

Using PSO algorithm PID controller and I-PD controller are designed and its gain values are found.

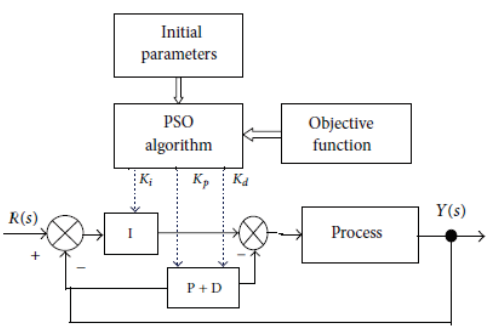

Fig. 3. Basic block diagram of PSO based I-PD controller

The parameters of PSO based PID controller and PSO based I-PD controller are listed in TABLE II.

TABLE II PARAMETERS OF CONTROLLER USING PSO ALGORITHM

	K_p	K_i	K_d
PID	0.4764	0.3336	0.2666
I-PD	2.01	0.37	2.78

V. RESULTS

Simulation work is carried out for the controllers designed and their Time domain specification and the Error indices values are calculated. The performance analysis is done for PID controllers in Acid, Neutral and Base region by keeping set point in 5, 7 and 12. The servo response of the controllers in Acid, Base and Neutral Region are shown in Fig. 4,5,6. And the regulatory response of the controllers in Acid, Base and Neutral region is shown in Fig. 7,8,9. The Time domain specification and error values are tabulated in TABLE III and TABLE IV respectively.

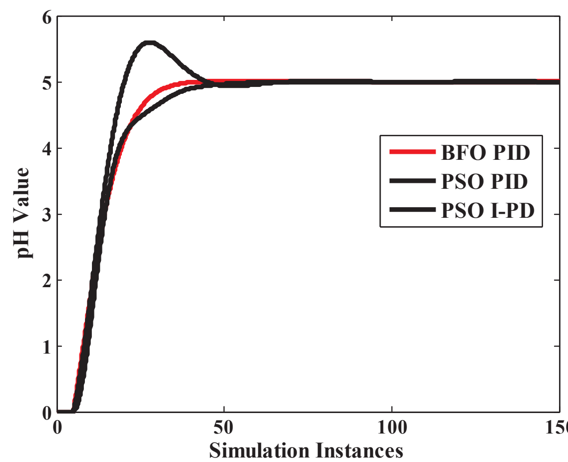

Fig. 4. Servo Response of controllers in Acid region

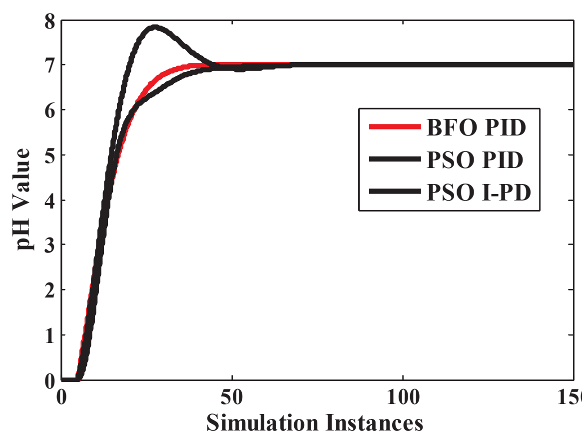

Fig. 5. Servo Response of controllers in Neutral region

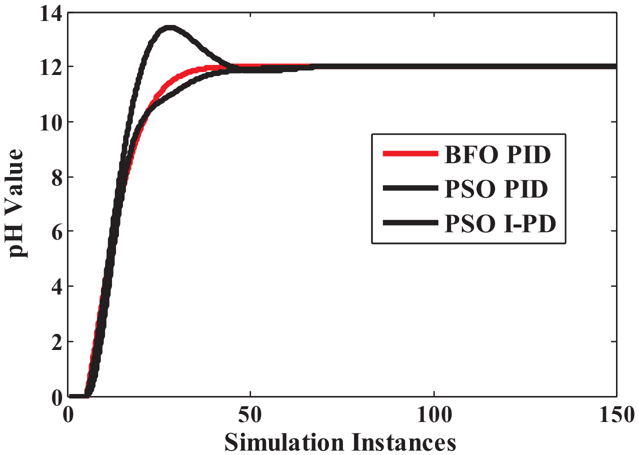

Fig. 6. Servo Response of controllers in Base region

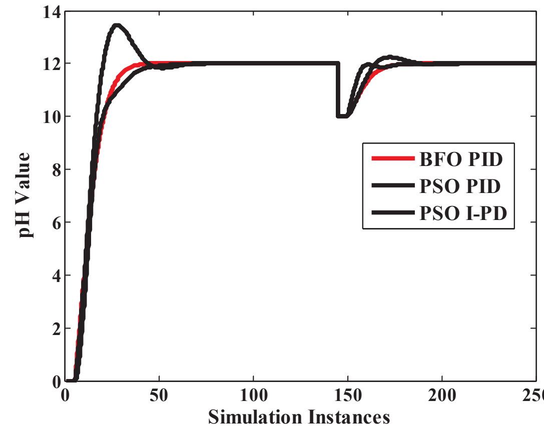

Fig. 9. Regulatory Response of Controllers in Base Region

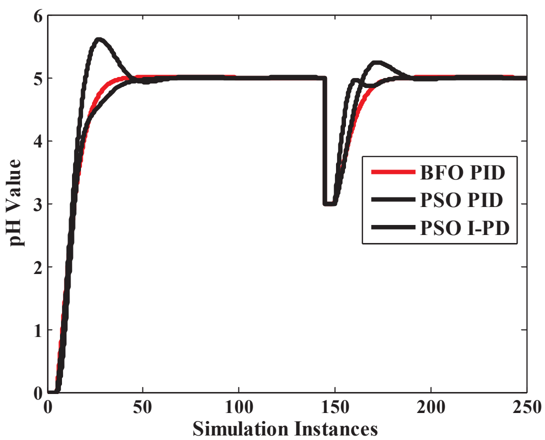

Fig. 7. Regulatory Response of Controllers in Acid Region

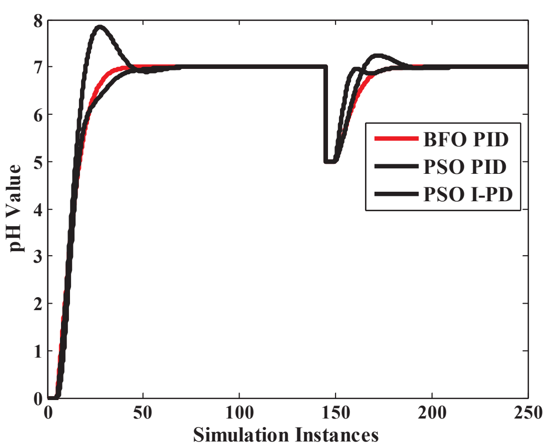

Fig. 8. Regulatory Response of Controllers in Neutral Region

TABLE III TIME DOMAIN SPECIFICATION

Controllers	**Region**	**Rise time**	**Settling time**	**Peak Overshoot**
BFO based PID Controller	Acid	14.2	42.7	0.011
	Neutral	17.2	44.6	0.005
	Base	18.3	64.2	0.001
PSO based PID Controller	Acid	10.4	85.1	0.592
	Neutral	10.5	87.01	0.831
	Base	11.3	69.8	1.42
PSO based I-PD Controller	Acid	19.2	89.7	0
	Neutral	18.1	75.6	0
	Base	17.3	92.1	0

TABLE IV ERROR INDICES

Controllers	**Region**	**IAE**	**ISE**	**ITAE**
BFO based PID Controller	Acid	70.1	4919	615.6
	Neutral	98.2	9642	861.8
	Base	168	28335	1477
PSO based PID Controller	Acid	53.33	2865	724.9
	Neutral	74.94	5616	1015
	Base	128.5	16505.12	1740
PSO based I-PD Controller	Acid	76.12	5795	757.2
	Neutral	88.7	11357.9	1060
	Base	106.6	33378.5	1817

VI. CONCLUSION

PID and I-PD controllers are designed using Optimization techniques like BFO algorithm and PSO algorithm and their performances are compared. It is shown graphically that the time domain specification in terms of settling time and ITAE, BFO based PID Controller is less. Error indices like Integral Absolute Error (IAE), Integral Square Error (ISE) of PSO based PID controller is comparatively less. On comparing the controllers based on settling time, peak overshoot and Integral Time weighted

Absolute Error (ITAE) BFO based PID controller gives better response for pH Neutralization process considered.

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