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Design and Implementation of Controllers for A Two-Tank Interacting Level Process Using PSO Techniques

[1]R.Soundariya , [2]Dr.S.Arulselvi

[1,2] Department of Process Control and Engineering, Annamalai University, Chidambaram, India

Abstract: **In this work, a two-tank interacting level process taken-up for study. The mathematical model of two-tank interacting process is derived. A conventional PI controller is designed based on process reaction curve with ZN techniques. To improve the performance of PI controller, fuzzy logic control is proposed and implemented for a two tank interacting process. To study and implement particles swarm optimization (PSO) technique in order to optimize PI control parameters. To improve the performance of PSO-PI controller, PSO-FLC is proposed and implemented for a two tank interacting process. To obtain servo and regulatory response with PI, fuzzy logic, PSO based PI controller and PSO based FLC controller. To implement PSO based controllers in real time system using VMAT CARD.**

Keywords: **Two-tank interacting process, PI controller, PSO-PI ,FLC controller and PSO-FLC.**

I. INTRODUCTION

PI controller is widely used control strategy to control most of industrial automation process because of its remarkable efficiency and simplicity. In this work, PI and fuzzy logic controllers are designed implemented for the two-tank interacting level process. The performances of above said controller are compared with that of PSO based on PI controller. AI techniques such as neural network, fuzzy system and neural-fuzzy logic have been widely applied to proper tuning of PID controller parameters. PSO technique is a very [3] uncertain algorithm that may or may not converge to the optimized values. In this work, a simple performance criterion in time domain is proposed for evaluating the performance of a PSO-PID and PSO-FLC controller that was applied to an interacting two-tank process. PSO is a populated search method for optimization of continuous nonlinear functions resembling the movement of organisms in a bird flock or fish school. Since the stochastic PSO algorithm has been found to be able to find the global optimum with a large probability and high convergence rate [4]. In this work, a simple performance criterion in time domain is proposed for evaluating the performance of a PSO-PI controller that was applied to a interacting two-tank process. For the tuning of the parameters of the membership functions of a fuzzy controller a novel PSO algorithm has been developed. The algorithm for the fuzzy controller has been encoded in MATLAB but a block diagram strategy is enabled to explain the algorithm.

A. PARAMETERS OF PSO:

The Velocity form (V) and position form (x) algorithm are given by

$$v_{id} = W^{*}v_{id} + c_1 * rand1 * p_{best} - x_{id} + c_2 * rand2 * g_{best} - x_{id} \quad (1)$$

$$x_{id} = x_{id} + v_{id} \quad (2)$$

Table I: Parameters of PSO algorithm

Parameter	Values	
Number of Iteration	20	
Dimension	3	
Swarm Size	90	
Correction Factor	C_1	1.2
	C_2	1.4

B. The PSO-PI and PSO-FLC learning algorithm is represented by following steps:

Step1 : Select the number of iterations (n) and the PSO learning rate (c_1, c_2).

Step2 : Randomly generate position vector X and associated velocity V of all particles in the population.

Step3 : Calculate each individual's fitness value, and then compare each individual's evaluation value with best global particle value g_{best} the personal best value p_{best}.Finally select the new best value (g_{best} and p_{best}).

Step4 : For every particle, update its own velocity and Position value.

Step5 : If iteration=n, then go to exit, otherwise go to step 3.

Step6 : The best particle's value will be selected as the finial parameter set to form desired PI controller and FLC controller.

II. PSO BASED PI (PSO-PI) CONTROLLER DESIGN

The block diagram of PSO based PI controller is shown in Fig 1. Also the flow chart to optimize the PI controller is shown in Fig 2.

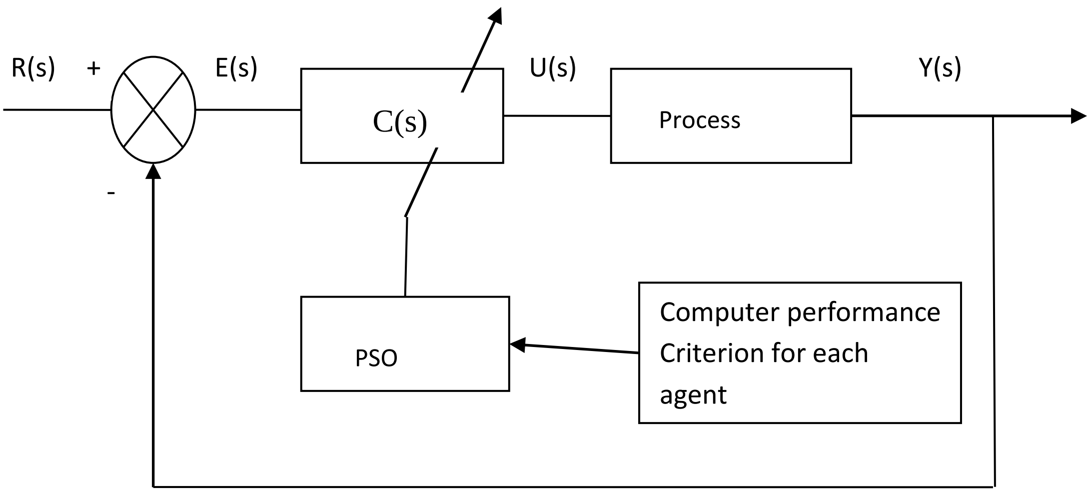

Figure 1. Design of PSO based PI controller

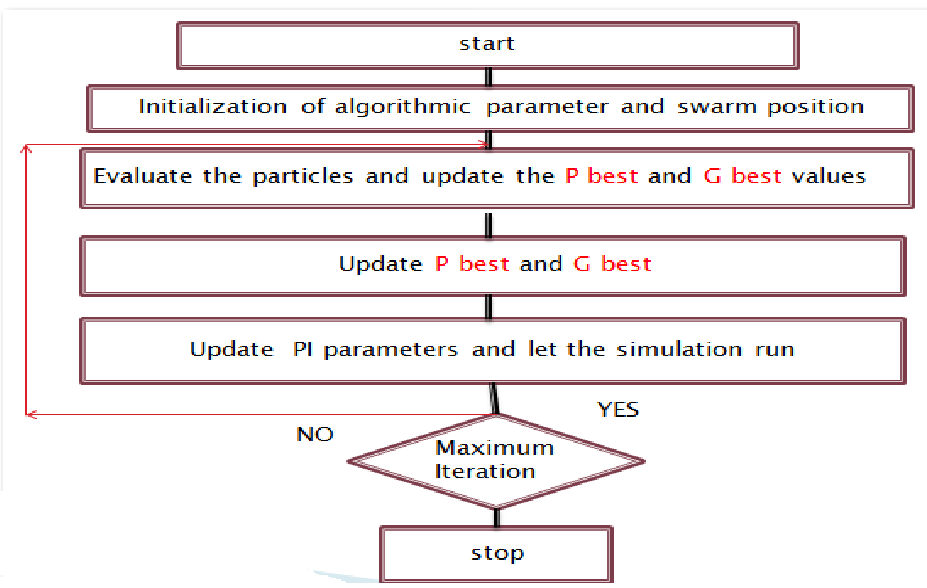

Figure: 2. Flow chart for PSO based PI controller parameter optimization

A. PSO PARAMETER FOR PI CONTROLLER:

PSO makes use of particles moving in an n dimensional space to search for solutions for an n-variable function optimization problem. The datasets are the sample space to search and each attribute is a dimension for the PSO. Performance of conventional PI and PSO-PI is shown in Table 1.

Table 1.Performance measures for K_p and K_c

Controller	K_p	K_c
PI	7.9351	56.61
PSO-PI	102.54	0.01546

B. SERVO RESPONSES FOR PSO-PI CONTROLLER:

The servo response for two tank level interacting process for step change h_2 6 to 8 cm, from 8 to 6 is shown in Fig.3 by implementing PI and PSO.

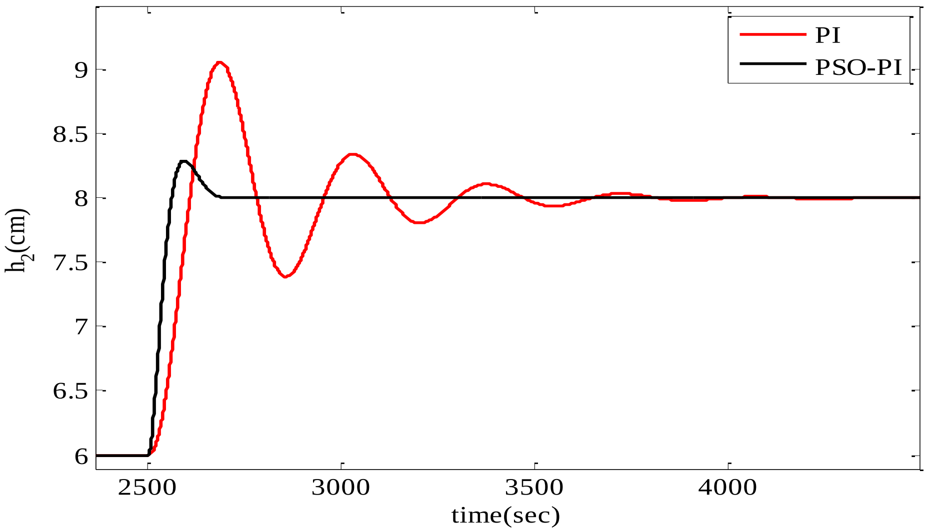

Fig 3. Servo response for step change in level h_2 fom 6 to 8 cm conventional PI and PSO-PI controllers.

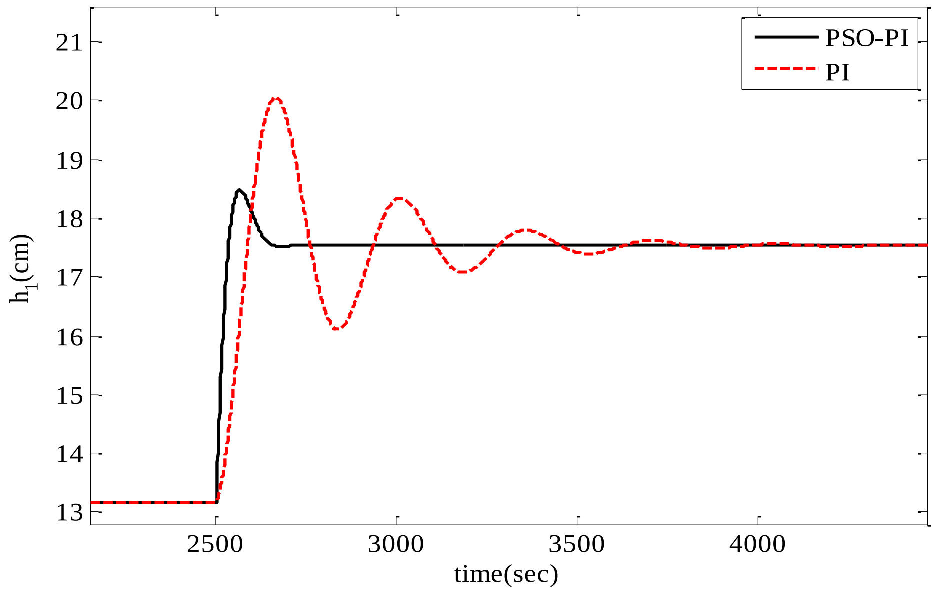

Fig 4. Servo response of level h_1 for step change h_2 with conventional PI and PSO-PI controllers.

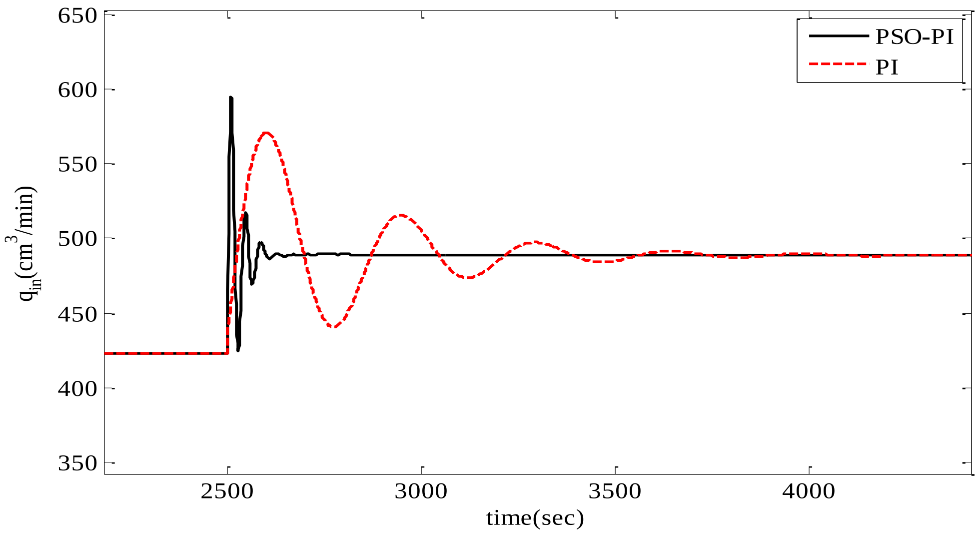

Fig 5. Response of conventional PI and PSO-PI controllers output for step change in h_2 from 6 to 8 cm

Table 2. Performance measure for conventional PI and PSO-PI controller

For step change in h_2 from (6-8)cm			
Controller	**t_s(sec)**	**%overshoot**	**ISE**
PI	**1877**	**13.2625**	**296.5**
PSO-PI	**479**	**2.9**	**89.08**

III. PSO USING OPTIMIZING FLC

The PSO technique is employed to tune the FLC parameters The approach employs MATLAB/M−file coding scheme in the Simulink /Embedded MATLAB Function block. The parameters to be optimized are the fuzzy scaling gains for the inputs and output signals. At each iteration, fitness values are evaluated for all the particles based on evaluation results, Pbest and Gbest are updated. Afterwards, modifications are applied based on the updated values and next iteration starts. The maximum iteration number is chosen 90 and population size is set to be 20 particles.

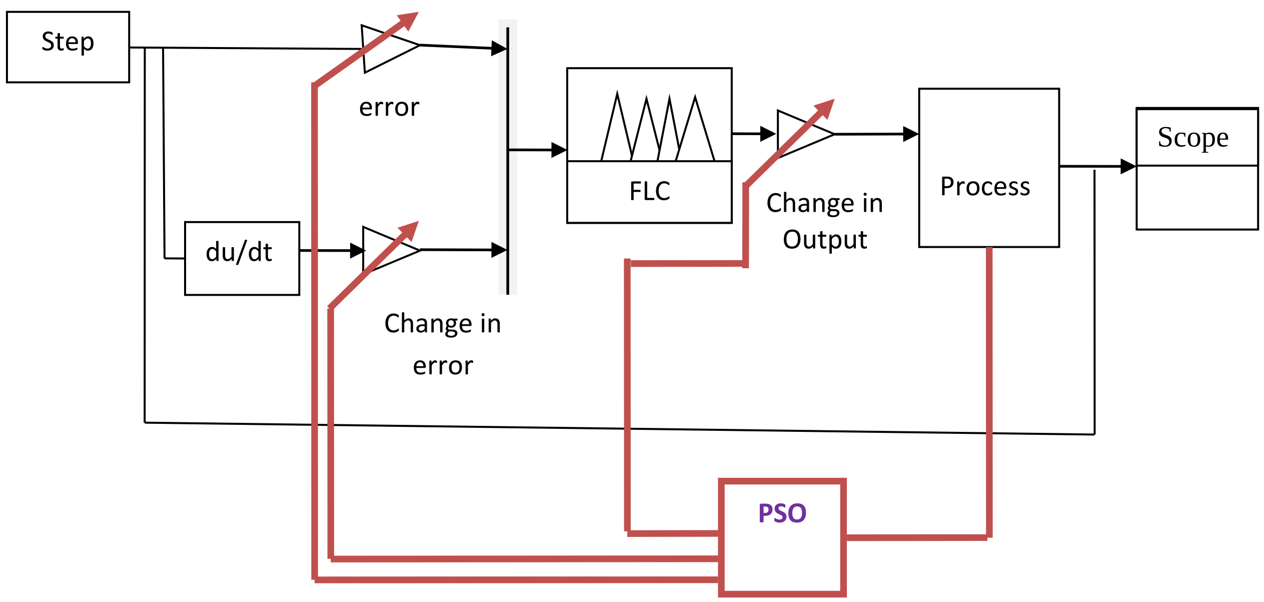

Figure: 6. Design of PSO based FLC controller

Table 2 .Performance measures for PSO based FLC

Controller	error	Change in error	Change in Output
PSO-FLC	0.04	40	55

A. SERVO RESPONSES FOR PSO-FLC CONTROLLER:

The servo response for two tank level interacting process for step change h_2 6 to 8 cm, from 8 to 6 is shown in Fig.7 by implementing FLC and PSO.

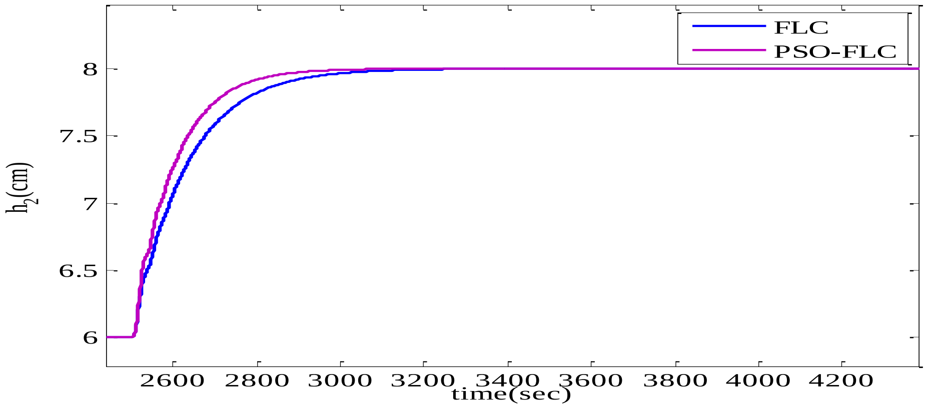

Fig 7. Servo response for step change in level h_2 fom 6 to 8 cm conventional FLC and PSO-FLC controllers.

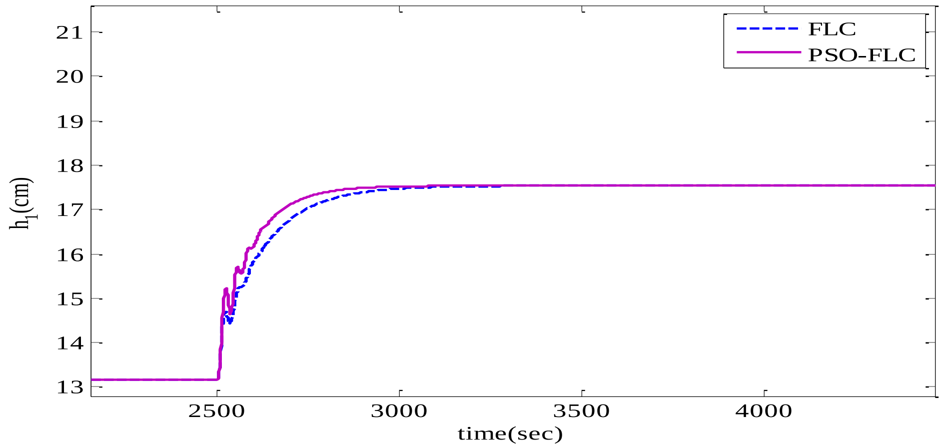

Fig 8. Servo response of level h_1 for step change h_2 with conventional FLC and PSO- FLC controllers.

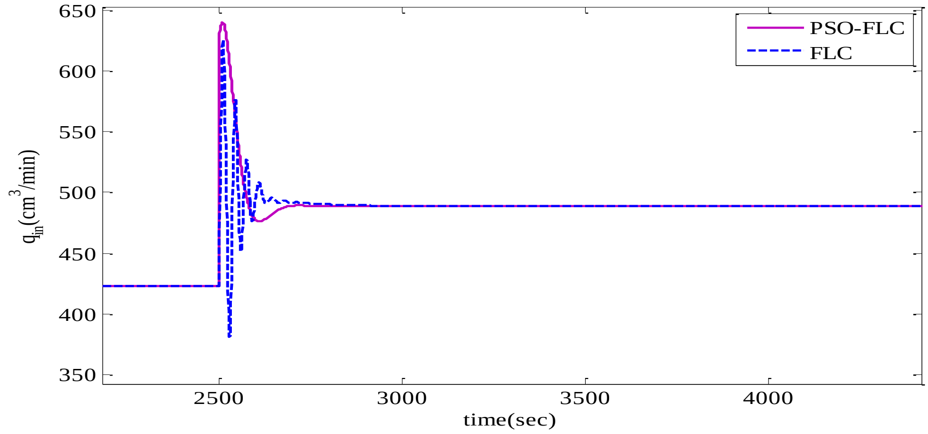

Fig 9 . Response of conventional FLC and PSO-FLC controllers output for step change in h_2 from 6 to 8 cm.

Table: 3. Servo response for conventional FLC and PSO-FLC controller

Servo response for h_2 (6-8)cm			
	t_s(sec)	%overshoot	ISE
FLC	704	-	427.5
PSO-FLC	521	-	394.5

IV. SIMULATED RESULTS

A. Servo responses of levels with PI , FLC and PSO:

The servo response for two tank level interacting process for step change h_2 6 to 8 cm, from 8 to 6 is shown in Fig.10 by implementing PI , FLC and PSO. From the results and Table 4, it is observed that the PSO-FLC gives better performance without overshoot than PSO-PI controller, but PSO-PI gives faster settling time and Integral square error.

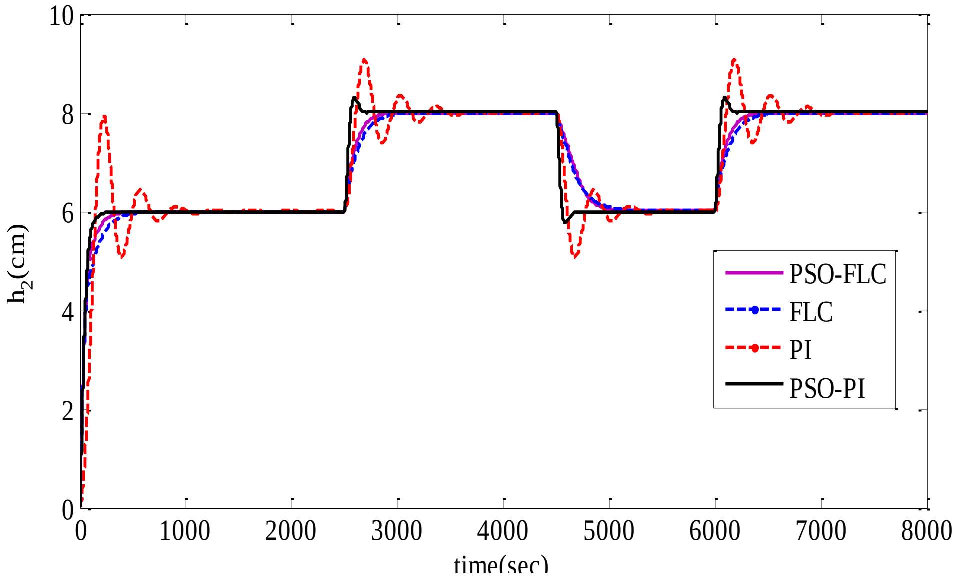

Fig 10. Servo response of level h_2 with PI, FLC,PSO-PI and PSO-FLC

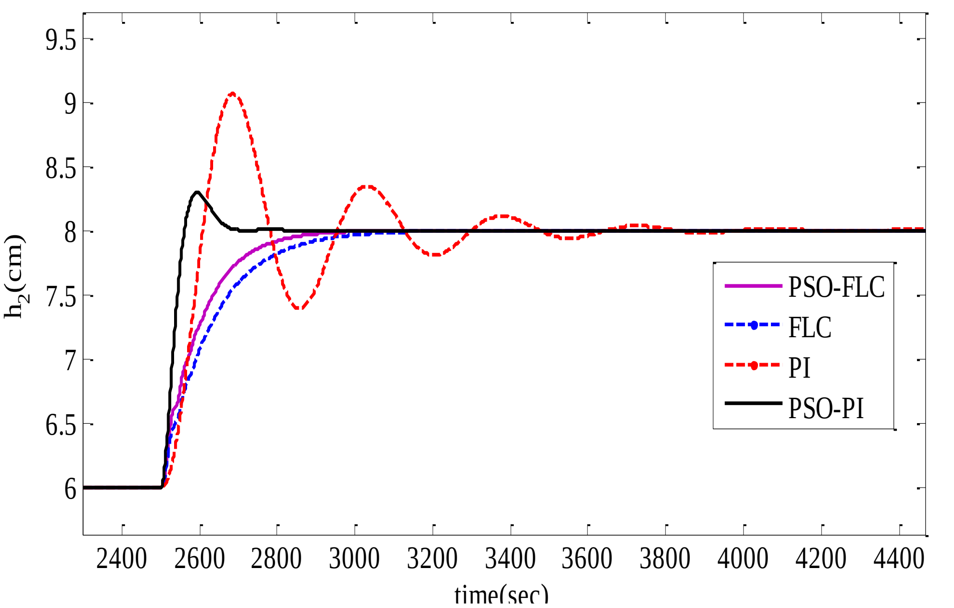

Fig: 11. Servo response of level with PI, FLC,PSO-PI and PSO-FLC (6-8) cm

Table 4.Performance measures for servo response of level h_2 with PI, FLC,PSO-PI and PSO-FLC (6-8) cm

Servo response for h_2 (6-8)cm			
	t_s(sec)	%overshoot	ISE
PI	1877	13.2625	296.5
PSO-PI	479	2.9	89.08
FLC	704	-	427.5
PSO-FLC	521	-	394.5

V. CONCLUSION

The simulation results of two-tank interacting process are given in this chapter. It is observed from the results that the PSO-FLC out performs with no overshoot than the PSO-PI controller, but PSO-PI gives faster settling time and Integral square error .For our convenient we can use either PSO-PI and PSO-FLC.

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