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PSO Algorithm based MRA- PI controller for a Two Tank Interacting Level Process

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Abstract— *Two Tank Interacting Level Process are mostly used in various process industries, such as metallurgical industries.A Two Tank Interacting Level Process is basically a nonlinear process. Liquids present in the tanks must be controlled, and the flow between tanks must be regulated in the presence of nonlinearity and inexact model description of the plant. This paper briefs the implementation of PSO based Model Reference Adaptive PI controller for a nonlinear Two Tank Interacting Level Process System. The mathematical model of Two Tank Interacting Level Process System is developed and PSO based Model Reference Adaptive (MRA) PI Controller is proposed for this level system*

Keywords: Two tank, PI controller, MRA-PI, GA.

1. INTRODUCTION

Control of such Two Tank Interacting Level Process is a difficult problem because of its non-linearity and changing in area of cross section. MRAC has received considerable attention, and many new approaches has been applied to practical process. Ayachierrachdi et.al., [1] presented a Direct Model Reference Adaptive Control (MRAC) for nonlinear time-varying system. The control strategy is based on two-steps; the first is initialization parameters of the controller using reduced number of observation.

In this paper the Two Tank Interacting Level Processhas been considered as a typical representative of inherently nonlinear system, thus it is an ideal choice for testing the modeling capability of the PSO based MRA-PI controller. The main contributions of this paper are the performance of the PSO based MRA-PI control Strategy on the model of the Two Tank Interacting Level ProcessProcess by simulation.In section 2 the process description of Two Tank Interacting Level Processis summarized. The MRAC is discussed in section 3.The design and structure of PSO based MRA-PI control mechanism is briefed in section 4.Simulation results are analyzed in section 5. Finally, section 6 is describing of the entire work.

2. PROCESS DESCRIPTION AND MATHEMATICAL MODELING

A simple nonlinear mathematical model is derived with a help of this diagram. Let H1 and H2 be the liquid level in each tank, measured with respect to the corresponding outlet. Considering a simple mass balance, the rate of change of liquid volume in each tank equals the net flow of liquid into the tank.

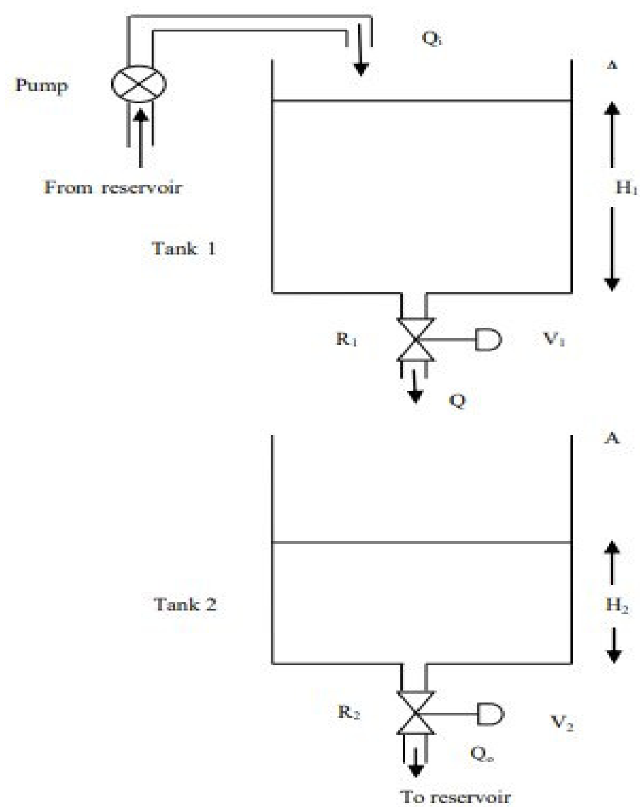

Fig. 1. Two tank non-interacting process

Assuming linear resistance to flow, transfer function of the Two Tank Interacting Level Processsystem through mathematical modeling is

G(s) = H2 (s)/ Qi (s) = R2 (τ1s+1)(τ2s+1)--- -->(1)

Where τ1 = AR1 and τ2 = AR2 are the time constants of Tank 1 and Tank 2 related to operating levels in the tank.

Flow rate of the pump is related as:

Qi(s) = ηVi(s); η is pump constant relating to control voltage.

Hence, overall transfer function of the process becomes

$Gp(s) = H2(s)/Vi(s)$

$= \eta R2/\ (\tau 1s+1)(\tau 2s+1)$ ----->(2)

Here H2 is controlled variable and Vi is manipulated variable.

Therefore obtained Transfer function of coupled two tank system non-interacting level process using coupled tank parameters from Table 1 is

$Gp*\ (s) = (2.9646)\ /$

$(126.5827s2+22.5018s+1)$- ->(3)

TABLE 1: Parametersof Two Tank Interacting Level Processsystem

Parameter	Description	Value	Unit
A	Cross-sectionalareaof tanks	138.9	cm^2
R1	Hydraulicresistanceofb all valve 1	0.081	sec/cm^2
R2	Hydraulicresistanceofb all valve 2	0.081	sec/cm^2
η	Pump constantrelatedto flowrateinto tank	36.6	$cm^3/v.sec$

3. MODEL REFERENCE ADAPTIVE PI CONTROL

When the disturbance andthe plant parameters are varying slowly or slower than the dynamic Characteristics of the plant, then a Model Reference Adaptive Control can be used.

MIT (Massachusetts Institute of Technology) Rule is that negative gradient of the cost function (J) depends on the time rate of change of θ, that is:

$$\frac{d\theta}{dt} = -\gamma\frac{\partial J}{\partial \theta} = -\gamma\epsilon\frac{\partial \epsilon}{\partial \theta} \quad (14)$$

The adaptation error $\varepsilon = y_p(t) - y_M(t)$. The parameter γ is gain of adaptation. The MIT rule is to less the squared model error $\in^2$ from function of cost.

$$J(\theta) = \frac{1}{2}\varepsilon^2(t) \quad (15)$$

The reference model for the MRAC generates the desired trajectory y_M, which the coupled tank level y_p has to follow. 2nd orderdifferential equation was selected as the reference model given by

$$H_M(s) = \frac{b_M}{s^2 + a_{M1} + a_{M0}}$$

$$K_p^* = \left(\frac{-\gamma_p}{s}\right)\epsilon\left(\frac{s}{a_0s^2 + a_{M1}s + a_{M2}}\right)e$$

$$K_i^* = \left(\frac{-\gamma_i}{s}\right)\epsilon\left(\frac{1}{a_0s^2 + a_{M1}s + a_{M2}}\right)e$$

The plant will be tested with fast response specification reference model. So,that the reference model has 1% as its percentage overshoot and setting time is 15 sec.Based on the desired specification the 2nd order transfer function of the ReferenceModel as follows

$$\mathrm{Gm(s)} = \frac{0.1041}{s^2 + 0.5332s + 0.1041}$$

4. PSO BASED MODEL REFERENCE ADAPTIVE PI CONTROL

In Model Reference Adaptive PI controller γ_p and γ_i values are set by trial and error method. Whereas in PSO based MRA-PI controller γ_p and γ_i values are obtained using PSO.Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr.Eberhart and Dr. Kennedy in 1995, inspired by social behaviour of bird flocking or fish schooling. Every particle monitors its directions in the issue space which are related with the best arrangement (fitness) it has accomplished up until now. (The fitness value is also stored.) This value is called Personal Best (P Best). Another “best” value that is followed by the particle swarm enhancer is the best esteem, acquired so far by any particle in the neighbours of the particle. This area is called Local best (L best) at the point when a particle takes all the populace as its topological neighbours, the best value is a Global Best and is called G Best. The projected position of i^{th} particle of the swarm x_i, and the velocity of this particle $v_i$at $(t+1)^{th}$ iteration are defined and updated as the following two equations

$$v_i^{t+1} = v_i^t + c_1 r_1 (P_i^t + x_i^t) + c_2 r_2 (g_i^t + x_i^t)$$

$$x_i^{t+1} = x_i^t + v_i^{t+1}$$

where i=1, …., n and n is the size of the swarm, c_1 and c_2 are positive constants, r_1 and r_2 are random numbers which are uniformly distributed, determines the iteration number, p_i represents the best previous position (the position giving the best fitness value) of the i^{th} particle, and g represents the best particle among all the particles in the swarm. At the end of the iterations, the best position of the swarm will be the solution of the problem. It cannot be always possible to get an optimum result of the problem, but the obtained solution will be an optimal one [2]-[4]

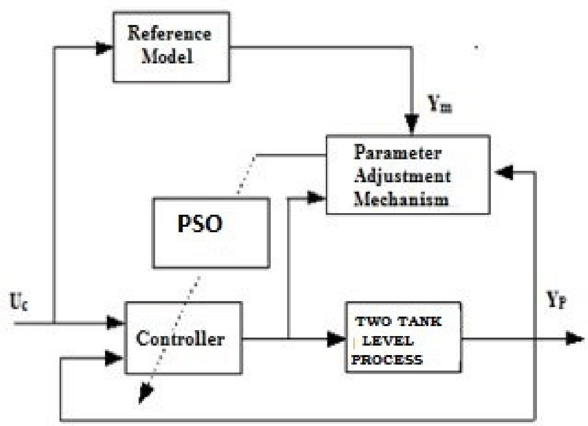

Fig. 2. PSO based MRA-PI control of Two Tank Level System.

5. RESULTS AND DISCUSSION

Performances of proposed controller are analyzed using step inlet at various level in the Two Tank Interacting Level ProcessProcess.

Initially the tank is kept at 35 cm of level of operating, after that, a step inlet size of 5 cm of level is supplied to control mechanism with PSO based MRA-PI control strategy.

In the same way, test runs of MRA-PI and conventional PI control values are carried out and their responses are presented in Figure.3. It is found that in PSO based MRA-PI makes the system to settle with minimum integral square error at all.

From the results, the performances are analyzed in terms of ISE and IAE are tabulated in Table 2.

It is also clear that proposed controller tracks the set point quickly with minimum overshoot.

The results prove that PSO based MRA-PI controller is appropriate for non linear process.

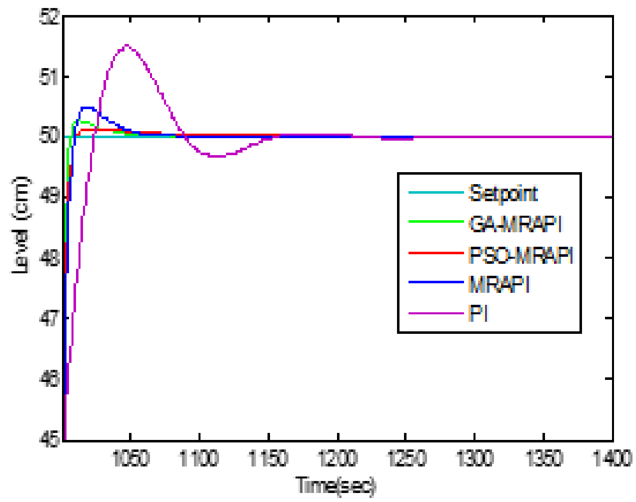

Fig. 3. Servo response of Two Tank LS with PI, MRA-PI and GA MRAPI, PSO MRAPI at the operating point of 50.

TABLE 2: Performance Indices at different Operating range.

Controller	ISE	IAE
	Operating Point (35 to 40 cm)	Operating Point (35 to 40 cm)
PI	145.3	64.8
MRA-PI	58	35.4
PSO based MRA-PI	51	31.16

6. CONCLUSION

In this paper, PSO based MRA-PI control strategy is developed and implemented for a coupled tank level system. This method is suitable for process control applications with a large delay, where a conventional PI controller yield a worst performance. The simulation results are furnished to brief the effectiveness of proposed controller with those of MRA-PI and conventional PI control approaches. The PSO based MRAPI are also proved that the proposed controller gives a extraordinary performance than the existing strategy of control.

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