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Analysis of Fractional Order PI Controller with Cuckoo Optimization for Multi Tank Process

T. Pravin Rose, G. Glan Devadhas

***Abstract:** pH neutralization procedure is measured as a standard process for testing non-linear controllers. Thus the research of the evidence of identity and control in pH neutralization procedure is very important. Wide-ranging researches in the proof of identity of pH neutralization procedure have been done by many relative experts for many years. In this paper authors propose design methodology and application of Adaptive Neuro-Fuzzy Inference System (ANFIS) with optimization algorithm to improve the prediction based on fractional PI controller. Therefore, this paper deals with tank size and its quantity mainly concerning multiple tanks.*

***Keywords:** Fractional Order PI Controller (FOPI), ANFIS and Cuckoo Search Optimization.*

I. INTRODUCTION

Various strategies in synthetic cleverness had been improved remedy troubles of the actual international the use of intellectual schemes, it has own abilties just like social assistances in sure domain names. Between them, fuzzy good judgment. The new neural network system has the most popular scheme and broadly carried out in business programs. Fuzzy common sense structures are generally implemented in moving industrial product.

NaregalkarAkshay et al., [1] presented the powerful treatment of waste water is very valuable in industries as a result of their unsafe impacts. It is imperative to keep up pH in unbiased area according to titration bend sign of solid acids that specifies a little change in input, gives tremendous change in yield in the range 6-8 pH value. Additionally there should be recognition and adjustment of non-straight qualities and aggravations, for example, temperature varieties that happen progressively plant situation. To diminish these continuous unsettling influences which influence the pH value and stay away from pH working point in the impartial zone [2]. This work incorporates outline of calculation to locate a reasonable tuning approach for different plant qualities and afterward to tune controller parameters. The tuning systems chose were Ziegler-Nichols technique, Astrom-Hagglund approach, Tsang-Rad strategy and Fruehauf tuning rules were utilized for PI (Proportional Integral) tuning. This makes adaptive tuning of PI Controller in different plant parameters and disturbances.

It was discovered that ZN technique gave most significant rise time and TR strategy gave the most satisfied settling time where as the better settling time was obtain at the cost of expanded delay contrasted with ZN technique [3]. It was likewise seen that FF strategy for the mostly eliminated the delay but give unsatisfied settling times. Subsequently the actualized calculation chooses reasonable tuning strategies under various plant conditions and controls the plant effectively.

Vijaya Lakshmi et al., [4] clarified about the three tank fluid level control framework assumes a critical part in process industries and its conduct is nonlinear in nature. Traditional PID controller ordinarily does not work effectively for such frameworks. This points with the plan of three intelligent controllers specifically display prescient, show reference and NARMA-L2 controllers in view of fake neural systems for a three tank level process. The execution files of canny controllers are analyzed in light of the time space determinations[5]. The execution of NN prescient controller indicates prevalence over different controllers regarding settling time.

Zulkarnay et al., [7] have proposed the present innovation of pH estimation and the use of pH in bio-medical. It additionally portrays non-invasive strategy for pH estimation. The advancement of pH meter can be seen from intrusively method to non-obtrusively strategy [10]. The wastewater treatment applications as a standout amongst the most difficult pH control issues experienced in industry. This is basically because of unsettling influences in the feed structure which are hard to deal with as various organizations will require diverse arrangements of control parameters.

Cleber Gustavo et al., proposed the modeling of pH control for process a management in a drinking water treatment plant. To assess the limp pump recurrence and the pH in the treated water, it can enhance the crude water quality and decline the lime utilization [11]. The current mathematical model can be a useful apparatus for a basic leadership process and production management to evaluate the day by day chemicals concoctions refills in the water treatment plant.

Narendra Khatri et al., recommended a web of things relies upon pH checking and control of metropolitan waste water for planting agriculture and applications [12], [13]. Wi-Fi shield for remote correspondence are utilized as the spindle equipment framework for developing a WSN. The vitality sparing is essential utilizing this framework. It speaks to the little answer for control the water quality by means of its pH to treat the municipal waste water and its reuse in the agriculture and gardening reason.

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Methods:

Multi tank process modelling

Derived from a scheme for tank plan by means of this fundamental thoughtful is proposed. This is shown in figure.2. Closed loop reaction of each and every tank by considering there is no change in reference (r1 = r2 = ... = 0) then becomes,

$$y_i(s) = \frac{1}{1+G_i(s)K_i(s)} G_{di}(s)d_i(s) = S_i(s)G_{di}(s)d_i(s) \quad (1)$$

Where d1=d &> 1, di = yi-1, Si(s) is the sensitivity task for tank i. merging this to form a transfer function starting from the turbulence 'd' to the last output y direct to,

The factorization for s is probable because three tanks are working under SISO schemes.

The basic benefit of FOC is that the fractional-order integrator weights the past by means of a function that crumbles with a power-rule train. The result is that, the each iteration results are calculated for the control algorithm. This generates an 'allocation of time constants', the consequence is there is no exacting time constant or significance frequency for the system. Fractional-order control demonstrates the guarantee for several controlled situations that undergo the conventional troubles of overshoot and resonance, in addition to time disperse purposes, for example thermal dissipation and chemical combination. Fractional-order control is also capable of holding back disordered behaviors in arithmetical models.

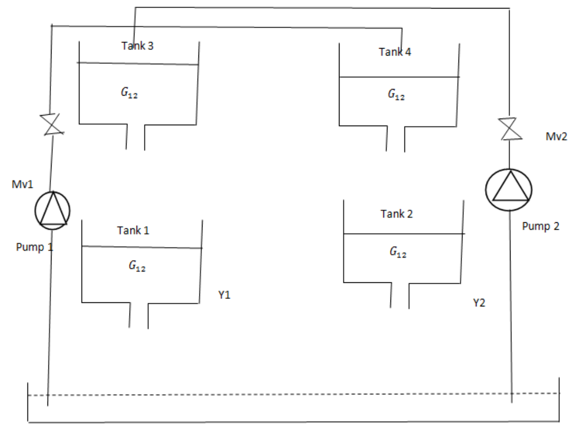

Fig. 1: Architecture diagram of the multi-tank process

The mathematical representation of the non-linear multi tank system can be derived below,

$$\frac{dh_1}{dt} = -\frac{a_1}{A_1}\sqrt{2gh_1} + \frac{a_3}{A_1}\sqrt{2gh_1} + \frac{\gamma_1 K_1}{A_1}v_1 \quad (2)$$

$$\frac{dh_2}{dt} = -\frac{a_2}{A_2}\sqrt{2gh_2} + \frac{a_4}{A_2}\sqrt{2gh_4} + \frac{\gamma_2 K_2}{A_2}v_2 \quad (3)$$

$$\frac{dh_3}{dt} = -\frac{a_3}{A_3}\sqrt{2gh_3} + \frac{(1-\gamma_1)K_2}{A_3}v_1 \quad (4)$$

$$\frac{dh_4}{dt} = -\frac{a_4}{A_4}\sqrt{2gh_4} + \frac{(1-\gamma_1)K_1}{A_4}v_1 \quad (5)$$

Fractional order Modelling

The combination of integral and derivative operators is known as Fractional calculus. The integral and derivative operators from the integer order case to the case where the order is the real number or even complex.

$$p_1 s^{a_1} y(t) + \cdots p_2 s^{a_2} y(t) + p_3 s^{a_3} y(t) = 0 \quad (6)$$

By applying Laplace transform in the above equation, after we obtain the transfer function. It is given as below,

$$P_x(s) = \frac{1}{p_1 s^{a_1} y(t) + \cdots p_2 s^{a_2} y(t) + p_3 s^{a_3} y(t)} \quad (7)$$

The fitness function is,

$$F = \sum_{i=1}^{f}(C_x(t) \quad (8)$$

Where,

$$C_x(s) = \frac{K}{\tau s+1} \quad (9)$$

The FOPI controller transfer function is

$$G_c(s) = (K_p + \frac{K_i}{s^{\lambda}}) \quad (10)$$

The FOPI controller depend on three categories, it is indicated below

(i) Phase margin constraint,

$$Arg\,[\,G\,(j\omega_c)] = Arg\,[\,G\,(j\omega_c)] + Arg\,[\,p\,(j\omega_c)] = -\pi + \emptyset(m) \quad (11)$$

(ii) Gain crossover frequency constraint

$$[\,G\,(j\omega_c)] = [\,G\,(j\omega_c)] + [\,p\,(j\omega_c)] = 1 \quad (12)$$

(iii) Robustness to loop gain variation constraint,

Which demands that the phase derivative with respect to the frequency is zero, namely, the phase Bode plot is flat, around the gain crossover frequency. It means that the system is robust are almost the same,

$$\frac{d}{d\omega} G\,(j\omega_c) = 0 \quad (13)$$

The function in MATLAB is used to find the FOPI controller parameter proportional gain K_p, integral gain K_i, and λ integral power.

In this paper put in force ANFIS controller for the primary order fuzzy version machine. By the use of improve the interpretability and computational performance. In generally, optimal and adaptive techniques are utilized. Sugeno FIS controller is mainly used. In fuzzy set model use the fuzzy set rule. This method is commonly used, because it reduce the interpretably. The fuzzy rule of the device is given in equation (14)

Rule 1:

Input: If x $=A_1$,y $=B_1$,

Output: $Z_1 = p_1$x + q_1y + r_1,

Rule 2:

Input: If x $=A_2$and y $=B_2$, (14)

Output:$Z_2 = p_2$x + q_2y + r_2,

Here A_i, B_i (i=1,2) are fuzzy sets, and $p_i q_i, r_i$ (i=1, 2) is design parameters that are obtained in training process.

In neuro-fuzzy techniques, the fuzzy system utilized a neural network in this way to get good parameter identification. The neuro fuzzy network which contain the fuzzy set rules which is based on data is the basis of the ANFIS controller. Here optimization topology is used. In this system capability of gathering the data from the fuzzy rules. This model can use the adaptive Fuzzy interference device of the network. The ANFIS controller consists of a few regulations, first of all, the controller primarily based on the shape learning algorithm and portioning algorithm. The parameter of this algorithm can be automatically update the hybrid parameter. Automatically update the structure and parameter of ANFIS controller. One of the time-consuming method is a sequential learning algorithm, it essentially needs the large. To avoid the problem, the automatic learning has been introduced.

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This model can be implemented in parallel connection and calculate the parameter, the proposed method, controller of the ANFIS is calculating the speed of the motor. Also, the learning ANFIS controller perform based on the three parameter which contain learning rate (g), forgetting factor (k) and momentum constant (a), is called as free learning parameters. Usually, the parameters are consistent during the operation.

Optimization

Optimization can be defined as a process of finding for the best possible solution to a given issues. Mathematically, it is a technique for finding a combination of parameters to minimize or maximize objective functions, i.e., a quantitative measure of a system's performance, subject to some constraints on the variables ranges:

$$\min(or\max)f(x), x=(x_1,x_2,\dots,x_N), \quad x\epsilon R^N \qquad (15)$$

Where
f = the objective or cost function(s),
x = the parameters to be optimized called design or decision variables, can be continuous, discrete or a mixture of both,
R^N = the design/search/solution space in real value,
N = number of decision variables.

II. SIMULATION RESULT

The servo and regulatory responses of the process with minimum phase as well as non–minimum phase characteristics are obtained and presented from Fig. 2 and 3.

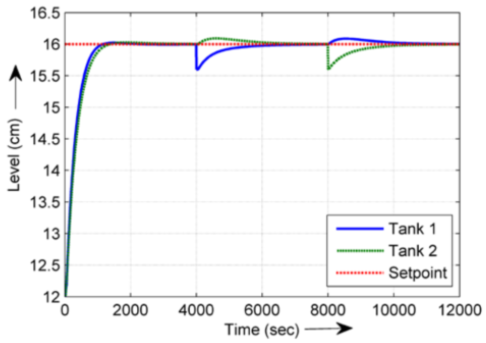

Fig. 2: Servo and regulatory responses of the process (minimum phase characteristics) with Predictive Fractional order PI control strategy

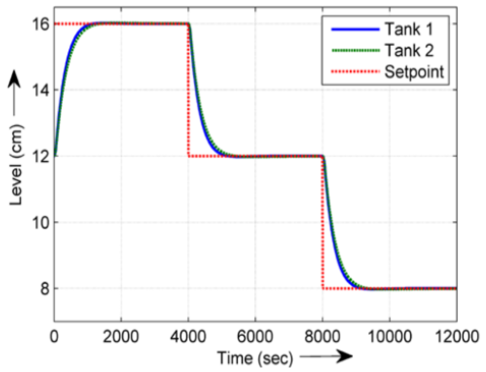

Fig. 3: Servo responses of the process (minimum phase characteristics) for multiple change in set point with Predictive Fractional order PI control strategy

Table 1: FOPI Controller various parameters

Controller	Fractional order	PI controller		
	K_p	t_i	K_{pred}	λ
Loop 1	1.633	550.4	0.019	1
Loop 2	1.145	447	0.012	1

III. CONCLUSION

Every pH neutralization industries have their own control schemes depending on their characteristics and needs. There are various effective control schemes used for pH neutralization.Fractional order PI controller with ANFIS optimization technique is used. The performance indices considered to evaluate the performance of the process are settling time, rise time, peak time, overshoot and ISE. Predictive fractional order PI control structure with optimization technique performs better than the other strategies with respect to settling time, peak time and rise time for non-minimum phase system.. The proposed system provides better performance than other existing systems.

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