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Implementation of ILC based Gain Scheduled PID Controller for Non Linear Spherical tank Level Process

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ABSTRACT

The proposed work deals with the application of Iterative Learning control based Gain scheduled PID controller in nonlinear level process control system. Gain scheduled PID controller is designed to enhance the performance of the conventional PID controller for nonlinear spherical tank process. It is based on linearization of the nonlinear model around selected operating points. The linear design methods are applied at each region in order to arrive at a set of linear control laws. A gain scheduler which fine tunes and schedules the controller parameters based on the value of set point given to the system. In order to improve the dynamic performance of closed loop system, Gain scheduled PID controller is hybridized with Iterative Learning controller. The performance of ILC-Gainscheduled PID is compared with gain scheduling PID in terms of set point tracking and performance indexes IAE, ISE, ITAE and ITSE.

Key words: Gain scheduling, PID controller,Iterative Learning Controller. Performance indexes

1. INTRODUCTION

The control of liquid level in a spherical tank is a basic challenging problem in chemical process industries because of the dynamic nonlinear behaviour. Due to inherent non linearity, most of the chemical process industries are in need of suitable control techniques to solve the problems. Hydrometallurgical industries, food process industries, concrete mixing industries and waste water treatment industries have been actively using the spherical tanks as an integral process element.An accurate knowledge of an adequate model is often not easily available.Proportional Integral Derivative (PID) Controller has been used in Industrial control applications for many decades. Controller design is very sensitive approach by using classical controller with fixed parameters. The basic limitationassociated with PID controller is the fact that it has linear controller and it can only operate in the zone of a single operating point, predicting the local behaviour of the nonlinear system.The reason is their wide popularity lies in the simplicity of design and good performance which includes lower overshoot and small settling time for slow process.

In this workspherical tank level process is modelled with five operating points. A gain scheduled PID controller using MATLAB Embedded function is implemented. As Iterative Learning Control is most suitable for those process produce repeatedly same error. In gain schedule method errors are repeated based on the set point. Further for improvising the performance of the control system ILC based Gain Scheduling PID were implemented and the comparative results are presented.

2. MATHEMATICAL MODELING OF THE SPHERICAL TANK SYSTEM

The mathematical equations describing the process behaviour must be derived so as to aid in studying the system and good controller design. Consider a spherical tank, as shown in figure 1, with radius R. The water flows in at a rate Fin and flows out at a rate Fout.

Volume of a sphere is given by,

$$V=\frac{4\pi h^3}{3}$$

According to mass balance equation,

$$\frac{dm}{dt} = F_i - F_o$$

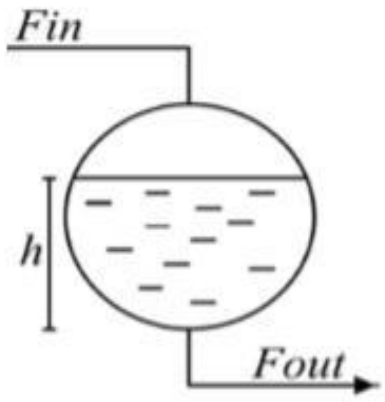


Figure 1: Mathematical model of a

Spherical tank

Where,
H ----Height of the liquid level in the tank
F_{in} ----Flow rate at inlet of the tank
F_{out} ----Flow rate at outlet of the tank
R-----Resistance to flow
dm/dt ----Rate of mass accumulation in the tank

$$\frac{d(v\rho)}{dt} = \rho F_i - \rho F_o$$

$$\frac{dv}{dt} = F_i - F_o$$

$$A\left(\frac{dh}{dt}\right) = F_i - F_o$$

$$\text{Let } F_0 = \frac{h}{R}(R \ = \text{valve resistance})$$

$$A\left(\frac{dh}{dt}\right) = F_i - \frac{h}{R}$$

$$A\left(\frac{dh}{dt}\right) = \frac{RF_i - h}{R}$$

$$AR\left(\frac{dh}{dt}\right) = RF_i - h$$

$$AR\left(\frac{dh}{dt}\right) + h = RF_i ------\to (1)$$

$$\text{At steady state, inflow} = \text{outflow}$$

$$h_s = RF_{is} ------\to (2)$$

$$\text{Eq } (1) - (2)$$

$$AR\frac{d(h - h_s)}{dt} + (h - h_s) = R(F_i - F_{is})$$

$$h - h_s = h\ ;\ F_i - F_{is} = F_i$$

$$AR\frac{dh}{dt} + h = RF_i$$

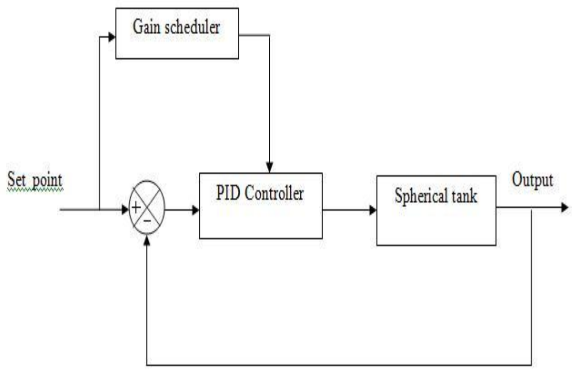
Taking laplace transform

$$ARsH(s) + H(s) = RF_i(s)$$

$$H(s)(ARs + 1) = RF_i(s)$$

$$\boxed{\frac{H(s)}{F_i(s)} = \frac{R}{1 + ARs}}$$

$$\text{where } R = \frac{2H_s}{F_o}\ ;\ RA = \tau = 4\pi RH_s$$



The total height of the spherical tank were divided into five operating points and corresponding transfer functions are derived as given below

EGION 1 (0-9cm):

$$\frac{H(S)}{F(S)} = \frac{0.864}{1+96.45s}$$

REGION 2(9-18cm) :

$$\frac{H(S)}{F(S)} = \frac{1.23}{1+219s}$$

REGION 3(18-27cm):

$$\frac{H(S)}{F(S)} = \frac{1.38}{1+257.75s}$$

REGION 4 (27-36cm):

$$\frac{H(S)}{F(S)} = \frac{1.52}{1+258.9s}$$

REGION 5 (36-45cm):

$$\frac{H(S)}{F(S)} = \frac{1.76}{1+174.5s}$$

Controller Design

Gain Scheduling PID

Fig2. Gain Scheduled PID

This block diagram shows that level control of spherical tank using Gain Scheduling method. Here PID controller is used as a controller to control the level of the spherical tank. The tank is divided into 5,regions with the interval of 9 cm in each region.For each and every region the process gain(k), dead time (td), time constant(τ) are calculated. From these values the proportional gain(Kp), integral gain(Ki), derivative gain(Kd) are calculated using Cohen coon tuning rules and are tabulated in table1. These values are scheduled according to the region and the values will be varied with respect to the level of the tank.

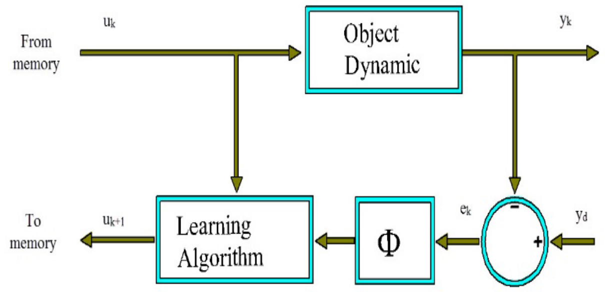
3.ITERATIVE LEANING CONTROLLER:

Table 1: PID tuning parameters

Operating point (in cm)	Kp	Ki	Kd
9	8.627	0.0245	6.279
18	29.87	0.051	2.889
27	32.314	0.053	2.802
36	25.681	0.0463	3.216
45	10.119	0.031	4.752

Iterative learning control attempts to improve the transient response by adjusting the input to the plant during future system operation based on the errors observed during past operation.

Fig.3 ILC based Gain Scheduled PID



The iterative learning Control (ILC) strategy is known as an adaptive control method through which the performance of a dynamic system becomes better and better based on some error conditions. The basic idea of ILC is that the performance of a system that enforces the same duty multiple times can be amended by learning from prior executions [6]. Fig. 3 demonstrates a block diagram of the Proportional type ILC. The input signal u_k and the output signal y_k are stored in memory when every time the system operates. The learning algorithm then evaluates the system performance error, $u_k = y_d - y_k$ where y_d is the desired output of the system. Based on this error signal, the learning algorithm then computes a new input signal u_{k+1}which is stored for use in the next trial, i.e., the next time instant the system operates. The next input command is selected in such a way that it causes the performance error to be reduced on the next trial or iteration

4. ILC BASED GAIN SCHEDULED PID:

The ILC based gain scheduled PID is shown in fig.4. The ILC block is cascaded to the existing PID controller. The proposed hybrid ILC structure uses the modified reference signal(yd) and the actual output of previous cycle (yi) to generate the new reference signal (yd,i+1)

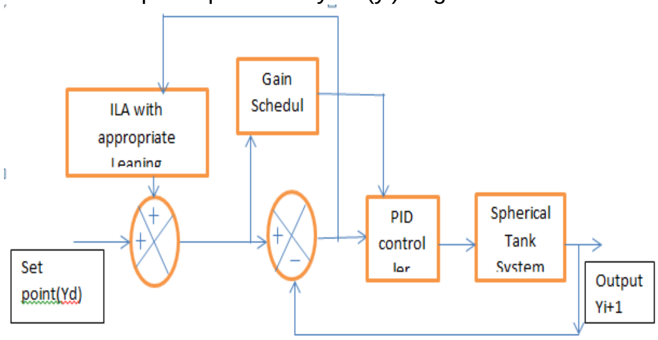


Fig.4ILC BASED GAIN SCHEDULED PID

5. RESULT AND DISCUSSION

The simulation results are shown in Fig.5. To assess the performance of ILC based Gain scheduled PID controller, the matlab simulation is carried out for set point tracking response for different set point and result is shown in fig. The controller performance is analysed based on performance criteria's IAE, ISE, ITAE and ITSE.

The measured values of IAE, ISE, ITAE and ITSE for both gain scheduled and ILC based Gain scheduled controllers are tabulated. From this table it is clear that ILC based gain scheduled PID gives lesser IAE, ISE, ITAE and ITSE.

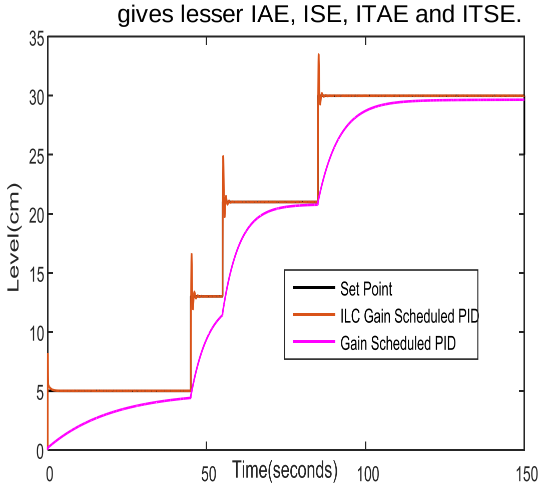


Fig.5 Simulation results

Table.2 Performance Criteria

Performance Criteria	Gain Scheduled PID	ILC based Gain Scheduled PID
IAE	266.2	5.90
ISE	994.2	14.50
ITAE	14733	334.4
ITSE	53619	857.41

6.CONCLUSION

In this work, the ILC based gain scheduled PID controller is designed for Nonlinear spherical level process. The set point tracking is done for testing the controller performance. The performance of the controller is assessed based on IAE, ISE, ITAE, and ITSE. The ILC based Gain scheduled PID control scheme was found to be an efficient control strategy for controlling such a highly nonlineardynamicsystem.it was found that the presented ILC -based controller was superior to theclassical PID controllerin that it could follow different desired set-points. Also it was observed that in proposed control strategy settling time is very low.

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