PSO based NNIMC for a Conical Tank Level Process

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Abstract - *The control of conical tank level process is complex because of its dynamics are nonlinear, time varying with change in gain of several orders. Hence in this work, modeling and control of conical tank level process is considered. First, the mathematical modeling of conical tank level process is developed and simulated. The entire operating region is divided into three linear zones to design a conventional PI controller. A small signal transfer functions are obtained for various operating regions by giving positive and negative step change in inflow rate. A conventional PI controller is designed using average of transfer function based on Z-N tuning method for each region. Simulation studies are carried out for setpoint tracking. However, conventional controller will not give satisfactory results for varying operating points due to non linearity and time varying nature of conical tank level process. In this work, PSO based Neural Network Internal Model Controller (NNIMC) is designed and its outputs are compared with those of conventional PI controller and NNIMC through simulation studies for setpoint tracking.*

Key Words: Non-linear, NNIMC and PSO

1.INTRODUCTION

Liquid level control systems mainly control the manipulated parameter of liquid level, which in industry have a wide range of applications in various fields. In the industrial production process, there are many places need to control the liquid level, and make the liquid level maintain accurately for a given value. The traditional method is to use classical PID method. However, the practical application of the output is uncertain, in order to input well to follow the changes of output, then we need a continuously detect the number in time, to realize the liquid precise control. To implement a PID controller, three parameters (the proportional gain, Kp; the integral gain, Ki; the derivative gain, Kd) must be determined carefully. Many approaches have been developed to determine PID controller parameters for single input single output (SISO) systems. Among the well-known approaches is the Ziegler-Nichols (Z-N) method and the Cohen- Coon method.

Conical tanks are mostly used in various process industries, such as metallurgical industries, food processing industries, concrete mixing industries and wastewater treatment industries. A conical tank is basically a nonlinear process due to the change in the area of cross section and the level system with change in shape. Conventional controllers are commonly used in process industries as they are simple, robust and familiar to the field operator. Real time systems are not precisely linear but may be represented as linearized models around a nominal operating point. The controller parameters tuned at that operating point may not reflect the real-time system characteristics due to variations in the process parameters. The variations in the process parameters can be overcome by continuous adjustment of the controller parameter's using intelligent techniques like Artificial Neural Network (ANN) Bhuvaneswari et.al., (2008). Conical tank find wide applications in process industries. Conical tank with gravity discharge flows are used widely as an in expensive to feed slurries and liquids with solid particles to unit operations. Control of such process is very handled by P.Aravind et.al., [53] and real time system designs are analyzed. An implementation of the PI controller is done by direct synthesis method and skogestad method. The PI parameters obtained by process reaction curve method gives better result than the other techniques.

D.Mercy and S.M.Girirajkumar (2013) analyzed the tuning of controllers for conical tank level process. Authors proposed tuning of PID control strategy using Z-N method and Genetic Algorithm technique. Comparison is done with other conventional techniques, the GA provide better results in terms of high stability, robust and reliable. Giriraj Kumar et.al., (2008) discusses the Particle swarm optimization Technique based design of PI controller for a real-time conical tank level process

In this work, PSO based NNIMC, NNIMC and PI controllers are designed and implemented for a non-linear conical tank level process. Section 2 describes the mathematical modeling and process description of conical tank level process. Section 3 deals with the design and implementation of PI controller.

2. MATHEMATICAL MODELING AND PROCESS DESCRIPTION

A mathematical model is a description of a process using mathematical concepts. The process of developing a mathematical model is termed as mathematical modeling. Mathematical modeling is used to explain the identified system and to study the effects of different components, and to make predictions about the process behavior. Mathematical models ca n take many forms, including but not limited to dynamical systems, statistical models, differential equations, etc. In this paper the proposed system includes the conical tank process whose area is variable throughout the height. The mathematical model of the conical tank is determined by the following assumptions.

- Level as the control variable

➢ Inflow to the tank as the manipulated variable. This can be achieved by controlling the input flow of the conical tank. The schematic diagram of conical tank level process is shown in Figure 1.

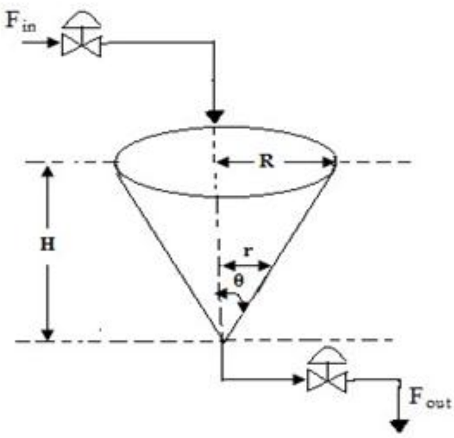

Fig -1. Schematic diagram of conical tank level process.

Inflow rate of the tank (Fin) is regulated using the valve and the input flow through the conical tank. At each height of the conical tank the radius may vary. This is due to the shape of the tank. The difference between the inflow and the out flow rate will be based on the cross section area of the tank and level of the tank with respect to time. The flow and the level of the tank can be regulated by proper modeling the tank. Operating Parameters are,

Fin - Inflow rate of the tank
Fout - Outflow rate of the tank
H - Total height of the conical tank.
R - Top radius of the conical tank
h - Nominal level of the tank
r - Radius at nominal level

Mass balance Equation is given by
Fin - Fout = A dh/dt
dh/dt= (Fin – Fout) / A (1)
Outflow rate of the tank, Fout = b√(h) (2)
Where, b is a valve coefficient
By substituting the values and considering the cross sectional area of the tank at any level h.
Cross sectional area of the tank, A = π r2
A = π R2 h2/ H2 (3)
Where radius, r = (Top radius of the conical tank)2(Nominal level of the tank)2 /(Total height of the conical tank)2

3 DETERMINATION OF PROCESS PARAMETERS OF CONICAL TANK LEVEL PROCESS

To determine the parameters of the conical tank level process, process reaction curve method is used. The entire operating region is divided into three regions. In the first region the level of the conical tank level process is brought to study state condition of 35 cm. Then an increase as well as decrease in inflow rate as of equal magnitude is applied. The change in level of the conical tank level process is recorded with respect to time for both cases. The responses is an 'S' shaped curve which is known as process reaction curve. From this curve process parameters like process gain (Kp), time constant (τ_p) and dead time (td) are estimated for both cases and average value is considered for the design of PI controller. The PI controller is designed using Zeigler-Nichols (ZN) tuning method. The obtained process and controller parameters are presented in Table I.

Region	Nominal operating point	k_p	τ_p (min)	td	k_c	T_i (min)
Region 1 (30-40 cm)	30	21.9	41.88	1.317	1.306	4.385
Region 2 (40-50cm)	40	25.31	85.37	1.662	1.826	5.53
Region 3 (50-60 cm)	50	28.2	147.4	2.287	2.056	7.615

4 DESIGN OF NNIMC AND PSO BASED NNIMC

The NNIMC is designed using developed forward and inverse models of conical tank level process (Geethanjali and srinivasan 2015). The block diagram of NNIMC for conical tank level process is presented in Figure. 2.

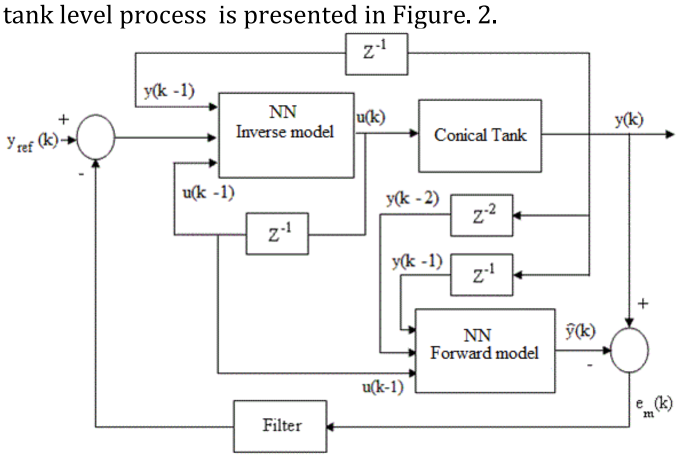

Fig-2. Structure of NNIMC for conical tank level process.

Normally, the learning rates of the forward and inverse neural models are selected by trial and error. In this work learning rate value is selected by using Particle Swarm Optimization algorithm. The developed PSO based forward and inverse models of conical tank level process are presented in Figure 3 and 4 respectively.

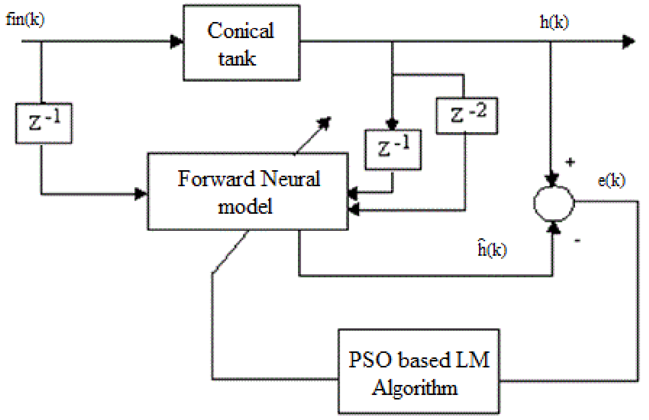

Fig-3. PSO based NN forward model of conical tank level process.

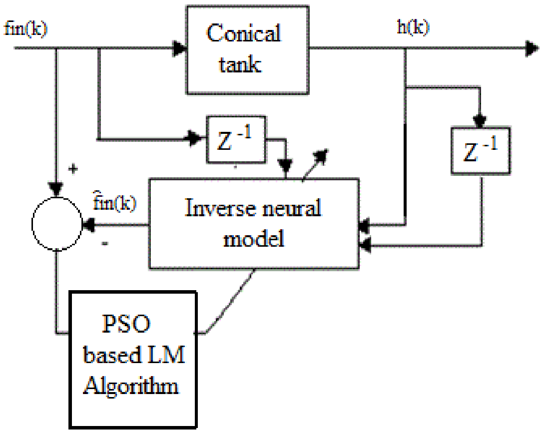

Fig-4. PSO based NN inverse model of conical tank level process.

5 SIMULATION RESULTS OF CONICAL TANK LEVEL PROCESS

In this section, the servo response of conical tank level process at three different operating points in the presence of PI, NNIMC and PSO based NNIMC through simulation has been carried out. The servo response of conical tank level process for all three regions is shown in Figure 5 and its controller output is shown in Figure 6. The performance measures of all controllers are given in Table II.

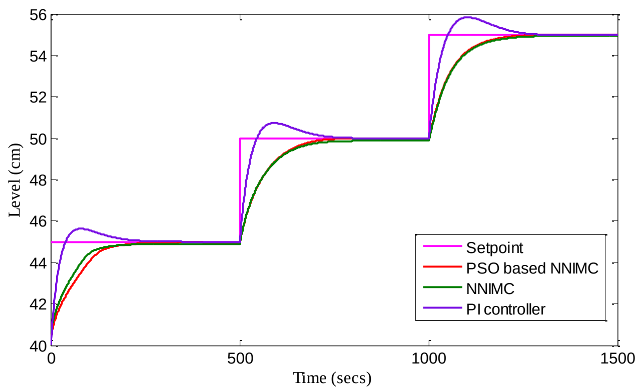

Fig- 5.Servo response of conical tank level process with PI, NNIMC and PSO based NNIMC.

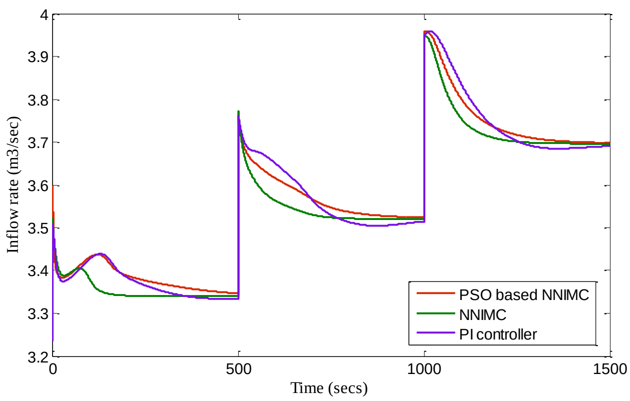

Fig-6. Controller output of conical tank level process.

Table -2: Performance measure for servo response of conical tank level process.

Controller	Integral Square Error			Integral Absolute Error			Settling time		
	SP change 40 to 45	SP change 45 to 50	SP change 50 to 55	SP change 40 to 45	SP change 45 to 50	SP change 50 to 55	SP change 40 to 45	SP change 45 to 50	SP change 50 to 55
PI	1827	1007	1304	941	429	559	453	211	215
NNIMC	1409	530	999	480	344	462	268	182	209
PSO based NNIMC	1316	525	918	434	304	423	266	179	205

6 CONCLUSION

In this work, PI, NNIMC and PSO based NNIMC are developed for a conical tank level process.. The servo response of conical tank level process at various operating points shows that the PSO based NNIMC produces better result when compared with NNIMC and PI controller. The simulated servo responses of conical tank level process shows that the PSO based NNIMC performance is better in terms of lesser integral square error value, lesser Integral absolute error and having faster settling time when compared with NNIMC and PI controller.

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