ISSN (Print): 2320 – 3765
ISSN (Online):2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 2, February 2013

Modelling and Simulation of Non Linear Tank

P.Aravind[1], M.Valluvan[2], S.Ranganathan[3]

PG Student[1], Department of Electronics and Instrumentation, JJ College of Engineering and Technology, Tiruchirappalli, TamilNadu, India

Assistant Professor[2], Department of Electronics and Instrumentation, JJ College of Engineering and Technology, Tiruchirappalli, TamilNadu, India

Assistant Professor[3], Department of Electronics and Instrumentation, JJ College of Engineering and Technology, Tiruchirappalli, TamilNadu, India

ABSTRACT:**This paper describes a nonlinear model of conical tank level control system and real time system designs are analysed and their implementation in SIMULINK is outlined. Level control of a conical tank is a complex issue because of the nonlinear nature of the tank. For each stable operating point, a First Order Process model was identified using process reaction curve method; the Control is done and comparison of the synthesis method and skogestad method is clarified.**

Keywords: Conical Tank, PI Control, Level, MATLAB

I. INTRODUCTION

A basic problem in process industries is control of liquid level and flow in process tank. Conical tanks are extensively used in process industries, petrochemical industries, food process industries and wastewater treatment industries. Control of conical tank is a challenging problem because of its non-linearity and constantly changing in area of cross section. Hence for these reasons the conical tank process is taken here. Conventional PID controllers are simple, robust provided the system is linear. But the process considered here has nonlinear characteristics which is represented as piecewise linearized models.multiple linear models of tank with many PI controllers were implemented. Many researchers have been carried out in the level control of the conical tank process. S. M. Giri Raj kumar, K. Ramkumar, Sanjay Sharma [1] explained Ants colony optimisation in level control of conical tank. N.S. Bhuvaneswari , G. Uma , T.R. Rangaswamy[2] carried out experiments in conical tank level control using Neural Network controllers. Swati Mohanty[3] designed Model Predictive Controller for floatation column . Artificial Neural Network modeling and multivariable Model Predictive Controllers are designed by Rahul Shridhar, Douglas. J. Cooper [4]. Unconstrained multivariable Tuning was proposed by R. Shridhar, D. J. Cooper [5]. The detailed description of designing MPC is explained by E. F. Camacho, Carlos Bordons[6]. The softwares and technology offers the potential to implement more advanced control algorithms but in industries they prefer a robust and transparent process control structure that uses simple controllers. That is why the PID controller remains as the most widely implemented controller despite of the developments of control theory.

This paper endeavours to design a system using two methods process reaction curve method and skogestad method of obtaining PI values Process reaction curve method is also known as first method, we obtain experimentally the response of the plant to a unit-step input. If the plant involves neither integrator(s) nor dominant complex-conjugate poles, then such a unit step response curve may look S-shaped curve. Such step response curve may be generated experimentally or from a dynamic simulation of the plant. The S-shaped curve may be characterized by two constants, delay time L and time constant T. The PID tuner allows achieving a good balance between performance and robustness. The PID tuner considers the plant to be the combination of all blocks between the PID controller input and output. Thus, the plant includes all blocks in the control loop, other than the controller itself.

The method, which can be denoted skogestad method [7] after the originator, is based on the direct method. The control system tracking function T(s) is specified as a first order transfer function. The objective of this paper is to show that by employing the proposed tuning of PI controllers, an optimization can be achieved. This can be seen by comparing the result of the PI tuner by various methods.

ISSN (Print): 2320 – 3765
ISSN (Online):2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 2, February 2013

II. MODELLING AND SIMULATION

Feedback control systems are often referred to as closed-loop control systems. In a closed-loop controlsystem the actuating error signal, which is the difference between the input signal and the feedbacksignal, is fed to the controller so as to reduce the error and bring the output of the system to a desiredvalue.The conical tank system, which exhibits the property of non-linearity, mathematical model is obtainedand simulated in SIMULINK. The process dynamics are analyzed in four segments so as toobtain effective models for the operating ranges. The operating ranges are concluded for 0-1.4 cm as model-1, 1.4-5.76 cm as model-2, 5.76-12.83 cm as model-3 and 12.83-23.04 cm as model-4.

The structure of conical tank system is illustrated in Fig 1. The tank level process to be simulated is single-input single-output (SISO) tank system as shown in Figure 2. The user can adjust the inlet flow by adjusting the control signal, *Fin*. During the simulation, the level 'h' will be calculated at any instant of time. In the SISO tank system, the liquid will flow into the tank through inlet and the liquid will come out from the tank through outlet. Here, we want to maintain the level of the liquid in the tank at desired value; so the measured output variable is the liquid level h.[8].

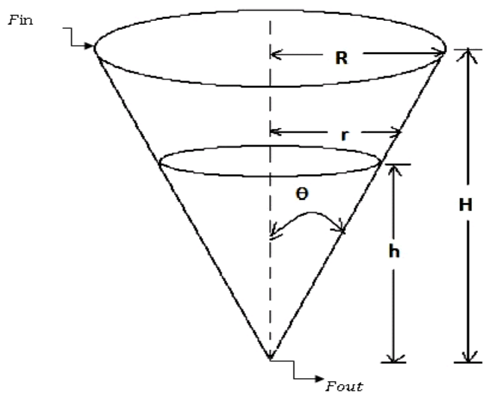

Figure 1 Structure of Conical Tank

A. Mathematical Modelling

The area of the conical tank is given by

$$A = \pi r^2 \qquad (1)$$

$$tan\theta = \frac{r}{h} = \frac{R}{H} \qquad (2)$$

$$r = R * \frac{h}{H} \qquad (3)$$

According to Law of conservation of mass,

Inflow rate - Outflow rate = Accumulation

ISSN (Print): 2320 – 3765
ISSN (Online):2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 2, February 2013

$$F_{in} - F_{out} = A\frac{dh}{dt} \tag{4}$$

$$F_{out} = k\sqrt{h} \tag{5}$$

Where, K is the discharge coefficient

On substituting (5) in (4), we get

$$F_{in} - k\sqrt{h} = A(\frac{dh}{dt}) \tag{6}$$

$$\frac{dh}{dt} = \frac{F_{in} - k\sqrt{h}}{A} \tag{7}$$

Where, $\frac{dh}{dh} - rate\ of\ change\ of\ height$

Therefore,

$$A = \frac{\pi * R^2 * h^2}{H^2} \tag{8}$$

Substituting the value of A in equation (8),we get

$$Fin - \ Fout = \frac{1}{3}\left[A\frac{dh}{dt} + \frac{h\left(2\,\pi\,R^2\,h\frac{1}{H^2}\right) * dh}{dt}\right] \tag{9}$$

The equation (9) describing the mathematical model for single conical tank level control, this equation is implemented in SIMULINK MATLAB and to obtain open loop response.

III. PROBLEM FORMULATION

ISSN (Print): 2320 – 3765
ISSN (Online):2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 2, February 2013

TABLE I
OPERATING PARAMETERS FOR TTCIS

Sl. No.	**Parameter**	**Description**	**Value**
1	R	Total radius of the cone	19.25cm
2	H	Maximum total height of the tank	73cm
3	Fin	Maximum inflow rate of the tank	400 LPH
4	K	Value co-efficient	55cm ^{2}/s

A. *Linearization*

The process steady stateinput output characteristics thus obtained shows the non-linear behaviour as the area varies in a non-linear fashion with the process variable height (h).To obtain a linear model process steady state input – output characteristics curve is divided into five different linear regions as shown in the Figure 4.

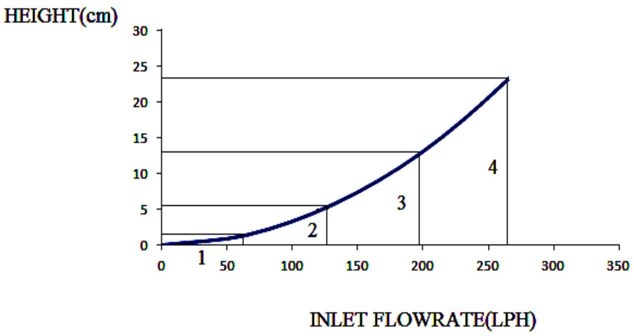

Figure 4: Piecewise Linearization of Input and Output Characteristics

IV. OPEN LOOP SYSTEM

The mathematical model is design in SIMULINK MATLAB and Open loop simulation results for step change in inlet flow rate is obtained.

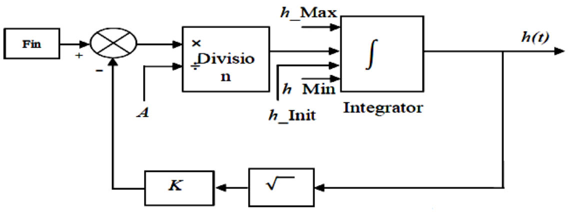

Figure 3: Open loop SIMULINK model

The obtained response from open loop test which represents first order transfer function with zero dead time.

$$G(s) = \frac{k_p e^{-\tau_d(s)}}{\tau s+1} \qquad (10)$$

ISSN (Print): 2320 – 3765
ISSN (Online):2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 2, February 2013

TABLE II
MODEL PARAMETERS OF CONICAL TANK

Region	**Inflow rate (LPH)**	**Height (cm)**	**Steady state gain**	**Time Constant (secs)**
1	0-66	1.44	0.0218	0.041
2	66-132	5.76	0.0654	0.24
3	132-198	12.83	0.109	1.97
4	198-264	23.04	0.155	11.75

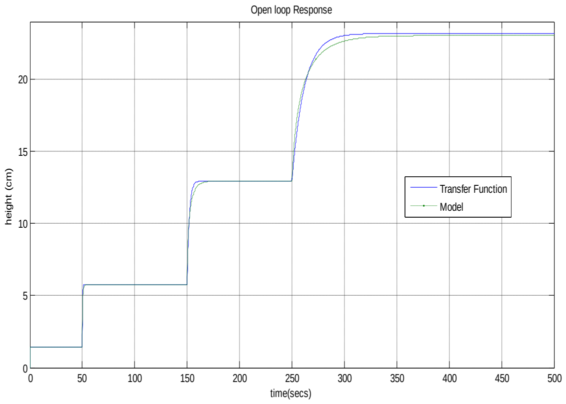

Figure 4: Open Loop Response

V. CONTROLLER DESIGN

A. *DIRECT SYNTHESIS METHOD*

Direct Synthesis is a model based tuning technique. It uses an identified process model in conjunction with a user specified closed loop response characteristic.[9] This is a model based tuning technique. It uses an identified process model in conjunction with a user specified closed loop response characteristic. An advantage of this approach is that it provides insight into the role of the 'model' in control system design.

The overall transfer function for set point change assuming,

$$G_m = G_v = 1 \tag{11}$$

$$G_{sp} = \frac{y}{r} = \frac{G_p G_c}{1+G_p G_c} \tag{12}$$

On rearranging the equation (11), we get

$$G_c = \frac{1}{G_p}\left[\frac{y/r}{1-(\frac{y}{r})}\right] = \frac{1}{G_p}\left[\frac{G_{sp}}{1-G_{sp}}\right] \tag{13}$$

ISSN (Print): 2320 – 3765
ISSN (Online):2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 2, February 2013

Remarks on the direct synthesis method:
1. It depends heavily on the model type.
2. It requires model inversion, which may cause problem for non-minimum phase processes.
3. PID controller may not be realized unless an appropriate model form is used to synthesis the control law.

B. SKOGESTAD METHOD

The method, which can be denoted skogestad method after the originator,is based on the direct method. The control system tracking function T(s) is specified as a first order transfer function. The objective of this paper is to show that by employing the proposed tuning of PI controllers, an optimization can be achieved. This can be seen by comparing the result of the PI tuner by various methods.

VI. SIMULATION RESULTS

The simulation result of Synthesis PI and skogestad with the various Operating point was obtained. The simulation was carried out in MATLAB Environment.The performance of the controller is compared [12] on the basis of Rise Time, Settling Time and Over Shoot.

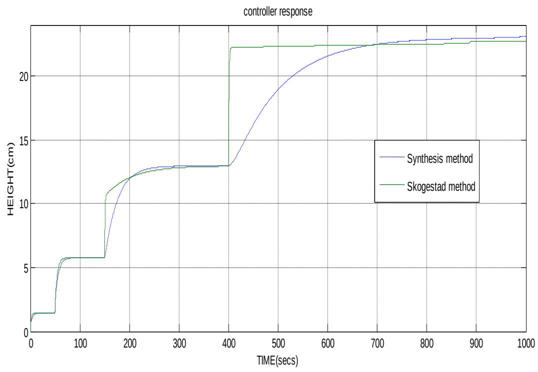

Figure 5: Comparison of Direct Synthesis and Skogestad Methods

TABLE III
COMPARISON OF SYNTHESIS PI AND SKOGESTAD

Set Point (cm)	**Controllers**	**K_P**	**K_I**
1.44	Synthesis	1.88	24.39
	Skogestad	6.666	4.629
5.76	Synthesis	7.339	4.166
	Skogestad	2	1.388
12.83	Synthesis	55.182	0.508
	Skogestad	0.1858	0.129
23.04	Synthesis	305.194	0.0851
	Skogestad	0.1613	0.112

ISSN (Print): 2320 – 3765
ISSN (Online):2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 2, February 2013

TABLE IV
COMPARISON OF SYNTHESIS PI AND SKOGESTAD

Set Point (cm)	**Controller**	**Rise time (secs)**	**Settling time (secs)**
1.44	Synthesis	15.5	15.5
	Skogestad	48	48
5.76	Synthesis	9.4	9.4
	Skogestad	110	110
12.83	Synthesis	342	342
	Skogestad	528	528
23.04	Synthesis PI	523	523
	Skogestad	1195	1195

VII. CONCLUSION

An implementation of the PI controller is done bydirect synthesis method and skogestad method, the PI parameters obtained by process reaction curve method gives minimum rise time and quick settling time response. The tank level control is such a process which is perhaps more often used in all industrial processes including electrical, petroleum industry, power sectors, development sites, paper industry, beverages industry, etc. so the controlled stable operation of this drive attracts the researchers always, still keeping more and more future scope in it.

REFERENCES

[1] S. M. GiriRajkumar, Dr. K. Ramkumar, Sanjay Sarma O.V," *Real time application of Ants Colony Optimization*," International Journal of Computer Applications (0975 - 8887) Vol 3 - No.8, June 2010.
[2] N.S. Bhuvaneswari , G. Uma , T.R. Rangaswamy," *Adaptive and optimal control of a non-linear process using Intelligent controllers*," Applied Soft Computing 9 , 182-190
[3] Swati Mohanty," *Artificial neural network based system Identification and model predictive control of a flotation Column",* Journal of Process Control 19 (2009),pp 991-999
[4] Rahul Shridhar, Douglas J.Cooper," *A Novel Tuning For Multivariable MPC*",ISA Transactions,vol - 36,No.4,pp 273- 280.
[5] Rahul Shridhar , Douglas J.Cooper," *A Tuning Strategy for Unconstrained Multivariable MPC*", Ind. Eng. Chern. Res. 1998, 37, 4003-4016.
[6] E. F. Camacho, Carlos Bordons "*Model Predictive Control*"2nd edition, Springer.
[7] Skogested, S, "*Simple analytic rules for model reduction and PID controller tuning*", Journal Process Control, 2003.
[8] S.Nithya, N.Sivakumaran, T.K.Radhakrishnan and N.Anantharaman" *Soft Computing Based Controllers Implementation for Non-linear Process in Real Time*" Proceedings of the World Congress on Engineering and Computer Science(WCECS)2010,Vol – 2.
[9] V.R.RaviT.Thyagarajan "*Application of Adaptive Control Technique to Interacting Non Linear Systems* "Electronics Computer Technology (ICECT), 2011 3rd International Conference on8-10 April 20112 pp: 386 – 392.
[10] Sukanya R. Warier, SivanandamVenkatesh "*Design of Controllers based on MPC for a Conical Tank System*"IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM -2012) March 30, 31, 2012.
[11] V.R.Ravi, T.Thyagarajan, M.MonikaDarshini**"***A Multiple Model Adaptive Control Strategy for Model Predictive controller for Interacting Non Linear Systems*"International Conference on Process Automation, Control and Computing (PACC),July 2011.pp:1 – 8.
[12] R.Valarmathi, P.R.Theerthagiri, S.Rakeshkumar*"Design and Analysis of Genetic Algorithm Based Controllers for Non Linear Liquid Tank System"*IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM -2012) March 30, 31, 2012.

ISSN (Print): 2320 – 3765
ISSN (Online):2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 2, February 2013

BIOGRAPHY

P.Aravind is a M E student in control and Instrumentation Engineering branch at J JCollege of Engineering and Technology,Tiruchirappalli,under Anna University, chennai, Tamil Nadu, India. He hold a B.Tech degree in Electronic and Instrumentation Engineering from SastraUniversity, Tanjore, Tamil Nadu, India. His research area in intelligent techniques.

M.Valluvan currently is a Assistant Professor in Department of Electronicsand Instrumentation Engineering at JJ college of engineering and Technology, Trichirappalli Tamil Nadu India. He received his B.E degree from JJ college of Engineering and Technology in 2009, M E Instrumentation Engineering from Madras Institute of Technology Chennai in 2011. His research area includes intelligent techniques.

S. Renganathan currently is a Assistant Professor in Department of Electronics and Instrumentation Engineering at JJ College of Engineering and Technology, Trichirappalli, Tamil Nadu India. He received his B.E degree from Angalaamman College of Engineering in 2004, M Tech Instrumentation and Control Engineering from Dr. MGR university Chennai in 2012 and he has industrial exposure of around 6 years. His research area includes intelligenttechniques.