Analyzing of Traditional Tuning Techniques of PI Controllers for FOPTD System

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Abstract— Conventional PI controller is the simplest well known controller used in utmost of the process. The main reason behind its popularity among engineers is its simplicity in tuning the parameters to achieve satisfactory performance in industrial applications. It fuses the properties of the P and I controller and it shows maximum overshoot. They are widely used because of their robustness, simplicity and successful practical application. In this process we are going to control the level of the tank using non-linear spherical tank. Here we are implementing using classical methods as well as T-L method. The system identification of the non-linear process is found by first order plus dead time model (FOPTD). The ability of the designed controller, in terms of tracking set point, is also compared and simulation results are produced.

Key words: PI, Z-N, modified Z-N, TL Method, nonlinear spherical tank process

I. INTRODUCTION

Spherical tanks are widely used both in industries and in private sector. To be more specific they are used in oil refineries, petrochemical industries, food processing industries and waste water treatment industries. One of the advantage of using a spherical tank is, it provides equal surface area, the evaporation is zero percentage when the tank is closed and also the pressure inside the tank remains constant. Controlling the level of the spherical tank is a tedious process, hence the level of the process is controlled by introducing various techniques. This is applicable for both open loop as well as closed loop process. And by using process reaction curve method, the transfer function model parameters for all regions and controllable parameters are produced using Z-N process. Z-N provides a closed loop response with a quarter decay ratio. The same is compared using a Tyreus -Luyben method and also to overcome

II. EXPERIMENTAL SETUP

The laboratory setup of a non- linear spherical tank consists of a rota meter, control valve, tank, electro pneumatic converter, pressure transmitter, data I acquisition card and personal computer (pc). Initially the spherical tank is filled with the fluid the amount fluid present is sensed by the level sensor used

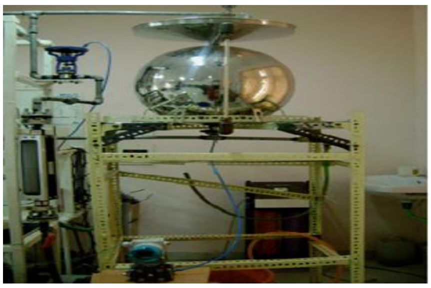

Fig. 1: Experimental setup

III. BLOCK DIAGRAM

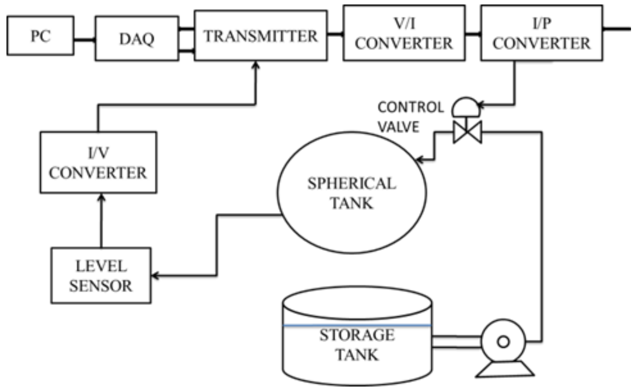

Fig. 2: Block diagram

IV. PI TUNING

PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. Thus PI controller will not increase the speed of the response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near and thus to decrease a reaction time of the controller.PI controllers are very often used in industry, especially when speed of the response is not an issue.

V. CONTROLLER DESIGN

The different types of tuning methods used for the non-linear processes are

(1) Ziegler-Nichols method
(2) Modified ZN method
(3) Tyreus-Luyben method

A. Closed loop Z-N method (ultimate gain):

It is based on adjusting a closed loop until steady oscillations occur. This is based on frequency response analysis.

B. Tyreus-Luyben Method:

This is applicable only for PI and PID controllers. It has an advantage in which the consumption of time is reduced and the system is forced to margin in case of instability.

Controller	kc	ki
PI	$kcu/3.2$	$2.2pu$

Table 1: controllers

C. Modified Z-N method:

This provides a steady state response with a 1/4 decay ratio. In case of large overshoots the results obtained are undesirable; hence we go for MZN method.

Controller	kc	ki
Some overshoot	$0.33kcu$	$pu/2$
No overshoot	$0.2kcu$	$pu/2$

Table 2: Modified Z-N method:

VI. RESULTS AND DISCUSSIONS

The spherical tank includes the conventional controller and is tuned using traditional methods like Z-N, modified Z-N and Tyreus-Luyben. The tuned parameters are analysed and the resultant graph is plotted. The tuning values are represented in the table below.

A. Tuning Parameters:

The FOPTD transfer function of a spherical tank in a non-linear process is:

$$\frac{6.857e^{-14.61s}}{229.81s+1}$$

B. Response Curve:

The below graph shows the responses of all the three controllers. From this we come to a conclusion that Tyrus-Luyben method reduces the integral time error compared to the other two classical methods.

Controller	kc	ki
P	0.5kcu	-
PI	0.45kcu	$pu/1.2$

Table 3: Controller

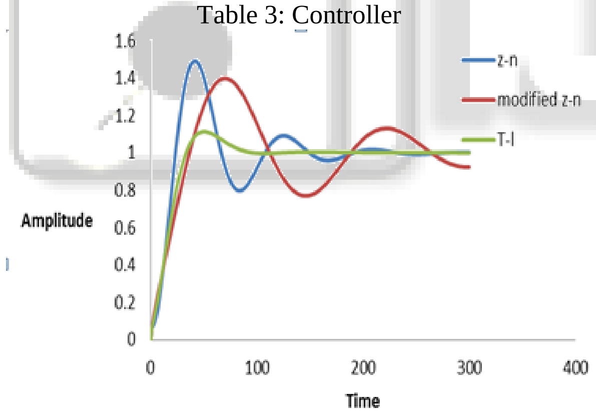

Fig. 3: Response Curve

C. Objective Functions and Error Values:

The integral is usually accepted as an honest live for the system performance. It's helpful to possess a criterion that plays a very little weight on initial error. These integrals are finite as long as integral state is zero. Some of the error criteria are used to determine the amount of error produced in the methods we used. Hopefully, smaller the error value larger the response obtained.

ISE (Integral square error): $\int_0^\infty e^{2(t)}.dt$

ITAE (Integral time absolute error): $\int_0^\infty t|e(t)|\,dt$

MSE (Mean square error): $(1/n\sum_{k=1}^{n}(ev(k))^2)$

Methods	ISE	ITAE	MSE
Z-N	27.2081	5.6873e+003	198.7303
Modified Z-N	2.8285e+003	8.5387e+003	140.8507
Tyrus-Luyben	1.0705e+005	8.4157e+003	22.8046

Table 4: Objective Functions and Error Values

D. Time Domain Specifications:

Controller	Kp	Ki
Ziegler-Nichols	2.1285	0.0573
Modified Z-N	0.946	0.0424
Tyrus-Luyben	1.478	0.0150

Table 5: Controller

From the response curve the time domain specifications like rise time, peak time, settling time and overshoot is been tabulated below.

Specifications	Rise Time	Peak Time	Settling time	%overshoot
Z-N	13.5	40	250	60
Modified Z-N	24	65	300	74.5
Tyrus-Luyben	24	56	200	23.8

Table 6: Time Domain Specifications

VII. CONCLUSION

This paper proposes the study of non-linear spherical tank using classical tuning methods. From this we infer that the error is been reduced and response holds well in T-L method. The T-L controller requires less oscillation time and also this provides positive result in case of peak time, settling time and peak overshoot. The error is also reduced when compared with Z-N as well as modified Z-N methods. Thus, by comparing all the three we come to a conclusion that Tyrus-Luyben shows "GOOD PERFORMANCE" and hence the simulation results are carried out using MATLAB.

REFERENCES

[1] W.L.Luyben, Process modeling, simulation and control for chemical engineers, second edition, Tata McGraw Hill USA : 1990.2. J.G. Zeigler, and N.B. Nichols, “Optimum settings for automatic controllers” Trans.ASME. Vol. 64, pp.759 –768, 1942.

[2] Sundaresan K. R, Krishnaswamy R. R, Estimation of time delay, time constant parameters in Time, Frequency and Laplace Domains, Journal of Chemical Engineering., 56, 257, 1978.

[3] Rahul Shridhar, Douglas J.Cooper," A Novel Tuning For Multivariable MPC,"ISA Transactions,vol - 36,No.4,PP 273-280.

[4] S. J. Qin and G. Borders, A multi region fuzzy logic controller for nonlinear process control”, IEEE Trans. on Fuzzy Systems, 2, 1994 ,PP.74-81.

[5] Rahul Shridhar , Douglas J.Cooper," A Tuning Strategy for Unconstrained Multivariable MPC," Ind. Eng. Chern. Res. 1998, 37, 4003-4016.

[6] Hirotaka Yoshida, Kenichi Kawata, Yoshikazu Fukuyana, Yosuke Nakanishi, A particle swarm optimization for reactive power and voltage control considering voltage stability, IEEE international conference on intelligent system applications to power systems (ISAP’99), Rio de Janeiro, April 4-8 1999.

[7] Parsopoulos and M. N. Vrahatis, Particle swarm optimizer in noisy and continuously changing environment, Indianapolis, IN, 2001.

[8] 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.
[9] 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.
[10] 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.
[11] G.I.Horn,; J.R. Arulandu,.; J.Gombas,.; J.G. VanAntwerp,.and R.D.Braatz,, "Improves filter design in internal model control". Ind.Eng.Chem.Res, Vol.35(10), pp. 3437 - 3441. 1996.
[12] E.P.Gatzke.;E.S.Meadows,.; C. Wang and F.J.Doyle,"Model based control of a four tank system". Computer Chem.Engr, Vol. 24(2), pp. 1503 – 1509, 2000.
[13] W. Tan.; H.J.Marquez and T. Chen,." IMC design for unstable process with time delays".J.Proc, cont, Vol .13, pp .203 - 213. 2003.
[14] S. Nithya.; Abhay Singh Gour;, N.Sivakumaran,.; T. K. Radhakrishnan.; N. Anantharaman.."Model based Controller design of shell and tube Heat exchanger" International Journal of Sensors & Transducers, Vol .84(10) ,pp. 1677-1686.2007.
[15] G.S. Cheng, and J.C.Hung,J.C ."A least-squares based self-tuning of PID controller", Proc IEEE South East Conference, North Carolina, 1985, pp. 325-332.
[16] E.S.Prabhu, and M.Chidambaram,." Robust control of a distillation column by the method of inequalities", Indian Chem.Engr. Vol 37, pp.181 – 187, 1991.
[17] K.R.Sundaresan .and R.R.Krishnaswamy,, "Estimation of time delay, Time constant parameters in Time, Frequency and Laplace Domains" Can.J.Chem.Eng, Vol. 56,.257 . 1978.
[18] S. Skogestad,. "Simple analytical rules for model reduction and PID controller tuning". J. Proc. Cont, Vol 13, pp .291 – 309, 2003.