Tuning of PID Controller for a open loop Pneumatic Process

S. Senthilkumar[1], K. Abhishek[2], R. Hariharan[3], P. Sathiya[4]
[1, 2, 3, 4] Department of Instrumentation and Control Engineering
[1, 2, 3, 4] Saranathan college of engineering, Trichy, India

Abstract- *The intention of the work is to sustain the pressure in the open loop at desired set value. Control of pressure is crucial in process industries. The pressurized tank has the characteristics of nonlinearity, indolence by tuning conventional PID methods. The proportional-integral-derivative [PID] controllers are the largely accepted controllers used in industry because of their remarkable effectiveness, simplicity of operation and broad applicability. Nevertheless, physical tuning of these controllers is time consuming, tedious and generally lead to poor performance PID controller is otherwise called as three term control is taken up here for treatise and testing. It has three invariable parameters and they are proportional, integral and derivative values which depend upon the present inaccuracy, aggregation of past errors and expectancy of future errors based on current rate of change of error respectively. At first, the real time pressure process is identified as first order plus dead time model. This study is conduct in the direction of find the optimum PID controller parameters (,) for first order process model. Many tuning methods have been proposed for PID controllers. First we have to find out the module which is suitable for this process by comparing two methods Process-Reaction-Curve (PRC) and SKogestad (SK) Method. Our purpose in this study is comparison of these tuning methods meant for single input single output (SISO) systems using computer simulation. The results of general simulations cover classical methods including Ziegler-Nichols (ZN) tuning (Frequency-response) ,Tyreus-Luyben (TL) and Cohen-Coon(C-C) tuning PID tuning have led to determine the optimum choice for tuning. The comparison is done between the performance criterion and time domain specifications.*

Keywords- MATLAB, PID Controller, Pressure process, Tuning Method

I. INTRODUCTION

Throughout 1930's three action controller with proportional, integral and derivative actions became commercially existing and gained widespread industrial acceptance. The PID controllers are well known to the control engineers and these have been the dominating form of feedback control in the field of process control to implement industrial applications. About 94% of all control loops are in the category of PID. This thrive is a result of many good features of this algorithm such as simplicity, robustness and wide applicability. The major strength of PID controllers is also due to its ability to handle sensible issues of actuator saturation and integral wind-up. Many various tuning methods have been projected from 1942 up to now for gaining better and more satisfactory control system response based on our enviable control objectives such as percent of overshoot, settling time and the manipulated variable behaviour. Some of those tuning methods have consider as one of these objectives as a criterion for their tuning algorithm and some of them have industrialized their algorithm by considering additional than one of the mentioned criterion. In this cram we have compared the performance of several tuning methods. For simulation study first, order systems with dead time have been employed and it was assumed that the dynamics of system is known.

To design and tune the controller to achieve the better performance it is indispensable to

- Obtain the active model of a system to control.
- Identify the desired closed loop performance on the basis of known physical limitations.
- Adopt controller strategies that would attain desired performance.
- Implement the resulting controller using suitable platform.
- Validate the performance of the controller and modify accordingly if required.

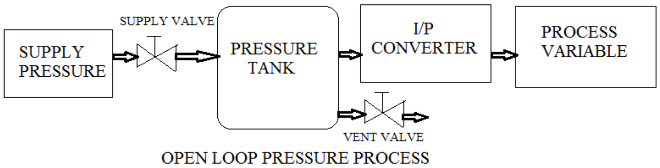
$$\mathbf{G(s) = Kc(1 + \left(\frac{1}{Ti}\right) + Td)}$$

In this,
Kc -proportional gain,
Ti -integral time,
Td -derivative time

A PID controller helps to bring down the difference between process variable and the set point by outputting the response with the desired value. PID controller has fixed state error value as zero, fast retort, short rise time, no oscillations and higher stability. PID controllers are preferred over PI controller because they reduce the overshoot and it also holds supplementary advantage of employability for higher order system. A PID controller propel a control signal that has a component proportional to error of a system, accumulation of error over time and the rate of change of the error with respect to time.

II. EXPERIMENTAL SETUP OF PRESSURE SYSTEM

The physical experimental system comprises of Pressure Tank, Supply Pressure, Inlet and Supply Valve and Current to Pressure (I/P) converter and Process Variable (PV).



Technical description of experimental setup

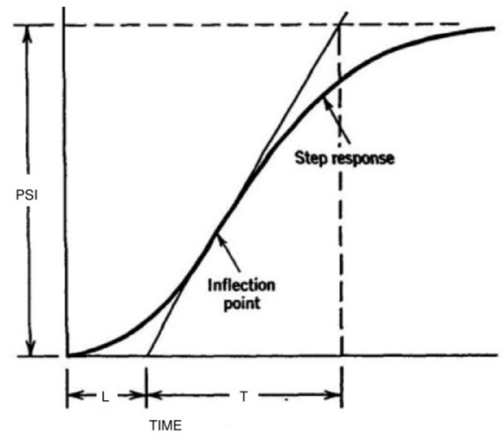
PART NAME	DESCRIPTION
Pressure tank	Opaque pressure vessel
Communication	RS232
Current to pressure converter	Input 4-20 mA , Output 3-15 psi
Control valve	Type: Pneumatic, Size: ¼", Input: 3-15 psig, Air to close, Linear
Supply and vent valve	Input 4-20 mA , Output 4-20 psig

The investigational loom for pressure process is done with the pressure control trainer kit. The control kit is interfaced with controller. Initially, the pressure vessel is abounding with pressurized air by using high pressure compressor air (HPC) at the inlet valve. The input valve is manually controlled which prepared to open partially. The pressure created inside the vessel is indicated by pressure gauge fixed on the head of the cylinder. The capacitive type pressure sensor attach along with the cylinder generates current proportional to the pressure present in the vessel. While current from pressure sensor is of least value, the output current is converted into voltage (I/V) by specific resistance. The output voltage signal is then acquired by the controller. Dynamic change of voltage is called as process variable; each voltage value gives equivalent pressure value.

Module Validation:

Process Reaction Curve Method

First place the controller in physical mode and wait for PV come to a steady state value. Next cause a step change in the output of X percent, say 5 to 10 %. The process variable PV after a certain time period instigate to change and form the loop called typical loop, process variable will approach some new value. The curvature traced by the change is called reaction curve. The reaction curve has shows all the dynamics of the process over and above the valve, process sensor, transmitter. Draw a line departure to the curve .Time between the point where this line intersect with the original process variable and point where the test begin is called the lag time, L. The slope of this tangent curve, d ((PV)/ (dT)), is called the reaction rate R. The output step change is DP and is expressed in percent units.

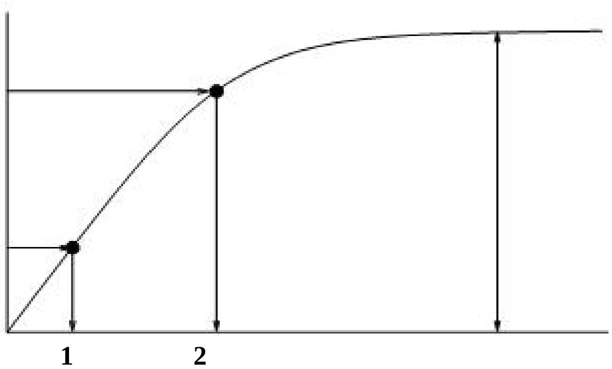


Process Reaction Curve (PRC)

Transfer function = $\frac{1.95}{17s+1}e^{-2s}$.

Skogestad method

It is a model-based method. It is supposed that you have mathematical model of the process that is also known as transfer function model. It does not matter how you derive the transfer function it can branch from a model derived from the physical principles and from calculation of model parameters (gain, time constant and time delay) and from an experimental response, characteristically a step response experiment with the process which is (step on the process input).There is a large number of tuning methods, it is my view that above methods will cover most practical cases. What about famous "Ziegler- Nichols" method the Ultimate Gain method (Closed-Loop method) and the Process Reaction curve method (Open-Loop method) The Good Gain method has many similarities with the Ultimate Gain method, but the latter method has one serious shortcoming, namely it requires control loop to brought the limit of stability during the tuning, Whereas Good Gain method requires a stable loop during tuning. The Ziegler-Nichols Open-Loop method is similar to a special case of Skogestad method, and Skogestad method is more applicable. Skogestad tuning method is a model based tuning where the controller parameters are expressed as a function which is of the process model parameters.



Time Vs System Response graph

1 → $T_{35.3}$
2 → $T_{85.3}$

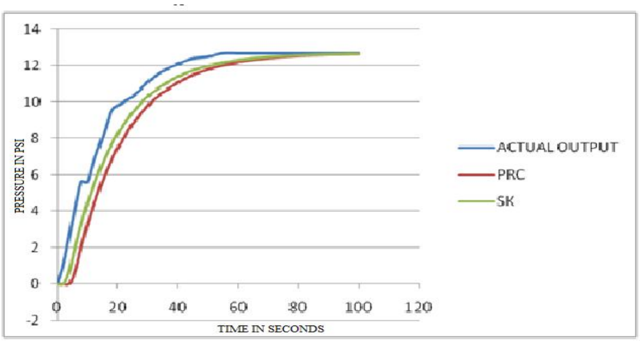
Formula:

Delay time td =1.3($t_{35.3}$)-0.29($t_{85.3}$)

Time constant T=0.67($t_{85.3}$-$t_{35.3}$)

Transfer function = $\frac{1.95}{16.08s+1}e^{-2.13s}$

Comparison of performance:



From the above graph we know that SKogestad Method will have close response similar to the actual response of the pressure process. Therefore we have to find out the controller tuning of SK method transfer function.

III. SYSTEM IDENTIFICATION

A. Ziegler-Nichols Method

This method is based on trial and error tuning will produce continuous oscillations that was first projected by Ziegler - Nichols (1942) this method is probably the most known and most widely used method for tuning of PID controller is also known as (**online or continuous cycling or ultimate gain tune method)**. Having the ultimate gain and frequency (Ku and Pu)

The advantage of Z-N method is it does not require the process model.

The disadvantages of this technique are

- It is time consuming because the operation of trial and error.
- It force the process into a condition of marginal stability that lead to unstable operation or hazardous situation due to set point changes or external trouble.
- This method is not applicable for processes that are open loop unstable.
- Some simple process do not have ultimate gain such as first order and second order process without dead time.

B. Tyreus–Luyben Method

Its procedure is quite similar to the Ziegler–Nichols method but final controller settings are dissimilar. Also this method only proposes settings for PI and PID controllers. Controller settings are based on the values of ultimate gain and period. Like Z-N method these methods are time consuming and force the system to margin instability. Many algorithms have been projected to solve these problems by obtaining critical data (Ultimate gain and Frequency) under more acceptable conditions.

C. Cohen-Coon Method

It is another Ziegler–Nichols type tuning algorithm called the Cohen–Coon tuning formula. Referring to the first order plus dead time model, which can approximately be obtained from experiments, denote

a = kL/T and **b = L/(L + T)**

The different controllers can be designed by the direct use of Table

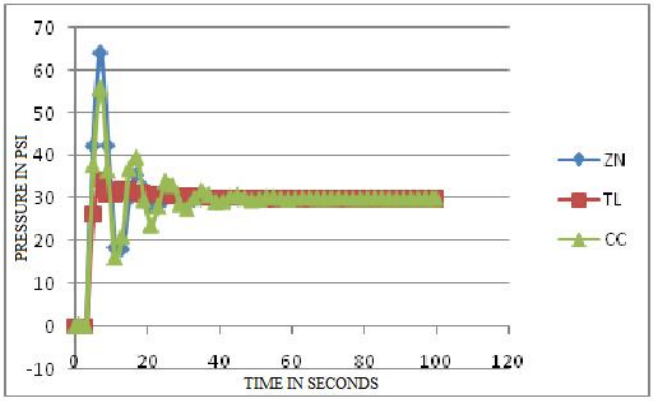
Controller parameters for tuning methods:

TUNING METHODS	Kc	Ti	Td
ZN	0.6Ku	Pu/2	Pu/8
TL	Ku/2.2	2.2Pu	Pu/6.3
CC	$\frac{1.35}{a}(1+\frac{(0.18b)}{(1-b)})$	$\frac{2.5-2b}{1-0.39b}L$	$\frac{0.37-0.37b}{1-0.81b}L$

Value of controller parameters for tuning methods:

TUNING METHODS	Kc	Ti	Td
ZN	4.96	3.14	0.785
TL	3.76	13.82	1
CC	5.36	48.6	0.143

Performance of tuning techniques:



IV. RESULT AND COMPARISION

The controller parameters are calculated and applied for set point from (0-30) psi. From the comparison of different tuning methods find which is suitable.

To find the best controller, the error reduction standards are necessary. Therefore, ITAE, IAE, ISE and MSE values are shown below in tabulation

TABLE: ERROR CRITERIA FOR PRESSURE PROCESS

TUNING METHODS	IAE	ISE	ITAE	MSE
Ziegler Nichol's Method	190.4	5100	931.3	2.409E+04
Tyreus Luyben Method	105.2	2570	319.6	6453
Cohen Coon Method	171.1	4128	808.3	1.764E+04

VI. CONCLUSION

In this paper we have proposed an effective method to design the PID controller that can be implemented in real time pressure process. First we have to find the module which is optimum by comparing Process reaction curve (PRC) and SKogestad (SK) method. From the observation SK method model more same as actual model. Then the result is shown that WJC-PID controller has given good results than ZN-PID and TL-PID controller. From the consequences, the response of WJC was shown satisfactory in terms of rise time, peak time, settling time, peak and peak overshoot when compared to the ZN-PID and TL-PID setting. From the response, it is witnessed that the CC-PID tracks the set point with less oscillation when compared to ZN-PID and TL-PID setting. The simulation results has proven that TL-PID control setting is more effective way in disturbance rejection and to enhance the stability of system.

REFERENCES

[1] Dr. Satya Shee and Omhari Gupta--- 'New Techniques of PID Controller Tuning of a DC Motor Development of a Toolbox' MIT International Journal of Electrical and Instrumentation Engineering, Vol. 2, No. 2, Aug. 2012, pp. (65-69) ISSN 2230-7656 (c) MIT Publications

[2] K. Mohamed Hussain,R. Allwyn Rajendran Zepherin, M.Shantha Kumar,S.M. Giriraj Kumar ---'Comparison of PID Controller Tuning Methods with Genetic Algorithm for FOPTD System'
K. M Hussain et al Int. Journal of Engineering Research and Applications www.i jera.com ISSN : 2248-9622, Vol. 4, Issue 2(Version 1), February 2014, pp.308-314 www.ijera.com

[3] A.Iyswariya, N.Nimitha, Aarthi K.J Veronica, R.Selvarasu --- 'Design of PI Controller using First Order Plus Time Delay Model for Process Control'International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) Volume 4, Issue 3, March 2015 687 ISSN: 2278 – 909X All Rights Reserved © 2015 IJARECE

[4] B Diwakar, M Gokul Anandh, R Brindaa, S R Jayashree Devi, P Aravind ---- 'IMC Based Design of PI Controller for Real Time Pressure Process' INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL,ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING Vol. 3, Issue 10, October 2015Copyright to IJIREEICE
DOI 10.17148/IJIREEICE.2015.31003 ISSN 2321 – 2004