The Optimum Controller Design for A Pressure Process

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Abstract- *Measurement of Pressure is one of the very necessary parameter in a process situation which needs to be controlled. In this paper the real time response of a pressure process is obtained. From the response the system transfer function is identified. PI controllers are successfully used in controlling liner with the suitable tuning methods. Mostly available tuning methods like Ziegler Nichol's method (ZN), and Internal Model Control (IMC), and Tyreus Luyben method (T-L) are used here to compare the responses using software MATLAB to get optimum controller for the pressure process.*

***Keywords*-** IMC, MATLAB, PI controller, T-L, Z-N

I. INTRODUCTION

Tuning a PI controller for a pressure process is a precondition which is otherwise will create a serious condition for boiling, chemical reaction, refining, extrusion, vacuuming, air conditioning and other reactions at higher end. Pressure control cause major safety, quality, and productivity problems. On addition to this high pressure inside an open loop system can cause a detonation. Therefore, it is highly preferable to keep the pressure inside the open loop system in control and to maintain it in the safety limit which becomes the precondition of pressure control. A proportional integral controller (PI) is a commonly used open loop feedback controller used in the process station that monitors the error signal which is the difference between the current output process variable and the actual set point. Error signal becomes the input to the (PI) controller which goes-on to condense the error with the adjustment of controller gain parameters as shown below in the equation

U (t) = kpe dt + ki∫ et dt

Where,
U(t) - control signal that depends on the gain values of proportional integral modes of the controller, KP-Proportional Gain, KI - Integral Gain, There are three parameters to be tuned with various tuning techniques to get the desired response and make the system controllable. Above equation u(t) is the control signal to the PI controller which is the summary of the gains of three different mode of controller along with error which vary for different modes used for proportional mode, error is the direct multiple with the gain of proportional action, integral, integration of error with value to time is multiplied with integral gain and for derivative differentiation of error multiplied with the derivative gain. Addition of all the three gives the input signal for PI controller.

II. EXPERIMENTAL SETUP OF PRESSURE PROCESS

In this setup the process tank is connected with supply valve and vent valve for safety purpose, In order to specify process tank pressure an indicator is fixed over the tank. The pressure transmitter used here is a two wire type (range 0-5 bar, output 4-20 mA) the transmitter is connected to the controller which is MATLAB. The control signal is fed to I/P converter (Input 4-20 mA, output 3-15 psig). I/P also connected with air filter regulator (range0-2.5 kg/cm^2). The pressure of the process tank is maintained.

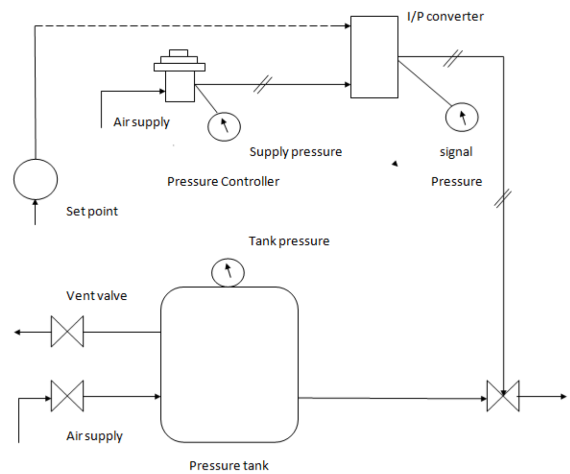


Figure 1: open loop pressure process

III. DETERMINATION OF PROCESS TRANSFER FUNCTION

Stephanopoulos, G[2] process design and control has been referred. Transfer function for the pressure process (SISO) system is obtained from the response of above process which is obtained until process settles without the effect of

PID controller action. The response is taken for open loop process without effect of controller. From the response gain of the process is determined and by two point method the values of delay time and time constant are calculated. Model justification is done by using two point methods the basic formulae for calculating time constant and delay time is given below

Two point method:

T= 1.5(t63.2%- t28.3%)
Ʈ= t32.2%- T

From the process we obtain a transfer function which is a first order plus dead time (FOPDT) of the form given below,

$$G(s)=\frac{kpe^{-\tau d(s)}}{\tau s+1}$$

Where,

K -A steady state gain of the process
Ɵs – A dead time of the process
Ʈ- A time constant of the process

Obtained transfer function for the system is,

$$G(s)=\frac{4.2e^{-0.4s}}{5.9s+1}$$

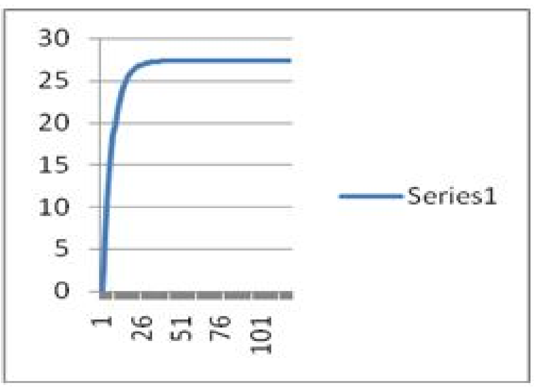


FIGURE: open loop response for pressure process.

A. ZEIGLER NICHOLAS METHOD (Z-N)

Ziegler–Nichols tuning rules have been widely used to tune PID controllers in process control systems where the pant dynamics are in particular known. Over many years, such tuning rules proved to be very useful. Ziegler–Nichols tuning rules can be applied to plants whose dynamics are known. (If the plant dynamics are known, many analytical and graphical approaches are available to design PID controller are available, in addition to Ziegler–Nichols tuning rules). Z-N method is a closed loop tuning method and in this case the controller remains in the loop as an active controller in automatic mode. This method is a conduct experiment and error tuning method based on constant oscillations that was first proposed by Ziegler and Nichol's in the year 1942. This method is probably the most known and widely used method for tuning of PID controller is also known as *online* or *continuous cycling* or *ultimate gain* tuning method. Having the critical gain and frequency (K_u and P_u) and using Table, the controller parameters can be obtained. A ¼ decay ratio has considered as design criterion for this method.

The resulting controller transfer function for PI.

Table 1: Tabulation for Z-N method

CONTROLLER	kp	τ_i	τ_d
P controller	0.5*kcu	--	--
PI controller	0.45*kcu	Pu/1.2	--

TUNING PROCESS INVOLVES:

When the process is in the steady state condition, remove integral and derivative modes by maximizing and minimizing controllable parameters. This leave a proportional controller alone in action Set a proportional gain K_c and slightly disturb the system either by changing the set point or the load variable. If the response decays, increase the gain value of K_c and repeat disturbing the system till sustained oscillations are obtained. The gain and the period of oscillation at this point are ultimate gain K_{cu} and ultimate period P_u. From these values and from the above table the controller parameters are obtained

KP = 3.66 KI = 3.66

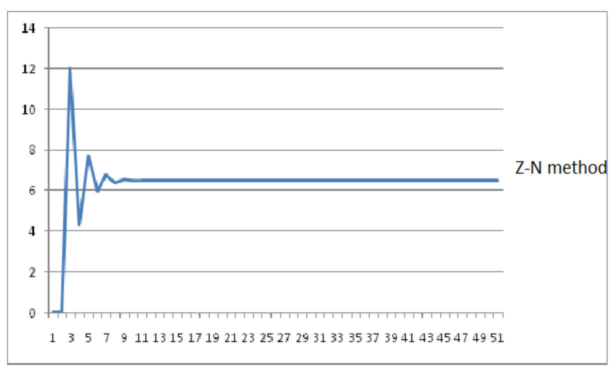


Figure: Open loop response for ZN method

B. INTERNAL MODEL CONTROL (IMC)

IMC has been used in this process. Internal model control (IMC), which is based on an accurate model of the process, lead to the design of a control system that is stable and robust. A robust control system is one that maintains suitable control in changes in the dynamics of the process In many industrial applications for control system, none of the above item is available, with the result that the system usually performs in a less than optimum manner. Determining the mathematical model and its uncertainty will be a difficult task. In the IMC method, the integral square error is implied.

IMC approach has two important advantages

It implicitly takes into account model uncertainty.

It allows designer to trade-off control system performance against control system toughness to process changes and modeling errors Proportional, integral and derivative constants.

Table 2: Controller Tuning Formula for IMC

CONTROLLER	K_{KC}	τ_i	RECOMMENDED λ/d (λ>0.2τ always)
PI controller	τ/λ	τ	>1.7
IMPROVED PI	$\frac{2\tau + d}{2\lambda}$	$\tau + d/2$	>1.7

Following tabulation is used to calculate the gain constant

The gain value of proportional, integral and derivative modes of controller using IMC tuning technique is given below. From the obtained values, the tuned response is obtained using MATLAB.

KP = 5 KI = 0.84

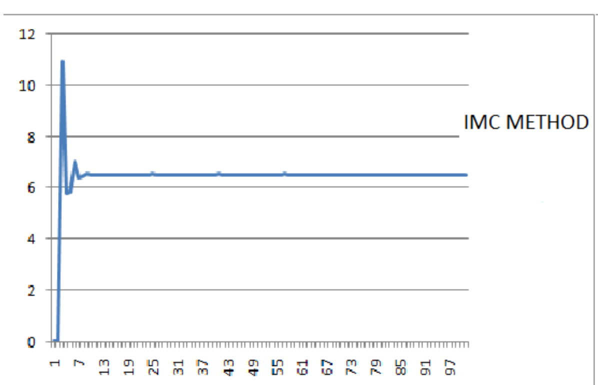


Figure 4: Response for IMC method

TYREUS – LUYBEN METHOD (T-L):

Tyreus – Luyben method procedure is quite similar to the Ziegler – Nichol's method but the final controller setting for PI and PID controller. These setting that are based on ultimate gain and like Z – N method this method is time consuming and forces the system to margin if instability.

KP = 2.29 KI = 0.86

CONTROLLER	KC	τ_i	τ_d
PI controller	$\frac{ku}{3.2}$	2.2pu	--

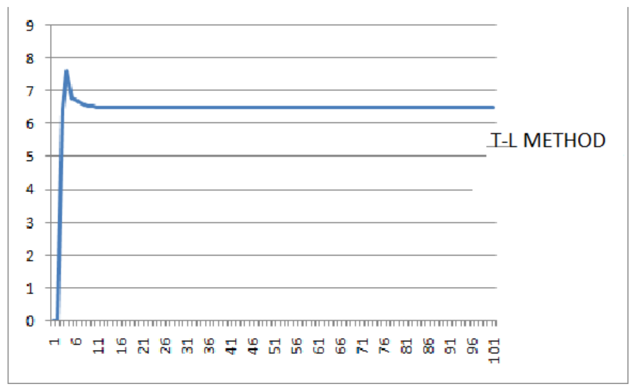
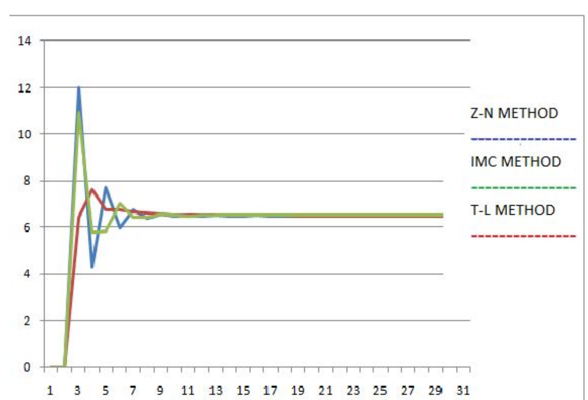


Figure 4: Response for TYREUS – LUYBEN (T-L) method.

V. COMPARISON AND RESULT ANALYSIS

The result of this paper is obtained by comparing the response of both the tuning methods (Z-N, IMC and T - L) and by calculating the time domain analysis from the responses. Controller with minimum settling time, minimum peak overshoot, and less error is chosen as the best controller.

COMPARISON OF ZN, TL, IMC



From the above response ZN method has high peak overshoot which is due the high integral gain of the controller which introduces a delay in the settling time of the system. On the other handle IMC has a perfect response required for a transfer function with no peak overshoot and absolute settling time with no oscillations.

VI. CONCLUSION

The PI Controller is tuned with the values of Proportional band, Integral time which is further converted into Proportional Gain (Kp), Integral Gain (Ki), with the help of kcu and pu values. From those values the Response is obtained using simulation done by MATLAB. The results presented prove the effectiveness of IMC tuned PI controller than Z-N method. Hence IMC would be the suitable tuning method for a pressure process. The feature of IMC illustrated in the work is considering the problem of designing a control system for a plant of a first order system with time delay and obtaining the possible result. The future scope of this work is aimed for providing a self-tuning PI controller with proposed algorithm to solve the complex issue in a real time problem.

REFERENCES

[1] P.Srinivas, K.Vijaya Lakshmi & V.Naveen Kumar "A Comparison of PID Controller Tuning Method For Three Level Process", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol-3, Issue-1, January 2014.

[2] P.Aravind, M.Valluvan & B.Sangeeth "Modal Based Controller Design for Level Process", International Journal of Computer Application (0975-887) Vol-88-No.18, February 2014.

[3] Mohammad Shahrokhi & Alireza Zomorrodi "Comparison of PID Controller Tuning Method", Department Of Chemical & petroleum Engineering, Apr 2014.

[4] Rajesh.T, Arun Jayakar.S & Siddharth.S.G "Design and Implementation of IMC Based PID Controller for Conical Tank Control Process", International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering Vol-2, Issue-9, September 2014.

[5] P.Aravind, M.Valluvan & S.Ranganathan "Modeling and Simulation of Non Linear Tank", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol-2, Issue-2, February 2013.

[6] Apurva Tripathi, Ram Lautan Verma & Md.Sanawer Alam "Study and Analysis of Various Tuning Method of PID Controller for AVR System", International Journal of Research in EEE Vol-1, July-September- 2013, pp.93-98.

[7] M.Venmathi, K.Sujatha, A.Nalini & M.Venmathi "Fuzzy and ANN tuning of PI Controller for Level Process Station", ACS international journal of computational intelligence Vol-1, issue-2 Dec 2010.

[8] K. Mohamed Hussain, R. Allwyn Rajendran Zepherin, M. Shantha Kumar," comparision of tuning methods of PID controllers for FOPTD system", International journal of innovative research in electrical, electronics, instrumentation and control engineering, vol 2,Issue 3,march 2014.

[9] Stephanopoulos, G.;"Chemical Process Control", pg: 510 Prentice-Hall, 1984.

[10] Coughanowr D.R.;"Process System Analysis and Control" pg: 378, 2nd edition McGraw- Hill, 1991.