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Design of Model Based PID Controller Tuning for Pressure Process

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ABSTRACT: Measurement of Pressure is one of the very essential parameter in a process station which needs to be controlled. This paper deals with obtaining the real time response of a pressure process from which the system transfer function is identified using two point method. The identified model is in the form of first order plus dead time (FOPTD). PID controllers are effectively used in controlling liner feedback systems with the suitable tuning methods. Predominantly available tuning methods like Ziegler Nicholas method (Z-N), and Internal Model Control (IMC), are used here to compare the responses using software LabVIEW to get the optimum controller for the pressure process.

KEYWODRS: PID controller, Tuning methods, IMC, Z-N, FOPTD, LABVIEW.

I.INTRODUCTION

Tuning a PID controller for a pressure process is a prerequisite which otherwise will create a critical condition for boiling, chemical reaction, distillation, extrusion, vacuuming, air conditioning and other reactions at higher end. On the other hand Poor pressure control can cause major safety, quality, and productivity problems. On addition to this high pressure inside a closed system can cause an explosion. Therefore, it is highly preferable to keep the pressure inside the closed loop system in control and to maintain it within its safety limits which becomes the prerequisite of pressure control.

A proportional integral derivative controller (PID) is a commonly used closed loop feedback controller used in 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 (PID) controller which endeavors to reduce the error with the adjustment of controller gain parameters as shown below in the equation. K. Mohamed Hussain, R.AllwynRajendranZepherin [1] explained comparision of tuning methods of PID controllers for FOPTD system.

$$U(t) = k_p e(t) + k_i \int e(t)dt + k_d \frac{de}{dt}$$

Where,

u(t)- control signal that depends on the gain values of proportional integral derivative modes of the controller, K_P- Proportional Gain, K_I - Integral Gain, K_d - Derivative Gain.These are the three parameters to be tuned with various tuning techniques available to get the desired response and to make the system controllable.

The above equation u(t) is the control signal to the PID controller which is the summation of the gains of three different modes of the controller along with the error which varies for different modes for proportional mode, error is the direct multiple with the gain of the proportional action For integral, integration of error with respect to time is multiplied with the integral gain and for derivative differentiation of error is multiplied with the derivative gain addition of all the three gives the input signal for PID controller

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II. EXPERIMENTAL SETUP OF PRESSURE PROCESS

In this setup the process tank is connected with a air supply valve and vent valve for safety purpose, In order to indicate the 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 LabVIEW. The controller is also fed with the set point, the control signal is fed to the I/P converter of (Input 4-20mA, output 3-15 psig) I/P is also connected with air filter regulator (range0-2.5 kg/cm^2). The output from I/P converter is given to the control valve (pneumatic; size: ¼" , Input:3-15 psig, air to close, characteristic: linear) from which the pressure of the process tank is maintained

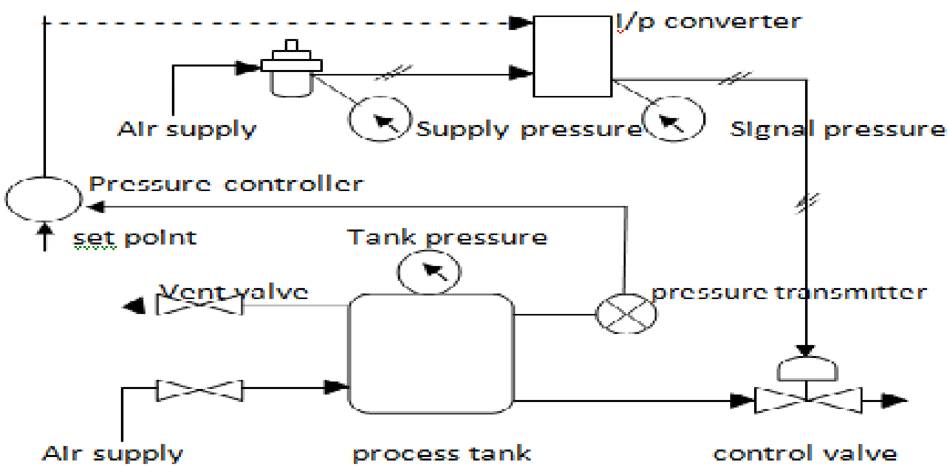

Figure 1: closed loop pressure process

III. DETERMINATION OF PROCESS TRANSFER FUNCTION

Stephanopoulos, G.[2] process design and control has been referred. Transfer function for the pressure process which is a (SISO) system is obtained from the response of the above process which is obtained until the process settles without the effect of the PID controller action. The response is taken for open loop process without the 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 validation is done by using two point method the basic formulae for calculating time constant and delay time is given below
Two point method:

$T=1.5(t63.2\% - t28.3\%)$

$\tau= t32.2\% - T$

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

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

Where,

K - Steady state gain of the process
Ɵs - dead time of the process
Ʈ- time constant of the process

Similarly, from the response of the process FOPDT transfer function is obtained which is shown below.

$$G(s) = \frac{0.33e^{-0.2197s}}{1.055s + 1}$$

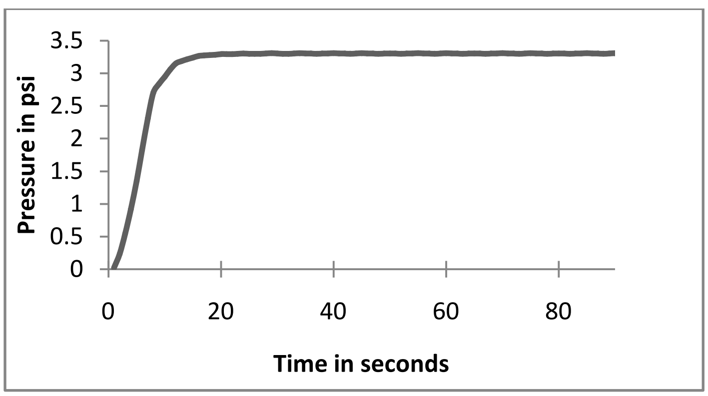

Figure 2: **open loop Response for pressure process**

IV. CONTROLLER TUNING METHODS

A.ZEIGLER NICHOLAS METHOD (Z-N)

Ziegler–Nichols tuning rules (and other tuning rules presented in the literature) have been widely used to tune PID controllers in process control systems where the pant dynamics are precisely known. Over many years, such tuning rules proved to be very useful. Ziegler–Nichols tuning rules can, of course, be applied to plants whose dynamics are known. (If the plant dynamics are known, many analytical and graphical approaches to the design of PID controllers 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 trial and error tuning method based on sustained oscillations that was first proposed by Ziegler and Nichols (1942) This method that is probably the most known and the most widely used method for tuning of PID controllers is also known as *online* or *continuous cycling* or *ultimate gain* tuning method. Having the ultimate gain and frequency (Ku and Pu) and using Table, the controller parameters can be obtained. A¼decay ratio has considered as design criterion for this method. The resulting controller transfer function for PID. Tuning of PID controller using Z-N method is explained in katsuhiko ogata [4].

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Controller	K_p	$τ_i$	$τ_d$
P controller	$0.5*k_{cu}$	-	-
PI controller	$0.45*k_{cu}$	Pu/1.2	-
PID controller	$0.6*k_{cu}$	Pu/2	Pu/8

Table 1: Tabulation for Z-N method

TUNING PROCESS INVOLVES:

- When the process is in steady state condition, remove integral and derivative modes by maximizing and minimizing the respective controllable parameters. This leaves proportional controller alone in action
- Set a proportional gain K_c and slightly disturb the system either by changing the setpoint 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 the ultimate gain K_{cu} and ultimate period P_u.
- From these values and from the above table the controller parameters are obtained

K_p= 18.18 **K_i= 2.00** **K_d =1.3998**

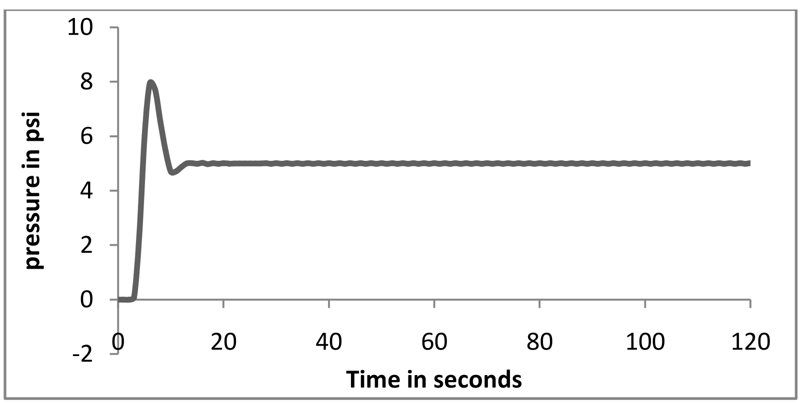

Figure 3: **Closed Response for ZN method**

B.INTERNAL MODEL CONTROL (IMC):

with reference to Coughanowr,[3] IMC has been used to this process. Internal model control (IMC), which is based on an accurate model of the process, leads to the design of a control system that is stable and robust. A robust control system is one that maintains satisfactory control in spite of changes in the dynamics of the process.

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In many industrial applications for control systems, none of the above items is available, with the result that the system usually performs in a less than optimum manner. Determining the mathematical model and its uncertainty can be a difficult task. In the IMC method, the integral square error is implied. IMC approach has two important advantages

- It explicitly takes into account model uncertainty
- It allows the designer to trade-off control system performance against control system robustness to process changes and modeling errors Proportional, integral and derivative constants.

The following tabulation is used to calculate the gain constant

CONTROLLER	**K.Kc**	**τi**	**τd**	**τF**	**RECOMMENDED $\lambda/d(\lambda>0.2\tau$ always)**
PID	$\frac{2\tau+d}{2(\lambda+d)}$	τ+d/2	$\frac{\lambda d}{2\tau+d}$	$\frac{\lambda d}{2(\lambda+d)}$	>0.25
PI	τ/λ	τ	-	-	>1.7
IMPROVED PI	$\frac{2\tau+d}{2\lambda}$	τ+d/2	-	-	>1.7

Table 2: Controller Tuning Formula for IMC

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

Kp=0.4498 **K_i= 0.7197** **K_d=0.41684**

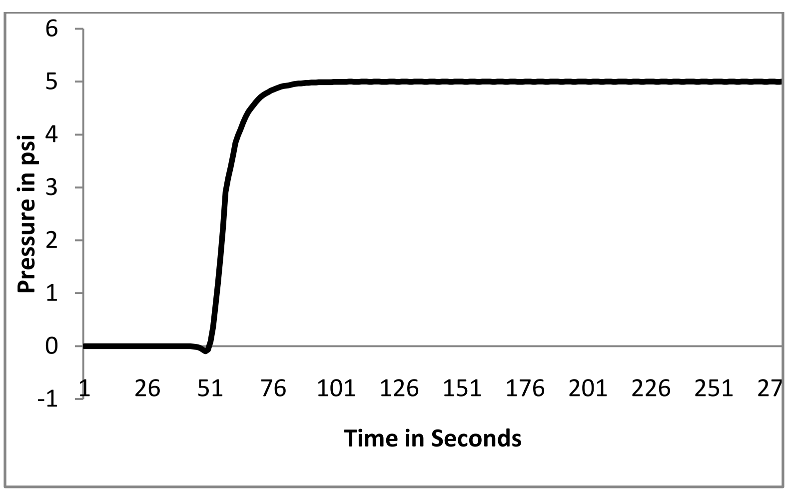

Figure 4: Response for IMC method

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V. COMPARISON AND RESULT ANALYSIS

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

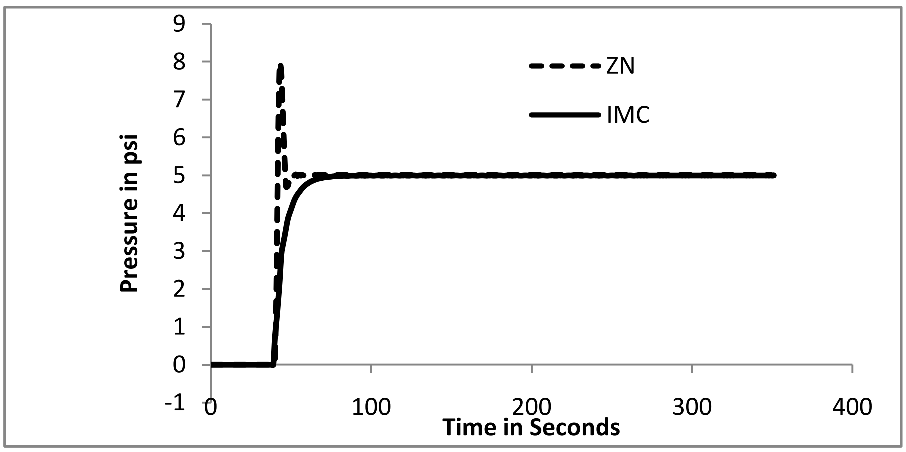

Figure 5: comparison of ZN and IMC

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 hand IMC has a perfect response required for a FOPDT transfer function with no peak overshoot and absolute settling time with no oscillations.

VI. CONCLUSION

The PID Controller is tuned with the values of Proportional band, Integral Time and Derivative time which are further converted into Proportional Gain (Kp), Integral Gain (Ki), Derivative Gain (Kd) with the help of k_{cu} and p_u values. from those values the Response is obtained using simulation done by LABVIEW. The results presented prove the effectiveness of IMC tuned PID controller than Z-N method. Hence IMC would be the suitable tuning method for a pressure process. The features of IMC illustrated in the work is by considering the problem of designing a control system for a plant of a first order system with time delay and by obtaining the possible results. The future scope of this work is aimed at providing a self-tuning PID controller with proposed algorithm so as to solve the complex issues for real time problems.

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