Volume 9, Issue 2, April 2022 ISSN: 2348-8565 (Online)

International Journal of Modern Engineering and Research Technology

Website: http://www.ijmert.org Email: editor.ijmert@gmail.com

Design and Implementation of Pressure Control Loop using IMC Based PID

Tejas Sunil Surve
B.E. Research Scholar
Instrumentation Engineering
Bharati Vidyapeeth College of Engineering,
Navi Mumbai, (M.S.) India
Email: tejassurve9895@gmail.com

Sarvesh Anil Sasane
B.E. Research Scholar
Instrumentation Engineering
Bharati Vidyapeeth College of Engineering,
Navi Mumbai, (M.S.) India
Email: sarveshsasane572@gmail.com

Ashutosh Shivendra Thakur
B.E. Research Scholar
Instrumentation Engineering
Bharati Vidyapeeth College of Engineering,
Navi Mumbai, (M.S.) India
Email: : thakurashutosh679@gmail.com

Shivansh Jaiprakash Sharma
B.E. Research Scholar
Instrumentation Engineering
Bharati Vidyapeeth College of Engineering,
Navi Mumbai, (M.S.) India
Email: shivsharmaansh@gmail.com

Jotiram Deshmukh
Assistant Professor
Department of Instrumentation Engineering
Bharati Vidyapeeth College of Engineering,
Navi Mumbai, (M.S.) India
Email: jotiram.deshmukh@bvcoenm.edu.in

ABSTRACT

Pressure process control systems have been refined and used in numerous implementations of in several process industries, pressure process plants are used, including chemical process industries, pharmaceuticals, wastewater treatment, power plants, etc. Measurement of Pressure is an essential parameter in different process industries which needs to be controlled. The objective of the work is to maintain the pressure in the closed loop at the desired setpoint. This work will deal with obtaining the real time response of a pressure process from which the system transfer function is identified. The piezoresistive measuring cell are essentially used in measurement of the gauge pressure and absolute pressure in a process control application. PID controllers are effectively used in controlling liner feedback systems with the suitable tuning methods. This paper focus on implementation of internal mode control (IMC) to obtain an optimal PID control setting for pressure process. The identification of the process system is done using the Process Reaction Curve method. To improve the robustness, internal model control method (IMC) is employed in tuning the PID controller. The results confirm that IMC-PID controller has improved dynamic performance on disturbance rejection.

Keywords:— *IMC, PID controller, Pressure process, PRC*

I. INTRODUCTION

This project belongs to process control loop and the loop under consideration is a Pressure Control (PC) Loop. Pressure control is important for many processes, for maintaining the stability and for producing the desired outcome of a process[1]. In pressure loops industry grade transmitter (E&H-PMP51CERAVAR) is used. During the pressure process, a control valve must be installed and a controller suitable in support of the framework must be selected. A PID is suitable in the majority of pressure management applications. There are hundreds of controllers of various brands and sizes to choose from, and the final decision will be based on the degree of performance and accuracy required, as well as budget constraints. The output of the pressure transmitter is connected to the measurement input of the controller, while the output of the controller is connected to the control valve. The set point can be manual or remote, depending on how the process connects to other parts of the plant. It is also necessary to trace the control actions of the controller.

PID control is the most common application of the control strategy today. With its simple structure and design, good robustness and wide application range, it is gradually highlighted in control theory. However, the existing PID controllers may not perform well in the complex control processes, such as the higher-order system and time-delay system[2]. Efforts have been put to fix this problem, and numerous effective controller design and tuning methods for complex processes have been stated. The optimization technique is used to determine the proportional, integral and derivative constants of these controllers. There are two commonly used methods of tuning, they are Ziegler-Nichols method and Cohen-Coon tuning method (very old methods) still widely used in several industrial applications because of their capability to achieve desired optimal performance. These traditional methods for tuning gain parameter results in large overshoot for servo and regulatory disturbances. Internal Model Control allow system designer to specify the anticipated system behaviour [2]. The robustness and performance of the model can be controlled by the single parameter (λ).In reality, a model is never perfect, so controllers must be designed to be robust, Internal model control (IMC) based PID controller has gained attention because of its robustness and single tuning parameter selection.

2. METHODOLOGY

2.1 Pressure Control Loop

Important Aspects of a Pressure Control System are Control Objective, Process Variable, Measurement Sensor, Measured Process Variable (PV) Signal, Set Point (SP), Controller Output (CO) or Manipulated Variable (MV), Final Control Element (FCE). The physical experimental system comprises of process tank, pressure transmitter, control valve, pressure controller, air supply, current to pressure converter, drain valve, compressor, and FRL unit.

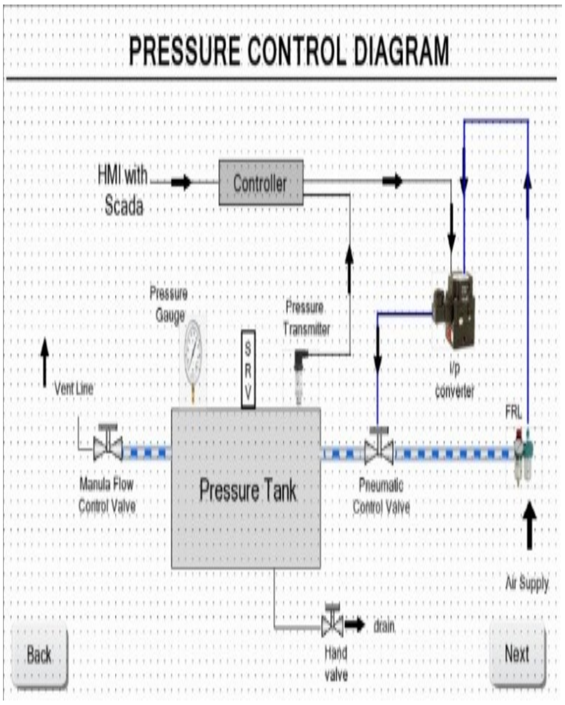


Figure 1: Process Flow Diagram of Pressure Loop.

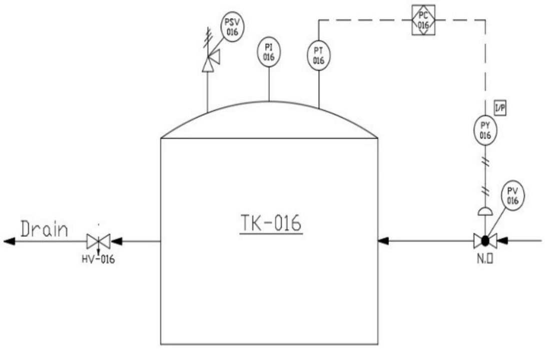


Figure 2: Piping & Instrumentation Diagram for Real time Pressure process.

Table I: Technical Description of Setup.

Part Name	Description
Process Tank	MOC: SS 304 Capacity: 10 Litres
Pressure Transmitter	Make: E&H- CERABAR PMP51 Sensing Element: Pie-zoresistive measuring cell
Pressure Gauge	Make SPAC Range: 0 to 10 bars
Safety Relief Valve	Range: 0 to 5 bars
Pneumatic Control Valve	Make: Pneucon Valve Type: Air to Close Cv= 0.63
I to P Converter	Make: Myko O/P: 4 to 20 mA I/P : 3 to 15 psi
Air Filter with Regulator	Make: Phoneix or Equivalent Range: 0 to 150 psi
Control Unit	Programmable Logic Controller Make: PVR Controls
Communication	RS 485/USB
Overall Structure Dimensions	LBH: 600*600*600 (mm)

2.2 Transmitters

In this project, industry grade transmitter is used for pressure measurement and transmitting the signal to the controller. The transmitter used is Cerabar PMP51 of Endress+Hauser. It is a digital pressure transmitter with metal membrane is typically used in process and hygiene applications for pressure, level, volume or mass measurement in liquids or gases. PMP51 is designed for high pressure applications up to 400bar. SIL2 according to IEC 61508 and IEC 61511.

Parameters	Values
Accuracy	Standard 0.1% Platinum 0.075%
Process temperature	-40°C...125°C (-40°F...275°F)
Pressure measuring range	1 bar...400 bar (15 psi...6000 psi)
Process pressure absolute / max. overpressure limit	600 bar (9000 psi)
Measurement distance	4000 m (13.123 ft) H_2O
Material process membrane	316L, AlloyC, Rhodium>Gold
Measuring cell	400mbar...400bar (15psi...6000psi) rela-tive/ absolute
Communication	4...20 mA HART PROFIBUS PA FOUN-DATION Fieldbus IO-Link

Benefits

- Accurate measurement of the process value even in the case of changing process temperature
- Process safety assured with small flush mounted process connections in hygienic applications
- Modular concept for easy replacement of display or electronics
- Easy menu-guided commissioning via on-site display, 4 to 20mA with Hart,

Profibus PA, Foundation Fieldbus

- Seamless and independent system integration (HART/PA/FF)
- Available with mounted manifolds: always fit, always tested for leaks

III. SYSTEM IDENTIFICATION

Process identification is nothing but the study of dynamics of the process. Process identification can be used to build a consistent model, after the process has been set in operation. Open loop identification is widely used it is a step change in input is applied to the process which will produce a corresponding response. There are several graphical user interface toolboxes available for modelling. Commonly Process Reaction Curve method is used which is based on the step response.

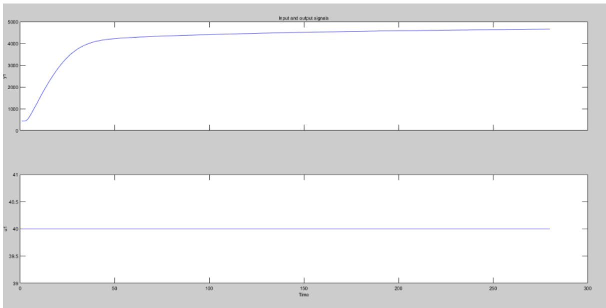


Figure 3: Plant Step Response

In this method, the small step change is introduced with the help of manual controller [4]. For every input, the transient is recorded. In the graph, a straight line is drawn tangent to the transient curve at the inflection point. The tangent line intersects the curve in time axis at a point called transportation lag (Ʈd). The apparent time constant (Ʈ) and the steady state gain (kp) are measured. The transfer function of the pressure process is a SISO system, obtained from the above process response which is obtained until the process is stabilized without influence of PID Controller Action [5]. For many processes, the process reaction curve is a S-shaped curve. This S shape curve is characteristic of many high-order systems and such plant transfer functions may be approximated by the mathematical model can be expressed as

$$\frac{k_p e^{-\tau_d(s)}}{\tau_s + 1}$$

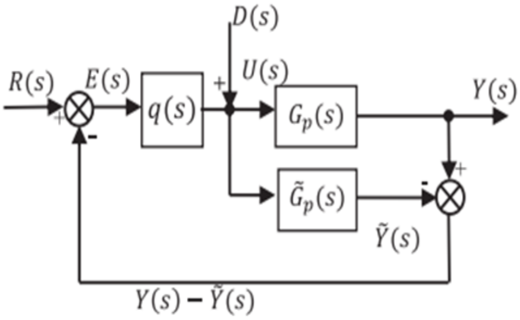


Figure 4: General Model of IMC

3.1 Internal Model Control (IMC) Strategy

Internal model control is based on a precise model based on the mathematical model of the process. The control system leads to stable and robust. A stable control system is one which keeps suitable control action for the dynamic changes in the control system. IMC-PID design steps for first-order plus dead time (FOPDT) process with open loop process gain, time constant, and dead time of the process respectively can be defined as[3]:

Step 1: Select the plant and consider the transfer function of the plant. Process dead time (θ) is approximated by the Taylor series or Pade's approximation technique. First-order Pade's approximation is found to be the most well accepted approach.

Step 2: Estimated process model obtained from Step I is factorized into inverting and non-inverting parts as given by

$$\tilde{G}_p = \tilde{G}_{p+}(s)\tilde{G}_{p-}(s)$$
$$= \frac{k_p}{(\tau_p s + 1)(0.5\theta s + 1)}(-0.5\theta s + 1).$$

Step 3: Model inversion is made for the invertible part.

$$\tilde{q}(s) = \tilde{G}_{p+}(s)^{-1}$$

Step 4: Add the filter to make q(s) proper. Now find the PID equivalent. Recall that we can expand the numerator term to find

$$g_c(s) = \left(\frac{1}{k_p}\right)\frac{0.5\tau_p\theta s^2 + (\tau_p + 0.5\theta)s + 1}{(\lambda + 0.5\theta)s}$$

we can multiply above equation by

$\tau_p + 0.5\theta / \tau_p + 0.5\theta$ to find the PID parameters

$$k_c = \frac{(\tau_p + 0.5\theta)}{k_p(\lambda + 0.5\theta)}$$

$$\tau_I = \tau_p + 0.5\theta$$

$$\tau_D = \frac{\tau_p\theta}{2\tau_p + \theta}$$

The above equations represent the conventional IMC-PID settings for FOPDT processes. With these settings, the IMC-based PID controller is capable of providing acceptable set-point tracking.

The robustness, disturbance rejection and dynamic performance of the system is openly associated to ⋋. If ⋋ is larger, the dynamic characteristics is poor with improved robustness. If ⋋ is small, robust of the system will become worse and improved dynamic characteristics. So, ⋋ selection plays a vital role in IMC-PI controller, so the selection of ⋋ need to compromise. Desired performance can be achieved by adjusting the filter time constant.

IV. Result and Discussion

The controller parameters are calculated and applied for set point 1psi. The servo response of the system was witnessed by giving set points of 1psi, 2psi, 3psi, 4psi. The deviation of pressure from reference point is noted.

$$G_p(s) = \frac{4e^{-3s}}{17s+1}$$

$$e^{-3s} = \frac{-1.5s+1}{1.5s+1}$$

$$G_p(s) = \frac{(-1.5s+1)}{(17s+1)(1.5s+1)}$$

$$= -1.5s + 1$$

$$\tilde{G}_{p-}(s) = \frac{4}{(17s+1)(1.5s+1)}$$

$$Q(s) = \frac{(1.5s+1)(17s+1)}{4(\lambda s+1)}$$

Ʈ1 = 1.5 Ʈ2 = 17 K= 4 β = 1.5

Now classical feedback controller equation is

$$C(s) = Kc\,[1 + \frac{1}{Ʈi(s)} + Ʈds]$$

$$Kc = \frac{Ʈ1 + Ʈ2}{K(\beta + \lambda)} = \frac{17+1.5}{4(1.5+2.4)} \quad [\lambda > 0.8\theta\,]$$

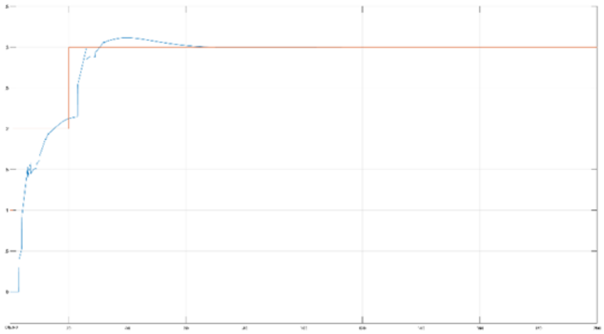
$$Kc = 1.186$$

$$Ʈ_1 = 17+1.5 = 18.5$$

$$Ʈ_2 = \frac{17*1.5}{17+1.5} = 1.378$$

$$K_i = \frac{1.186}{18.5} = 0.0641$$

Optimum values occur at= ⋋ 5



K_p = 0.711K_i = 0.0641K_d = 1.634

Figure 5: Servo Response of Process

V. CONCLUSION

The control of pressure in tanks is one of the basic problems in process industries. To overcome this IMC PID controller is implemented. We have proposed an efficient way to design the PID controller that can be implemented in a real-time compression process. IMC structures have claimed improvements in control quality compared to PID for simple systems where a properly tuned PID controller would show a good result. From the consequences, the response of IMC was shown satisfactory as compared to other tuning methods. From the response, it is witnessed that the IMC-PID tracks the set point with lessoscillation. The simulation results have proven that IMC-PI control setting is more effective way in disturbance rejection and to enhance the stability of system.

REFERENCES:

[1] D. N. Pawar, "Designing IMC based Controller for Process Loops", IRJET, Navi Mumbai, 2021.

[2] P Aravind, "IMC Based Design of PI Controller for Real Time Pressure Process", IJIREEICE, Tiruchirappalli, 2015.

[3] Ujjwal Manikya Nath, Chanchal Dey & Rajani K. Mudi, "Review on IMC-based PID Controller Design Approach with Experimental Validations", IETE Journal of Research, 2021.

[4] Dr. Duraid Fadhel Ahmed, Dr. Salam K. Hassan & Mr. Lokman Aziz Abdul -Karim, "Stability Analysis and Design of Pressure Control System", Tikrit Journal of Eng. Sciences/ Vol.15/No.3/September 2008, (64-76).

[5] P. Aravind, "Design of Model Based PID Controller Tuning for Pressure Process", IJAREEIE, Tamilnadu, 2015.

* * * * *