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Real time Controlling and Monitoring of Level and Pneumatic process using LabVIEW

Mr.P.Thirumurugan¹, Arshad Alam Mohammed .M^{2*}, Karthikeyan.S³, Marimuthu.D⁴, Vijay.P.S⁵

¹Assistant Professor, Department of ICE, Saranathan College of Engineering, Tamil Nadu, India.

^{2, 3, 4, 5} UG Student, Department of ICE, Saranathan college of Engineering, Tamil Nadu, India.

*Corresponding author

Abstract

This paper represents the National Instruments LabVIEW based real design of Proportional-Integral-Derivative (PID) controller for Level and Pneumatic pressure control. The level tank and pneumatic tank is SISO (Single Input Single Output) system. This project aims at designing and implementing a conventional PID controller for level and pressure process at the two different process stations. Level control of a liquid and pressure control of a gas or air in a process tank is achieved by a PID controller through an actuator. The PID controller gives response outputs which have minimum overshoot and minimum steady state error. The process block diagram is formulated using LabVIEW icons, controls and indicators. The PID controller is tuned using various tuning techniques.

Keywords: PID controller, LabVIEW, level control, pressure control, process tank, DAQ.

1. Introduction

Level control and pressure control plays a vital role in process control industry like, power plant, petrochemical industry etc. This process enables the continuous process in which the change in process parameter is adjusted to get desired performance. This can be implemented by using PID controller and monitoring in LabVIEW front panel.

The fuzzy PID control theory is used for controlling the output flow which arbitrary controlled. Since the conventional PID controller output is uncertain for achieving the desired results. Thus the fuzzy control algorithm used in liquid level to get desired performance. These results have precise control and have square of error up to 0.0008[1]. PLC control and fuzzy algorithm of a closed loop system for liquid level which has nonlinear, big lag mathematical model is difficult to achieve by conventional PID control. The fuzzy PID control system can automatically and manually start pump and stop and switching the alarm fault. [2].

The controller is tuned by conventional method such as Ziegler Nicholas, to tune the control action. Later this is designed in PID incremental fuzzy control system and inverse neuro mode controller. This is implemented in LabVIEW and compared with other implementation [3]. In LabVIEW based PI controller for controlling CE coupled tank system, it uses two PI controllers to maintain the liquid level accurately. This PI sub VI is available library that provides reasonable performance. The PI controller is derived from the mathematical model of the process. The change in system parameter provides robustness. [4]

This paper is based on PLC control system, to control liquid level in tank using wireless sensor. The maximum and minimum level of this tank is measured by magnetic response of sensor. This response signal can be controlled by PLC to pump water from system to maintain actual performance. [5]. This paper presents the implementation of fuzzy based level control using SCADA. The PLC is connected to the level control set. The fuzzy algorithm membership function is designed in Matlab Simulink. This algorithm is implemented in PLC. The SCADA is used to monitor the process such as actuator, valve position and level in the tank. [6]

The PI controller is implemented in PLC to control the level. Using NI-LabVIEW, a SCADA screen is developed to monitor the process and communicate between PLC and LabVIEW is carried by MODBUS RTU. The mathematical model is formulated by mass balance equation and results are compared with other performance of controllers [7]. The output pressure of needle valve in the hydraulic circuit is designed and controlled using PID controller. The servomotor is used to control the needle valve by acquiring the control signal from controller. The pressure sensor at the outlet is used to measure the pressure and given as feedback signal [8].

The pressure parameter in wind tunnels used for the testing purpose. The pressure regulating valve is incorporated in the wind tunnels so that pressure variation can be achieved during test section. The variation in pressure is developed by PID controller to maintain the pressure in regulating valve. This process can be monitored in LabVIEW. [9]. The control of pressure in fuel pressure regulator. This can be designed using BP neural network of PID controller. The PID controller parameters such as K_p , K_d and K_i are adjusted with self-learning capability of neural network which provides precise control over the traditional control of PID. This program has been implemented in LabVIEW software and it also used to monitor the process [10]. The supervisory hierarchical fuzzy controller for regulating real time pressure control system. The intelligent fuzzy algorithm system is designed for set point changes and load disturbances. This fuzzy algorithm is implemented in ARM 7 microcontroller based board for nonlinear system. The supervisory hierarchical fuzzy controller has better performance, robustness and stability as compared with other results [11].

The main objective is to give a proper model of the pressure and Level control system and thereby making easier the real implementation and controller tuning. The other objective is it is an automation process and it can be controlled using our PC and Laptops. The output of the process can be stored and it can be retrieved and reviewed. This program can be easily interfaced with other real word components for controlling the process effectively.

2. Controller

A PID controller is a device used in industrial control applications to regulate flow, temperature, pressure, level, speed and other process variables. A control loop feedback mechanism is used by PID controllers to control the process variables and it is the most accurate ,precise and stable controller. PID controllers have three modes of control:

1. Proportional (P)
2. Integral (I)
3. Derivative (D)

Each of the three control modes reacts differently to the error occurs accordingly. The amount of output response produced by each control mode is adjustable by changing the controller's tuning settings gives time domain specifications. The PID controller gives an

output response which has minimum overshoot and low steady state error as compared to other controllers. But it has less oscillations and it may affects the system stability.

The relationship between the input $r(t)$ and output $c(t)$ with error signal $e(t)$ can be formulated for PID controller is given as

$$C(t) = K_p e(t) + K_I \int e(t) dt + K_D de(t)/dt \quad (1)$$

In Laplace domain, the transfer function of the system is given as follows:

$$G(S) = K_p + K_I/s + K_D s \quad (2)$$

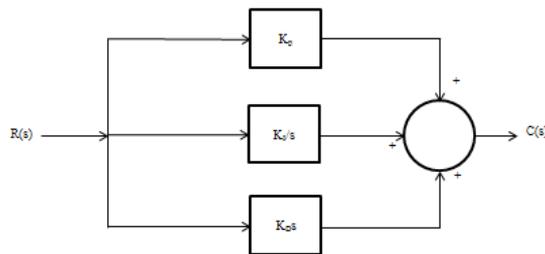


Fig.1 - PID block diagram

III. SCHEMATIC DIAGRAM

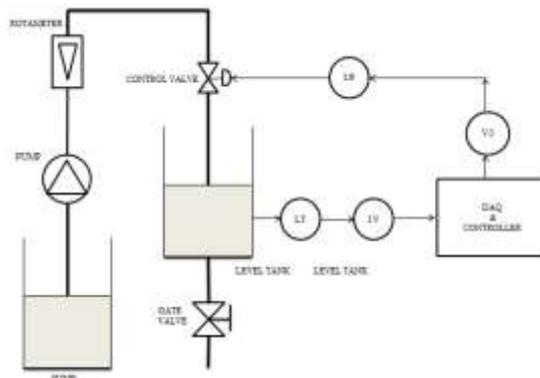


Fig. 2 - Schematic diagram (level tank system)

This Fig 2 represents the general schematic diagram of the level process control system. The water at ground level sump may be pumped to the process level tank through a pneumatic normally open control valve. The electrical pump is energized with the AC supply of 50 Hertz frequency and 230 volt. The liquid flow to the level tank may be regulated by a rotameter in terms of litres per hour (LPH). A gate valve can be used to influence and deviate the level inside the tank if any deviation occurs. The level in the process tank from the process station may be acquired using any active sensor like IR, proximity sensors or passive transducers like resistive, inductive, capacitive level transmitters through any data acquisition module (DAQ) or NI-myRIO. The controller will give an actuating signal to the pneumatic control valve (normally open or close) through a current to pressure (I/P) converter follows flopper nozzle mechanism which will give manipulating signal so as to maintain the level in the process tank.

This Fig.3 represents the general schematic diagram of the pneumatic control system. The air from the compressor can be supplied to pressure tank. The supply air may be regulated by a gate valve. The pressure inside the process tank can be acquired using any passive or active sensors or through any pressure transmitters of (4-20)mA range from the pneumatic pressure process station. The process variable may be fed to the controllers through any data acquisition module so called myRIO.

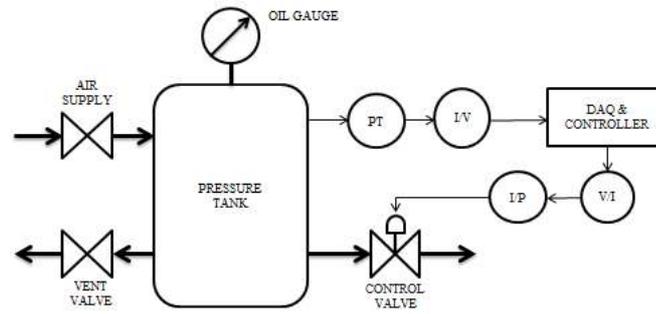


Fig. 3 - Schematic diagram (Pressure tank system)

The controller will give a actuating a signal to the pneumatic control valve so as to track the set point (normally open or close operated in 3 to 15 psi with maximum 100 psi supply).

3. LabVIEW Programming

LabVIEW (Laboratory Virtual Engineering Workbench) is both a software and hardware platform and development environment for a visual programming language from National Instruments of US. Each VI has three components block diagram, connector pane and front panel. LabVIEW ties the creation of user interfaces (called front panels) into the development cycle. LabVIEW programs or subroutines are called virtual instruments (VIs). Each VI has three components: a block diagram, front panel and icon/connector panel. The front panel is built using control palette and indicators built by function palette. Controls are inputs – they allow a user to supply information to the VI. Indicators in block diagram are the outputs – they indicate or display, the results based on the inputs given to the front panel of VI. The back panel, which is a block diagram, contains the graphical source code. All of the objects placed on the front panel will appear on the back panel as terminals. The back panel also contains structures and functions which perform operations on controls by users and output data to indicators. The structures and functions are found on the Functions palette and can be placed on the back panel. Collectively controls, property nodes, indicators, structures and functions will be referred to as nodes.

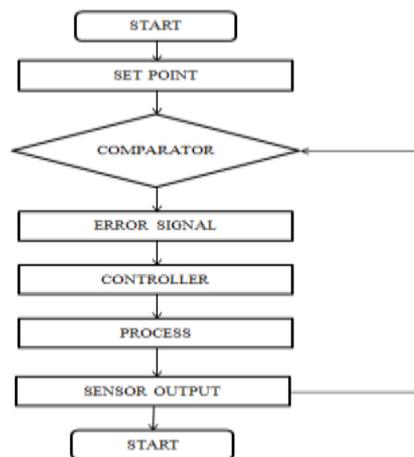


Fig. 4 - Flow chart

Setpoint is given to comparator through operator. Sensor output is given to comparator. Comparator output is the error signal. If error signal occurs, it goes to controller and controller controls the process by using the control valve.

An Virtual Instrumentation (VI) program has a user interface called Front Panel. We program and build the front panel by using controls and indicators of LabVIEW, which are the interactive input and output terminals of the VI and sub VI. Controls are push buttons, knobs, dials, and other located on the controls palette of front panel.

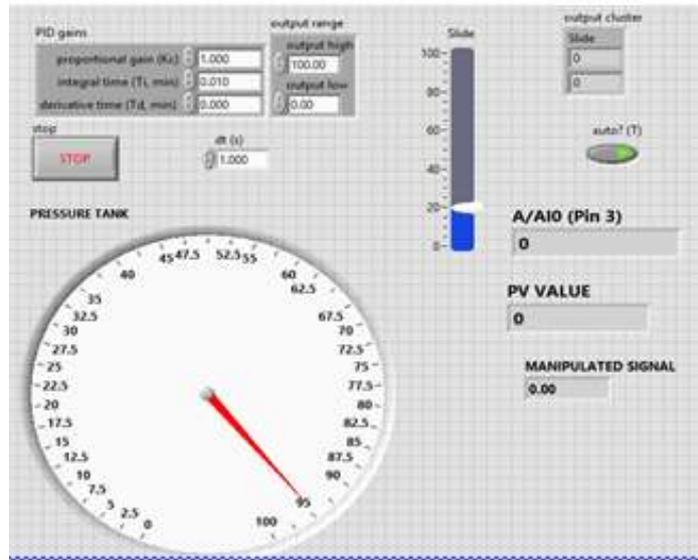


Fig. 5 - Pressure Process Front Panel

In Figure 6, this figure represents the front panel of the pressure process in NI-LabVIEW. The vertical slide is used to set the setpoint for the pneumatic process. The Pressure Tank indicator shows the pressure inside the process tank. The change in pressure value reflects the process variable change of the pneumatic system. The P, I&D values are given to the PID gain block such that the response of the process is recorded in the process chart waveform of the pressure process .The output cluster is used to display the process variable and the setpoint given to the given process. Stop button is used to terminate the program of the pressure process.

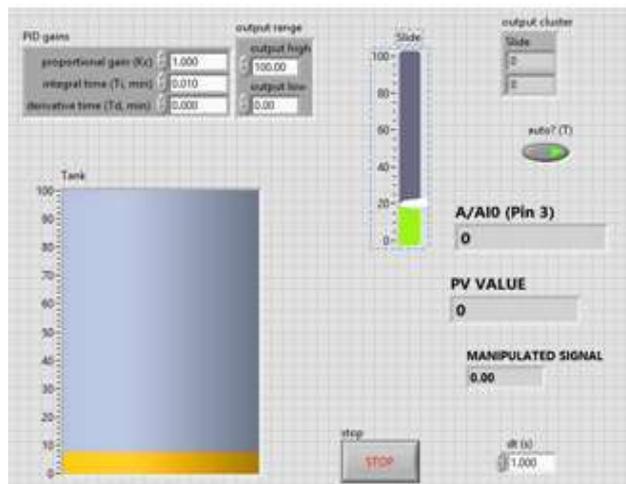


Fig. 6 - Level Process Front Panel

In the Figure 5, similar to pressure process, the vertical slide is used to set the setpoint for the level process. (The setpoint is the input parameter given defined as the desired or target value for an essential variable or process value of a specific system). The Level Process Tank indicator shows the level inside the tank may be cylindrical – linear system. (The change in level value represents the change in process variable). The P, I&D values are given to the PID gain block the response of the process is recorded in the process chart waveform graph. The output cluster is used to display the process variable and the setpoint given to the process. Stop button is used to terminate the program of process.

4. Controller Tuning

A PID controller is considered to be a traditional one it is used in many process industries. The representation or the implementation of the process may vary, but the performance of it is still continuing by providing its efficiency and stability. The PID controller can thus be said to be the “bread and butter” of control engineering. It is an important component in every control engineer’s tool box .

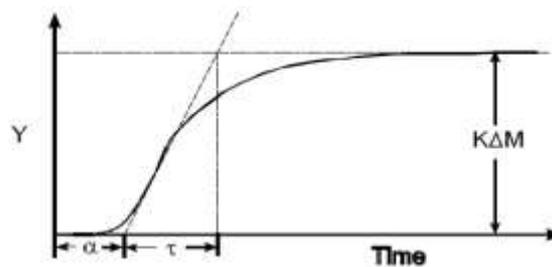


Fig. 7 - Process Reaction Curve

The Fig.7 shows the process reaction curve which is used to determine the transfer function of the given system. It is also known as the S-shaped curve. L denotes the delay time and τ denotes the time constant which is 63.2% of final value and K denotes the gain of the system. It is identified by doing an open loop step test of the process for identifying the process model parameters. For PID controller, there are thousands of tuning methods available and for these processes model Ziegler Nichol, Cohen Coon and Skogestad methods can be used.

4.1. Ziegler Nichol’s Method I

It is introduced in 1940's which made a big impact among the control engineers regarding the control of a process using PID technology. Ziegler Nichol's is a kind of technique which provides the improved performance, ease of use, low cost. Even though, it is widely used due to the stability concern engineers used it reluctantly. It is a heuristic tuning rule which attempts to provide the efficient values for the process containing PID controller. .

Table 1 - Formulae for Ziegler Nichol I

Control Mode	K_p	τ_i	τ_d
P	$\frac{1}{K} \left(\frac{\tau}{\alpha} \right)$	-	-
PI	$\frac{0.91}{K} \left(\frac{\tau}{\alpha} \right)$	3.33α	
PID	$\frac{1.2}{K} \left(\frac{\tau}{\alpha} \right)$	2.0α	0.5α

4.2. Cohen Coon Method

It starts with a low value of K_p and perturb the system input to an oscillation in output. By increasing the K_p value, sustained oscillation is observed. K_u used is the smallest value of K_p , which achieves oscillation and P_u is the period of oscillation at K_u . COHEN COON procedure is quite similar to the Ziegler– Nichols method but the final controller settings are different. Also this method only proposes settings for PI and PID controllers.

Table 2 - Formulae for Cohen Coon

Type	K_c	τ_i	τ_d
P	$\frac{1}{k} \left(\frac{\tau}{\alpha} \right) \left[1 + \frac{1}{3} \left(\frac{\alpha}{\tau} \right) \right]$		
PI	$\frac{1}{k} \left(\frac{\tau}{\alpha} \right) \left[0.9 + \frac{1}{12} \left(\frac{\alpha}{\tau} \right) \right]$	$\alpha \left[\frac{30 + 3 \left(\frac{\alpha}{\tau} \right)}{9 + 20 \left(\frac{\alpha}{\tau} \right)} \right]$	
PD	$\frac{1}{k} \left(\frac{\tau}{\alpha} \right) \left[\frac{5}{4} + \frac{1}{6} \left(\frac{\alpha}{\tau} \right) \right]$		$\left[\frac{6 - 2 \left(\frac{\alpha}{\tau} \right)}{22 + 3 \left(\frac{\alpha}{\tau} \right)} \right]$
PID	$\frac{1}{k} \left(\frac{\tau}{\alpha} \right) \left[\frac{4}{3} + \frac{1}{4} \left(\frac{\alpha}{\tau} \right) \right]$	$\left[\frac{32 + 6 \left(\frac{\alpha}{\tau} \right)}{13 + 8 \left(\frac{\alpha}{\tau} \right)} \right]$	$\left[\frac{4}{11 + 2 \left(\frac{\alpha}{\tau} \right)} \right]$

4.3. Skogestad Method

Skogestad’s PID tuning method 1 is a model-based tuning method where the controller parameters are expressed as functions of the process model parameters..

Table 3 - Formulae for Skogestad

TYPE	G(S)	K_p	T_i	T_d
TIME CONSTANT	$\frac{K}{TS+1}$	$\frac{K}{Tc+T}$	$\min(T,c(Tc,T))$	0.00

5. Graphs and Results

The graphs and waveforms for the level and pressure process has been recorded through the controller parameters obtained from the Cohen coon and Ziegler Nichols method.

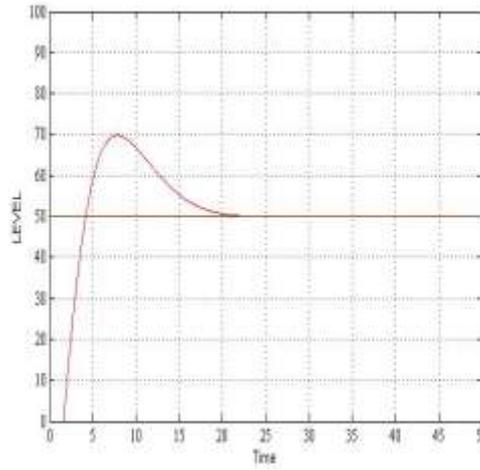


Fig. 8 - Response by Cohen Coon method (Level)

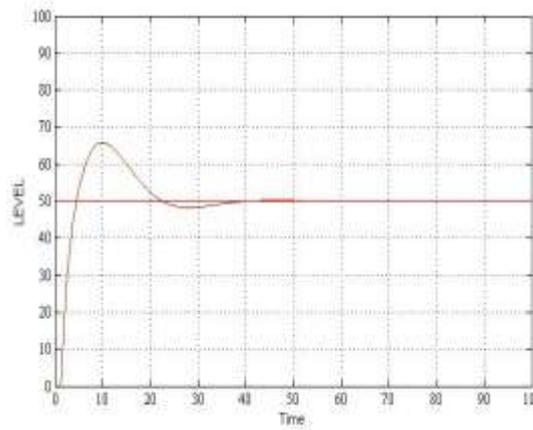


Fig. 9 - Response by ZN I method (Level)

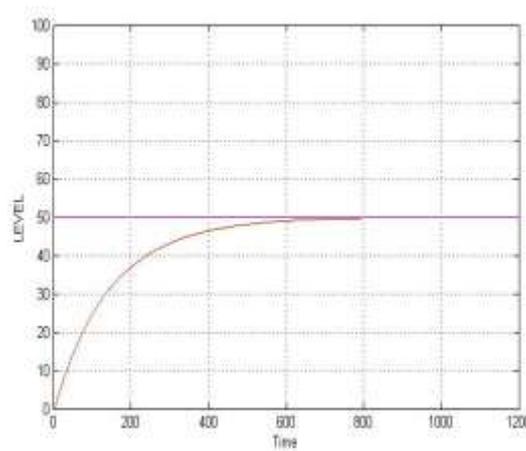


Fig. 10 - Response by Skogestad method (Level)

The above graphs are the responses of the level process. The response for the pressure process and its waveforms are given below

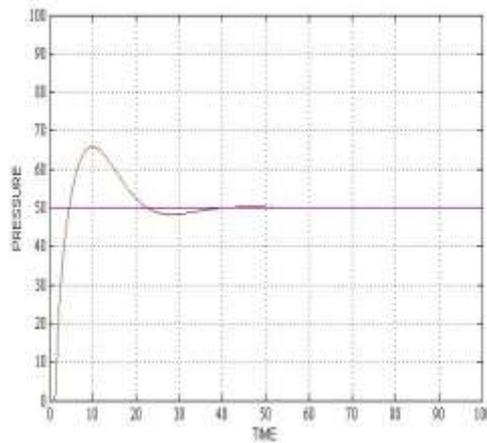


Fig. 11 - Response by Cohen Coon method (Pressure)

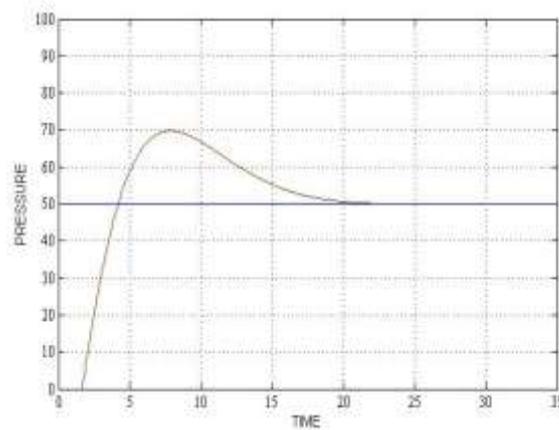


Fig. 12 - Response by ZN I method (Pressure)

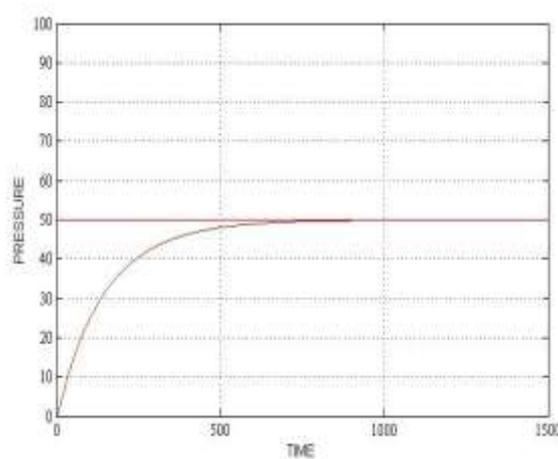


Fig. 13 - Response by Skogestad method (Pressure)

6. Conclusion

In this paper we initially find out the response of an open loop pressure and level process. By using two methods Process Reaction Curve find the module which has value closer to actual response. By using the transfer function find the optimum value of PID by comparing three different tuning techniques Ziegler-Nichols (Z-N), Skogestad, Cohen-Coon (C-C) from the response find the optimum PID value. Comparing the response of three tuning methods on basis of time domain specifications and performance error criteria it is found that Skogestad method will have optimum value. The pressure and level value is acquired in terms of voltage and produces corresponding manipulating signal based on the setpoint and current process variable value. Corresponding output in terms of is generated by including the optimum value of PID controller and with the help of I/P converter and pneumatic control valve.

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