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Labview Based Gain scheduled PID Controller for a Non Linear Level Process Station

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Abstract: *The primary aim of this paper is to get advantage of computer based system. The Hardware PID is replaced with soft PID that has equal controlling capabilities as that of instrument. Virtual Instrumentation PID controller is implemented using software called LabVIEW developed by National Instruments. We have used a Data Acquisition board (DAQ) for interfacing with the hardware. This DAQ card is product of the same company National Instruments.The process is a Multi-loop Trainer set up mounted with a tank whose level has to be controlled using a feedback control loop. The flow of project execution is: The measured inputs to the designed PID will be provided by Level transmitter. The designed PID will be generating the necessary controlling electronic signal. This signal will be acquired by DAQ card. The DAQ card transfers it to the I / P converter which will convert the electrical pulses 4-20mA into pneumatic signal 3-15psig to actuate the control valve. This virtual PID can replace hard wired PID. By virtual PID implementation we are getting freedom of reconfiguration and flexibility of control strategy*

Keywords: *I/P coverter , LabVIEW, PID Controller, pressure transmitter*

I. Introduction

This project aims to design a suitable controller which can be incorporated with any non-linear processes. Conical tank level is the best examples for a non-linear process. Hence, a conical tank system is used here as the plant for the design and analysis of a suitable controller for non-linear processes.PID controller is a three action most widely used controller is process control. Here "P" represents proportional control action, "I" represents integral control and "D" represents derivative control action. It has tuning constants which brings the process value as close to the desired operating point i.e. set point . Setting the parameters of PID is called as tuning of PID controller, which controls the respective control actions. In most conditions ,the requirement is that the controller should act in such a manner that the process value is as close to the set point as possible. The control engineer uses the PID algorithms to achieve this. Proportional action: It simply amplifies the error based upon the gain. P mode generates offset. Integral action: The integral term magnifies the effect of long-term steady- state errors, applying ever-increasing effort until they reduce to zero. Derivative action: The derivative part is concerned with the rate-of-change of the error with time: If the measured variable takes longer duration to approach the set point the derivative action would speed up the controller action so that the process variable will rapidly reach the set point. Derivative action makes a control system behave much more intelligently. High value of Derivative constant would make controller action oscillatory. To obtain soft PID controller is possible by programming the PID algorithm using some high level language such as C , Fortran, Use of high level language allow us to use floating-point math [6][7]. LabView is a very good high level language with an additional advantage of built in graphical user interface (GUI). It is quite user-friendly software and flexible to give better system performance. To provide improvements is an easy task in LabVIEW based soft PID. The system performance can be observed by the graphical representations of set point, process value, control signal, etc. The transient specifications such as overshoot, settling time, offset error, response time can be obtained from the graphs and PID algorithm can accordingly change the proportional gain, reset time and derivative time in order to get desired performance.

II. System Modeling

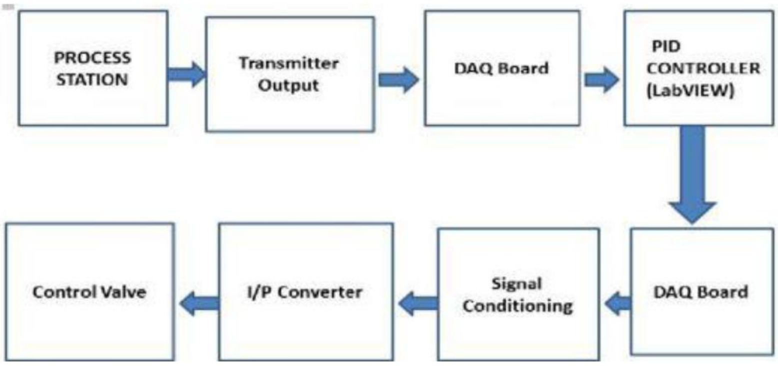


Fig. 1 Process Block Diagram

[3][4] Figure 1 shows the process block diagram of overall system. Level is measured by level transmitter, outputs of which is 4-20 mA signal. This transmitter signal is fed to LabView Based PID Controller through DAQ. LabView based PID Controller which is used generates the control signal. The control signal is a voltage signal, which is converted to current using V-I convertor circuit. The output of V-I is given to I/P convertor which manipulates the inlet flow control valve.

The level process station used here is a Non-linear plant of YOKOGAWA. The plant has two tanks, tank 1 (spherical) and tank 2 (conical), which is having capacities of 56 L and 33 L respectively. Two tanks are attached with two level transmitters . These level transmitters will give analog current output 4 20 mA as the level (or volume) varies from 0 – 100.

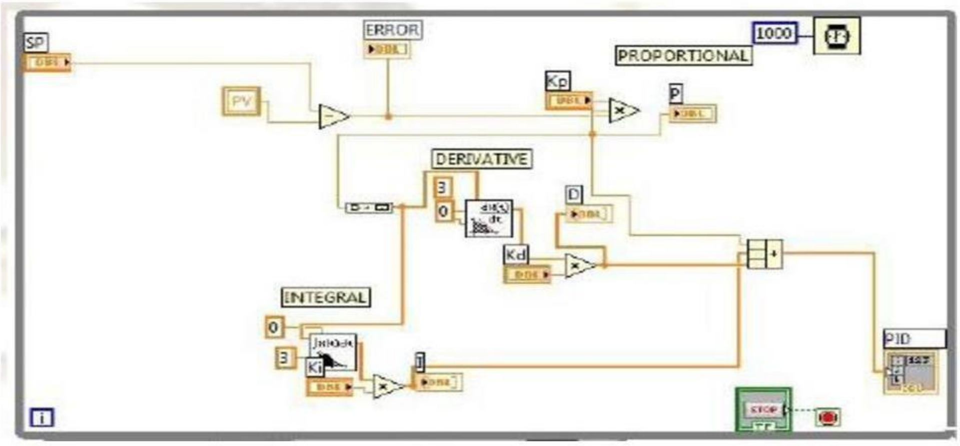


Fig 2 PID Block Diagram

PID Controller

Here for controlling level of process setup PID controller is used. The existing hardware based PID is bypassed and LabView based PID is designed. Figure shows Block Diagram VI. For programming Block diagram VI in LabView a While Loop is selected and transmitter signal acquired by DAQ Asst was converted from 4-20mA to 1-5 Volts and given to PID VI input as process variable. Numeric Indicator Tank tool is used which displays real time level in the tank. Set point is given through Numeric Control of Vertical pointer slide tool. PID Input / Output range is set to 1-5 Volts. D(t) is set to 1. PID gains selected by trial and error method and given as input to PID VI. The output of PID controller is given to DAQ Asst. 2 to generate control output at output port. The PID Controller output is also viewed on numeric indicator tool simultaneously. All three real time values of controller output, process variable and set point are displayed on waveform chart.

NI DAQ PCIe 6321

NIX Series multifunction data acquisition (DAQ) devices provide a new level of performance with the high- throughput PCI Express bus, NI-STC3 timing and synchronization technology, and multicore-optimized driver and application software. PCI Express offers dedicated bandwidth of up to 250MB/s in each direction to each device, and X Series devices feature a native PCI Express interface with optimizations for high throughput.

III. Simulation and Result

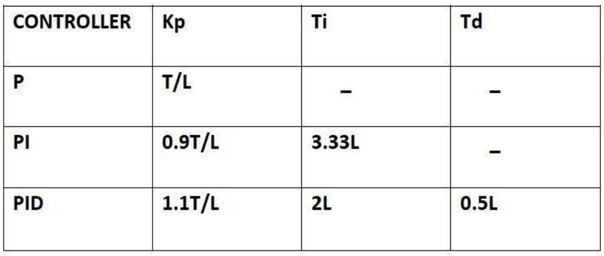
Design of the Gain Scheduled PID Controller

A proportional-integral-derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems.A PID controller calculates an "error" value as the difference between a measured process variable and a desired setpoint. [5]The controller attempts to minimize the error by adjusting the process control inputs. The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV). The proportional, integral, and derivative terms are summed to calculate the output of the PID controller. Defning u(t) as the controller output, the final form of the PID algorithm is:

$$u(t) = K_P\, e(t) + K_p K_i \int e(t)dt + k_p\, k_d \frac{de(t)}{dt}$$

Quarter Amplitude Decay Ratio

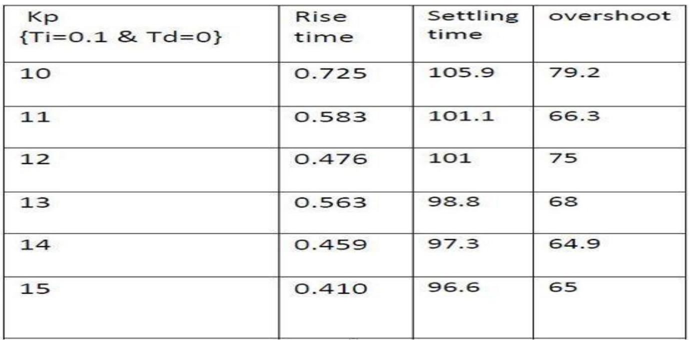
[1][2]The design of PID controller involves the selection of the controller paramerets (Kp, Ti and Td). The starting values of the PID controller settings can be obtained from the following tuning formulas. This tuning formula is according to the quarter amplitude decay ratio.



CONTROLLER	Kp	Ti	Td
P	T/L	–	–
PI	0.9T/L	3.33L	–
PID	1.1T/L	2L	0.5L

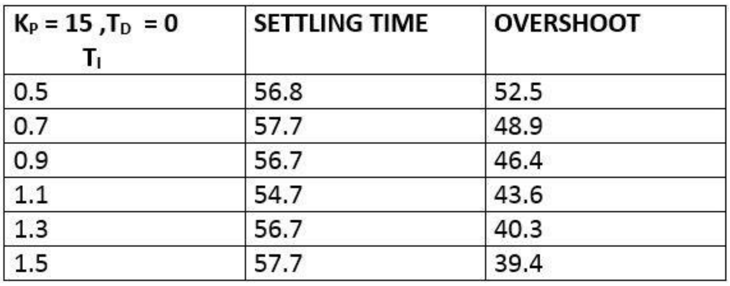
Table 1.1 Quarter Amplitude Decay Ratio

The table indicates the step response (simulation results) of the system with proportional only controller for various values of Kp.



Kp {Ti=0.1 & Td=0}	Rise time	Settling time	overshoot
10	0.725	105.9	79.2
11	0.583	101.1	66.3
12	0.476	101	75
13	0.563	98.8	68
14	0.459	97.3	64.9
15	0.410	96.6	65

The value of Kp at which minimum deviation in overshoot is taken as the optimum or best value. So, here Kp =15 is selected.



K_P = 15 ,T_D = 0 T_I	SETTLING TIME	OVERSHOOT
0.5	56.8	52.5
0.7	57.7	48.9
0.9	56.7	46.4
1.1	54.7	43.6
1.3	56.7	40.3
1.5	57.7	39.4

Ti value at optimum overshoot and minimum settling time is selected. So, Ti= 1.1, is selected.

K_P =15, T_I = 1.1 T_D	RISE TIME	OVERSHOOT	SETTLING TIME
0.02	2	44.8	19.4
0.05	2	44.6	19.5
0.1	2.1	44.1	19.5
0.2	2.2	43.3	19.6
0.4	2.4	41.7	19.8
0.5	2.4	41	19.8
1	2.6	37.7	20.2

Thus the PID controller is designed with the following controller settings:

K_P	T_I	T_D
15	1.1	0.4

Gain Scheduled PID Controller

Here, the controlled output (percentage of valve opening) is divided into four regions, the Region 1 corresponds to the valve opening from 0 - 25 . region 2 corresponds to25 - 50 ., region 3 corresponds to 50 -75 .and region 4 corresponds to 75-100 .The PID controller settings must be found out for each region. This can be done by the same procedure as described above . Thus the region wise modelling is as follows:

REGION	K	L	T	G(S)=$\frac{K}{Ts+1}e^{-Ls}$
1: 0-25%	1.11	14.29	124.64	G(S)=$\frac{1.11}{124.64s+1}e^{-14.29s}$
2: 25-50%	1.32	14.29	115.91	G(S)=$\frac{1.32}{115.91s+1}e^{-14.29s}$
3: 50-75%	1.57	14.29	100.85	G(S)=$\frac{1.57}{100.85s+1}e^{-14.29s}$
4: 75-100%	1.73	14.29	92.19	G(S)=$\frac{1.73}{92.19s+1}e^{-14.29s}$

REGION 1: 0-5. T.F=1.11/124.64S+1

Kp	RISE TIME	OVERSHOOT
10	0.965	76.27
12	0.833	74.38
15	0.76	71.17
17	0.62	68.87
18	0.61	68.89

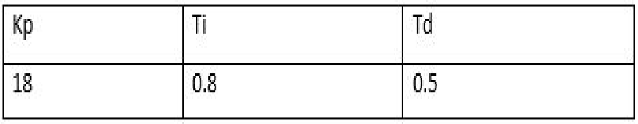
Minimum difference between overshoot and minimum settling time for best Kp

Kp=18 Ti	RISE TIME	OVER SHOOT	SETTLING TIME
0.2	0.9	63	84.93
0.4	2	63.5	80.04
0.6	2	54.6	78.72
0.7	2	54.1	78.72
0.8	2	56.7	78.72

Moderate overshoot and minimum settling time for best Ti

Kp=18 Ti	RISE TIME	OVER SHOOT	SETTLING TIME
0.2	0.9	63	84.93
0.4	2	63.5	80.04
0.6	2	54.6	78.72
0.7	2	54.1	78.72
0.8	2	56.7	78.72

Moderate settling time and overshoot is taken into consideration, Td=0.5. Thus the PID controller is designed with the following controller settings:

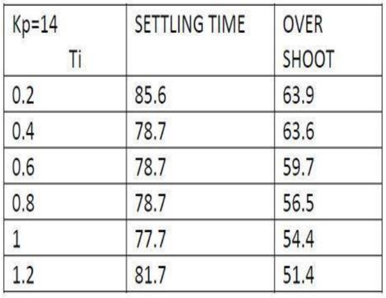


Kp	Ti	Td
18	0.8	0.5

REGION 2: 25-50.
T.F = (1.32)/115.91S+1

Kp	RISE TIME
10	0.645
11	0.726
12	0.781
13	0.626
14	0.626
15	0.554

Minimum rise time and moderate values for overshoot settling time is selected as the optimum value



Kp=14 Ti	SETTLING TIME	OVER SHOOT
0.2	85.6	63.9
0.4	78.7	63.6
0.6	78.7	59.7
0.8	78.7	56.5
1	77.7	54.4
1.2	81.7	51.4

Maximum deviation of over shoot with moderate value of settling time. Ti=0.6

Kp=14 Ti=0.6 Td	OVER SHOOT	SETTLING TIME
0.01	62.07	62.4
0.02	65.11	62.3
0.05	65.24	62
0.1	69.91	61.7
0.2	70.61	60.9
0.5	72.26	58.8
1	74.68	55.5

Minimum deviation of over shoot with minimum settling time Thus the PID controller is designed with the following controller settings:

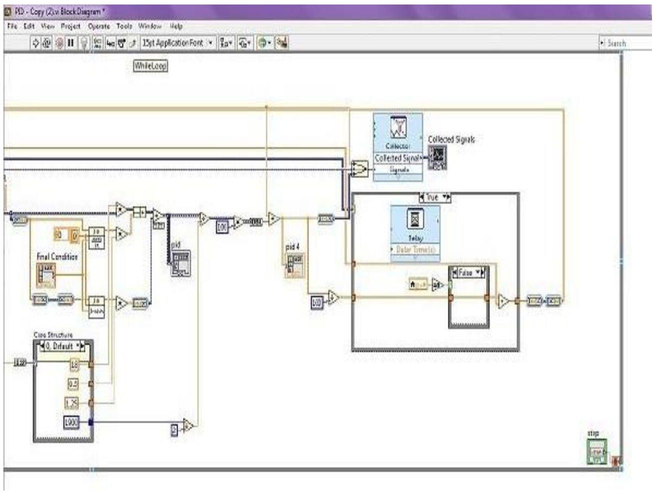
K_p	T_i	T_d
14	0.6	0.2

Thus all the regional transfer functions are considered and the corresponding PID controller settings are calculated.

REGIONS	Kp	Ti	Td
Region 1	18	0.8	0.5
Region 2	14	0.6	0.2
Region 3	13	0.8	0.5
Region 4	13	0.6	0.5

IV. Results and Observation

The PID controller shows good results in terms of response time and precision but, due to linearization of the non-linear conical process, four appropriate PID controllers were used. This project replaces the conventional PID instrument with a virtual controller. It saves time of manufacturing of instrument. Since the PID logic can be designed on LabVIEW in a very short period, as the manufacturing of instrument requires plenty of skills which cannot be implemented in a short span of time. Practically this application needs no maintenance and very easy to upgrade, whereas instruments require timely maintenance and their up-gradations is very difficult.



A typical non-linear process is modelled with the help of a conical water level control plant. The investigations in NI LabVIEW show that the new system developed would be highly flexible and easy in controlling the level. This work can be extended by a Fuzzy controller which rules out linearization and can also avoid the use of four appropriate PID controllers. It has many adjustable parameters which when well chosen, give a response that has good time domain characteristics.

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