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Real time process flow and implementation to get the open loop response depending on time domain specification and error criteria

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Abstract
In general, flow can be observed in three forms of state; like solid, liquid, and gas. But the difference of operation of liquid flow we executed is based on the differentiation of pressure because the flow transmitter used here is DPT (Differential Pressure Transmitter). For the control of flow process PID controller is used which is considered as a traditional one but still it is used desirably by most of the engineers which provides ease of access and accurate tuning of parameters.

Keywords: Implementation, differential pressure transmitter, multiparadigm

Introduction

MATLAB (Matrix laboratory) is a multiparadigm numerical computing environment and fourth generation programming language. Developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, Java, FORTRAN and Python.

Lab VIEW is a system-design platform and development environment for a visual programming language and is used for creating test, measurement and automation application. Lab VIEW uses icons instead of lines of text create application. Lab VIEW uses dataflow programming where the flow of data determines execution. NI-ELVIS is a combination of hardware and software which provides a suite of scientific instruments primarily for educational purpose. Virtual instrumentation provides an ideal platform for developing instructional curriculum and conducting scientific research [1-5]. At first the open loop response of the system is obtained by interfacing the real time system with the NI-ELVIS through 15 PIN D-connector. The flow transmitter output (4-20) mA is converted into voltage values with the aid of resistor.

The values are transmitted to the Elvis. The values transmitted are acquired using DAQ and tabulated using write to measurement file thena graph is obtained. From the response between flow and time the transfer function parameter (kp, td, τ_p) values are calculated using SK method. Various PID values are calculated for the transfer function and the simulation of flow process is done in MATLAB. Depending on the output, time domain specification and error criteria the best controller for the real time flow process is found.

Experimental Setup

It consist of the process tank, rotameter, I\P convertor, flow transmitter and computer. The inlet range of the rotameter is (10–100) LPH which pass the flow to the storage tank with the help of centrifugal pump of 0.5 HP causing the level to increase. The flow in the tank is sensed by differential pressure transmitter. Differential pressure transmitter is of two capacitance type and the range is from (0-200) mm. I\P convertor is of pneumatic actuator with air to close type as shown in figure 1.

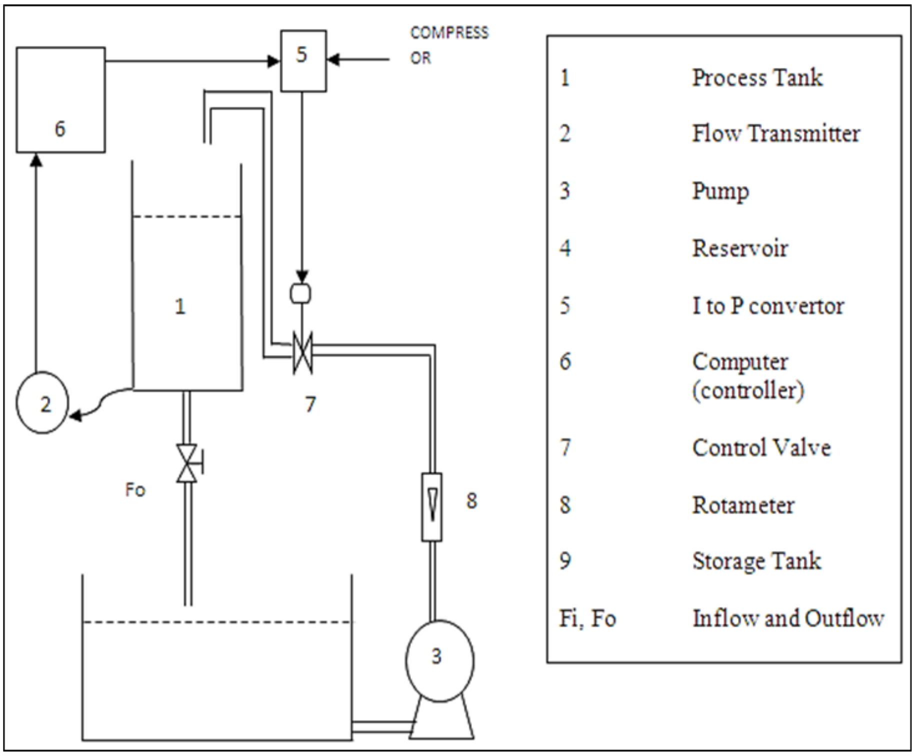

Fig. 1: Experimental Setup.

Process Identification

Open Loop Response

Initially the open loop values of the kit is taken using NI-ELVIS through 15 pin D-connector. To obtain the transfer function, the readings are taken between flow and time by SK method.

$t_d=1.3t_{35.3}–0.29t_{85.3}$

$\tau_p=0.67(t_{85.3}–t_{35.3})$

Determination of transfer function

A transfer function is the ratio of the output of a system to the input of a system, in the Laplace domain considering its initial conditions and equilibrium point to be zero. If we have an input function of *X(s)*, and an output function *Y(s)*, we define the transfer function *H(s)* to be:

$$H(s) = \frac{Y(s)}{X(s)}$$

The general format of the transfer function is:

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

Where;
Kp: is the gain of the process,
Td: is the dead time and
τ: is the time constant of the system.

From the above readings, the graph is plotted and the parameters (kp, td, t) are calculated using SK method.

$$\mathrm{G(s)} = \frac{0.126e^{-14.27(s)}}{60.97s + 1}$$

Tuning Methods

Ziegler Nichol's Method

The Ziegler–Nichols tuning method is a heuristic method of tuning a PID controller. It was developed by John g. Ziegler and Nathaniel Nichols. It is performed by setting the I (Integral) and D (derivative) gains to zero. The "P" (Proportional) gain, K_p is then increased (from zero) until it reaches the ultimate gain K_u, at which the output of the control loop oscillates with a constant amplitude. K_u and the oscillation period T_u are used to set the P, I, and D gains depending on the type of controller used. Z–N tuning creates "quarter wave decay". This is an acceptable result for some purposes, but not optimal for all applications.

Modified Ziegler Nichol's Method

Modified ZN rules are based on K_u and P_u. Loops tuned for good load disturbance, attenuation are generally damped. Set point change response and can modify from set point weighing.

Tyreus-Luyben Method

It is considered to be a conservative approach than Ziegler Nichol's method and so it gives better performance with small value for dead time. But when the value of dead time is large it gives a sluggish performance.

CHR Method

CHR is proposed by Chien, Hrones and Reswick. They developed the tuning both for setpoint tracking and disturbance rejection. Inturn it is also useful for calculating the above specified methods for 20% overshoot and no overshoot, which is very useful when applications are concerned.

Internal Model Control

Internal model can be controlled through either feedback or feed forward control. Two primary types of internal models have been proposed–Forward and Reverse model. In simulation, models can be combined together to solve more complex movement task.

Minimum integral error criteria
Modern complex control systems usually require more sophisticated performance criteria than those presented so far. The error and time are very important factors that must be considered simultaneously. A performance index is a single measure of a system's performance that emphasize those characteristics of the response that are deemed to be important. The notion of a performance index is very important in estimator design using linear-state-variable feedback. A fairly useful performance index is the integral of the absolute magnitude of the error (IAE) criterion [2-5].

$$\mathrm{IAE}={}_0\!\int^{\infty}|\,e(t)\,|.dt$$

By utilizing the magnitude of the error, this integral expression increases for either positive or negative error, and results in a fairly good underdamped system. For a second order system, this error has a minimum for a damping ratio of approximately 0.7. Another useful performance index is the integral of the square of the error (ISE) criterion.

$$\mathrm{ISE}={}_0\!\int^{\infty}e^2(t).dt$$

By focusing on the square of the error function, it penalizes both positive and negative values of the error. For a second order system, this error has a minimum for a damping ratio of approximately 0.5.
A very useful criterion that penalizes long-duration transients is known as the integral of time multiplied by the absolute value of the error (ITAE). This performance index is much more selective than the IAE or the ISE.
The minimum value of its integral is much more definable as the system parameters are varied. For a second order system, this error has a minimum for a damping ratio of approximately 0.7.

$$\mathrm{ITAE}={}_0\!\int^{\infty}t|e(t)|.dt$$

Other figure of merit which has been proposed is the integral of time multiplied by the squared error (ITSE) or mean squared error (MSE). The performance index is:

$$\mathrm{MSE}={}_0\!\int^{\infty}t.e^2(t).dt$$

Results and Comparison
Tabulations
PID controller tuning values for the cylindrical flow process implemented in a cascade real system for the different tuning methods are shown in Table 1.From the simulated response representing the real time level process, their characteristics are determined and listed out in a tabulated form in Table 2.To find the best controller, the error reduction standards are necessary. Therefore, ITAE, IAE, ISE and MSE values are shown in Table 3.

Table 1: PID values for different tuning methods

Tuning Methods	Kp	Ki	Kd
Ziegler Nichol's Method	45.42	2.241	230.09
Chien Hrones Reswick Method	20.345	0.333	145.16
Internal Model Control	3.811	0.055	1.436
Modified Ziegler Nichol's Method	15.14	0.747	24.54
Tyreus Luyben Method	23.65	0.2652	152.140

Table 2: Time Domain Specifications

Tuning Methods	Settling Time	Rise Time	Peak Time
Ziegler Nichol's Method	150	19.937	32.68
Modified Ziegler Nichol's Method	430	47.26	80.9
Tyreus Luyben Method	250	0	0
Chien Hrones Reswick Method	420	66.662	100
Internal Model Control	900	0	0

Table 3: Performance Error Criteria

Tuning Methods	IAE	ISE	ITAE	MSE
Ziegler Nichol's Method	176.4177	173.9964	1.0675e+004	0.5781
Modified Ziegler Nichol's Method	201.6456	166.8347	1.1839e+004	1.1613
Tyreus Luyben Method	196.6686	2.9054e+005	1.1864e+004	1.1942
Chien Hrones Reswick Method	206.0393	2.9247e+005	1.1909e+004	1.1711
Internal Model Control	290.7575	281.4983	1.2419e+004	0.9352

Graphs
Initially the flow is set at 20 mm in rotameter and after the set point is reached, the flow rate is changed to 30 mm which results in the range of flow values from 0.4-1.49 v. The above figured graph Figure 2showsa way to find the transfer function of the flow process.

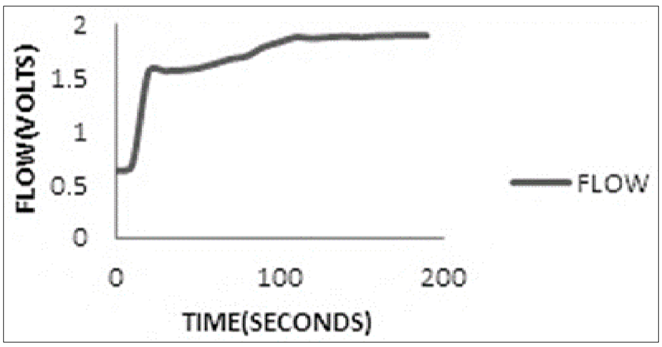

Fig. 2: Open Loop Response.

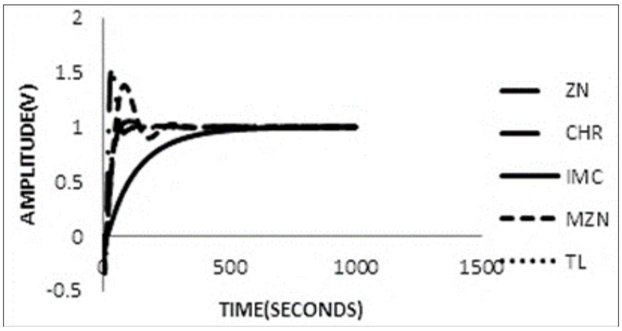

Fig 3: Response for Diverse Tuning PID Controller Methods.

By using the above tabulated PID values for the real time flow process, the tuning methods like ZN, IMC, CHR, TL and MZN are implemented in the MATLAB software in a simulink environment. The response from the scope of the simulation is figured in Figure 3.

Conclusion

Thus from the above work, a real time process for flow is studied and implemented to get the open loop response depending on time domain specification and error criteria the best controller is obtained. On considering peak time, rise time Tyreus Luyben method is considered best. But when comparing the error criteria the Ziegler Nichol's method is considered best among the other tuning methods.

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