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Tuning Pid Controller for a Two Tank Process and Its Parameter Monitoring using IoT

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Abstract:- In ancient days, the industrial parameters such as level, pressure, flow, temperature etc are measured and are converted to the actuated variable as required by the associated actuators and final control elements. In all the process industries, among the various controllers, a Proportional, Integral and Derivative (PID) controller is the most widely used controllers because of their robustness, easy implementation reduction of error for current, past and future disturbances which might arise in a process. Various tuning methods were proposed in literature out of which the Minimum error integral criteria method, IMC (Internal Model Control), 2DOF (Two-Degree-Of-Freedom) method have been suggested for optimum setting of PID controller parameters. In this paper the performance of PID controller is analyzed for various tuning techniques in the case of two tank interacting process control system. The various tunings are performed using MATLAB software. Apart from acquiring the data and processing it, the data can be transmitted to real world with the help of IoT technology. The major industrial problem that has to be rectified is effective transmission of data. The collection and displaying the data on spot is the most commonly used technique. These data are also made to be viewed to the other chief officers and officials off duty through a common portal so that any mishap can be identified and rectified easily. The main industrial parameters in a process tank are measured, processed and is viewed or displayed using Internet of Things (IoT) from any far place using Texas processor interlinked with Wi-fi module.

Key Words: PID controller, Optimization, MATLAB, IMC, 2DOF, ISE, IAE, Internet of Things.

I. INTRODUCTION

The most significant controller which is used in all over industries is nothing but PID controller which has been in engineering practice for over seven decades. More than 95% of control loops are of the Proportional-Integral-Derivative (PID) type. A Proportional-Integral-Derivative (PID) controller is a three-term controller. This PID method is simple and more flexible method and is popular among all other control methods. The determination of the proportional (k_p), derivative (k_d) and integral (k_i) constants are known as tuning of PID controller. The equation of PID controller is given as follows:

$$G_c(s) = k_c(1 + \frac{1}{T_i s} + T_d s)$$

Where, k_c= proportional gain, T_i= integral time constant and T_d= derivative time constant.

The proportional action will look into current situation and takes action for present error which is measured across. The integral action takes necessary steps to eliminate the sum of past accumulated errors created due to disturbance and the Derivative action takes necessary steps for eliminating errors and other disturbances which might affect the system in the near future. Thus, the PID controller allows contributions from present, past and future controller inputs.

The mathematical model of the two tank interacting process is obtained after conducting the experiment by making the level of the liquid present in the tank to attain its steady state for the applied speed of the pump presented in Litres per hour. After obtaining the transfer function model, open loop system performance was studied.Then to improve the transient and steady state performance, controllers are designed. The main objective of the proposed paper is to improve the time domain specifications such as Rise time,Settling time, Maximum overshoot etc., The response is simulated using MATLAB and the time scale is compared for the various tuning methods.On the comparison study of the above methods it states that the AMIGO method produces largest peak overshoot and settling and the Fine Tune method produces smallest maximum overshoot and settling time. [9]

A detailed analysis of varied tuning methodologies like Ziegler-Nichols method, Modified Ziegler-Nichols methods, Tyreus – Luyben method, Damped Oscillation method Cohen Coon method, CHR method, Fertick method, Ciancone and Marline method, Internal Model Control (IMC) methods were analysed. Minimum Error Integral Criteria (IAE, ISE, ITAE, ITSE) methods were also taken for consideration. The above methods are compared for varied time domain specifications and the computer simulations are obtained with the help of MATLAB.[10].

The transfer function of the two tank interacting level process is derived by designing the system and deriving the general equation using the formulae. The various tuning methods are studied with the help of time domain specification comparisons. [1]

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II. TWO TANK INTERACTING SYSTEM

Figure 1 Two Tank Interacting System

Table 1 Interacting Tank Specifications

Parameters	Specifications
Tank Diameter	11 cm
Tank Height	20 cm
Rotameter Displacement Level	100

The two-tank system consist of pump, control valve, process tank, supply tank, rotameter, main power, supply switch, pump switch. The liquid level in the tank is measured by scale. The two-tanks are connected in series; the output of first tank is connected to the input of the second tank. The main objective of the two-tank system is to track a set point and stabilize the level in the tanks. If the changes in the first tank level system make some significant changes in the second system and the response of the second system also changes then, the two systems are said to be interacting system. The liquid flow through two single capacity processes which is connected in series is taken into account here. The data that are collected from the interacting system is finally fed to the cloud. Through the access of Internet of Things (IoT) the data are monitored with the web access.

The pump speed is adjusted and kept at 40 lph. The liquid is poured into tank 1 and since the two tanks are in interacting mode, tank 2 also gets disturbed by the flow of water. The pump is driven till steady state arises in both the tanks. The time period and the equivalent tank height are monitored continuously till steady state. The readings are recorded and it is tabulated in Table-2.

Table 2. Time Vs Tank Height

t(S)	h_1(S)	h_2(S)
10	5.8	2.7
20	7.2	2.9
30	8.5	3.4
40	9.7	3.7
50	10.9	4.2
60	11.9	4.7
70	12.7	5.3
80	13.5	5.3
90	14.5	5.9
100	15.2	7.0
110	16.2	7.7
120	16.2	7.7
130	16.2	7.7
140	16.2	7.7
150	16.2	7.7

The transfer function model is derived as follows:

Tank 1

$$m - q_1 = A_1 \frac{dh_1}{dt} \quad (1)$$

$$m - \frac{(h_1 - h_2)}{R_1} = A_1 \frac{dh_1}{dt} \quad (2)$$

By taking Laplace Transform

$$m(S) - \frac{h_1(S)}{R_1} + \frac{h_2(S)}{R_2} = A_1 S h_1(S) \quad (3)$$

$$\frac{h_1(S)}{R_1} + A_1 S h_1(S) = m(S) + \frac{h_1(S)}{R_1}$$

$$h_1(S) = \left[m(s) + \frac{h_2(S)}{R_1}\right]\left[\frac{R_1}{(1+\tau_1 S)}\right] \quad (4)$$

where, $A_1 R_1 = \tau_1$

Tank 2

$$q_1 - q_2 = A_2 \frac{dh_2}{dt} \quad (5)$$

$$\frac{h_1 - h_2}{R_1} - \frac{h_2}{R_2} = A_2 \frac{dh_2}{dt}$$

But,

$$\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_e}$$

$$\therefore \frac{h_1}{R_1} - \frac{h_2}{R_e} = A_2 \frac{dh_2}{dt}$$

Taking Laplace Transform

$$\frac{h_1(S)}{R_1} - \frac{h_2(s)}{R_e} = A_2 S h_2(S) \quad (6)$$

$$h_1(S) = h_2(S) \frac{R_1}{R_e}[1 + \tau_2 S] \quad (7)$$

where, $A_2 R_e = \tau_2$

on equating equations (4) and (7)

$$\left[m(S) + \frac{h_2(S)}{R_1}\right]\left[\frac{R_1}{(1+\tau_1 S)}\right] = h_2(S)\frac{R_1}{R_e}[1 + \tau_2 S]$$

$$\frac{m(S)}{(1+\tau_1 S)} = \frac{h_2\{[R_1(1+\tau_1 S)(1+\tau_2 S] - R_e\}}{[R_e R_1(1+\tau_1 S]}$$

$$\frac{h_2(S)}{m(S)} = \frac{R_e R_1}{([R_1(1+\tau_1 S)(1+\tau_2 S)] - R_e)} \quad (8)$$

The general equation is given as,

$$G(S) = \frac{R_2}{(1+\tau_1 S)(1+2\tau_2 S)} \quad (9)$$

The transfer function for the two tank system is,

$$G(S) = \frac{0.654}{2728S^2 + 168S + 1} \quad (10)$$

III. TUNING METHODS AND TECHNIQUES & RESULTS

The transfer function is used to represent the data graphically using MATLAB software. The graph is initially represented in the non-tuned form, then the transfer function is tuned and suitable values of $k_P, k_{i,} k_d$ and n are found.

The open loop response curve is shown in the figure 2 and it is inferred that the response does not reach its final steady state value for a unit step input. Various control strategies were studied and the simulations were done for improving the performance in time domain A PID controller with self tuning was analyzed and followed by IMC controller and a PID controller with two degrees of freedom.

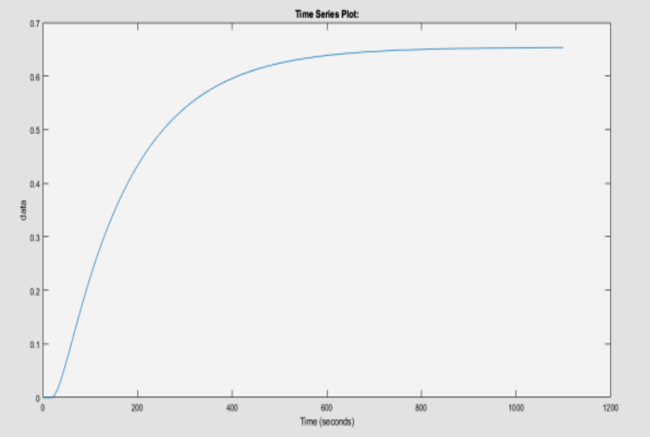

Figure 2: Open Loop Response

Many new techniques are proposed by the academic control community. Internal Model Control (IMC) is a commonly used technique. IMC provides a transparent mode for the design and tuning of control. One of the main advantages of the IMC for auto tuning is that it does good set-point tracking. IMC structure provides a suitable framework for satisfying this objectives.IMC was introduced by Garcia and Monari. Using the IMC design procedure, controller complexity depends exclusively on two factors: the complexity of the model and the performance requirements started by the designer.

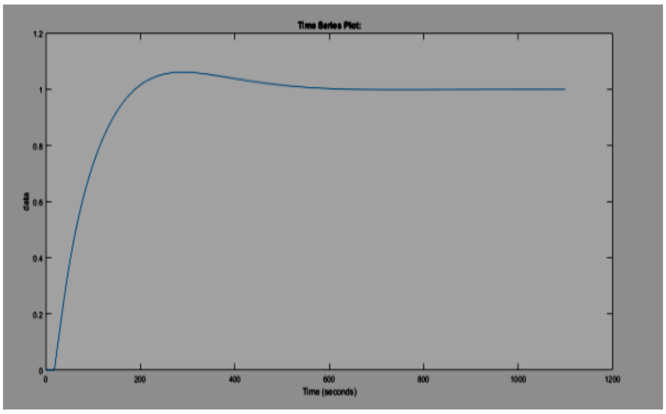

Figure 3 Closed Loop Response With Auto Tuned Pid Controller

It was inferred from the graph that, the system has reached its steady state for the unit step input. Several other controllers were tried for reducing the settling time and rise time.

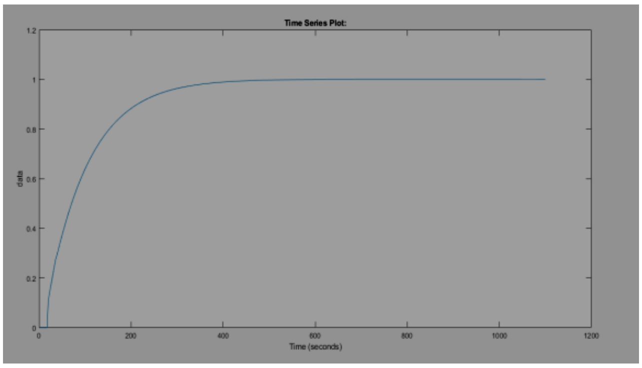

Figure 4 Closed Loop Response With IMC based PID Controller without disturbance

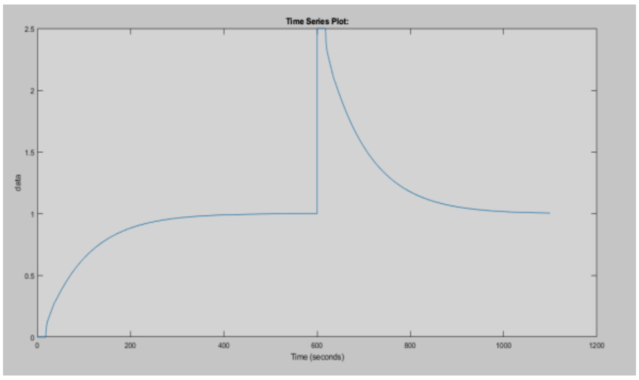

Figure 5:Closed loop response with IMC Based PID

controller for the disturbance input given at 600 seconds. Two-Degree-Of-Freedom (2DOF) generates an output signal based on the difference between a reference signal and a measured system output. The block computes a weighted difference signal for the proportional and derivative actions according to the set point weights (b and c) that is specified. The block output is the sum of the proportional, integral, and derivative actions on the respective difference signals, where each action is weighted according to the gain parameters P, I and D. A first-order pole filters the derivative action.

With the help of the respective tuned values and graphical analysis the various programming indices such as IAE, ISE and Auto Tuned values are found.

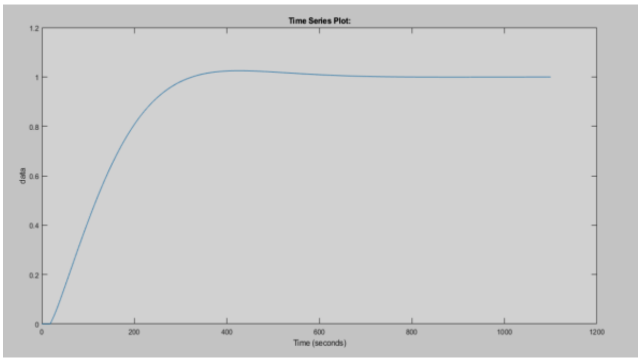

Figure 6 2DOF PID controller response without disturbance input

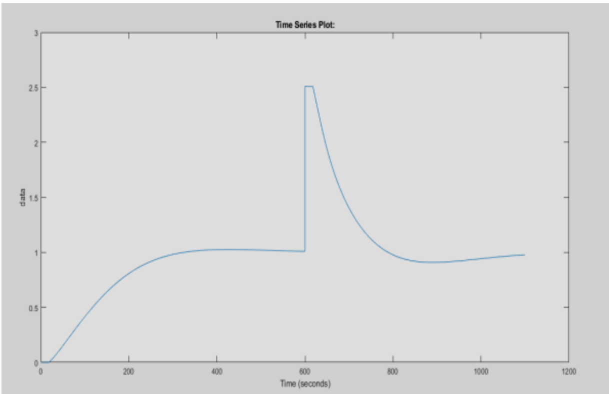

Figure 7 2DOF PID controller response with disturbance input at 600 seconds.

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The table 3 illustrates the performance of various control techniques employed.

It was found that IMC based control technique is more efficient in delivering optimal time response specifications with less rising time and settling time.

2 Degrees of Freedom PID controllers are efficient in tackling performance measures such as Integral Square Error(ISE), Integral Absolute Error(IAE)

Tuning Methods	Rise Time (S)	Settling Time (S)	Over Shoot	IAE	ISE
Open Loop	50	540	0.4	88.2	50.8
Closed Loop	50	800	0	-	-
WITH DISTURBANCE					
2 DOF	150	500	0.49	84.7	43.1
PIDF 2	75	600	0.41	86.0	43.6
PIDF	25	550	0.54	85.5	43.5
I-PDF	85	650	0.30	83.9	43.9
IDF-P	80	620	0.91	89.8	43.7
PI-DF	125	525	0.52	87.7	43.5
IMC	80	450	0.45	243	176
WITHOUT DISTURBANCE					
2 DOF	75	700	0.42	101	55
IMC	25	450	0	98.0	54.4

TABLE 3 Comparisons Of Various Tuning Methods

IV. MONITORING AND TRANSMITTING LIQUID LEVEL VIA IoT

Now a days, IoT form a major technology is transmitting real time data to the user at varied locations.With the help of Mobile Telnet, it is possible to transfer data to the users mobile. With the help of Texas launching pad and its associated grove, Wifi module, it is possible to transfer real time data continuously to the cloud network which can be viewed and control action can taken at any place.

Connecting Texas Processor for IoT transmission

The processor and the sensor units are interfaced together through jumper wires and cables in Texas Processor. The processor is linked to the computer to add the software program to the processor system. he program is fed up in the Energia software application. The program is run in the computer and uploaded to the processor.

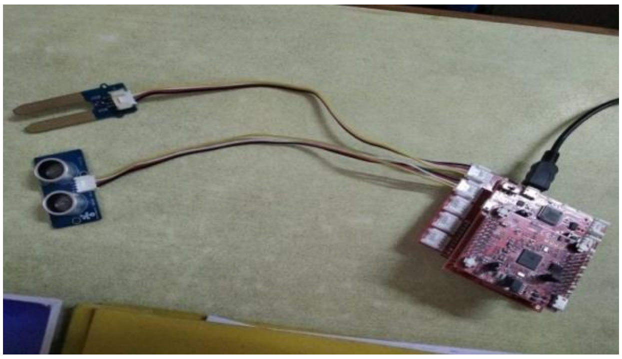

Figure 8 Interfacing sensors with Tiva C processor

The processor is connected to ultrasonic sensor for the collection of data of the level of the process tank. The output of the program which is uploaded in the Energia Software is viewed or displayed in the Tera Term software or to the connected device through internet or to mobile.

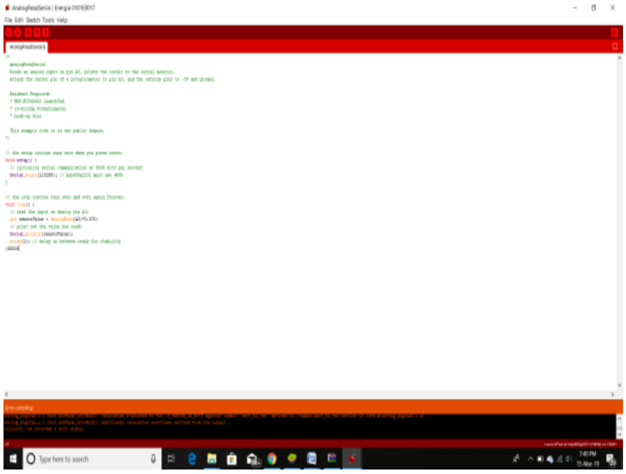

Figure 9 IoT program in energia platform.

V. CONCLUSION

The paper explains the design and working of the PID controller for a second order two tank interacting system with and without disturbance. The various types of tuning methods were implemented and their performances are analyzed. The Internal Model Control (IMC) PID controller gives the best result for second order two tank interacting system with least settling time. The process parameters were also transmitted to external computer or to the user mobile through IoT.

REFERENCE

1. P Srinivas, K VijayaLakshmi, V Naveen Kumar. "A Comparison of PID Controller Tuning Methods for Three Tank Level Process. IJAREEIE, January 2014.
2. K Astrom, T Hagglund. PID Controllers: Theory, Design and Tuning. The Instrumentation, Systems and Automation Society(ISA), 1995.
3. Neil Kuyvenhove,. "PID Tuning Method and Automatic PID Tuning Study with MathCad", Calvin College of Engineering 315 December 19, 2002.
4. Marlin T E; "Process Control", 2nd edition, Mc graw-Hill, 2000.
5. P Srinivas, K VijayaLakshmi, V Naveen Kumar. "A Comparison of PID Controller Tuning Methods for Three Tank Level Process. IJAREEIE, January 2014.
6. J Nagrath, M Gopal, "Control System Engineering", New Age International Publications, 2002.
7. K Ogata: "Modern Control Engineering", Prentice-Hall India, Fourth Edition.
8. K J Astrom and T Hagglund, "The Future of PID Control", IFAC J Control Engineering Practice, 2001.
9. Kiran H Raut, Dr, S.R. vaishnav, Dept of Electrical Engineering "A Study on Performance of different PID Tuning Techniques".
10. Mohammad Shahrokhi and Alireza Zomorrodi Dept of Chemical and Petroleum Engineering "Comparison of PID Controller Tuning Methods.