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Analysis of Non-Interacting Level Process using various PI Control Settings

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Abstract

The aim of this paper is to implement optimum controller settings for a level process. The objective of the controller is to maintain the level inside the process tank in a desired value. The real time implementation of the process is designed and implemented using MATLAB. Two tank non-interacting process is considered for analysis. The model is identified as first order plus delay time (FOPDT) process. Controller design is compared based on conventional Proportional Integral (PI) with Internal Model Control (IMC), ziegler nichol's method(Z-N) and Tyreus and Luyben method (TL) and also based on the terms of performance indices. Out of the control algorithms Tyreus and Luyben outperforms in minimum overshoot, faster settling time, better set point tracking and produces lower performance indices.

Keywords: conventional controller, Non-Interacting process, PID Control, Level process.

1. Introduction

In industries wide range of advancement in along with the evolution of control design. Controllers plays the important role in maintaining the process for the desired set point. This work is shown along with the various control tuning techniques that are performed along with the system identification and model validation. This section is dealt with the level process by the multi-variable system where the experimentation is done in non-interacting process. The main objective of this work is to find out the best and suitable controller which provides efficient control action.

1.1. Need for PI control

A PID controller is majorly used in industry where heating and cooling processes are controlled like fluid level monitoring and control, flow control etc. Defining Set point and process variable is considered to be the primary parameter for control. A process variable is the one which needs to be controlled and set point is the desired value for the parameter, you are controlling. Designing a PI controller is an essential process in any closed loop process which needs to be adaptive for the process thus determining the controller gain values for proportional(kp), integral(kI), and derivative (kd) is an effective part in controlling a process[5].

1.2 Non- Interacting Process

When two tanks doesn't have any interaction with each other, that is the outlet flow from tank 1 discharges directly into the atmosphere before spilling into tank 2, and the flow through R 1 depends only on h 1 .The variation in h 2 in tank 2 does not affect the transient response occurring in tank 1. This type of system is referred to as a *non-interacting* system.[1]We shall assume the liquid to be of constant density, the tanks to have uniform cross-sectional area, and the flow resistances to be linear. Our idea is to find a transfer function that relates h 2 to q, that is, H 2 (s)/ Q (s).The approach will be to obtain a transfer function foreach tank, Q 1 (s)/ Q (s) and H 2 (s)/Q 1 (s), by writing a transient mass balance around each tank these transfer functions will then be combined to eliminate the intermediate flow Q 1 (s) and produce the desired transfer function. the overall transfer function is the product of two first-order transfer functions, each of which is the transfer function of a single tank operating independently of the other

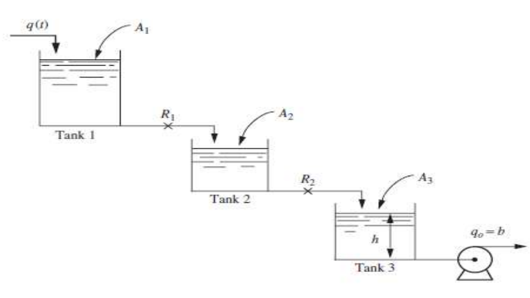

Figure 1. Block diagram of Non Interacting process kit

[4]Non interacting comes under the level process. Which is mainly used in industrial purposes. It consists of a transparent vessel supplied with water from a reservoir by a centrifugal pump. The water reaches the vessel through a level control valve. The final control element in a level control loops usually a valve on the input and/or outflow connections of the tank. Because it is often critical to avoid tank overflow, redundant level control systems are sometimes employed. The water level in the vessel is measured by a differential pressure transmitter with connections to the top and the bottom of the vessel. The signal from the level transmitter provides the process variable to the controller. The controller provides a signal to the current to pressure transmitter (I/P), which modulates the air supply to level control valve, and hence flow to alter the level in the vessel.

2. System Identification

Open loop response is done in the real time environment without the use of controller and feedback

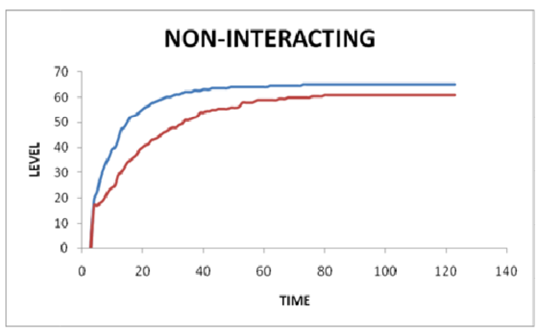

Figure.2 Open Loop Response For Level Process

From the tabulated response of the non-interacting system the following system identification methods are carried out. This is done to obtain the optimum results of gain (K), delay time (td) and time constant (τ). The following are the various types of system identification techniques that we have proceeded, which also includes the model validation at the end as the result of this system identification process. They are as follows

2.1. Tangential Method

From the list of readings, the transfer function parameters K (process gain), td (dead time) and τ_p (time constant) are determined.

$$G(S) = \frac{2.2338}{4635s^2+148s+1} e^{-12s}$$

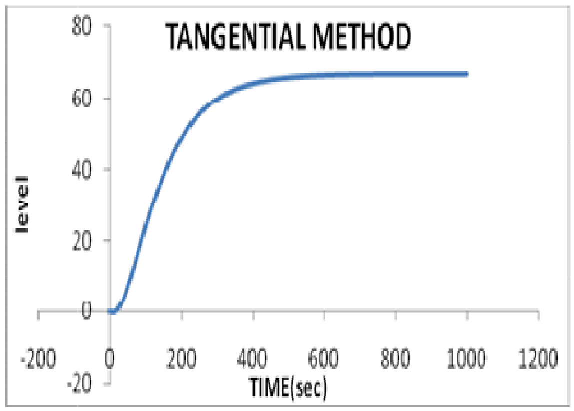

Figure.3 Response of Tangential Method

2.2. SK Method

Sundaresan and Krishnaswamy use the normalized response $\frac{y}{KM}$ of the model to a step-forcing function: $U(s) = M/s$ at two different times, t_1 and t_2. These times are selected such that the normalized response reaches 35.3% at t_1 and 85.3% at t_2. The recipe gives the estimated values of the time constant and delay time by

td = 1.3 (t35.3) – 0.29 (t85.3)

τp = 0.67 (t85.3 – t35.3)

The transfer function identified through this method is as follows

$$G(s) = \frac{2.2338}{4.147.836s^2+135.34s+1} e^{-10.1s}$$

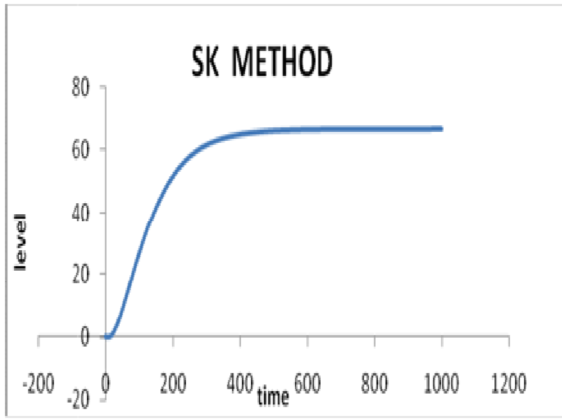

Figure 4. Response of S-K method

2.3. Two Point Method

In this method the transfer function is calculated by using the formulae given below and from the open loop response Observes the output relative change y0(0...100%) y0 = (y−y1)/(y2−y1). Here the time required for the process output to make 28.3% and 63.2% of the long-term change is denoted by t28.3% and t63.2%, respectively. The time constant and time delay can be estimated.

$$t_d = t63.2 - t28.3$$

$$\tau_p = 1.5\,(t63.2 - t28.3)$$

The transfer function identified through this method is as follows:

$$G(s) = \frac{2.2338}{5049s^2+151.5s+1} e^{-10.1s}$$

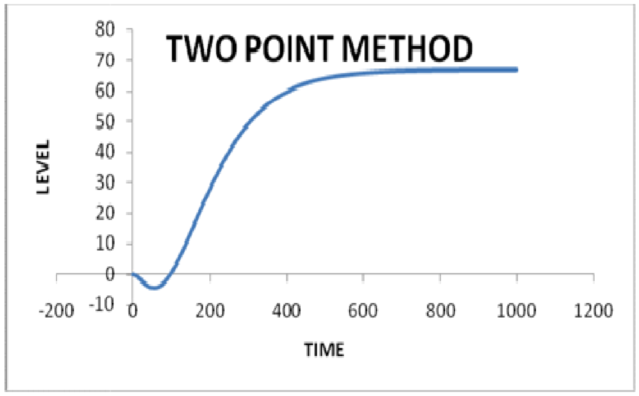

Figure.5 Response of Two point Method

The above system identification techniques provides the response which are displays above. They provide the values of gain (K), delay time (td) and time constant (τ) for each corresponding techniques respectively. They are tabulated which are as follows:

Table 1: Transfer function parameters

SYSTEM IDENTIFICATION METHOD	K_p	τ_1	τ_2	Td
TANGENTIAL METHOD	2.2338	4635	148	12
SK METHOD	2.2338	4147.836	135.34	10.1
TWO POINT METHOD	2.2338	5049	151.5	101

From the above tabulation, the modal validation is found to be recognized through SK (Sundaresan-Krishnaswamy) method. This is identified by comparing the response of the system along with the various system identification methods that are represented as follows

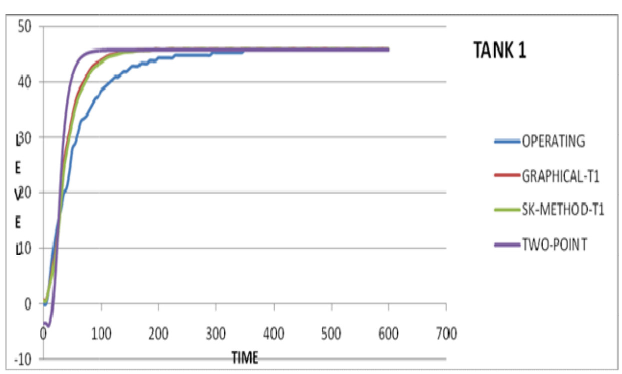

Figure .6. Comparison Of The Response Of System Identification Methods (Tank 1)

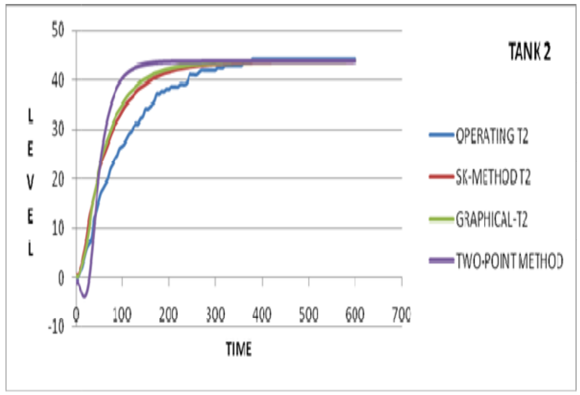

Figure.7. Comparison Of the Response Of System Identification Methods (Tank 2)

The identified model is given in the form of the following:

$$G(s) = \frac{2.2338}{4147.836s^2+135.34s+1} e^{-10.1s}$$

3. PI CONTROLLERS DESIGN:

A PID controller is majorly used in industry where heating and cooling processes are controlled like fluid level monitoring and control, flow control etc. Defining Set point and Process variable is considered to be the primary parameter for control. A process variable is the one which needs to be controlled and set point is the desired value for the parameter, you are controlling.A PID controller is considered to be a traditional one it is used in many of the process industries. The representation or the implementation of the process may vary, but the performance of it is still continuing by providing its efficiency. PID control is used at the lowest level; the multivariable controller gives the set points to the controllers at the lower level. 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. For PID controller, there are thousands of tuning methods available and for this process model Ziegler Nichol’s, Tyreus Luyben, Internal Model Control and Genetic Algorithm are done. For the derived model validation process ,the following conventional tuning techniques has been calculated. With the following tuning techniques the propotional and intergral gain values are calculated. The tuning techniques are as follows:

3.1. Ziegler Nichol's Method

It is introduced in 1940's which made a big impact among the control engineers regarding the control of a process using PID technology.[2] 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. Using ZN method, PID loops are used for practical applications to improvise performance. This method requires Ku (ultimate gain) and Pu (ultimate time period). To find the values bode and root locus are needed, which can be found by coding in an M-File. It provides a table to find Kp, Ki and kd values by substituting the determined Ku and Pu values.

Table 2:Ziegler Nichols Tuning Parameters

PID PARAMETERS	Kp	Ki
ZN TUNING FORMULA	0.45Kcu	Kp/(Tu/1.2)
ZN BASED TUNED VALUES	3.375	0.044

3.2 Tyreus-Luyben Method

[3]It starts with a low value of Kp and perturb the system input to an oscillation in output. By increasing the Kp value, sustained oscillation is observed. Ku used is the smallest value of Kp, which achieves oscillation and Pu is the period of oscillation at Ku. Tyreus-Luyben 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. These settings are based on ultimate gain and period. Like Z-N method this method is time consuming and forces the system to margin if instability.

Table 3: Tyreus-Luyben Tuning Parameters

PID PARAMETERS	Kp	Ki

TL TUNING FORMULA	Kcu/3.2	Kp/(2.2Tu)
TL BASED TUNED VALUES	2.593	0.0117

3.3 Internal Model Control

[3]The Internal Model Control (IMC) structure provides a suitable framework for satisfying these objectives. IMC was introduced by Garcia and independently by a number of other researchers. Using the IMC design procedure Morari (1982), but a similar concept has been used previously and, controller complexity depends exclusively on two factors: the complexity of the model and the performance requirements stated by the designer. The goal of this article is to show that for the objectives and simple models common to chemical process control, the IMC design procedure lead naturally to PID-type controllers, occasionally augmented by a first-order lag. Furthermore, the proposed procedure provides valuable insight regarding controller tuning effects on both performance and robustness in control and estimation theory. . For $\lambda = 2.5$ the IMC-based PI controllers are unstable. An additional recommendation is that $\lambda >$
$0.2\tau p$ for this example the requirement is that $\lambda > 2$ .In this tuning method the λ value is identified as $\lambda=100$ by trial and error process which is proceeded within the identified limits. The identified values are as follows:

Table 4: IMC Tuning Parameters

PID PARAMETERS	Kp	Ki
IMC TUNING FORMULA	$(\tau1+\tau2)/Ku*\lambda$	$Kp/(\tau1+\tau2)$
IMC BASED TUNED VALUES	5.160	0.00120

4. COMPARISION OF TUNED VALUES:

Based on the tuned values from the above methods closed loop response is obtained which is shown in [fig.9] the matlab comparison of the closed loop response.[2]From which result analysis is done to determine which tuning method is suitable for level process. Table 4 describes the comparison of tuned values from different methods the controller gain(kp)and(ki)

Table 5: Comparision of tuned values

TUNING METHODS	KP	KI
ZIEGLER NICHOL'S	3.375	0.044
TYREUS-LUYBEN	2.593	0.0117
INTERNAL MODEL CONTROL	5.160	0.00120

As a result of this tuning analysis the best controller method that fits for the non-interacting process in the multivariable system is shown in [Fig: 9] representation as tyreus –luyben method which is defined by its settling time which is smaller than the two other tuning techniques which also possess less oscillations than the other two tuning techniques.

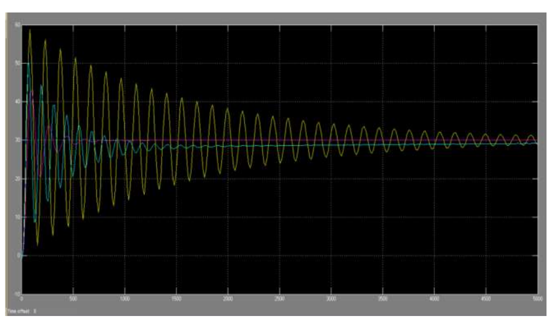

Figure. 8. comparison of closed loop response

In the figure 8, the yellow line indicates the response of Z-N method, blue line indicates the IMC method and pink colour indicates TL method

4.1. Time domain specifications

The performance characteristics of a controlled system are specified in terms of the transient response to a unit step input since it is easy to generate & is sufficiently drastic. The transient response of a practical C.S often exhibits damped exhalations before reaching steady state. In specifying the transient response characteristic of a C.S to unit step i/p, it is common to specify the following terms, as shown in Table 6.

Table 6:Time Domain Specifications Of Non-Interacting Process

TUNING METHODS	SETTLING TIME (seconds)	RISE TIME (seconds)	PEAK TIME (seconds)	PEAK OVERSHOOT (%)
ZIEGLER NICHOL'S	196	39.825	15	27.2
TYREUS-LUYBEN	125	39.95	64.05	39.7
INTERNAL MODEL CONTROL	700	75	0	0

4.2 Performance error criteria

The shape of the complete closed-loop response from time t=0 until steady state has been reached, could be used for the formation of a dynamic performance criterion. Unlike the simple criteria that use only isolated characteristics of the dynamic response, the criteria of this category are based on the entire response of the process. [6]The integral criteria has the advantage of being more precise, that is, more than one combination of controller settings will usually give a ¼ decay ratio, but only one combination will minimize the respective integral criteria. The various error criterions are, as shown in table 7.

Table 7: Error criteria for Non- Interacting process

TUNING METHODS	ITAE	IAE	ISE
ZIEGLER NICHOL'S	1.473e+006	992.3	402.5
TYREUS-LUYBEN	1.409e+004	100.2	47.37
INTERNAL MODEL CONTROL	1.102e+006	471.3	104.1

5. Conclusion

Based on the attained graphs & readings for level process controlling we have established that the modal validation deals best with the SK METHOD and TYREUS AND LUYBEN which has the minimum oscillations and reduced settling time observed from the time domain analysis also from error criteria analysis (TL) method has the less error value, is suitable tuning methods that provide enhanced performance than any other tuning techniques for the non-interacting LEVEL process. Thus this concludes with simulation of non-interacting process.

REFERENCES:

[1]. blog.opticontrols.com/archives/105," A Tutorial on NON-INTERACTING PROCESS"

[2]. P V Aravind, Balachandra Pattanaik, "Reliability of PID Controller for a Real Time Sensor Interfaced Temperature Process", Sensor and Journal, IFSA Publishing, ISSN(print): 2306-8515,ISSN(online):1726-5479, Volume 231, Issue 3, Page No: 10-14, March 2019.

[3]. Mohammad Shahrokhi and Alireza Zomorrodi, "Comparison of PID Controller Tuning Methods ", 2012

[4]. Ogata K."Modern Control Engineering", 1997, 3rd edition, *PrenticeHall.*

[5]. Coughanowr D.R.;"Process System Analysis and Control", 2nd edition McGrawHill, 1991

[6]. P Aravind, Naveen Kumar A B, "Design of State Feedback Control for a FOPDT System", International Journal of Interdisciplinary Current Advanced Research, ISSN(print): 2663-0931,ISSN(online):2663-2594, Volume 1, Issue 1, Page No: 1 – 4, January 2019.

[7]. Bing Song, Shuai Tan, Hongbo Shi, Key principal components with recursive local outlier factor for multimode chemical process monitoring, *Journal of Process Control,* Volume 47, November 2016, Pages 136–149, 2016.

[8]. Ana S.R. Brásio, Andrey Romanenko, Natércia C.P. Fernandes, Lino O. Santos, First principle modeling and predictive control of a continuous biodiesel plant, *Journal of Process Control*, Volume 47, Pages 11–21, 2016.

[9]. D. Dinesh Kumar, B. Meenakshipriya , Design of Heuristic Algorithm for Non-linear System, *Rev. Téc. Ing. Univ. Zulia.* Volume 39, No 6, Pages 10 – 15, 2016.

[10]. Murillo-Marrodan, A.; Garcia, E. & Cortes, F, A Study of Friction Model Performance in a Skew Rolling Process Numerical Simulation, *International Journal of Simulation Modelling,* Volume 17, Number 4 Pages 569-582, 2018.

[11]. S. Ramachandran , P.Aravind, V.Venkataraman, G.Subramanian, "Validation of a Neural Network Model for a Nonlinear Process by Parameter Estimation", International Journal of Applied Engineering Research, Volume 9, Number 24 , Pages 29051-29062, ISSN 0973-4562, 2014.