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Comparative of Diverse Methods for a Nonlinear Process

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***Abstract**— Control of liquid level in a process plays a crucial role in process industries. PID control schemes are most widely used in process control systems represented by chemical processes because of its robustness, simplicity and its excellence in linearity performance criterion. The main objective of model-based controller is to compensate the shift in process and maintain the liquid level on its required target value. Our goal in this paper deals with the study of using a three term control namely the PID controller to find the best tuning method amongst the five tunings methods implemented here such as Ziegler Nicholas (Z-N), modified Z-N, IMC (internal model control, TL (tyreus luyben), CHR (chien hrones reswick) for an single input single output (SISO) liquid level control system. Various time performance criteria's namely IAE, ISE, ITAE has been used for comparison for high stability and reliability. Compared to the conventional PID tuning methods, the emerged results shows that good performance can be achieved with the proposed IMC method based on its high stability, minimum values of rise, settling time criterions.*

***Index Terms**— PID controller, Tuning method, imc.tl.*

I. INTRODUCTION

PID controllers are a family of controllers. PID controllers are sold in large quantities and are often the solution of choice when a controller is needed to close the loop. The popularity of PID controller is that it gives the designer a larger number of options and those options mean that there are more possibilities for changing the dynamics of the system in a way that helps the designer. A PID controller operates the present, past and the future errors present in a feedback system

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

Different forms of controllers are found almost in every area where controlling is essential. In DCS (Distributed control system), PID control plays an important role. The controllers can act as a standalone device when it is embedded in special purpose control systems. PID control is often combined with logic, sequential functions, selectors, and simple function blocks to build the complicated automation systems used for energy production, transportation, and manufacturing. Many sophisticated control strategies, such as model predictive control, are also organized hierarchically.

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 Nicholas, Tyreus Luyben, Chien Hrones Reswich, Modified ZN and Model predictive control are done. Initially, in the section 3,the process model is derived from the real time running process and then in the section 4,the above specified tuning methods formula are used for calculating K_p, K_i and K_d values which are required for controlling a process through PID control. The process values (K_P, k_i, K_D) that are found from the calculation are simulated in the matlab.From the simulation process, various characteristics of the process like time domain specifications (peak time, rise time, peak overshoot and settling time) are found out. In section 5, the error criteria for a process (ITAE, IAE, ISE, and MSE) are discussed. The time domain specification and performance index values are tabulated below. In section 6, based on the values of the tabulation, the most suitable controller is found out and for comparability, the comparison graph is shown below.

II. MODELING OF CONICAL TANK

Mathematical modeling is used to explain the identified system and to study the effects of different components, and to make predictions about the process behavior.

The mathematical model of the conical tank is determined by the following assumptions.

Level as the control variable

- Inflow to the tank as the manipulated variable. This can be achieved by controlling the input flow of the conical tank. [1]

Inflow rate of the tank (F_{in}) is regulated using the valve and the input flow through the conical tank .The radius may vary at each height of conical tank which is due to the shape of the tank. The cross sectional area and level of the tank brings out the difference between inflow and outflow rate.So, by proper modeling the flow and level can be regulated.

Operating Parameters are,

F_{in} - Inflow rate of the tank

F_{out} - Outflow rate of the tank

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H - Total height of the conical tank.
R - Top radius of the conical tank
h - Nominal level of the tank
r - Radius at nominal level

Mass balance Equation is given by

$$F_{in} - F_{out} = A\ dh/dt$$

Outflow rate of the tank, $F_{out} = b\sqrt{(h)}$

On substituting the above values at any level h.

Cross sectional area of the tank, $A = \prod r^2$

$$A = \prod R2\ h2/\ H2$$

Where radius, r = (Top radius of the conical tank) ^{2}(Nominal level of the tank) ^{2} / (Total height of the conical tank) ^{2}

Therefore, $r = R^2h^2/H^2$

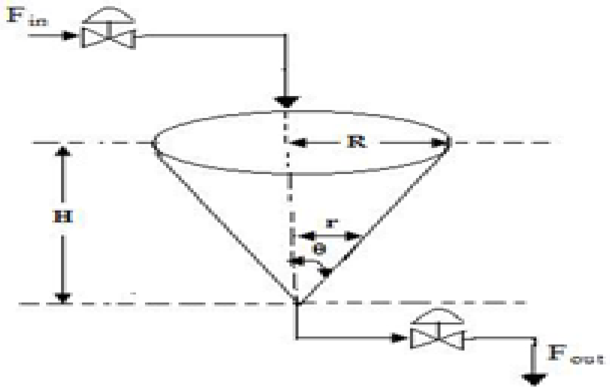

Figure 1. Schematic Diagram of the System

Transfer function of the conical tank is given by taking the partial differentiation of the linearized equation and its corresponding Laplace transform, [1].

$$H(s)/\ F_{out}\ (s) = k\ e^{-\theta s}/\tau\ s+1$$

$$\text{Where, } \tau = 2A\sqrt{(h)}/b$$

$$K = 2\sqrt{(h)}/b$$

The transfer function is FOPTD process and the appropriate tuning technique is used to stabilize the system. Based on the specification the transfer function is given by

$$G(s) = \frac{0.04}{15.9s+1}e^{-4.9s}$$

III. Tuning Methods

A. 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 B.Nichols. It is performed by setting the I[integral] and D[derivative] gains to zero. The P (proportional) gain, Kp is then increased (from zero/until it reaches the ultimate gain, Ku, at which the output of the control loop oscillates with a constant amplitude, Ku and the period of oscillation Pu are used to set the P, I, and D gains depending on the controllers used.The proportional, integral and derivative values of Ziegler Nichol's are Kc=112.2, Ki=16.69, Kd=188.49.

B. Tyreus Luyben Method:

It is one of the conservative tuning methods of PID controller. It depends on the dead time of the process and if it is small it gives a good response and if it exceeds larger value then it results to a sluggish response.Ku and Pu also plays a role in their response curve. The proportional, integral and derivative values of Ziegler Nichol's are Kc=58.43, Ki=1.97, Kd=124.45.

C. Modified Ziegler Nichol's:

Response of large overshoot and undesirable oscillations seek the method called modified Ziegler nichol's.The response of this method has small overshoot. The proportional, integral and derivative values of Ziegler Nichol's are Kc=61.71, Ki=9.18, Kd=276.41

D. Model Predictive Control:

Model predictive control is an advanced method of process control that has been in use in the process industries in chemical plants and oil refineries since 1980's.In recent years ,it has also been used in power system balancing models.MPC rely on dynamic models of the process most often linear empirical model obtain by system identification. The main advantage of MPC is the fact that it allows the current time slot to be optimized while keeping future time slots in account.

Table 1: PID Values of Various Methods

Tuning Methods	KP	KI	KD
Ziegler Nichol's	112.2	16.69	188.49
Tyreus Luyben	58.43	1.97	124.45
Chien Hrones Reswich	77.06	3.46	177.23
Modified Zn	61.71	9.18	276.41

IV. Tuning of Minimum Integral Area Criteria

To identify the best controller, the error responses of various tuning methods are calculated and tabulated. It is also called to be the time performance criteria based on the error responses. The values to be considered for identifying are ITAE, IAE, ISE, MSE values.

A. Integral Time Absolute Error:

It amplifies the effect of small errors in the presence of larger time amplitude. It's comparatively slower than ISE but it has lesser oscillation.

$$ITAE = \int_0^{\infty} t\ |e\ (t)\ |dt$$

B. Integral Absolute Error:

It is suitable for eliminating smaller errors.IAE allows larger deviation than ISE i.e. smaller overshoot

$$IAE = \int_0^T |e(t)|dt \qquad (4)$$

C. Integral Square Error:

In integral square error, the error is integrated over time. Squaring of large errors will be much bigger so it eliminates the large errors quickly but small errors persist for long period.

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$$ISE = \int_0^T |e^2(t)|dt \qquad (5)$$

V. RESULT AND COMPARISON

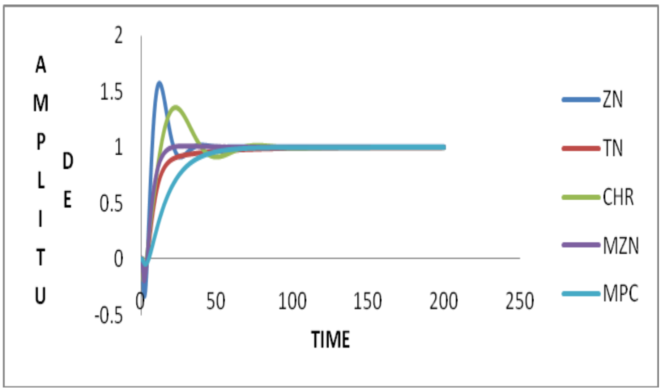

Figure 2. Comparison Chart

Table 2: Comparison of Time Domain Specifications

Tuning Methods	Peak Time	Rise Time	Peak Overshoot	Settling Time
Ziegler Nichol's	12.264	7.5	1.542	43.2
Tyreus Luyben	0	0	0	150
Chien Hrones Reswich	30	21.46	1.016	112
Modified ZN	22	13.27	3.353	100
Model Predictive Control	0	0	0	

In the above table the various types of time domain specification values like rise time, peak time, settling time and peak overshoot are tabulated

Table 3: Comparison of Performance Index

TUNING METHODS	ITAE	IAE	ISE	MSE
ZIEGLER NICHOL'S	1.6774e+005	394.62	120.8861	0.0115
TYREUS LUYBEN	2.744e+004	115.922	3.6203	5.4391e-005
CHIEN HRONES RESWICH	10.6637	1.0116e+003	10.663	0.0146
MODIFIED ZN	8.7897e+004	2113.3558	32.3449	0.019
MODEL PREDICTIVE PAPER	5e+005	999	999	-

In the above table the performance index values of error criteria are tabulated and based on the above two table values, the suitable controller are found out.

VI. CONCLUSION

From the investigation of the above specified five tuning algorithm, the best controller for the analyzed model are found based upon the time domain specifications and performance index values which are tabulated in table 2 and 3.The controller which has the characteristics of low rise time, less peak time, low overshoot and earlier settling time leads to the best one which is shown in figure 2.Therefore from the above interpretation, the most suitable controller is MODEL PREDICTIVE CONTROL

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