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# Tuning of PID Controller for superheated Steam Temperature System using Modified Zeigler-Nichols Tuning Algorithm

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*Abstract*— ***This paper explains the tuning of superheated steam temperature system using Modified Zeigler tuning Algorithm. PID control has a wide range of applications in industrial control. Since many process plants use PID to control the dynamics involved in the process. It has been found possible to set satisfactory controller parameters from less plant information than a complete mathematical model.The fifth order model of super-heated temperature system is converted into first order model with delay using process reaction curve method. The analog PID controller is designed for superheated steam temperature system using Modified Zeigler tuning algorithm and Zeigler Nichols algorithm and results are compared.***

***Index Terms— Criterion of Optimality Tuning Rules, Figures of Merit, Process reaction curve.***

## I. INTRODUCTION

PID control has a wide spectrum of applications in industrial control. The choice of analog controllers is related to the model of the process to be controlled. Tuning is adjustment of parameters to achieve estimated response. The step response of the system should have minimum overshoot and one quarter–decay ratio and also include minimum rise time, and minimum settling time. The boiler has many variables to be precisely controlled for efficiency and safety. Among those variables, super-heated steam temperature is one of the important variables. The fifth order model of super-heated steam temperature is used for study [3], [4].

The analog controllers were tuned for delay plus first order transfer function model. The superheated steam temperature system is to be reduced from fifth order to first order transfer function model.

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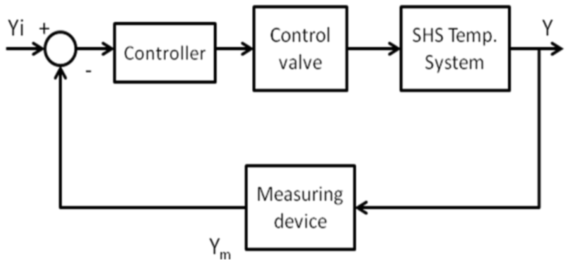



FIGURE 1: BLOCK DIAGRAM OF SHS TEMPERATURE CONTROL SYSTEM

Formula to identify delay plus first order system [3], [4]:

$$G_n(s) = \frac{ke^{-Ls}}{Ts+1} \quad (1)$$

k - Gain
L - Time delay

Many industrial processes are nonlinear and thus it is complicate to describe mathematically. However, it is known that a good many nonlinear processes can be satisfactorily controlled using PID controllers provided controller parameters are tuned well.

The Transfer function of super heated temperature system [10]

$$G_p=1.3882/(19S+1)^5 \quad (2)$$

Therefore, the identified delay plus first order system using Process reaction curve method is

$$\frac{Ke^{-LS}}{TS+1} = \frac{0.771167e^{-56.278S}}{42.934S+1}$$

### A. PID Controller

PID controller calculates an error value as the difference between a measured processed variable and a desired set point the controller minimize the error by adjusting the process control inputs. The main structure of a PID control system is highlighted in Fig. 2, where it can be observed that in a PID controller, in order to generate the proportional, integral, and derivative actions, error signal e(t) is used as a result the signals weighted and summed to form the control signal u(t) which is applied to the plant model. [1],[2] The mathematical derivation of the PID controller is

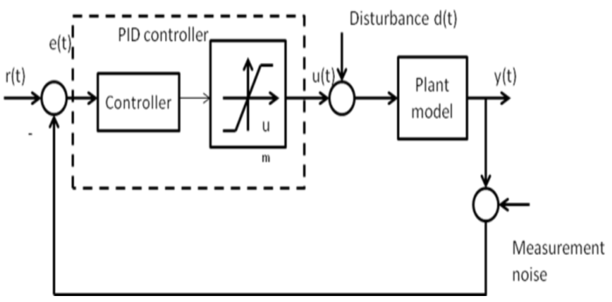



FIGURE 2: BLOCK DIAGRAM OF PID CONTROLLER

$$u(t) = K_p\left[e(t) + \frac{1}{T_i}\int_0^t e(\tau)d\tau + T_d\frac{de(t)}{dt}\right] \quad (4)$$

Where u(t) is the input signal to the plant model, the error signal e(t) is defined as e(t) = r(t)−y(t), and r(t) is the reference input signal.

### B. *PID Derivative Controller*

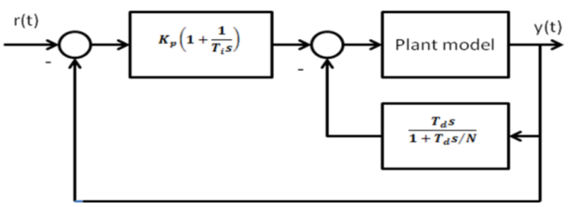



FIGURE 3: BLOCK DIAGRAM OF PID CONTROLLER WITH DERIVATIVE IN FEEDBACK

$$G_c(s) = K_p(1 + \frac{1}{T_i s}) \quad (5)$$

$$H(s) = \frac{(1+K_p/N)T_iT_d s^2 + K_p(T_i+T_d/N)+K_p}{K_p(T_i s+1)(T_d s/N+1)} \quad (6)$$

## II. ZIEGLER–NICHOLS TUNING FORMULA

### A. *Empirical Ziegler–Nichols Tuning Formula*

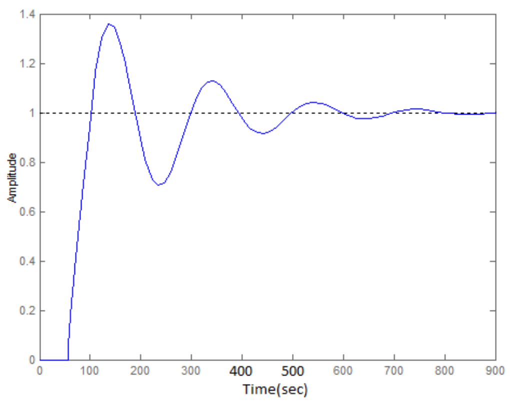
An important empirical tuning formula was proposed by Ziegler and Nichols in the earlier 1942. The tuning formula is acquired when the plant model [7,8] is presented by a first-order plus dead time (FOPDT) which can be expressed by

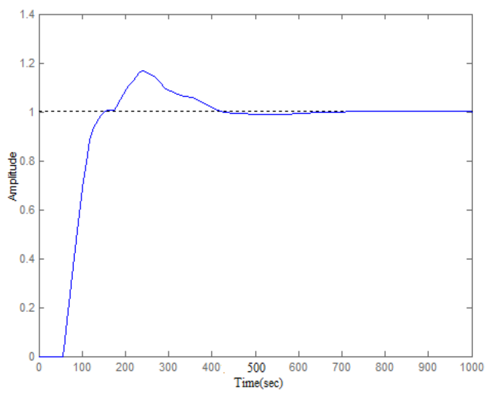
$$G_n(s) = \frac{ke^{-Ls}}{Ts+1} \quad (9)$$

In actual process control systems, many number of plants can be approximately modeled . If the system model can't be physically derived, experiments can be carried to bring out the parameters for the approximate model.[5],[6]For example, if the step response of the plant model is calculated through an experiment, the output signal will be recorded. from which the parameters of k, L, and T (or a, where a = kL/T ) can be brought out by process reaction curve method. Highly advanced curve fitting methods can also be used. With L and a, the Ziegler–Nichols formula in Table1 can be utilized to get the controller parameters.

TABLE1:FORMULA FOR PARAMETERS OF ANALOG CONTROLLERS BASED ON ZEIGLER-NICHOLS ALGORITHM

| Controller type | from step response | | |
|---|---|---|---|
| | $K_p$ | *Ti* | *Td* |
| P | 1/a | | |
| PI | 0.9/a | 3L | |
| PID | 1.2/a | 2L | L/2 |





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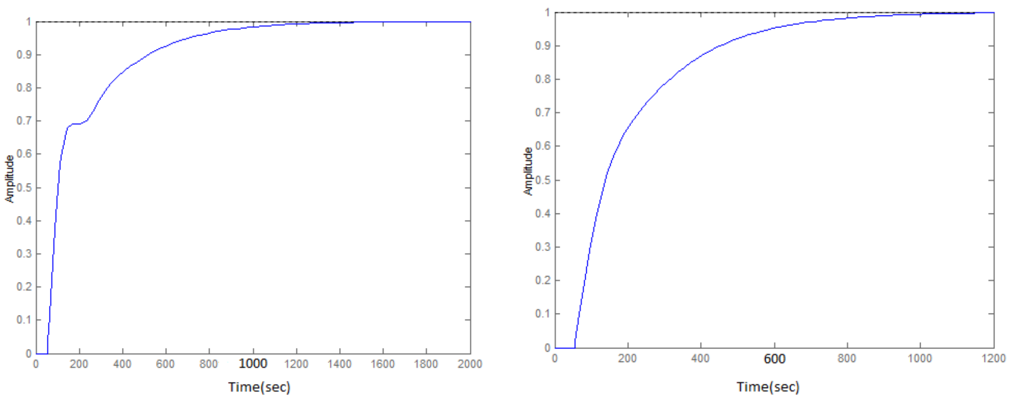


FIGURE 4: STEP RESPONSE OF PID CONTROLLER FOR (A) SHS SYSTEM USING ZEIGLER NICHOLS TUNING ALGORITHM, (B) DERIVATIVE IN FEEDBACK LOOP USING ZEIGLER NICHOLS TUNING ALGORITHM, (C) SHS SYSTEMUSING MODIFIED ZEIGLER NICHOLS TUNING ALGORITHM (ΦB=45°, RB=0.45), (D) SHS SYSTEMUSING MODIFIED ZEIGLER NICHOLS TUNING ALGORITHM (ΦB=45°, RB=0.45).

Modified Zeigler-Nichols Tuning Algorithm: The PID controller can be designed such that

$$K_p = \frac{r_b \cos(\emptyset_b - \emptyset_a)}{r_a} \qquad (7)$$

$$\omega_o T_d - \frac{1}{\omega_o T_i} = \tan(\emptyset_b - \emptyset_a) \qquad (8)$$

Clearly, *Ti* and *Td* are not unique. To get a unique PID design, it is a usual practice to set *Td* = *αTi*, where *α* is a constant. Given an *α*, *Ti* and *Td* can be obtained uniquely from

$$T_d = \alpha T_i \qquad (10)$$

By inspection, it is seen that the Ziegler–Nichols tuning formula is a special case when *α* = 1/4. The Ziegler–Nichols tuning formula can be rewritten as follows:[8,9]

$$K_p = K_c r_b \cos\emptyset_b \qquad (11)$$

$$T_i = \frac{T_c}{\pi}\left(\frac{1+\sin\emptyset_b}{\cos\emptyset_b}\right) \qquad (12)$$

$$T_d = \frac{T_c}{4\pi}\left(\frac{1+\sin\emptyset_b}{\cos\emptyset_b}\right) \qquad (13)$$

where *ra* = 1/*Kc*, *φa* = 0, and *α* = 1/4.

It can be seen that the PI or PID controllers can be designed by a suitable choice of *rb* and *φb*. The design problem is then one of selecting suitable values for these two parameters to give the appropriate performance. This is called a modified Ziegler–Nichols PI/PID tuning.[11,12]

Table2: Performance of PID Controller based on various tuning methods

| Sl.No | Time Domain Specifications | PID controller Z-N settings | PID controller with derivative in feedback using Z-N settings | PID controller with modified Z-N settings | |
|---|---|---|---|---|---|
| | | | | $\emptyset_b$=20°, $r_b$=0.2 | $\emptyset_b$=45°, $r_b$=0.45 |
| 1 | Rise Time | 1.6924 | 2.8686 | 6.0835 | 3.9521 |
| 2 | Settling Time | 663.5979 | 397.5467 | 776.0153 | 954.6468 |
| 3 | Settling Min | 0.1813 | 0.1436 | 0.1901 | 0.3744 |
| 4 | Settling Max | 1.3579 | 1.1677 | 0.9997 | 1.0000 |
| 5 | Overshoot | 35.7860 | 16.7660 | 0 | 0 |
| 6 | Undershoot | 0 | 0 | 0 | 0 |
| 7 | Peak | 1.3579 | 1.1677 | 0.9997 | 1.0000 |
| 8 | Peak Time | 135.2266 | 239.8240 | 1.5933e+003 | 2.8747e+003 |

## III. CONCLUSION

The delay plus first order system for super heated steam temperature control is identified using process reaction curve method .By comparing the responses of PID Controller tuning using Ziegler–Nichols tuning formula exhibits strong oscillation in the set-point response and a large overshoot. The response PID controller for super heated steam temperature system tuned using modified zeigler tuning algorithm has no overshoot and no oscillations. Hence it can be concluded that the modified tuning method is advantageous over the original Ziegler–Nichols PI/PID tuning technique.


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