Computer Engineering and Intelligent Systems
ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online)
Vol.9, No.5, 2018
www.iiste.org

Cohen-Coon PID Tuning Method: A Better Option to Ziegler Nichols-Pid Tuning Method

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Abstract

Controller loop tuning is the process of manipulating the parameters (gains) in a proportional-integral-derivative (PID) controller in order to give satisfactory response to the process system. A satisfactory response is one that exhibits the desired speed of response, yet meets the required accuracy and stability criteria. Control processes are generally tuned under operating conditions, as opposed to start-up conditions, so that the process variable is stable at an operating point. In the industry, the PID human tuning method normally applies to machinery tuning is the Ziegler Nichols (ZN) tuning method, known as the ZN-PID tuning method. However, this PID controller tuning method is ineffective in the control of nonlinear and complex system with varied parameters, large inertia and large delay, as it tends to give a very higher overshoot, higher rise time and higher settling time in the system operation. These disturbances, due to the nonlinearity of the system under control cause the controller to produce poor responses at the output, leading to poor system performance. The limitations in this ZN-PID tuning method could be overcome by using Cohen-Coon-PID (CC-PID) tuning method to drive the system plant. In a nutshell, this research work takes a look at the CC-PID tuning method as betterment to the current ZN-PID tuning method being mostly used in the industrial machinery control. This research work finds application in any PID controlled plant.

1.0 Introduction

For a process control system to work correctly, its control loop(s) must be tuned, by selecting the constants K_p, T_i, and T_d that will be used with the proportional, integral, and derivative actions of a controller. With these constants at the proper levels, the controller can effectively and efficiently regulate the process variable to the set point. Controller loop tuning entails the process of manipulating the gains in a PID controller so that the response of the process system is satisfactory (Bryan and Bryan, 1997). Satisfactory response allows for desired speed of response, yet meets the required accuracy and stability criteria. Control processes are generally tuned under operating conditions, as opposed to start-up conditions; this makes the process variable to be stable at an operating point. In the process industries, ZN-PID controller tuning method is commonly applied, since it can easily be understood by plant operators and is of easy application. However, this PID controller tuning method is ineffective in the control of nonlinear and complex system with varied parameters, large inertia and large delay, as it tends to give a higher overshoot, higher rise time and higher settling time in the system operation. The limitations in this ZN-PID tuning method could be reduced to a minimum level by using CC-PID tuning method to drive the system plant. This will bring about a reduction in the system energy consumption to give effective cost in the system running.

2.0 Literature Review

John Ziegler and Nathaniel Nichols developed the Ziegler-Nichols open- loop tuning method in 1942, and it remains a popular technique for tuning controllers that use proportional, integral, and derivative actions in the industrial sector. Control system performance, in close-loop format is often measured by applying a step function as the set point command variable, and then measuring the response of the process variable. Commonly, the response is quantified by measuring defined waveform characteristics. These are; rise time, percentage overshoot, settling time, steady-state error. PID controller primary function is based on the comparison between the reference input signal with the output signal of the control system to effect control action. The difference which is termed the error signal is the basis on which the controller depends for required performance (Ogata, 2009). Three important parameters are involved with PID control action; Proportional (which depends on the present error), Integral (which depends on the accumulation of past errors), and Derivative (which is a prediction of future errors that are based on current rate of change) (Araki, 1984)

2.1 PID Parameters Tuning

The process of setting the optimal gains for P, I and D to get an ideal response from a control system is called tuning. There are different methods of tuning in control system; Guess and check, Ziegler-Nichols, Chien-Hrone-Reswick, Cohen-Coon and the Wang-Juang-Chan. Out of these, the Chien-Hrones-Reswick (CHR), Cohen-Coon (CC), Wang-Juang-Chan (WJC) and the Ziegler-Nichols tuning methods shall be discussed.

The CHR tuning method was proposed for both the set-point regulation and disturbance rejection in a system (Sheel and Gupta, 2012). In addition one qualitative specification on the overshoot can be accommodated. Compared with the traditional Ziegler–Nichols tuning formula, the CHR method uses the time constant T, delay time L and gain k.

The CC is a tuning method based on the Ziegler–Nichols type tuning algorithm (Wang, Juan and Chang, 1995). Referring to the first order plus dead time model, which can approximately be obtained from experiments, denote by $a = kL/T$ and $\tau = L(L+T)$.

The WJC is a tuning method based on the optimum integral of time and absolute error (ITAE) criterion. This PID tuning algorithm proposed by Wang, Juang, and Chan is a simple and efficient method for selecting the PID controller parameters. If the k, L and T parameters of the plant model are known, then the PID controller parameters can be derived (Chien, Hrones and Reswick, 1952).

The Ziegler-Nichols method is another popular method of tuning a PID controller, this was established in 1942 (Cohen ad Coon, 1953). It is very similar to the trial and error method wherein I and D are set to zero and P is increased until the loop starts to oscillate. Once oscillation starts, the critical gain K_c and the period of oscillations P_c are noted. The P, I and D are then adjusted.

2.2 Related Work

Aydogdu and Korkmaz (2011) asserted that Controllers designed by the Ziegler-Nichols rules, give closed loop systems with high overshoot and poor robustness. Therefore, the method resulted into a control system not enough to control process dynamics smoothly. In order to decrease the disadvantages of ZN method, nonlinear PID approach was thought. Consequently, it gave lower overlapping, short settling time than Ziegler – Nichols, for the third order systems.

Sheel and Gupta (2012) use the software developed for PID tuning tested for testing various types of systems and the result of case study of DC motor speed control was developed for four classical methods of PID controller design. In trajectory control for variation in reference speed when WJC and CHR were used, zero over shoot was observed. When ZN step response method was applied it provided minimum settling time and nearly minimum rise time too. In case of rise time Cohen-Coon method was faster in this case. Out of these five methods tested here. The CHR method gives zero overshoot for trajectory control and the settling time is nearly equal to the settling time of WJC method, but the rise time in both these methods is more than twice that in ZN and Cohen-Coon methods. From the responses taken in disturbance rejection mode the ZN step response method provides better results out of these five methods used here for case study.

3.0 Methodology

This research work is carried out on CC-PID control scheme for industrial plant control. This is aimed at reducing the high overshoot, high rise time experienced by the ZN-PID system, so as to improve the system output performance. The system simulation was run using Matlab R2007a edition environment.

3.1 PID Controller Design

A PID controller is a system that combines the actions of all three controller modes. A PID controller, also called a three-mode controller, can be used to control almost any process that involves lags and dead times. The basic expression for the process variable output (u) for a standard parallel PID industrial controller is:

$$u(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de(t)}{dt} U \quad \text{---------------- (3.4)}$$

Where: K_p = Proportional gain, K_i = Integral gain, K_d = Derivative gain.

The control action of the plant shall be determine by K_p, K_i and K_d. It is to be noted that excessive K_p tends to instability of the system, excessive K_i leads to overshoot, while excessive K_d could also lead to instability of the system. To eliminate all these drawbacks in the system, a CC-PID is introduced to supervise PID controller.

3.2 The PID Controller Parameter

The human supervised PID controller was made to run the plant. Two tuning techniques were applied in this research work, they are; Ziegler-Nichols and the Cohen-Coon tuning techniques. The PID parameters used for each tuning method is as shown;

Ziegler-Nichols: $K_p = 750$, $K_i = 15$, $K_d = 3750$
Cohen-Coon: $K_p = 820$, $K_i = 10$, $K_d = 2750$

The differences in the transient and stationary response wre noted.

The transfer function for the kiln, which indicates the process behavioural response to an input change, is a second order type which is represented in Equation 3.1

$$H_p = \frac{75}{2700S^2+120s+1} \quad (3.1)$$

4.0 Results and Discussion

4.1 Performance of Various Tuning method

4.1.1 Performance with ZN-PID method

Figure 4.1 shows the system control performance for ZN-PID method. The rise time was 0.0158sec., with a settling time of 0.1308sec, and percentage overshoot of 17.4%.

4.1.2 Performance with CC-PID method

Figure 4.2 shows the system control performance for CC-PID method. The rise time was 0.0203sec with a settling time of 0.1292 sec, and percentage overshoot of 11.6%.

4.1.3 Comparison of the Tuning Techniques

Although, for the ZN-PID tuning method, the rise time was lower (0.0158Sec) compared to that of the CC-PID tuning method (0.0203), but has a poor settling time and a percentage overshoot of 0.1308sec and 17.4% respectively compared to that of the CC-PID of 0.1292 and 11.6% respectively. Therefore, the CC-PID tuning method brings about reduction in energy consumption, and hence, reduction in output cost. This is shown in Table 4.1.

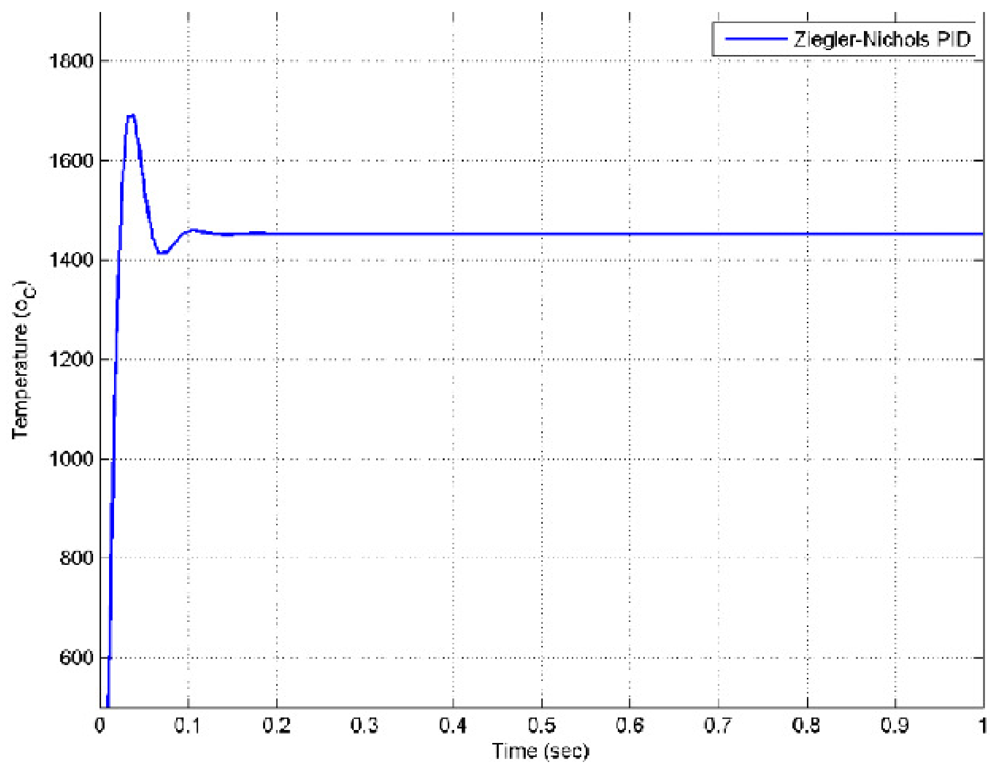

Figure 4.1: Plant response to Ziegler-Nichols PID controller Tuning System

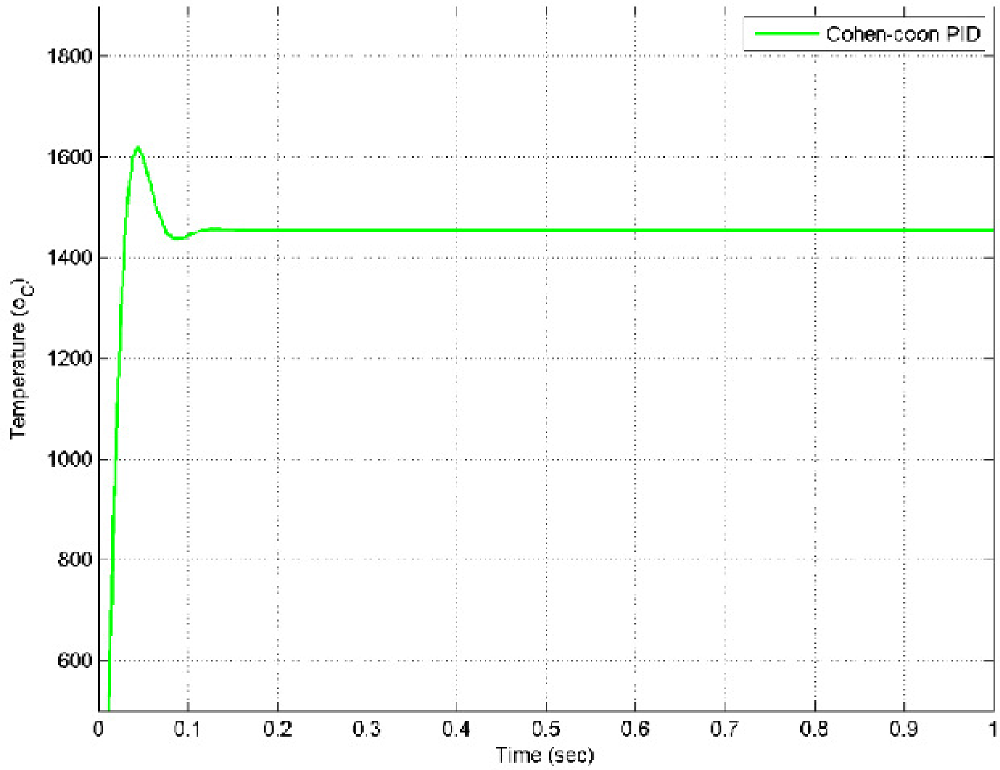

Figure 4.2: Plant response to Cohen-Coon PID controller Tuning System

Table 4.1: Comparison of the Tuning Techniques

Tuning Technique	Rise Time (Sec)	Settling Time (Sec)	% Overshoot
Ziegler-Nichols	0.0158	0.1308	17.4
Cohen-Coon	0.0203	0.1292	11.6

Conclusion

From the analysis in section 4, CC-PID based tuned controller for system control performs relatively better than the ZN-PID tuning method. Although the two are conventional classical PID controller which requires tuning by experienced personnel, and also require the precise solution to full mathematical model of the system to be controlled, the CC-PID is better in the sense that it gives a reduction in energy consumption due to its low percentage overshoot and settling time; therefore, could be used to as a better substitute for the Ziegler-Nichols-PID (ZN-PID) tuning techniques in the industrial sector.

2 CONTRIBUTION TO KNOWLEDGE

The major contribution to knowledge of this research work is;

It reduces the amount of heat generated by the plant as energy efficiency of plant operation is experienced and enhance production time and cost compared to the ZN-PID tuning method.

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