

## Reliability of PID Controller for a Real Time Sensor Interfaced Temperature Process

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**Abstract:** The day to day requirement of technical parameters for industry being analysed by many researchers, but here we considered the analysis of temperature. Then the temperature process model is identified as first order plus dead time model (FOPDT). For the obtained model the Proportional-Integral-Derivative (PID) controllers are tuned using traditional technique, Zeigler – Nichols (ZN) method, then particle swarm optimization technique (PSO). Tuned PID controllers values are implemented in closed loop environment using Matlab Simulink platform. A comparative analysis is proposed and the efficiency of the controller is evaluated based on time domain specification and error criterion analysis being achieved. For minimizing the error and enhancing the process reaction time with controller reliable parameters is proposed for the real time industrial application.

**Keywords:** PID controller, Z-N method, PSO, Temperature process, First order system.

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### 1. Introduction

Proportional Integral Derivative Controller has been used in Industrial control applications for a long time [1]. The reasons for their wide popularity lies in the simplicity of design and good performance, which includes low percent overshoot and small settling time. Integral depends on past error, where it can overcome the offset but its overshoot value is more. Derivative depends upon the future error, but it can overcome both offset and overshoot, but it cannot be used separately. For a fair comparison of different PID settings, both time domain performance. And frequency domain robustness should be considered. Numerous [11, 2, 5] methods have been projected for tuning these controllers [12, 6], but every method has some constraint. As a result, the design of PID controller still remains a challenge before researchers and engineers.

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 ( $k_p$ ), integral ( $k_i$ ), and derivative ( $k_d$ ) is an effective part in controlling a process.

### 2. Real-Time Temperature Process

The Fig. 2 explores the system schematic arrangement of temperature process setup. The

process setup consists of heating tank fitted with solid state relay controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by Rota meter in the range of (6-60) LPH is shown in Fig. 1. Temperature sensor, RTD type PT 100 is used for temperature sensing. It has control unit, which is a digital indicating controller with RS 485 communication. A Solid state relay (SSR) is used to control heat generation in the heater with input 4-20 mA D.C., Capacity 20 A. A process tank is made up of stainless steel and a volume of 0.5 litre. The overall dimension of the process station is 400w×400d×330h mm.



Fig. 1. Temperature Process Setup.

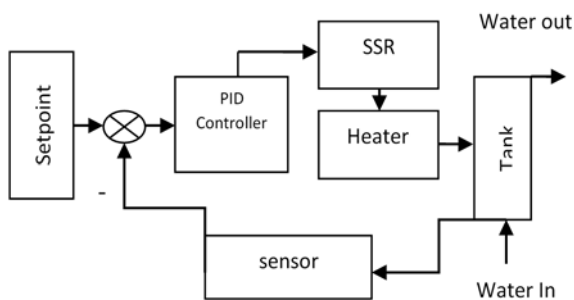


Fig. 2. Schematic arrangement of temperature process.

In order to get open loop response, following procedure should be done:

1. Start the process station and choose the open loop.
2. Enter 40 % in the controller output and wait the process to reach the steady state.
3. Then apply step change by increasing the controller output from 40 % to 60 % and allow the process to reach the steady state. Fig. 3 shows the open loop response of the temperature process. The change in controller output will affect in power supplied to the heater through solid state relay.

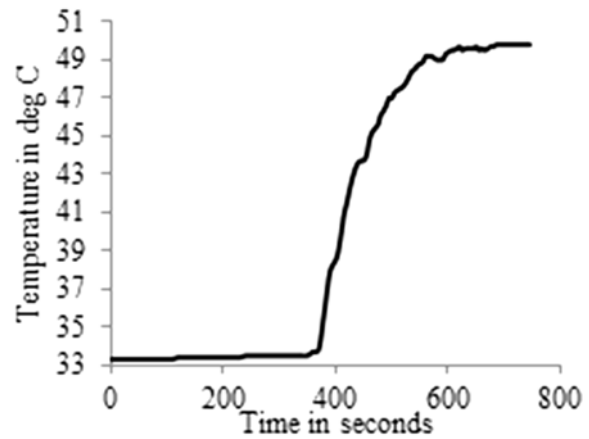


Fig. 3. Open loop response.

The Process Transfer Function has been determined by the Experimental Process mentioned above and is shown in Eq. (1).

$$G(s) = \frac{0.85}{56.5s + 1} e^{-380s} \quad (1)$$

The Experiment is carried out and the response is taken until the steady state is reached without the use of the controller [10]. The response of that process without controller will be a curve with some dead time and steady state time. By that, Gain of the process can be determined which is the ratio of output to the input, Time Constant can be calculated which is the time difference from dead time to steady state and Dead time (i.e.) the time period for which the output is not responding to the input is also determined.

### 3. Controller Tuning

#### 3.1. Ziegler-Nichols Method

The Ziegler-Nichols [1] design methods are the most popular methods used in process control to determine the parameters of a PID controller [2]. Ziegler Nichols tuning methods (ZN tuning methods) are the principal methods used in PID controller tuning. This method is also called to be online-tuning method. Given the magnitude and phase, we can determine gain parameter of the model, frequency  $f$  through pi-radians, plant gain  $K$ , gain margin  $K_u$  and  $P_u$ , ultimate gain.

The estimation of proportion response is classified "affectability" or "throttling range", the previous being valve be in motion per pen motion, the last is corresponding or the pen motion important to give full valve movement. Sensitivity adjustment is necessary if optimum control stability is to be attained [6]. Proportional, integral and derivative gain values are obtained by solving  $k_p=0.45K_u$  and  $T_i=0.5P_u$ , ( $K_i=K_p/T_i$ ) and  $T_d=0.125P_u$ , ( $K_d=K_p/T_d$ ).

### 3.2. PSO-Algorithm

#### 3.2.1. Implementation of PSO Algorithm

The optimal values of [2] of the conventional PID controller parameter esteems are particles whose qualities are particles and whose qualities are adjusted in order to limit the objective function, here for this situation is the error criterion. For the PID controller plan, it is guaranteed the controller settings unsurprising outcomes in a stable closed loop system. The method for getting optimal PID controller esteems is appeared in Fig. 4.

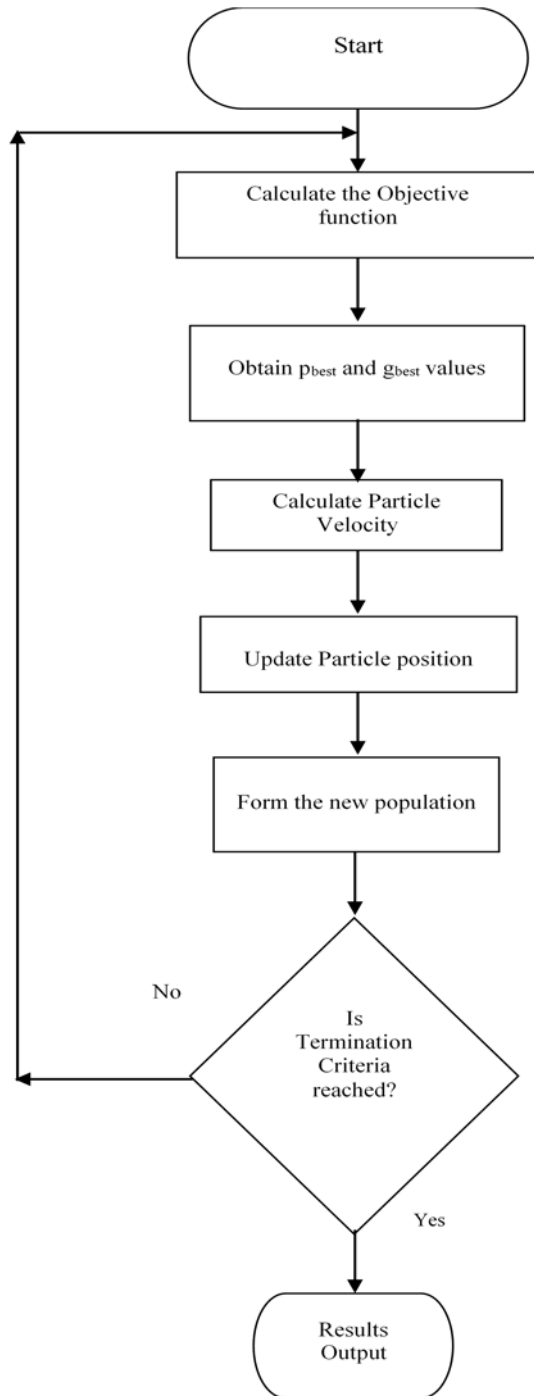


Fig. 4. PSO Flow Chart.

#### 3.2.2. Selection of PSO Parameters

To start up with PSO, certain parameters are required. Choice of these criterion selects to a great extent the ability of global minimization [3]. The most extreme speed changes the capacity of getting away from local optimization and refining global optimization. The size of swarm adjusts the prerequisite of global optimization and computational expense. The PSO parameter are used in the algorithm, to find optimal solution.

PSO Selection Parameters:

Population Size	100
Number of Iterations	100
Velocity constant, c1	2
Velocity constant, c2	2

#### 3.2.3. Performance Index for the PSO Algorithm

The objective function is estimated depends on the error rule. The execution of a controller is best assessed regarding error guideline. Controller's execution is assessed regarding Integral Absolute Errors (IAE) rule that is given by,

$$IAE = \int_0^T |e(t)| dt \quad (2)$$

The IAE weights the error with time and subsequently stresses the error esteems over a scope of 0 to T, where T is the settling time.

#### 3.2.4. Termination Criteria

End of streamlining algorithm can happen either when the maximal number of cycles gets over or with the obtainment of agreeable wellness fitness value. Fitness value is the reciprocal value of error, since we consider for a minimization of objective function. In this work the end criteria is inspected to be the maximum number of cycles. The adaption of the values for the first iteration for  $K_p$ ,  $K_i$  and  $K_d$  are shown in Fig. 5, Fig. 6 and Fig. 7 respectively.

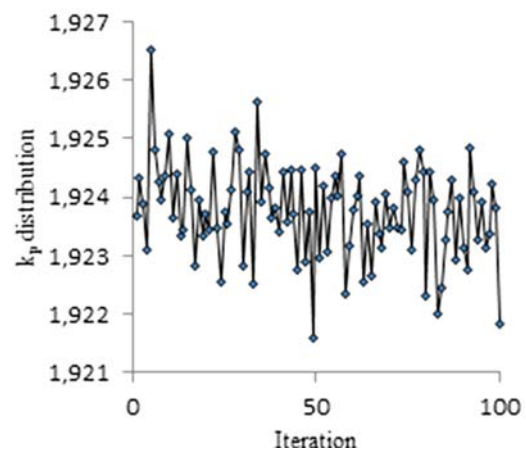


Fig. 5. Distribution of  $K_p$ .

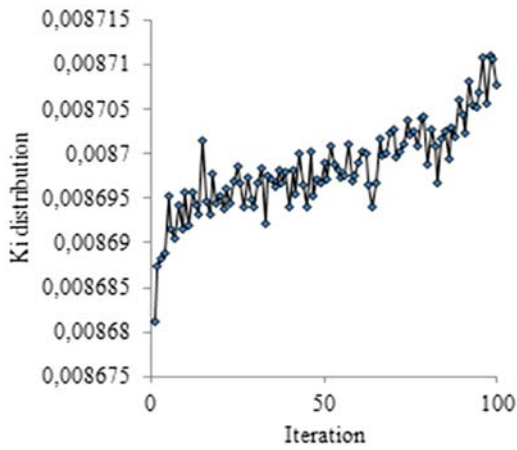


Fig. 6. Distribution of  $K_i$ .

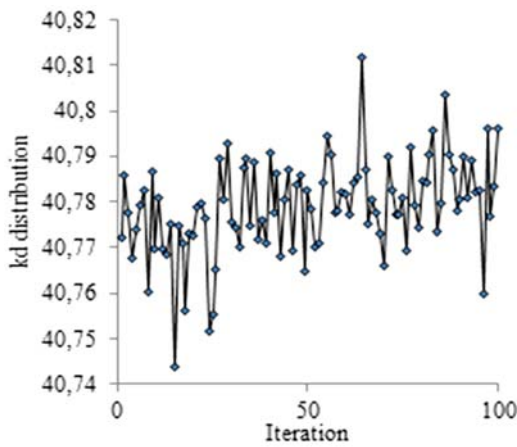


Fig. 7. Distribution of  $K_c$ .

#### 4. Results and Discussions

Obtained PID controller values using conventional tuning method and optimization method are implemented and test tested in MATLAB Simulink Environment.

PID controller values obtained using conventional tuning method is as follows:

$$K_p=1.464, K_i=0.0062, K_d=86.37$$

PID controller values obtained using particle swarm optimization method is as follows:

$$K_p=1.9218, K_i=0.0087, K_d=40.7960$$

Table 1. Time Domain Specifications.

Controllers	ZN based PID	PSO based PID
Settling time	1500	1000
Rise Time	278	126
Peak Time	600	0
Peak Overshoot	10	0

The obtained PID controller values, is implemented in MATLAB Simulink environment in order to get closed loop response is shown in Fig. 8.

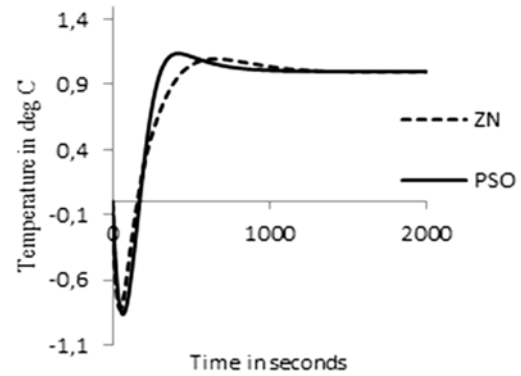


Fig. 8. Comparison of ZN and PSO for temperature process.

Table 2. Performance Index.

Controllers	ISE	IAE	ITAE	MSE
	e+003		e+005	
Ziegler-Nichols	4.3094	3.2625	4.9048	0.2878
Particle Swarm Optimization	4.3788	3.0845	3.3164	0.2742

#### 4.1. Servo Regulator Regimentation

A servo control loop [8] is one which responds to a change in set point. The set point may be changed as a function of time and therefore the controlled variable must follow the set point. Initially, value 0.5 is given as set value and then at particular instant a set point value is shifted to new value. The controlled variable follows the new set point value and PSO follows quicker than the conventional controller response is shown in Fig. 9.

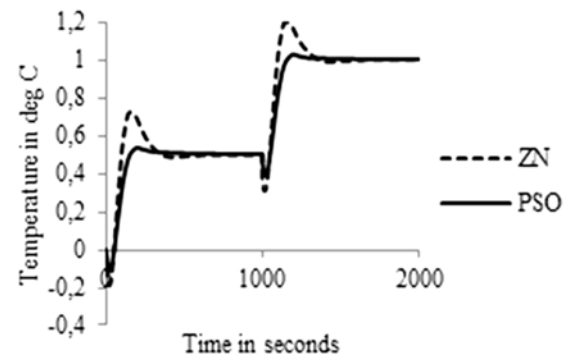


Fig. 9. Comparison of servo performance for ZN and PSO.

In regulatory control loop, a settled process variable is disturbed at particular instant, a process

variable which responds to a change, and controller helps to bringing the variable back to original steady state value.

Regulatory control is by distant more common than servo control in the process industries. The above is the general description of the servo-regulatory responses [7]. The responses shown in Fig. 10, shows that the comparative closed response of two controller methods. A process is disturbed at particular time instant, process response to disturbance and PSO reacts quickly for disturbance and PSO hold on best.

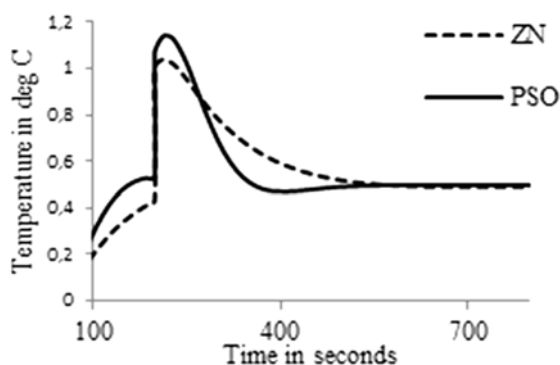


Fig. 10. Comparison of regulatory performance of ZN and PSO.

## 5. Conclusion

The performance of the conventional and PSO based PID controller values is analyzed in FOPDT model of temperature process. For both conventional and optimization PID controller tuning methods, the set point tracking and disturbance rejection analysis were performed. The PSO based PID controller tracks the set point, eliminates the disturbance faster and reaches steady state response. Simulation results have been given to show that the PSO based PID controller performance gives superior results and efficiency is justified by time domain analysis and error criterion analysis. Further, this process can be analyzed using various advanced control schemes such as Neural

Network, Fuzzy logic control, Ant Colony optimization and other tuning techniques.

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