

Wireless Experimental PID Temperature Control with Different Tuning Methods

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Abstract: In this study wireless experimental input/output data obtained from The Cussons P3005 type process control simulator. The Proportional-Integral-Derivative(PID) algorithm which is written in MATLAB is utilized to wireless temperature control and experiments achieved by using MATLAB/Simulink program. Ziegler-Nichols and Cohen-Coon tuning parameters which are determined with dynamic analyses are applied to the PID algorithm and the experimental control results compared by observing the temperature profiles. The wireless temperature control was applied to the system successfully and the efficiency of the this two tuning methods was observed by calculating the Integral Square of the Error (ISE) and the Integral Absolute value of the Error (IAE) from experimental results. The lower values of ISE and IAE, Cohen-Coon tuning method was discovered to be better than Ziegler-Nichols tuning method for this process. Wireless control technique can be proposed for industrial heating-cooling systems.

Keywords: Matlab/Simulink, PID algorithm, heating-cooling system, wireless temperature control, Single Input-Single Output (SISO)

I. INTRODUCTION

In recent years, applications of wireless technology have evolved in many areas due to their large applicability and development possibilities, especially in the monitoring, automation and control of the systems. Research on wireless connection has mainly been focused on protocols and algorithms for applications, in which large, random and static deployment is the norm and in which node mobility and network performance assurances are not considered critical. In addition, there is only a finite source of energy which must be optimally used for processing and communication. Nowadays, several application sectors such as traffic control, military surveillance, healthcare monitoring, industrial automation, urban sensing/computing and incorporate the use of wireless sensor, usually in direct connection from the data collection point [1]. Wireless networks offer unprecedented flexibility ranging from high density sensing capabilities to deployment in areas where wired devices may be difficult or impossible to deploy (such as inside waterways and high-temperature areas in oil refineries) [2].

The important benefits of wireless technology are the reduced installation cost, high speed links, and easy setup of connections among different devices/appliances both financially and in labor, as a considerable investment is made in the wiring of factories. The use of wireless technology is

not only a replacement of cables, the benefits go beyond that. With wireless devices, increased flexibility is gained, as sensors can be placed more freely in a plug-and-play fashion, even on rotating machines. Cable failures are eliminated and wireless communication is robust, as it can be done over several paths in a mesh network. Finally, there are the opportunities for new applications that are enabled by wireless control. An example is an industrial wireless sensor network that provides additional real-time information of the system, allowing better control and enabling independent monitoring [3].

Today PID controllers are the most common control systems in the industry due to the good cost, benefit ratio, simplicity and robustness they are able to provide. Due to their applicability, PID controllers are widely used at the different areas. There are many tuning methods for PID control for processes. Ziegler-Nichols and Cohen-Coon methods are two of the old and most popular analytical tuning methods [4-6].

MATLAB, developed by the MathWorks Inc., has been a powerful software for mathematical computations and visualisations. SIMULINK is a part of MATLAB for modelling, simulation, and analysis of dynamical systems in a flowsheeting environment. SIMULINK includes a comprehensive block library of sinks, sources, linear and nonlinear components, and connectors. Users can also customize and create own block models using the S-Function format. For modelling, SIMULINK provides a graphical user interface(GUI) for building models as block diagrams, using click-and-drag mouse operations [7-9].

Temperature control is very important in chemical processes because it keeps all substances at the set temperatures and at the same time it is necessary that chemical reactions are take place at the constant temperatures. Conventional control studies with electrical cable is often used, but there's a new method of achieving the same results with wireless temperature control. In the present study, process control simulator is used for wireless PID temperature control application by utilizing MATLAB/Simulink program and the compatibility of the wireless technology that is used for process control purpose, is shown.

II. EXPERIMENTAL SYSTEM

The process control simulator consists of two main units, an instrument console and a framework carrying the process equipment which is shown in Figure 1. The instrument console contains the electronic flow, level, temperature controllers and electrical switchgear. It is connected to the process equipment by several cable assemblies. The process equipment consists of a water tank, water circulating pump, electrical water heater, two vessels, two electrically positioned control valves and a heat exchanger. In process control simulator, twelve manual valves are available for different process experiment loops. In the simulator, temperature measurement and control can be made at four different points which are first tank, heater output, second tank input and output. The system developed for transferring data between the computer and the panel. Data transfer is achieved wirelessly by using the two antenna are found in the laboratory connected to the computer and outside connected to the process simulator. Control valves outputs are connected to the modules, the necessary calibrations are made. The water is pumped via the electrical heater into the reactor up to a certain level. The water then flows back to the sump tank via the cooler. Heat is fed to the water by the heater and residual heat removed by the cooler so as to return the sump tank water temperature to a suitable base level. Heater which is connected on-line to the computer is used as a manipulated variable [10].



Figure 1. Experimental system: Process simulator, control panel and computer on-line connected to simulator with wireless technology

Firstly, the dynamic analysis have been made and controllability of the system is observed. After 300s steady state of the temperature, a step change is given to the system in the face of the heater capacity change from 10% to 80% and system's response to this effect which is the heater outlet temperature has been observed. A first order plus dead-time model parameters which are the model gain, the time constant and the model dead-time are obtained from the process reaction curve shown in Figure 2. Ziegler-Nichols and

Cohen-Coon tuning parameters are determined with dynamic analyses are given in Table 2. These parameters are applied to the PID algorithm and the wireless experimental control results compared by observing the temperature profiles which is shown in Figure 4 and Figure 5. Wireless PID temperature control algorithm applied using MATLAB/Simulink program for set point 30°C and 40°C.

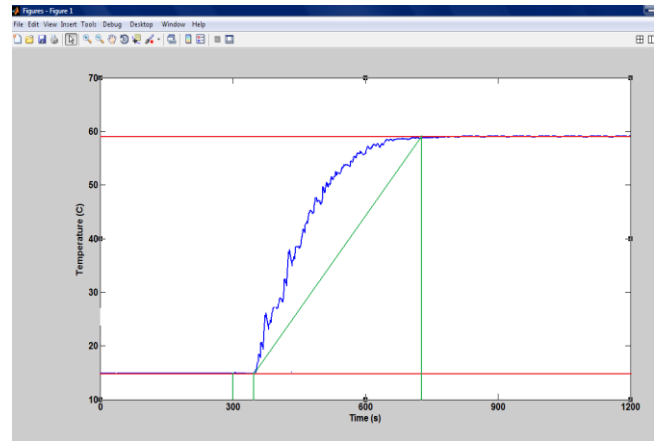


Figure 2. Matlab figure of process reaction curve

Transfer function of PID controller;

$$G_C = K_c \left(1 + \frac{1}{\tau_I s} + \tau_D s \right) \quad (1)$$

Table 1. PID tuning parameters equations [6]

Parameter	Ziegler-Nichols	Cohen-Coon
K_c	$K_u/1.7$	$\frac{1}{K_p} \frac{\tau}{td} \left(\frac{4}{3} + \frac{td}{4\tau} \right)$
τ_I	$P_u/2.0$	$td \frac{32 + 6(td/\tau)}{13 + 8(td/\tau)}$
τ_D	$P_u/8.0$	$td \frac{4}{11 + 2(td/\tau)}$

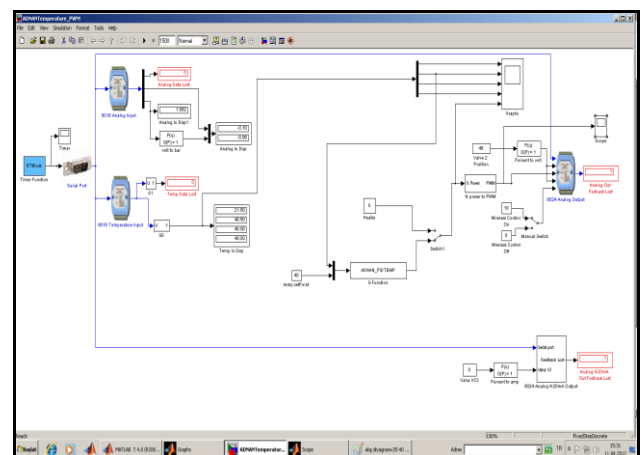


Figure 3. Matlab-Simulink flow chart for wireless temperature control

III. RESULTS AND DISCUSSION

Conventional two PID tuning methods have been used to determine the control performance by using different set points as shown in Figure 4 and Figure 5. As a means of comparing the performance of the controller the Integral Square of the Error (ISE) and the Integral Absolute value of the Error (IAE) are computed for the closed-loop process output,

$$ISE = \sum_0^t [y(t) - r(t)]^2 \quad (2)$$

$$IAE = \sum_0^t |y(t) - r(t)| \quad (3)$$

where $y(t)$ is the output value and $r(t)$ is the set point value. The differences between the two control tuning techniques were also shown clearly and numerically by calculating the IAE and ISE values and the results of the calculations are as tabulated below (Table 3). As can be seen from Table 3 above, the ISE and IAE values of Cohen-Coon tuning technique were found to be lower than those of the Ziegler-Nichols tuning technique.

Table 2. PID tuning parameters for Ziegler-Nichols (Z-N) and Cohen-Coon (C-C) methods

	K_c	τ_I	τ_D
C-C	4.87	1.82	0.29
Z-N	6.23	2.59	0.46

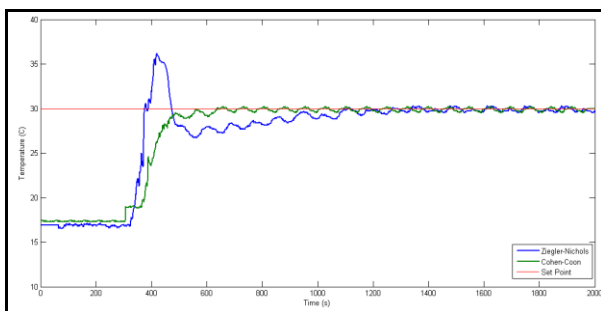


Figure 4. Wireless temperature control results:set point 30 °C

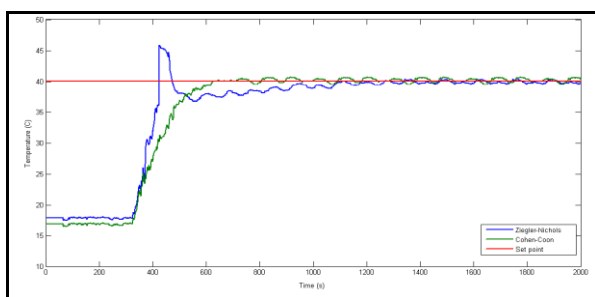


Figure 5. Wireless temperature control results:set point 40 °C

Table 3. Calculated ISE and IAE values by experimental data for Z-N and C-C methods

Set Point	ISE		IAE	
	Z-N	C-C	Z-N	C-C
30 °C	4219.56	2945.82	1327.80	1099.00
40 °C	4879.61	3687.39	1569.10	1218.40

The wireless communication method was applied to examine the effect of approximate system responses to estimate the model parameters of the system. An experimental PID control parameters were obtained with Cohen-Coon and Ziegler-Nichols tuning techniques and the wireless temperature control was applied to the system successfully using Matlab/Simulink program. The lower values of ISE and IAE, Cohen-Coon tuning method was discovered to be better than Ziegler-Nichols tuning method for this process. This wireless control technique can be proposed for industrial heating-cooling systems.

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