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ELECTRONIC ENGINEERING

Development of Supervisory Control and Data Acquisition Based Manufacturing System Using PID Control

Min Zaw Oo[#1], Aye Wint Mon[*2], Hla Myo Tun[#3], Zaw Min Naing[^4]

[#]*Department of Electronic engineering, Mandalay Technological University*
Mandalay, Myanmar

[*]*Department of Electronic Engineering, Technological University (Sitway)*
TU (Sitway Campus), Sitway, Myanmar

[^]*Technological University (Maubin), Myanmar*

[1]minzawoo.mtu@gmail.com
[2]wintmon28@gmail.com
[3]hmyotun@myanmar.com.mm
[4]zawminnaing@pmail.ntu.edu.sg

***Abstract*— In this research, the main theme is the system integration of SCADA Based Mini Factory Design Using PID Control. The integrated system is composed of the master terminal unit (MTU) and the remote terminal units (RTUs). The main function of master terminal unit are Acquire data from RTUs within the region, Log and display this data on a local operator station, Pass data back to the master station, and Pass on control requests from the master station to the RTUs in its region. The remote terminal unit means PLC, DCS or IED is located at a remote location in industrial automation, which is composed of the actuator systems and the sensory systems. The communication system uses industrial Ethernet communication system, which combines the master terminal unit with the remote terminal units. To integrate both systems, the signal classification, baud rate of communication system and system characteristics considered PID control is designed with signal and measurement theory.**

***Keywords*— PID control, SCADA, Manufacturing System, mathematical Model Design, Mini-factory Design.**

I. Introduction

Computer-based supervisory control and data acquisition (SCADA) systems have evolved, from standalone, compartmentalized operations into networked architectures that communicate across large distances. In addition, their implementations have migrated from custom hardware and software to standard hardware and software platforms. These changes have led to reduced development, operational, and maintenance costs as well as providing executive management with real-time information that can be used to support planning, supervision, and decision making. Some of the characteristics, performance requirements, and protocols of SCADA system components require adapting information-system security methods in industrial settings. Supervisory control and data acquisition (SCADA) systems are vital components of most nations' critical infrastructures. They control pipelines, water and transportation systems, utilities, refineries, chemical plants, and a wide variety of manufacturing operations. SCADA provides management with real-time data on production operations; implements more efficient control paradigms, improve plant and personnel safety, and reduce costs of operation. These benefits are made possible by the use of standard hardware and software in SCADA systems combined with improved communication protocols and increased connectivity to outside networks, including the Internet. However, these benefits are acquired at the price of increased vulnerability to attacks or erroneous actions from a variety of external and internal sources.

II. SCADA Based Mini-Factory Design

A. Design Block Diagram

The SCADA system architecture is shown in Fig. 1. This system consists of three levels to control the field elements from the operator. The first level is operator level, the second level is communication level and the third level is field level. The stability techniques are based on the PID control for master terminal units (MTUs).

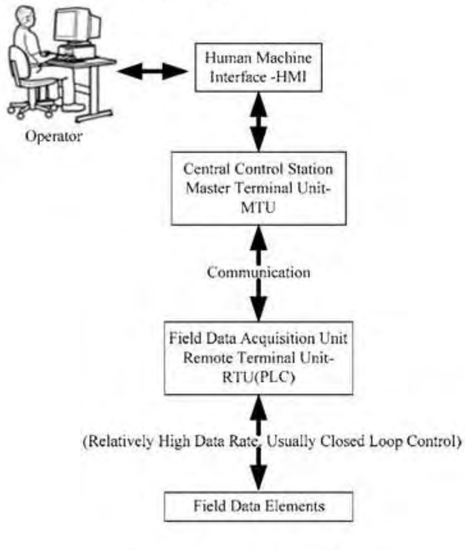

Fig. 1 SCADA System Architecture

B. Second-Order Process and a PID Controller

In the processing industry, PID controllers play a crucial role in keeping our plants running – virtually everything from simply filling up a storage tank to complex Mini-Factory. PID control is the most commonly used strategy for programmable controllers in the industry. PID Controllers have been in use for many years, due to their ease of use and ability to effectively control a wide range of plants. In recent years there has been substantial interest in auto-tuners for PID controllers. As the name suggests, these (semi)-automatically determine the gains for a PID controller. Much of this work has been based around the relay auto-tuner, which uses a relay to determine the critical gain and critical period for a given system. This can then be used in conjunction with tuning rules, including extensions to the Ziegler Nichols rules to calculate the gains for the PID controller. PID control is a widely used control most of the industrial automation process because of its remarkable efficacy, simplicity of implementation and broad applicability. The PID control algorithm is a three-term linear control strategy that uses proportional control as its major control term, integral action to largely remove steady state error, and derivative control to add stability to a loop and thus facilitating the use of higher proportional action.

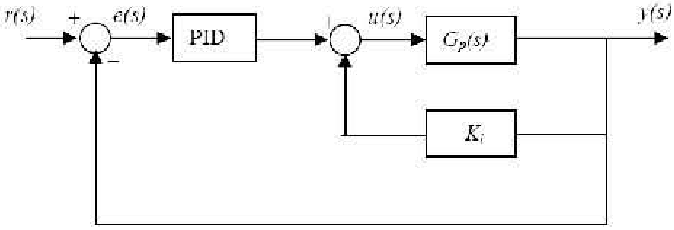

Fig. 2 Block diagram of two loop controller

C. Integrating Process

For controller design purpose, we used the following simple integrating process:

$$G_p(s)=\frac{K}{(\tau s\text{-}1)}e^{-Ls} \tag{1}$$

With proportional controller in the inner feedback loop, the internal closed-loop transfer function $G_I(s)$ can be obtained as

$$G_I(s)=\frac{G_p(s)}{1+K_I G_p(s)}=\frac{Ke^{-Ls}}{\tau s\text{-}1+KK_I e^{-Ls}} \tag{2}$$

By using a Taylor series expansion, the time delay term in the denominator of equation (2) can be approximated by

$$e^{-Ls}\cong 1\text{-}Ls+0.5L^2s^2 \tag{3}$$

By substituting

$$G_I(s)\cong G'_p(s)$$

$$=\frac{Ke^{-Ls}}{0.5KK_I L^2 s^2+(\tau\text{-}KK_I L)s+KK_I-1} \tag{4}$$

Here, $G'_p(s)$ denotes the second-order plus time-delay model obtained from the Taylor series expansion method. Since the characteristic equation of $G'_p(s)$' should have negative poles to be stable, the following condition must be satisfied from the Routh-Hurwitz stability criterion

$$K_{min}=\frac{1}{K}<K_I<\frac{\tau}{LK}=K_{max} \tag{5}$$

For optimum disturbance rejection, it was proposed as:

$$K_I=\sqrt{K_{min}K_{max}}=\frac{1}{K}\sqrt{\frac{\tau}{L}} \tag{6}$$

Then

$$G_p(s)=\frac{\frac{K\sqrt{L}}{(\sqrt{\tau}-\sqrt{L})}e^{-Ls}}{\frac{0.5L^2\sqrt{\tau}}{(\sqrt{\tau}\text{-}\sqrt{L})}s^2+\frac{(\tau\sqrt{L}\text{-}L\sqrt{\tau})}{(\sqrt{\tau}\text{-}\sqrt{L})}s+1} \tag{7}$$

The design method proposed can be directly used to design controller

$$b_0=\frac{K\sqrt{L}}{(\sqrt{\tau}\text{-}\sqrt{L})}$$

$$a_2=\frac{0.5L^2\sqrt{\tau}}{(\sqrt{\tau}\text{-}\sqrt{L})}$$

$$a_1=\frac{(\tau\sqrt{L}\text{-}L\sqrt{\tau})}{(\sqrt{\tau}\text{-}\sqrt{L})} \tag{8}$$

$$\begin{bmatrix}K_p\\K_i\\K_d\end{bmatrix}=\frac{\pi}{2A_m KL\sqrt{L}}\begin{bmatrix}(\tau\sqrt{L}\text{-}L\sqrt{\tau})\\(\sqrt{\tau}\text{-}\sqrt{L})\\0.5L^2\sqrt{\tau}\end{bmatrix} \tag{9}$$

From Fig. 2, $e(s)=r(s)\text{-}y(s)$, the process input $u(s)$ can be written as

$$u(s)=\left(K_p+\frac{K_i}{s}+K_d s\right)[r(s)\text{-}y(s)]\text{-}K_I y(s)$$

$$=(K_p+K_I)\left[\frac{K_p}{K_p+K_I}r(s)\text{-}y(s)\right]+\left(\frac{K_i}{s}+K_d s\right)e(s) \tag{10}$$

Let $b=\frac{K_p}{K_p+K_I}$ and $K'_p=K_p+K_I$ we can be obtained $u(s)$ in the following form:

$$u(s)=K'_p(b\times r(s)\text{-}y(s))+\left(\frac{K_i}{s}+K_d s\right)e(s) \tag{11}$$

The net result of inner feedback loop is the equation (11) which is the two-degree of freedom PID controller, where K'_p, K_i, K_d and set-point weighting are PID settings as shown in Fig. 3.

The effect of K_I is reflected in the PID controller design, we can ignore the inner feedback loop and directly design PID controllers for integrating or unstable time delay processes by equation (9).

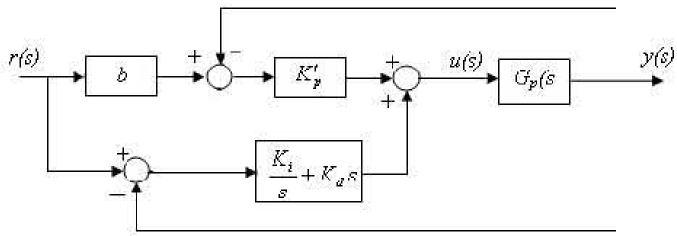

Fig. 3 Implementation of PID control for integrating and unstable Processes

D. Research Example

The integrating process transfer function is as follows:

$$G_p(s) = \frac{e^{-0.2s}}{s(s+1)} \quad (12)$$

The control performance of the proposed method is compared with PID tuning methods for integrating processes. PID controller settings for each method are listed in Table .1.

TABLE I
PID CONTROLLER SETTINGS FOR RESEARCH EXAMPLE

Gain and Phase Margin Method	
K_p'	3.0994
K_i	2.618
K_d	2.6704
b	0.6768

III. SIMULATION RESULT OF PID CONTROL

The normal manufacturing system could not be stable for running condition. But the PID controller for stable system is added to the unstable system for manufacturing system. The present manufacturing system is for process industry.

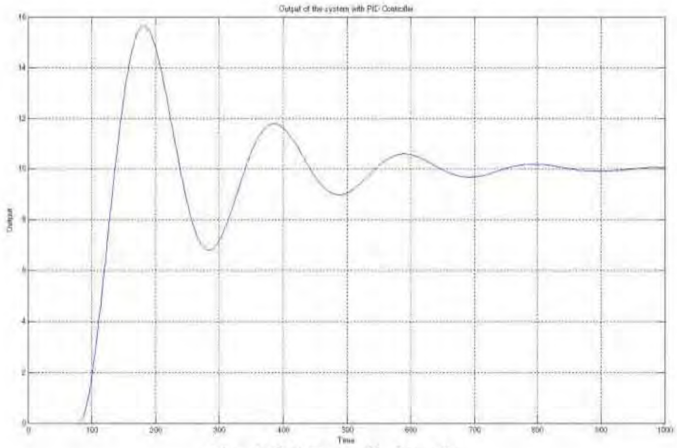

Fig. 4 PID Controller Results

IV. CONCLUSION

In this paper the author presents the how to control the unstable spare parts batch process industry by PID controller. The stability analysis of remote terminal units (RTUs) could be designed by applying the ideas of that PID control techniques. The author used the MATLAB PID commands for simulation results. According to the simulation results, the steady state error will be zero at infinite time. By changing the simulation parameters from this paper, we could analyze difference applications for other control system to be stable. After applying the PID controller, the condition of that factory will be reached to the stability state.

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