Implementation of Digital PID Controller in Siemens PLC S7-300

Dinh Van Nghiep[#1], Lam Hung Son[#2]
[#]*Thai Nguyen University of Technology, Thai Nguyen, Vietnam*

Abstract

The paper proposes an approach to design and implement temperature control base on digital PID controller in PLC. Hence it always guarantees the adaptive robust tracking stability of obtained closed loop systems in real time without using an additional penalty function in objective function as usual. The obtained control results by using this controller have confirmed its promising applicability in practice.

Keywords

Siemens PLC, digital PID, FB58

I. INTRODUCTION

A control system is a combination of components, which senses, manages and regulates the behavior of another system to produce the desired output. Automation is the process where different methods or control systems are used to manage a process. In industrial control, Programmable Logic Controller (PLC) has the extremely wide range of applications. PLC and PLC based controllers are the most important and useful control systems. Since these successful and beneficial control systems are produced, the PID control methodology has been extensively studied by researchers and well understood by practitioners. Most of PID controllers have been developed on the state-space model with this assumption that all state variables are measurable or on the input-output model for a linear system. PID controllers have been widely used in many industrial processes because they have only three control parameters and we can easily understand their physical meanings. There are many classical techniques for designing and tuning PID controller parameters (K_P, K_I, K_D) which can be easily understood and applied. By adjusting these three gain values, the settling time, overshoot and rise time of the system can be controlled in order to obtain a desired system output. Even though many control systems using PID control have proved satisfactory, it still has a wide range of applications in industrial control. PID controllers in Siemens PLCs are exclusively professional. They are distinguished by their classification for using in different kinds of control systems. In step 7 Siemens PLC programming software, different function blocks of PID are designed for various kinds of systems. These function blocks are compatible with their own control systems. In the following parts of this paper, continuous PID control with FB41 (CONT_C) function block, its implementation and performance will be discussed.

II. MAIN CONTENT

A. *PID Algorithm*

Parallel structure, three-term functionality and a typical structure of a PID control system are depicted in Fig 1. A mathematical description of the PID controller is shown in the following Equations (1, 2):

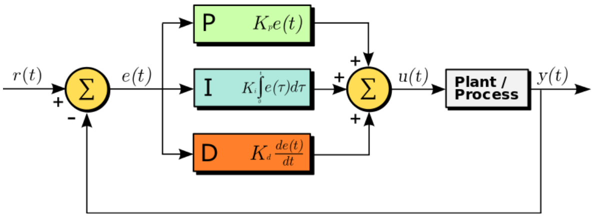

Fig 1: Control system with PID controller

$$u(t) = K_P\left[e(t) + \frac{1}{T_I}\int_0^t e(\tau)d\tau + T_D\frac{de(t)}{dt}\right] \quad (1)$$

$$u(t) = K_P e(t) + K_I\int_0^t e(\tau)d\tau + K_D\frac{de(t)}{dt} \quad (2)$$

where $u(t)$ is the control signal and $e(t)$ is the error signal. The reference value is called the Set Point (SP). The difference between the Process Variable (PV) and the Set Point (SP) is the error signal e(t) : $e(t) = r(t) - y(t) = PV - SP$. In which: K_P , $K_I = \frac{K_P}{T_I}$ and $K_D = K_P * T_D$ are the proportional gain, the integral gain and the derivative gain respectively.

1) *Proportional Term*

The proportional term provides an overall control action proportional to the error signal through the all pass gain factors. Decreasing the error and increasing the oscillation of the system are caused by increasing the proportional gain. Tuning theory and practical implementation shows that the proportional term should influence the output.

2) Integral Term

The integral term reduces steady-state errors through low-frequency compensation. Integral term is proportional to the integral of the error. As it integrates the error over the time, it can lead to the overshoot of present value to the Set Point value [1,2,3,4,5].

3) Derivative Term

The derivative term improves transient response through high-frequency compensation. The rate of error changes is the contribution of the derivative term. It gives an additional control by predicting errors and future behavior of the system.

Due to its variable impact on system stability, derivative action is rarely used in practice. In other word, the pure derivative action is never used because of the derivative kick produced in the control signal for a step input and the undesirable noise amplification. Therefore, it is usually replaced by a first-order low pass filter.

Table I . Effects od Independent P,I and D Tuning on Closed – Loop Response

Parameter	Rise Time	Over-shoot	Settling Time	Steady State Error	Stability
Increasing K_P	Decrease	Increase	Small Increase	Decrease	Degrade
Increasing K_I	Small Decrease	Increase	Increase	Large Decrease	Degrade
Increasing K_D	Small Decrease	Decrease	Decrease	Minor Change	Improve

B. PID Control in Siemens PLCs

The Function Blocks (FBs) of the PID control package consist of controller blocks for Continuous Control FB41 (CONT_C), for step control FB42 (CONT_S), for Pulse Duration Modulation FB43 (PULSEGEN), for continuous temperature control FB58 (TCONT_CP) and for temperature step control FB59 (TCONT_S). A controller created by the FBs consists of a series of sub functions that you can activate or deactivate. Apart from the actual controller with its PID algorithm, integrated functions can also be used for processing the set point, process variables and adapting the calculated manipulated variables.

Both slow processes (temperatures, tank levels etc.) and very fast processes (flow rate, motor speed etc.) can be controlled without any restriction in terms of the type of process. Good control quality can be achieved only if the type of the controller is appropriate to the situation and adapts to the time response of the process.

C. Design and Tuning of PID Controller

There are several methods for tuning the PID loop. The most effective methods generally involve in the development of some forms of process model, and then choosing P, I, and D based on the dynamic model parameters. Manual tuning methods can be relatively time consuming, particularly for systems with long loop times.

The choice of method will depend largely on whether the loop can be taken "offline" for tuning or not, and on the response time of the system. If the system can be taken offline, subjecting the system to a step change in input, measuring the output as a function of time, and using this response to determine the control parameters are considered as the best tuning method.

Designing and tuning of a PID controller is not easy when stability and short transient of the system are desirable. Repeated changes of initial designs through computer simulation need to be done to achieve a desired performance of the system. Control parameters (K_P, K_I or T_I, K_D, or T_D) must be tuned jointly to the optimum values for the desired control response. There are individual effects of these three parameters on the closed loop performance of stable plants which are summarized in Table 1. For example, while K_I and K_D are fixed, increasing only K_P can rise time, increase overshoot, slightly increase settling time, decrease the steady-state error and decrease stability margins.

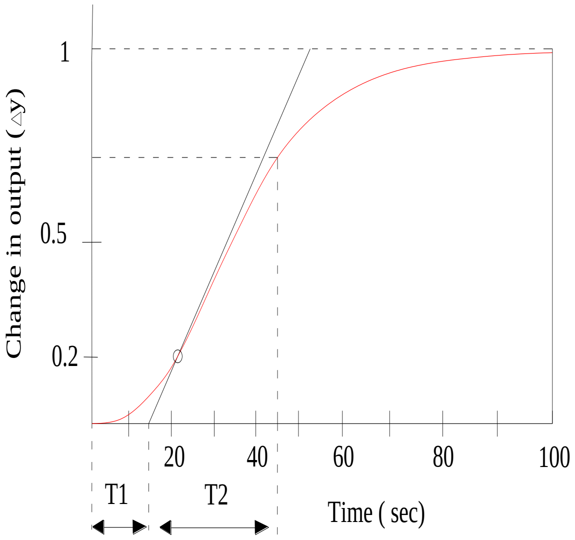

Fig 2: the characteristic of resistance furnace

$K = 0{,}18$

$T_1 = 15{,}1$

$T_2 = 31{,}1$

$$W_P(s) = \frac{C(s)}{R(s)} = \frac{K e^{-sT_1}}{1 + sT_2} = \frac{0.18e^{-15{,}1s}}{1 + 31{,}1s}$$

For manual tuning in online system, one of the methods is first setting all gains to zero. The increase in the K_P value until the constant oscillation of the output is obtained, and then the K_P should be set to approximately half of that value for a quarter amplitude decay type response. After that, K_I is increased to minimize the P term offset in a particular time for the process considering that too big value K_I can be a cause of instability. Finally, increasing K_D, if required, leads the system to become acceptably quick to reach the Set Point and decrease the oscillation. However, the overshoot of the system is a result of too much K_D. A quick PID controller loop normally has small overshoots to achieve quickly the desired value; but some systems cannot receive the desired overshoot. In these systems, K_P value should be set remarkably less than half of the K_P setting which provoked oscillation to make over-damped in the closed-loop system.

Design and tuning of the controller and selecting of its static (P component) and dynamic (I and D component) parameters are dependent on the static behavior (gain) and the dynamic characteristics such as time lag, dead time, reset time etc of the process. Different methods in designing and tuning of the PID controller are applied for a variety of types of continuous systems.

The modified auto-tuning PID controller was implemented in a SIEMENS PLC and family products including SIMATIC S7-300 and S7-400. FB50 is a PID Self Tuner in Step 7 Tune PID Library by Siemens which can be used for tuning parameters of PI/PID regulators in the function blocks FB41, FB42, software packages Standard PID Control, Modular PID control and function modules FM 355C6.

III. IMPLEMENTATION OF PID CONTROLLER IN PLC

The program structure in order to conduct PID controller of PLC consists of some function blocks as follows: OB1, OB35, OB100, FB58 (fig 3) and DB58; where the OB35 block samples and then calculates PID control algorithm; the FB58 - calling function block uses data in the DB58 block.

The following simulation was carried out with particular parameter values of TRMS given in Table I.

Table II.Parameters of the Pid Controller Based on FB58

Symbol	Definition	Value	Unit
T_S	Cycle	0.1	*s*
K_C	Gain	0.1	
T_I	Reset time	200	s
T_D	Derivative time	1	s

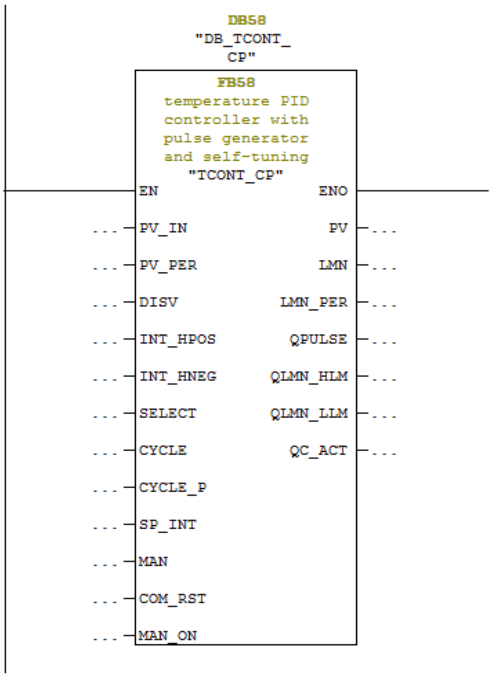

Fig 3: Control function block FB58 of PLC S7-300

Fig 4: Temperature control system implemented with PLC S7-300

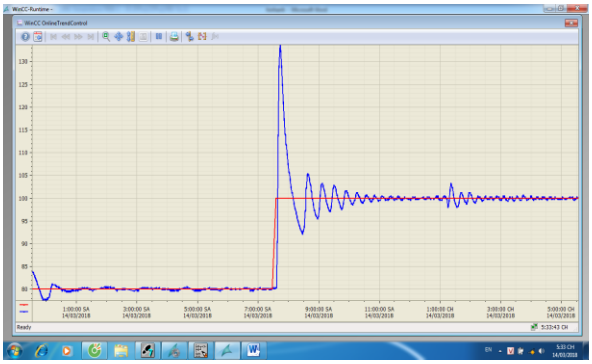

Fig 5: Control result with Step references in WinCC

The fig 4 and fig 5 show the real time PID controller with PLC S7-300 and the result. The result show that temperature of resistance furnace tracking reference with small steady-state error.

IV. CONCLUSIONS

PID controller remains a widely applicable and significant control technique due to effective implementation, simplicity in use and understanding. These reasons explain why the PID controller cannot be replaced by other higher order controllers. The advantages and successful results of the PID controller can be obtained by understanding the nature of a particular system, choosing the proper design and tuning of this controller. Tuning and design of the controller, depending on the nature of each system can be varied according to the system characteristics.

PID controllers in Siemens PLCs are seen as efficient and widely used in industry. They are also common in complicated and professional systems. There are various function blocks such as continuous control FB41 (CONT_C), step control FB42 (CONT_S), continuous temperature control FB58 (TCONT_CP) and temperature step control FB59 (TCONT_S) to control different kinds of systems.

In this paper, PID function block with continuous control FB58 (TCONT_CP) has been discussed as the major concept of PID controller function block in Siemens PLCs which can be used for all kinds of systems by implementing the correct design and tune. To implement FB58, specifying the proper addressing and correct values of 26 inputs and 9 outputs is essential. As the result, due to applying the standard structure of PID controller in Siemens PLCs by FB58 in online and offline mode, the speed of response to reach the maximum manipulated value has been studied.

REFERENCES

[1] Babak Rooholahi and P. Lokender Reddy. (2015), “Concept and Application of PID Control and Implementation of Continuous PID Controller in Siemens PLCs”. Indian Journal of Science and Technology.

[2] Lakshmi Narayana K, Naveen Kumar V, Dhivya M, Prejila Raj R. Application of ant colony optimization in tuning a PID controller to a conical tank. Indian Journal of Science and Technology. 2015 Jan; 8(S2):217–23.

[3] Sethuramalingam TK, Nagaraj B. PID controller tuning using soft computing methodologies for industrial process - A comparative approach. Indian Journal of Science and Technology. 2014; 7(S7):140–5.

[4] Meena AR, Senthil Kumar S. Design of GA tuned two-degree freedom of PID controller for an interconnected three area automatic generation control system. Indian Journal of Science and Technology. 2015 Jun; 8(12):1–10.

[5] Chakravarthi MK, Vinay PK, Venkatesan N. Design and simulation of internal model controller for a real time nonlinear process. Indian Journal of Science and Technology. 2015 Aug; 8(19):1–6.