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Practical analysis of PID control and switching control in constant value temperature control system

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Abstract: **The purpose of constant value temperature control system is to make the temperature of the controlled object constant at a certain value, for the specific temperature control system, there are many control methods can achieve good control effect, control methods are not the same. Based on PID control and switching control, this paper describes its control principle and method, the selection of supporting relays, applicable occasions and other specific use cases, and provides ideas, choices and references for personnel who are about to do constant value temperature control systems**

Keywords: - **constant value temperature control system; PID control; switching control; Matching relays.**

I. Introduction

Temperature control is widely used in various fields of society, and is often used in the control of water supply temperature in testing tests such as sanitary ceramics, hose showers, and nozzles. The control of the test water supply temperature is constant value temperature control, the purpose of which is to make the test water supply temperature constant at the set temperature during a certain test process, and the required temperature fluctuation range is within the required deviation range.

At present, the commonly used temperature control system at home and abroad can be roughly divided into the following two types according to the control principle: switching control method, PID control method [1], etc., whether the user writes the control program or directly selects the intelligent temperature controller, its related technology is relatively mature. The current switching control method is generally simple on or off, which is not ideal for temperature stability and temperature maintenance in the actual use process, but the advantage is low cost. PID control has certain requirements for the controller, and generally uses solid-state relays or frequency converters to control the execution of components. The advantage is that the control accuracy is high, but the cost is correspondingly high.

II. Switching temperature control

Figure 1 below show the switching control [10] is to control the heating (or cooling) system of the system on and off by determining the relationship between the current actual temperature of the controlled quantity in the system and the target temperature. If the current actual temperature is higher than the target temperature, turn off the heating, or turn on the refrigeration system; If the current actual temperature is lower than the target temperature, turn on the heating, or turn off the refrigeration system. This control method is relatively simple, and can be achieved by writing a control program inside the controller or PLC.

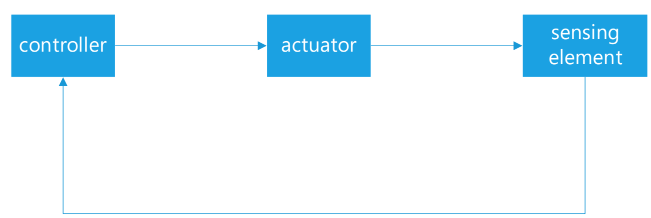

Figure 1 Switching control schematic

When the switching amount is controlled, the on-off of the heating or cooling system is usually controlled by contactors. In practical applications, according to the requirements of the actual system and temperature accuracy control, under the premise of meeting the control accuracy, the contact frequency can be reduced by setting the target temperature deviation or setting the delay in the PLC [7].

The switching quantity control cannot overcome the hysteresis during the temperature change, and the system temperature fluctuates greatly. Therefore, some multi-group heating temperature control systems are proposed, which can be

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controlled by segmented switching to reduce the temperature hysteresis, so as to improve the temperature control accuracy. Example: A water tank heating system, there are three groups of heating rods, the electrical design of the three groups of heating rods are controlled separately, in the PLC, through the actual temperature of the tank and the target temperature deviation value judgment, control which groups of heating rods to enable. (Example: When the actual temperature of the water tank deviates greatly from the target temperature, three sets of heating rods work at the same time; When the actual temperature of the water tank deviates from the target temperature is small, turn off one set of heating rods, and two sets of heating rods work; When the actual temperature of the water tank is close to the target temperature, only one set of heating rods is left to work. This segmented switch control method can reduce the temperature hysteresis and maintain the stability of the temperature compared to the simultaneous start and stop of three sets of heating components.

Figure 2 and Figure 3 below show temperature control under two different methods of control, respectively.

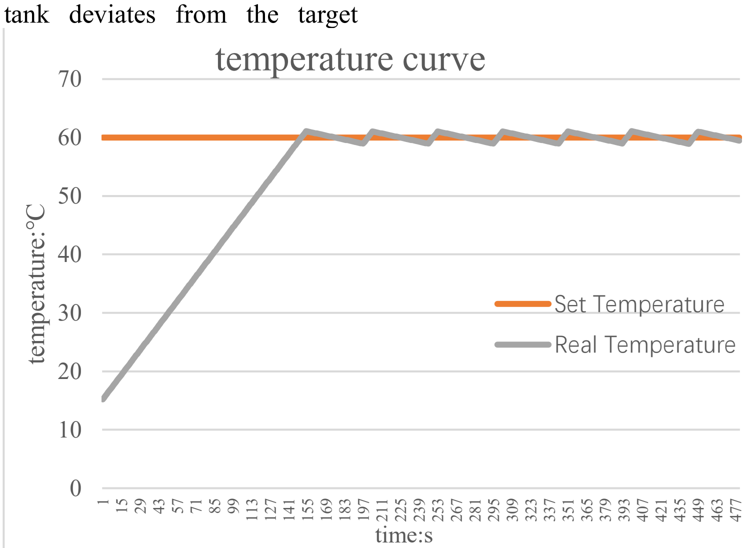

Figure 2 Simultaneous start-stop temperature control curve

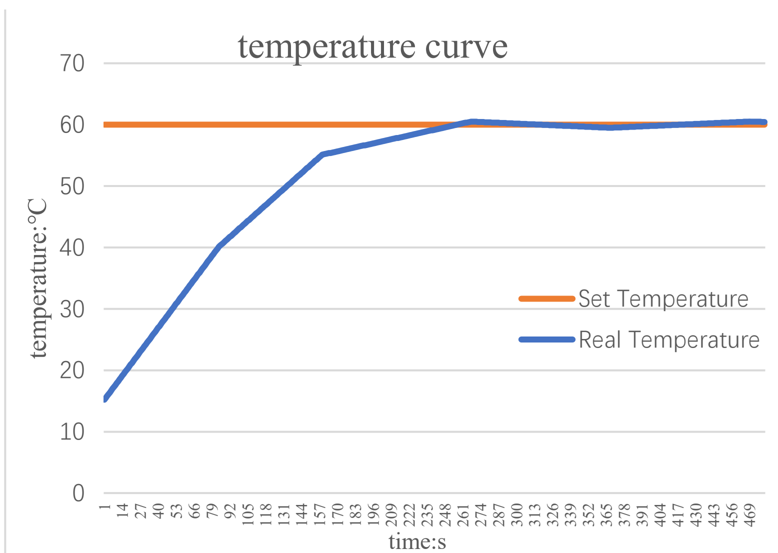

Figure 3 Start-up temperature control curve

Switching quantity control method is simple, suitable for operation, high heating efficiency, suitable for controller output signal only on and off two states, no intermediate state system. The switching controller switches the output only when the temperature crosses the set point. In the heating control, the output is on when the temperature is below the set value, and the output is off when the temperature is above the set value. Whenever the temperature crosses the set point, the controller switches the output state, so the process temperature will continuously cycle from below the set point to above the set point and back to below the set point. And because it can not overcome the lag in the process of temperature change, the system temperature fluctuation is large, and the control accuracy is not high. If this separate control method is used, the actual temperature can be reduced as much as possible to exceed the set temperature, and the temperature rise is relatively stable, but the temperature will still overshoot. Therefore, the switching quantity control method is suitable for occasions where the temperature accuracy is not high.

III. PID temperature control

PID control [2] is composed of proportional control part P, integral control part I, and differential control part D, referred to as PID control. The basis of PID is proportional control, which is the most direct control; The integration control can eliminate static differences, and for objects with large hysteresis such as heating, the integration parameter can be selected to be larger; Differential control is a kind of advanced control, the change of deviation to control the effect, so that the deviation disappears in the bud, as long as the change trend, immediately produce a control effect, help to reduce overshoot, overcome oscillation, make the system tend to be stable, improve the dynamic performance of the system. PID control, from static and dynamic aspects of control, by adjusting the parameter value of PID, can achieve fast, smooth, accurate tracking, to achieve accurate temperature control, suitable for strict temperature requirements of the occasion.

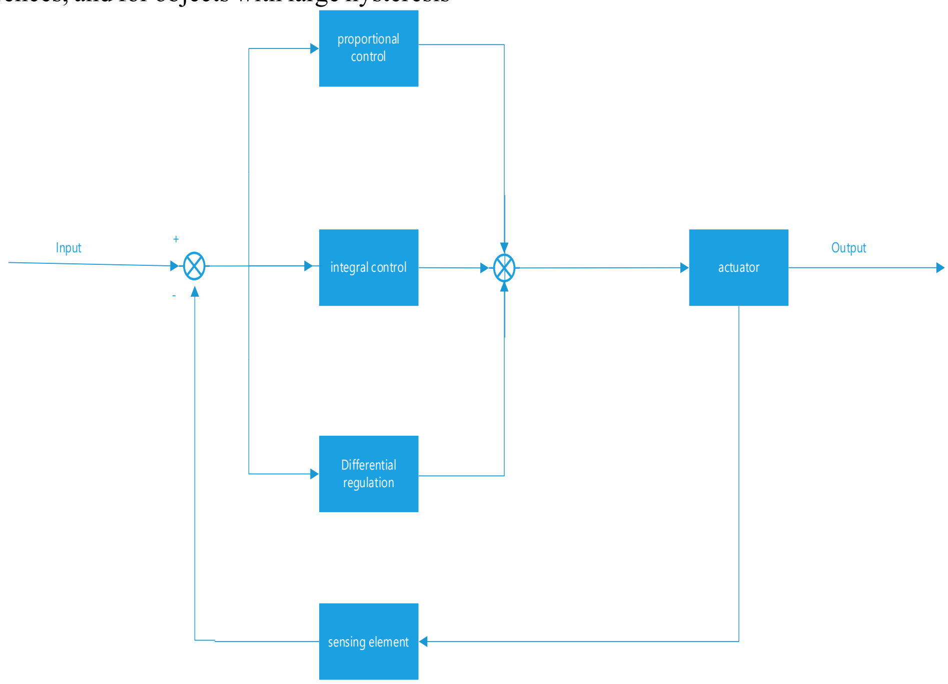

Figure 4 PID schematic

PID is now one of the most commonly used control methods in industrial production, whether it is an intelligent PID controller or a programmable controller PLC with PID function [9], the technology is very mature. At present, the commonly used PID control generally has the function of PID parameter self-tuning [3], of which the automatic adjustment of PID controller parameters is realized through intelligent adjustment or self-correction and adaptive algorithms, which can automatically calculate the best according to the controlled object PID control parameters.

At present, the general controller of commonly used intelligent temperature controller adopts PID fuzzy control technology, and uses advanced digital technology to form a fuzzy control to solve the problem of inertial temperature error through the combination of pvar, Ivar, Dvar (proportional, integral, differential) three aspects. When writing the control program through the programmable logic controller PLC, according to the system adaptability, the PID parameters are adjusted to achieve a good control effect. In the process of adjusting PID parameters, due to the different systems, many parameter adjustment processes may be required, and many methods can be used for reference in the practice of PID temperature control in different domestic industries: predictive adaptive PID control methods suitable for temperature systems, based onPID hierarchical control method[4], intelligent PID control[8], etc., the fundamental principle is still based on PID control foundation, users can adjust and control according to the actual situation of the system.

The characteristics of the PID algorithm are detailed below:

A. In the PID control role, the proportional effect is the basic control; Differential action is used to speed up system control; The integral action is used to eliminate static differences.

B. As long as the intensity of the three control laws of proportion, integration and differentiation is appropriate, it can not only be quickly adjusted, but also eliminate the residual difference, and a satisfactory control effect can be obtained. Generally, for the PID adjustment parameters of temperature, please refer to P="50%~80%", I="150~500"s, D="0~200"s, However, the volume of the water tank and the power of heating or cooling are different, and need to be adjusted according to the actual situation.

C. When Kp is small, the system is more sensitive to the introduction of differentiation and integration links, integration will cause overshoot, differentiation may cause oscillation, and overshoot will increase when the oscillation is strong.

D. When Kp increases, the overshoot caused by the integration link due to lag gradually decreases, and if you want to continue to reduce the overshoot, you can introduce the differential link appropriately. Continuing to increase Kp The system may be unstable, so introducing Kd to reduce overshoot while increasing Kp can ensure better steady-state characteristics and dynamic performance even when Kp is not very large.

E. When Kp is small, the integration link should not be too large, and when Kp is large, the integration link should not be too small (otherwise the adjustment time will be very long), when using segmented PID, the integration can be separated under the right conditions, and better control effects can be achieved. This is because the system lag is eliminated when the steady-state error is about to meet the requirements. As a result, the system overshoot will be significantly reduced.

F. The PID calculation formula is as follows (1)

$$u(k) = K_P e(k) + K_i \sum_{n=0}^{k} e(n) + K_d\,(e(k) - e(k-1)) \quad (1)$$

G. The general steps for the adjustment of P ID are as follows:

1) First determine the proportional gain P, first remove the integral adjustment and differential adjustment of PID, generally you can set i=0, d=0, and adjust it to Pure proportional adjustment, gradually increase the gain ratio P from 0, and when there is a temperature fluctuation, gradually decrease the gain ratio P until the temperature oscillation disappears, and record the current The gain ratio P value, the input range of the gain P is 50~80% of the maximum value allowed by the system

*2)*Secondly, determine the integration time constant I, when the gain ratio P is determined, first set a large initial value of the integration time constant I, observe its adjustment status, and then gradually decrease the I value until the temperature regulation system oscillates, and then slowly increase Ivalue until the oscillations of the thermoregulation system disappear. Set the integration time constant I of PID to 120%~180% of the current value

*3)*Finally, the differential time constant D is determined, and when the gain ratio P and the integration time constant I are confirmed, observe the condition of the temperature regulation system, under normal circumstances, the differential time constant D is set to 0 without setting。 However, sometimes, due to the different conditions of the system, it may be necessary to slightly adjust the differential time constant D, and the adjustment method is consistent with the adjustment method of the gain ratio P and the integration time constant, and the final value is 3 0% ~ of the adjustment value About 50%.

*4)*When the gain ratio P, integration time constant I, and differential time constant D are determined, the PID parameter needs to be fine-tuned with the load until it meets the requirements of the temperature regulation system. The effect of PID adjustment under ideal conditions is shown in Figure 5 below.

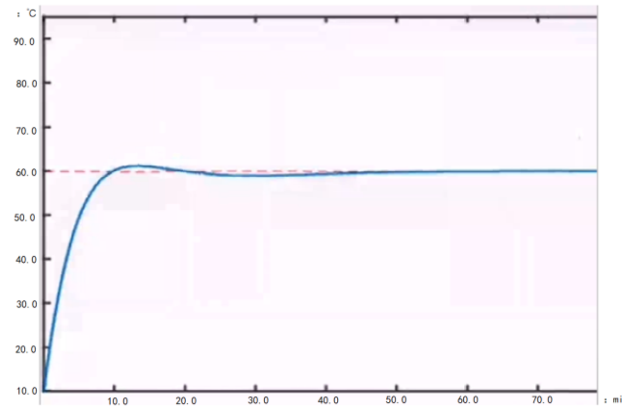

Figure 5 PID rendering

For some existing controllers, most of them contain PID control library. For example, programmable controller PLC, and then through the design circuit, design program, PID parameter pre-adjustment, with load for accurate adjustment, can realize PID adjustment, can greatly reduce the PID debugging steps and PID debugging time. Figure 6 shows the control panel in the PID adjustment tool of Siemens 200 smart PLC. Before PID self-tuning adjustment is started, the whole PID control loop must work in a relatively stable state (stable PID means that the actual temperature is close to the set temperature value, and the output does not have irregular movements or changes. The output value of the loop basically changes or fluctuates around the center of the control range.

Ideally, the loop output value should be near the center of the control range when the self-tuning starts. The self-tuning process adds some small step changes to the output of the loop, which makes the control process oscillate. If the loop output is close to either limit of its control range, the step change introduced by the self-tuning process may cause the output value to exceed the minimum or maximum range limit. If this happens, self-tuning error conditions can be generated, and of course the recommendations will be suboptimal. It can carry out self-adjustment through the PID adjustment assistant of the controller to realize the precise control and adjustment of PID.

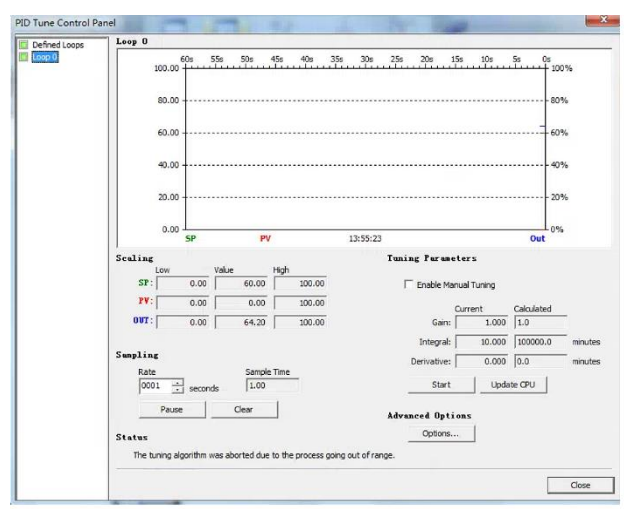

Figure 6 PID regulation control panel of Siemens 200 smart PLC

When PID is controlled, the on-off of heating or cooling systems is often controlled by solid state relays. This is also only for this situation to study, because after PID calculation, the output frequency is very high, there may be several actions a second, which is for ordinary electromagnetic contactors [5], manifested is non-stop adsorption, release, considering the contactor life and site noise problems, generally use PIDWhen controlling, a solid state relay [6] is used to control the on-off of the heating element or refrigeration element. Moreover, if the programmable logic controller PLC is used for control, considering the life of the PLC relay, the PLC must also be output in the form of a transistor.

PID control method is a very classical control algorithm, and the control system is a closed-loop control. The temperature control equipment can work under different power, and the temperature control can realize the error control of the actual temperature and the set temperature. At the same time, based on the classical PID control algorithm, also derived a fuzzy control PID algorithm, neural network control PID algorithm, genetic PID control algorithm, adaptive generalized prediction and control PID and now often mentioned intelligent PID algorithm and so on. In practical applications, different control methods are selected according to specific application occasions, different heating objects, different control requirements and control accuracy. Or the combination application of PID algorithm.

IV. Conclusions

With the development of science and technology, the technical pace of constant value temperature control system has been moving forward, so that many temperature control methods, starting from the most fundamental control theory, are divided into switching control method and PID control method. However, the choice of PID control method or switching control method mainly depends on the specific system requirements, the switching control efficiency is high, suitable for temperature control occasions where the temperature accuracy requirements are not high and do not need to be adjusted frequently; PID control can realize accurate temperature control, suitable for occasions with strict temperature requirements, high precision and high stability. For the specific temperature control system, the user needs to choose and design according to the actual situation of the system, and can also combine the two control methods according to the actual situation to achieve better temperature control effect.

Acknowledgments

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