Application of anti integral saturation cascade PID control algorithm in superheated steam temperature control

Zhe Sun*, Chunhui Liu, Ming Li, Junda Zhao, Yao Xu

CHN ENERGY SHUANGLIAO POWER GENRATION Co., Ltd.

Corresponding author: * email: 12023942@chnenergy.com.cn
b email: shunqi110@qq.com

Abstract. At present, most units adopt the superheated steam temperature control system with cascade PID control structure. However, because most cascade PID control algorithms have no anti-integral saturation function, the automatic control of boiler superheated steam temperature cannot be put into operation normally. On the existing cascade PID superheated steam temperature regulation system, we judge the deviation value of the main regulator and the output value of the auxiliary regulator, and cancel the integration function at an appropriate time. When the input deviation signal turns over, the regulating system can immediately enter the normal regulating state, so that the cascade PID superheated steam temperature regulating system can timely and accurately regulate the superheated steam temperature. The fuel cost is saved by about 155,600 yuan per year.

1. Introduction
Superheaters of modern boilers work under the conditions of high temperature and high pressure. Superheated steam temperature at superheater outlet is the highest point of working fluid temperature in the whole steam-water trip of the unit. Too high or too low superheated steam temperature of the boiler will seriously threaten the safe and stable operation of the unit. At present, most units adopt the superheated steam temperature control system with cascade PID control structure. However, because most cascade PID control algorithms have no anti-integration saturation function [1], the automatic control of boiler superheated steam temperature cannot be put into normal operation.

2. Achievement implementation background and problems in the prior art

2.1. Implementation Background
The superheater of modern boiler works under the condition of high temperature and high pressure, and the superheated steam temperature at the outlet of the superheater is the highest point of the working medium temperature in the whole steam-water stroke of the unit, if the superheated steam temperature is too high or too low, it will seriously threaten the safe and stable operation of the unit. At present, two-stage spray desuperheating control mode is mostly used in large unit units. For the superheated steam temperature control system with two-stage spray desuperheating, if only the control effect of the steam temperature at the boiler outlet is considered, the first-stage spray desuperheating is equivalent to coarse adjustment, and the second-stage spray desupercooling is equivalent to fine adjustment. The steam temperature characteristics under the disturbance of desuperheating water belong to the dynamic characteristics of the object control channel. This characteristic is the basis for
the design, analysis and tuning of the superheated steam temperature control system. Because of the large delay and inertia in the control channel of the steam temperature object, it is not enough to control the steam temperature only by using the single-loop regulation scheme according to the temperature deviation of the superheater, and the multi-loop system should be formed by introducing the leading signal which can respond to the disturbance in advance. As to improve the steam temperature control quality. Now the cascade PID steam temperature control system is the most widely used.

There are many factors affecting the superheated steam temperature. Under some working conditions, the heat exchange of the superheater is seriously unbalanced, and the superheated steam temperature can not be effectively adjusted only by desuperheating water. At this time, the desuperheating water regulating valve may be fully opened for a long time but the superheated steam temperature is still higher than the set value, or the desuperheating water regulating valve may be closed for a long time but the superheated steam temperature is still lower than the set value. When the above conditions occur, the main regulator of the superheated steam temperature control system with cascade control structure will appear over-integral saturation, and the longer the time is, the more serious the integral saturation will be, until it is limited by the amplitude of the regulator [2]. When the input deviation signal is reversed, it takes a long time for the regulation system to exit the saturation region and cannot enter the normal regulation state immediately. The existence of integral saturation will seriously affect the response time of the regulation system and reduce the regulation quality. The reason for over-integral saturation is that the main regulator has an integral function. As long as the deviation exists, the output of the regulator will continue to increase (or decrease) in an attempt to overcome the deviation, but the system does not have this ability. This technology is studied to solve the problem of over-integral saturation of cascade PID control algorithm, so as to ensure that the superheated steam temperature is controlled within a reasonable range and the unit operates safely and stably.

2.2. Existing technical solutions

The cascade PID superheated steam temperature regulation system (as shown in Figure 1) has two closed-loop control loops: an inner loop (or called a secondary loop) consisting of a leading zone of a regulated object, a leading steam temperature (temperature after a desuperheater) transmitter γB2, a secondary regulator, an actuator KZ and a desuperheating water regulating valve; The outer loop (or main loop) is composed of the inert zone of the controlled object, the superheater temperature transmitter γB1, the main regulator and the inner loop. The leading steam temperature can quickly respond to the disturbance, especially the spontaneous disturbance of the desuperheating water. The auxiliary regulator changes the desuperheating water flow according to the change of the leading steam temperature, and plays a role in coarse regulation of the superheater temperature [3]. The main regulator corrects the secondary loop, When the superheater temperature deviates from the given value, the main regulator outputs a correction signal to make the auxiliary regulator continuously adjust the desuperheating water flow until the superheater temperature returns to the given value. In steady state, the leading steam temperature may be stabilized at a value different from the original value, but the superheater temperature must be equal to the given value [4].
2.3. Disadvantages of the prior art
The cascade PID superheated steam temperature control system can effectively overcome the problem of large delay and inertia of the steam temperature control channel object characteristics. Because the main regulator in most cascade PID control structures has no anti-integral saturation function, if the superheated steam temperature is put into automatic control mode, it is easy to cause the problem of too high or too low superheated steam temperature. Especially when the load is low, this phenomenon is more obvious. If the manual control mode is adopted, the workload of operators will be increased, and it is inevitable that the adjustment will not be timely, which is not conducive to the safe, stable and economic operation of the unit.

3. Achievements, innovation points and basis
In the cascade PID superheated steam temperature control system, sometimes the superheated steam temperature is still higher than the set value when the desuperheating water control valve has been fully opened for a long time, or the superheated temperature is still lower than the set value when the desuperheating water control valve has been closed for a long time. When the above conditions occur, the main regulator of the superheated steam temperature control system with cascade control structure will appear over-integral saturation. The longer the time, the greater the degree of integral saturation until it is limited by the limiter of the regulator [5].

This achievement is based on the existing cascade superheated steam temperature control system, through the judgment of the deviation value of the main regulator and the output value of the auxiliary regulator, the integral effect is cancelled at an appropriate time. When the input deviation signal is reversed, the regulating system can immediately enter a normal regulating state, so that the cascade
4. Implementation steps and design process
The main loop of the cascade superheated steam temperature regulation system is composed of the function conversion corresponding to the unit load command, temperature offset, superheater outlet temperature, variable parameter PID controller and the secondary loop [6], which completes the fine regulation function of superheated steam temperature. The secondary loop (i.e. execution-level control loop) is composed of the temperature after the desuperheater, the output value of the primary loop, the variable parameter PID controller and the desuperheating water control valve, and is used to regulate the flow of desuperheating water of the superheater. When the system is in the automatic state, if the superheated steam temperature is higher than the set value, the instruction output by the cascade PID control algorithm is increased, and the opening of the desuperheating water regulating valve is increased. Increase the desuperheating water flow. If the superheated steam temperature is lower than the set value, the instruction output by the cascade PID control algorithm is reduced, and the desuperheating water flow is reduced. When the system is in the manual state, the operator manually controls the opening of the desuperheating water regulating valve to keep the superheated steam temperature within a reasonable range.

In the cascade PID superheated steam temperature regulation system, the deviation action type of the primary regulator is 0 (i.e., the set value minus the measured value), and the deviation action type of the secondary regulator is 1 (i.e., the measured value minus the set value). When the superheater outlet temperature is lower than the set value and the desuperheating water regulating valve is closed, that is, when the deviation of the main regulator is greater than 0.1 and the output value of the auxiliary regulator is less than 0, the integral function of the main regulator will be cancelled. That is, the integral time is equal to 99999 (similar to infinity) to prevent integral saturation, untimely opening of the desuperheating water regulating valve, and overtemperature of the superheater outlet temperature; When the superheater outlet temperature is higher than the set value and the desuperheating water regulating valve is fully opened, that is, the regulator deviation is less than -0.5 and the output value of the auxiliary regulator is greater than 100, the integral function of the main regulator is cancelled, that is, the integral time is equal to 99999. To prevent integral saturation, the desuperheating water regulating valve is not closed in time, and the superheater outlet temperature is too low. The logic configuration of the above overall technical scheme is shown in the following engineering configuration diagram.
5. **Practical application and popularization**

This work adopts the control method and logic, after the actual test for a long time, has strong adaptability and reliability, makes the results particularly suitable for integral saturation resistance cascade PID control algorithm, the results of the control logic of writing, adopt the general logic function block configuration, writing simple, readability is stronger, Engineering and technical personnel through a variety of brand decentralized control system (DCS), programmable logic controller (PLC) and other computer control equipment to achieve its function, to use brought great convenience. In the process of use, the deviation value of the main regulator and the output value of the cascade PID control algorithm can be determined according to the actual situation of the equipment, so the results also have a wide range of applicability. By using the anti-integral saturation cascade PID control algorithm, the automatic control of superheated steam temperature is reliable, the labor intensity is greatly reduced, and the economy and safety of the unit are improved.

6. **Conclusion**

By judging the deviation value of the main regulator and the output value of the auxiliary regulator and canceling the integral function at an appropriate time, the control method discussed in this paper successfully solves the problem that the superheated steam temperature of the boiler is easy to be too high or too low in the process of automatic control. At the same time, it also solves the problem of anti
integral saturation of the main regulator in most cascade PID control structures. The accuracy and reliability of automatic control of superheated steam temperature of the unit are guaranteed. According to the statistics of relevant departments, increasing the superheated steam by 1 °C saves 0.144 g / 10 million hours of standard coal. According to the unit's annual power generation of 2.1 billion kWh and the unit price of standard coal of 650 yuan / ton, the fuel cost is saved by about 155600 yuan. It has made outstanding contributions to tapping the potential and increasing efficiency of thermal power units, and greatly increased the competitiveness of thermal power units.

References
[1] New PID control and its application [M]. Mechanical Industry Press, edited by Yonghua Tao, 1998
[2] MATLAB simulation of advanced PID control [M]. Electronic industry press, Jinkun Liu, 2016
[3] Research on multivariable disturbance suppression control method of thermal process [D]. Jianzhong Zhu, Southeast University, 2019
[4] Research on advanced control strategy of superheated steam temperature system [D]. Liu Wan, North China Electric Power University, 2016
[5] Research on fault diagnosis of superheated steam temperature control system in thermal power plant [J]. Yuning Liang. Research on modern state-owned enterprises. 2016 (08)
[6] Integral saturation in digital PID control [J]. Jin Yang. Huadian technology. 2008 (06)