PID regulator on thermal power simulation machine

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Abstract. For the reality of thermal power units and the training needs of operating crew, introduce the PID regulator on the thermal power plant simulation machine. Depending on the various needs of simulation modeling, introduce the PID regulator control algorithm and some auxiliary functions. Through simulation of the actual unit, Verify that the controller has good dynamic performance and robustness.

Introduction

In the historical development of the automatic control of production process, PID control is the oldest and most energetic basic control method. Because PID control has a simple principle and is convenient, adaptable and robust , it has been widely used in electrical production. Large-scale thermal power plant occupies a dominant position in China's electric power industry. A large-scale thermal power generating units has the characteristics of high efficiency, high level of automation, and so on, so the quality requirements to operating crew are relatively high. The traditional apprenticeship has been difficult to meet the actual needs of the field production. Therefore, the simulator for thermal power generating unit plays an increasingly important role in electrical production.

At present, the simulator for thermal power generating unit is increasingly used for training line personnel in power plant operation and make them master of startup, shutdown, and monitor, operation, and processing in normal or accident conditions. These trainings become realized through monitoring and control system on the simulator. Therefore, the control system simulation is important as the same as the simulation for primary device and main system of power unit, and is an important part of the simulation system of power plant. Although DCS is used extensively in the automatic control system of power plant, but as for its control strategy, the classic PID algorithm is dominant. therefore, the PID regulator simulation also plays an important role in the control system simulation.

Control algorithm of PID regulator

A regulator which is controlled in accordance with proportional, integral and derivative is called PID regulator for short. PID regulator is the most widely used kind of control and regulation laws in industrial processing control systems[2]. Not only can it break down to proportional control(P), proportional integral control (PI) and proportional derivative control (PD) based on the actual needs of the scene, but also some PID regulators can be combined into several complex controls, such as cascade control, ratio control and so on[3].

An control law for ideal continuous PID control law can be described in formula like this:

$$u(t) = K_p \left[e(t) + \frac{1}{T_i} \int_0^t e(t)dt + T_d \frac{de(t)}{dt} \right] + u_0 \tag{1}$$

In the formula, $e(t)$ is the input deviation; $u(t)$ is the output of control process; K_p is the proportional gain; T_i is the integral time; T_d is the derivative time; u_0 is the initial control value.

In order to make the computer calculate the formula, we must be convert a continuous PID control algorithm into a discrete PID control algorithm. For every sampling period which is set to T_s,

conduct once data sampling, control system operation and data output. The discrete PID control algorithm can be derived from a continuous ideal PID control algorithm through discretization directly. Use the following relational expression for discretization[4]:

$$\begin{cases} \int_0^t e(t)dt \approx T_s \sum_{i=0}^k e(i) \\ \dfrac{de(t)}{dt} \approx \dfrac{e(k)-e(k-1)}{T_s} \end{cases} \tag{2}$$

So discrete PID control algorithm can be expressed as the following equation:

$$u(k) = K_p \{ e(k) + \frac{T_s}{T_i} \sum_{i=0}^k e(i) + \frac{T_d}{T_s} [e(k)-e(k-1)] \} + u_0 \tag{3}$$

$\sum_{i=0}^k e(i)$ related to all the states in the past, tedious calculation and taking up too much memory, which are why use the incremental algorithm, $\Delta u(k) = u(k) - u(k-1)$. Obtain a formula after simplification:

$$\Delta u(k) = K_p \Delta e(k) + K_I e(k) + K_D [e(k) - 2e(k-1) + e(k-2)] \tag{4}$$

In the formula, $\quad \Delta e(k) = e(k) - e(k-1)$; $\quad K_I = \dfrac{K_P T_S}{T_i}$; $\quad K_D = \dfrac{K_P T_d}{T_s}$.

In addition, for some of the control features of the simulation machine, do some processing as follows.

1) Due to the PID controller output direct drive has a actuator module with proportional characteristic , and it needs to track the actual valve location during the period of manual control, so using the integral incremental type position control algorithm smooths the deviations integral terms.

2) The derivative action of ideal PID equation for the response of differential effect of high frequency interference is too sensitive. It's prone to oscillate in control process and so adopting incomplete derivation. Derivative action in a long time keeps the equal condition on the trend of deviation change. It can improve the quality of control system.

3) proportional, integral and derivative action are independent of each other, to allow operators to directly understand and adjust the control parameters on the control effect.

Therefore, the control algorithm that PID controller module actually using is:

$$u(k) = u_p(k) + u_i(k) + u_d(k) \tag{5}$$

In that, proportional term is $u_p(k) = K_p e(k)$;

The integral term is $u_i(k) = u_i(k-1) + K_p \dfrac{T_s}{2T_i} [e(k)+e(k-1)]$;

The derivative term is $\dfrac{T_d}{T_s + T_d} \{ u_d(k-1) + K_d [e(k)-e(k-1)] \}$;

K_d is the Differential amplification coefficient.

Establish a simulation model for PID regulator

Because PID controller module is a composite module, the structure also took into account a number of other auxiliary functions.

1) Set an output limits, ensuring that the output signal is in the allowable range.

2) Set a polarity switch, for user-friendly establishment of PID controller to the polarity relationship between input deviation and output control.

3) Set an automatic and manual switch, to achieve undisturbed switching of control mode and automatic tracking of control algorithms. When set to automatic, the output is the result by PID control algorithm for computing input deviation : $u(k) = u_p(k) + u_i(k) + u_d(k)$. When set to manual,

the output is the racking data: $u(k) = x_i(k); u_i(k) = x_i(k) - u_p(k) - u_d(k)$. In the formula, $x_i(k)$ is the tracking signal.

4) Set a feedforward part. For large delay and multi-interference controlled plant, increase feedforward control function in the control loop. The feedforward controlled variable is $u_f(k) = K_f x_f(k)$, where, K_f is a feedforward coefficient and $x_f(k)$ is a feedforward signal. The formula of Feedforward-feedback compound control is:

$$u(k) = u_p(K) + u_i(k) + u_d(k) + u_f(k) \qquad (6)$$

5) Set a dead zone. That is a process control system which allows certain variable to change within limits which is help to avoid frequent action of executive component.

Simulation example

Apply the above PID functions to the actual 350 MW thermal power plant simulation machine. The simulator supports the whole process from model development, debugging, operation to analysis. According to control schematic diagram or configuration diagram of the actual unit from the plant, select the appropriate simulation models to connect configuration, and the appropriate parameter value for initialization to achieve a specific control system simulation
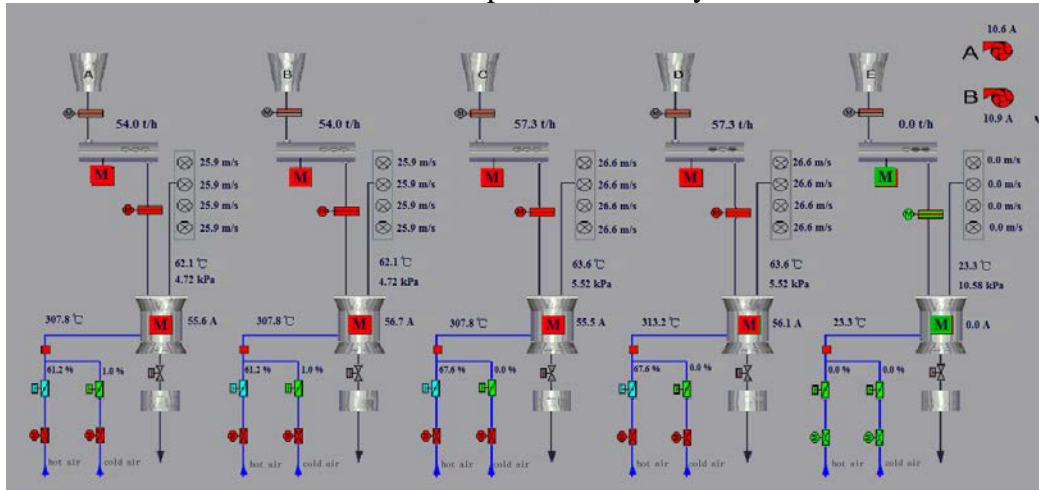

Fig 1 350 MW thermal power plant simulation

After building the simulation loop, impose 10% of the load disturbance on the DEH control system of steam turbine, to observe the control characteristics of power control loop, as shown in fig 2. After imposing a step disturbance on the high water level, we can observe a characteristic that the level returns from 320 mm to the presupposed 200 mm, as shown in fig 3.
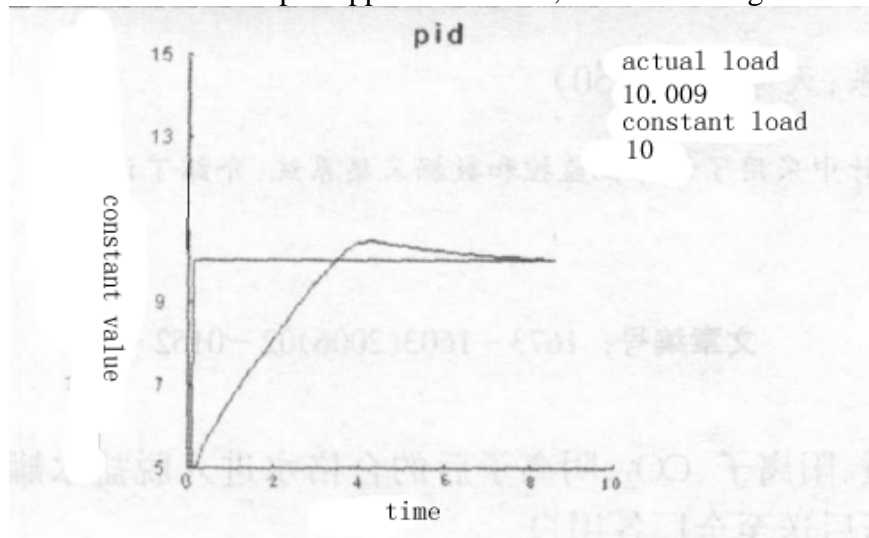

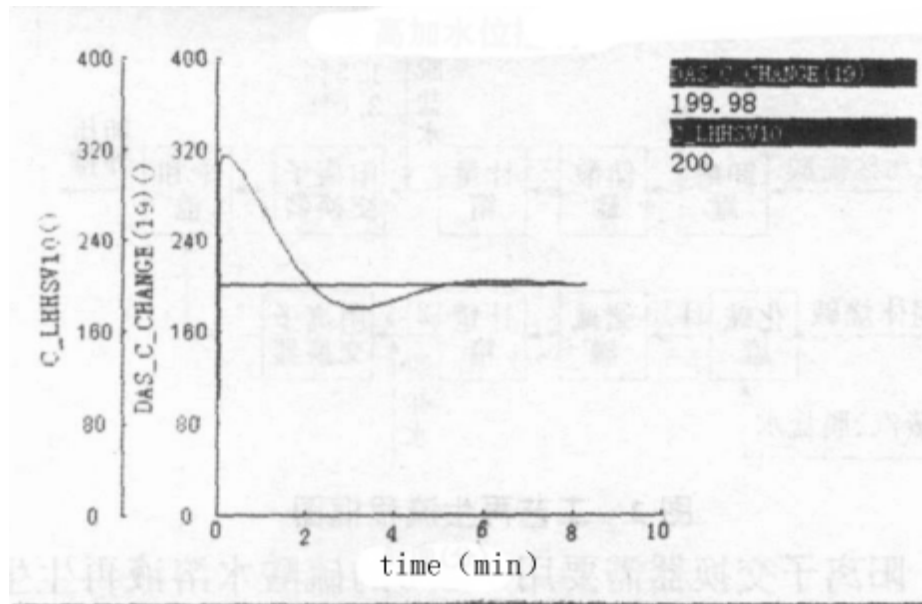Fig 2 the control characteristics of load disturbance in 10%

Fig 3 high water level control

Conclusion

The above simulation shows that PID regulator algorithm can meet the technical requirements of thermal power simulator. This modeling approach was applied in the simulation process of 350 MW thermal power units. The simulation machine get all the praise from the plant operating personnel, and it can reflect the dynamic characteristics of the actual control system.

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