CHEMICAL ENGINEERING TRANSACTIONS

VOL. 62, 2017

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216

DOI: 10.3303/CET1762185

Design of Chemical Water Auto-control System in Power Plant Based on PLC

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To effectively process the chemical waste water in power plant, a set of control system based on PLC upgrading and reform for chemical water is designed in this paper. In the process of treating chemical water, there are many operating procedures, complex technology and scattered positions and many pieces of equipment. With remote I/O control thought in this paper, the hot-standby series of PLC of Schneider is used as lower computer to form a set of chemical water treatment system. The subsystem monitoring screens are concentrated in one central control room to achieve remote monitoring and local/remote control on the whole chemical water system. In reform process, aiming at the regeneration link of chemical water desalination process in power plant, a prioritization scheme of single closed-loop control is put forward and simulated in MATLAB. In simulation result, the concentration of Na+ on cation bed is finally maintained to be 8.3μg/L; electric conductivity of water on anion bed is finally maintained to be 0.5μS/cm. This completely meets the standards of water discharge. In conclusion, the chemical water auto-control system based on PLC can not only achieve real-time detection but also raise the work efficiency of power plant. It has certain reference value to further reform on power plant.

1. Introduction

Chemical water treatment plays important function in the boiler system of power plant. Common natural water contains suspended solids, colloid and inorganic salts (Liu and Bai, 2014). If chemical processing is not operated, scaling and severe corrosion will be caused to boilers; normal production of factory may be even influenced. Therefore, natural water shall be chemically processed in power plant and impurity shall be dislodged before being put into boiler. However (Li et al., 2017), small quantity of suspended particles can be residual after common natural water is precipitated. Our naked eyes cannot see them. The water needs to be further filtered and purified (Kenawy et al., 2013). Chemical water processing technology of thermal power plant can guarantee reliable quality of water and raise production efficiency (Sun, 2014). Some chemical workshops still use old chemical instruments to operate offline sampling, which lowers timeliness and accuracy of data collection (Ji and Wu, 2013). This can lead to unstable quality of water and influence the normal operation of boiler. Therefore, a set of high-level automatic control production system must be built to raise automation level of water processing, assure quality of water and guarantee the high efficiency of production (Mo, 2015).

Aiming at the above, this paper takes Guizhou Anshun Power Plant as project background and upgrades chemical water processing system (Zhang et al., 2014). After being upgraded and reformed, the automation level of enterprises can be enhanced to achieve remote monitoring and control, save manpower cost and raise efficiency of enterprises.

2. Chemical Water Processing Technology

2.1 Technological process

Natural water is in constant state of motion. In its circulation process, it contacts air, soil, dusts, mineral, rocks and various wastes. At the same time, microorganisms and aquatic organisms propagate, which brings

Please cite this article as: Li Xie, Tinghong Yang, 2017, Design of chemical water auto-control system in power plant based on plc, Chemical Engineering Transactions, 62, 1105-1110 DOI:10.3303/CET1762185

impurities to water (Xie et al., 2013). The impurities in natural water can be divided into suspended solids, colloid and solute. Solute can be divided to be solute gas, solute inorganic ion and solute organic substance (Güttel, 2014). Suspended solids are the tiny particles in water whose diameter is longer than 100nm. People can directly see them by optical microscope or naked eyes, such as decayed body of plants and animals, alga, sand and bacteria.

The main inorganic ions dissolving in natural water are Na+, K+, Mg2+, Ca2+ and Cl-, CO32-, SO42-. They account for above 96% of total inorganic ions in natural water. If the impurities and ions in natural water cannot be processed and unqualified water enters heat exchange equipment or high-pressure boilers, metal strength will decline and local distortion of pipelines will be caused. At the same time, thermal equipment will be corroded and economic loss will be caused. Therefore, raw water must be chemically processed before they are transmitted into boiler (Stucki, 2013; Yang, 2014).

2.2 Raw water preprocessing

Raw water pre-processing is to eliminate the suspended solids, colloid and some organic matters in water. Technological process is: raw water → coagulating sedimentation → filtering. In natural water, the smaller suspended particles are, the more difficult sedimentation will be. Besides, colloid will not become sediment only relying on gravity. Coagulation is to coagulate small suspended particles and colloid to be large particles through adding coagulant. In the function of gravity, they can become sediment. The process is usually completed in accelerated mechanical clarifier. It is the most common way of raw water pre-processing. The coagulants frequently used in factory are aluminum ion salt and iron ion salt.

Compounds of aluminum sulfate: aluminum sulfate (rough-wrought and purified), aluminium potassium sulfate (potassium alum) and aluminum ammonium sulfate (ammonium alum). Aluminum sulfate and alum are white crystals. Their aqueous solution is acidic. PH value of water can be lowered if they are put into water. When large quantity of aluminum ion salts are put into water, the content of negative ions of strong acid in water will increase prominently.

Ferrous sulfate: blue semitransparent crystal. It is soluble in water and its aqueous solution is acid. Some Fe2+ are oxidized to be Fe3+ in brown in air. The following coagulation reaction will happen when it is put into water:

$$\mathrm{Fe}SO_4 + 7H_2O \rightarrow Fe(OH)_2 + H_2SO_4 \tag{1}$$

$$4Fe(OH)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3 \tag{2}$$

To oxidize Fe2+ to be Fe3+, the PH value of water must reach 8.5 and above. In this condition, dissolved oxygen contained in water can be used to accelerate oxidization. When PH value of raw water is low, bleaching powder or chlorine will be added to oxidize Fe2+. However, the method cannot be used if the content of organic matters is large or chroma of raw water is dark. This may corrode drug-feeding equipment. Through above technological procedures, the content of large particles and colloid in water can be largely decreased.

2.3 Design of feedback model

The feedback control model of cation bed is firstly designed. Normally, the concentration of Na+ in the water of cation bed is required to be lower than 50μg/L. When the concentration is higher than 50μg/L, cation bed will be invalid. 5% HCL regenerated liquid shall be sprayed to positive ion exchange resin at cation bed to regenerate it and recover the capability of exchanging Na+ in water. Correspondingly, the concentration of Na+ will decline and become normal. In the process, regarding the concentration of Na+ as controlled object and regarding HCL regenerated liquid as input variable, when the controlled object changes abruptly, give it a feedback control immediately to stabilize the concentration in certain scope. The control diagram is shown in Figure 1.

As for anion bed with desalination processing, the index of the quality of water from anion bed is conductivity. If conductivity is larger than 5μS/cm, it will indicate the water is unqualified and anion bed is invalid. 8% NaOH regenerated liquid will be sprayed to the cation-anion exchange resin in anion bed to regenerate it. The purpose is to eliminate the anions in water and get pure water. The conductivity of water will decline to be lower than 5μS/cm. In this process. In this process, conductivity is controlled object and the level of NaOH regenerated liquid is input variable. When the controlled object becomes abnormal, give it a feedback control immediately to stabilize conductivity in certain scope. The control diagram is shown in Figure 2.

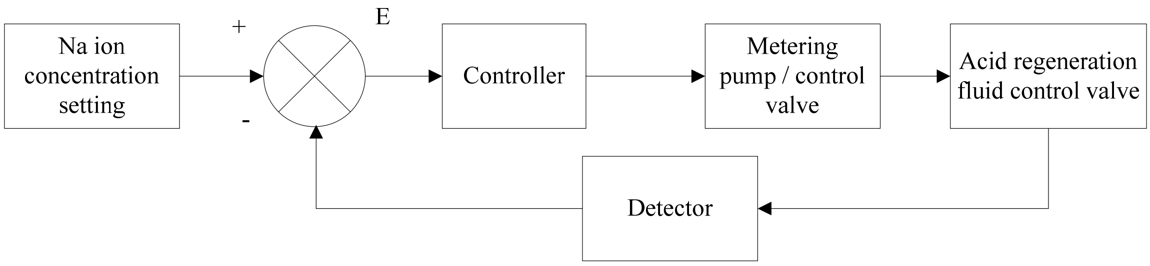

Figure 1: Principle diagram of regeneration control principle of positive bed

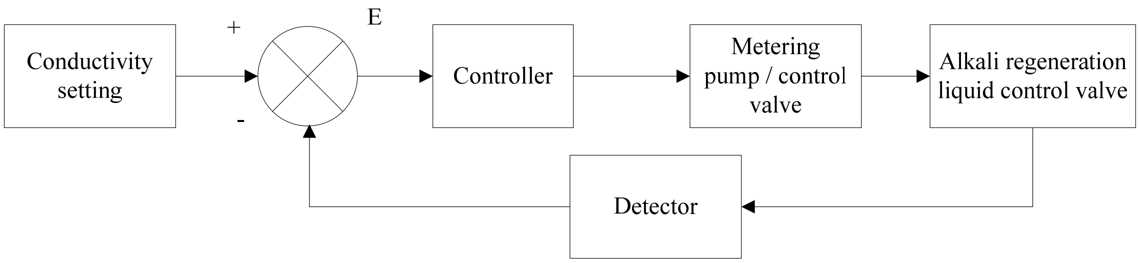

Figure 2: Principle diagram of regeneration control of native bed

3. Data Analysis and System Operation Debugging

3.1 Chemical water treatment auto-control system

The procedures of chemical water treatment auto-control system are complex in power plant. Taking reverse-osmosis water treatment control for example, firstly start reverse-osmosis water-feeding pump, reductant metering pump and electric slow entry valve; 5s later, start high-pressure water-feeding pump; 3 minutes later, open entry and drainage valve; 3 minutes later, close entry and drainage valve; open pneumatic washing valve and pneumatic drainage valve; start reverse-osmosis washing pump; after reverse-osmosis washing for 10 minutes, the ions in water can be eliminated. Table 1 shows the procedures of reverse-osmosis water treatment.

Table 1: List of hardware configurations for chemical water treatment systems

No.	Control Project / Program	Reverse osmosis feed water pump	High pressure feed pump	Pneumatic flushing valve	Time(Sec)
1	Initial stage	○	○	○	
2	Start-up stage	●	○	○	
3	Stop stage	○	○	●	Valve in place
4	Washing stage	○	○	●	5-10 min(adjustable)

(●start of equipment; ○stop of equipment)

Different simulation results can be got if computer system is used to make simulation analysis. Figure 3 shows the result of simulating predictive fuzzy control system; figure 4 shows the simulation curve got from the change of controlled object.

In the simulation result of Figure 4, prediction link in predictive fuzzy control can compensate lag link. This effectively avoids the oscillatory occurrence of pure lag link in common control system. Therefore, ideal control effect can be got to meet the requirement of field control.

In comparison between the simulation curve in figure 4 and that in figure 5, we can get the following conclusion. In the condition that predictive model and control strategy do not change, step response still has satisfying performance index if the controlled object changes. It indicates the control scheme can overcome the disadvantage of traditional Smith predictive compensation control method making quality bad owing to the error of model. It is robust with certain value of engineering application.

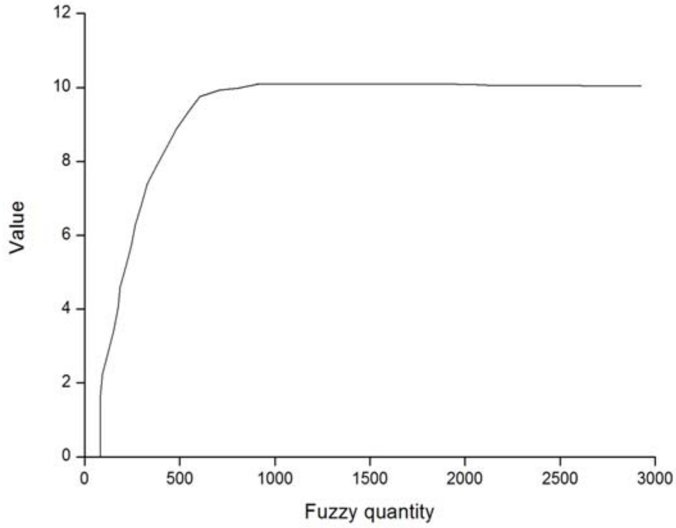

Figure 3: Simulation curve of predictive fuzzy control

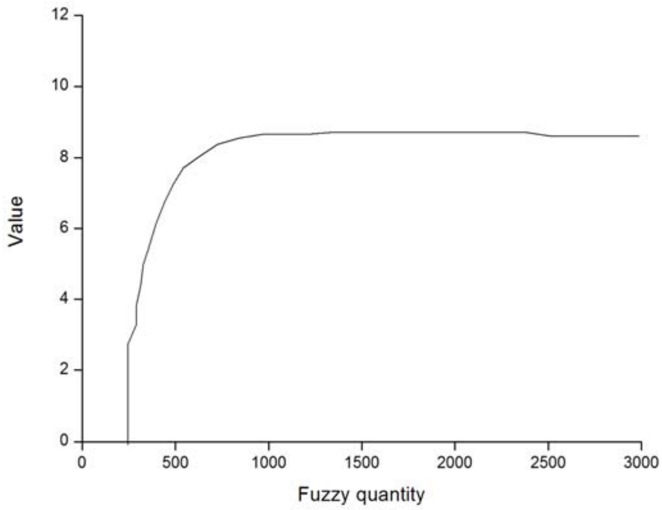

Figure 4: Simulation curves of different controlled objects

3.2 Comparative analysis on field data and simulation data

After the system is put into operation, we especially monitor the concentration of Na+ in the outlet of cation bed and the conductivity in the outlet of anion bed. This is for the comparison with the data got from subsequent simulation. From the record of factory, we can know that it is detected per two hours. Detection results are shown in Table 2.

Table 2: Conductivity detecting

Time / Index	12:00	14:00	16:00	18:00	20:00
Na^+ concentration of positive bed effluent (μg/L)	8.74	8.74	8.74	10.1	11.2
Conductivity of negative bed effluent σ(μS/cm)	0.48	0.48	0.48	0.56	0.51

In analysis on above data, the quality of water meets national requirement: sodium concentration≤50μg/L; conductivity σ ≤ 5μs/cm (25°C). However, the detection is hysteretic and timed detection. We can see that the value during 14:00-16:00 is same because the water in water tank of boiler is full and the link of water regeneration is stopped. Water is regenerated at 18:00 and the index changes. Although control indexes are reasonable, they are not optimal and control is not coherent.
Through drawing a single-feedback closed-loop control circuit in MATLAB, the regeneration link of cation bed and anion bed can be simulated. Cut-and-trial method is used to constantly adjust the value of K. Finally, the controlled variables reach stable status. The concentration of Na+(μg/L) in the outlet of cation bed and the conductivity in the outlet of anion bed are respectively shown in Figure 5 and Figure 6.

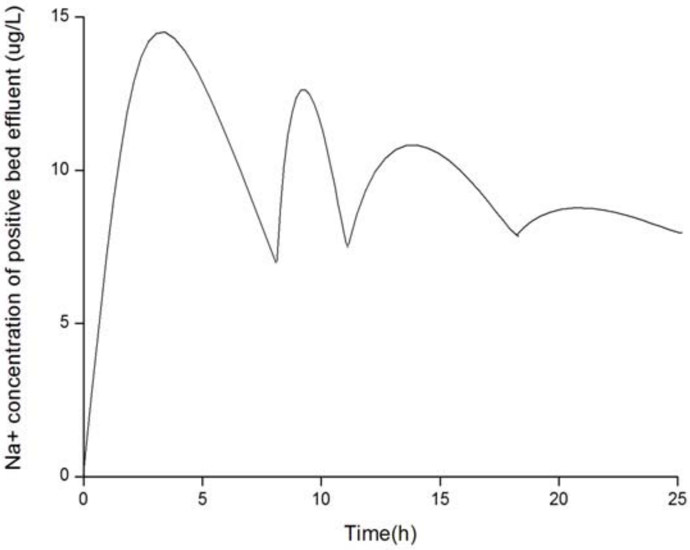

Figure 5: Na+ concentration of positive bed effluent

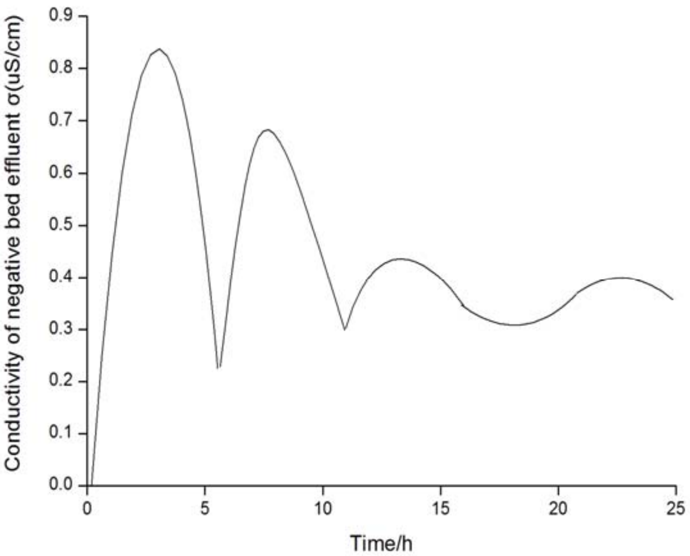

Figure 6: Conductivity of negative bed effluent

In the figure, the concentration of Na+ at cation bed is maintained to be 8.3μg/L finally; the conductivity of outlet at anion bed is maintained to be 0.5μS/cm finally. It not only meets the standards of water discharge: the concentration of Na+at cation bed≤50ug/L; the conductivity of outlet at anion bed σ≤5us/cm (25°C). Comparing with actual measurement, the degree of stability is higher. In addition, real-time monitoring is achieved and work efficiency is raised. This has certain reference value.

4. Conclusions

Chemical water treatment control system is a very important link of power plant. Before being put into boiler, raw water must be chemically processed. This guarantees pure water without scaling formation in boiler. In this way, the efficiency of boiler system can be raised and the rate of fault can be lowered. Taking chemical water treatment control system of a power plant in Guizhou as actual case, this paper makes comparative analysis on the data collected on site and the data simulated through online pre-debugging and actual debugging. This offers valuable reference to the upgrade and reform of power plant. Through upgrade and reform of the system, the automation operation level of enterprises can be raised; remote monitoring control can be achieved; manpower cost can be saved; efficiency of enterprise can be raised.

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