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Study on Water Saving Scheme of Thermal Power Plant Based on Water Balance Test

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***Abstract*—As a major industrial water user, thermal power plants have always been the focus of water-saving work. Through the analysis of two of the water balance test results of once-through cooling power plants along the lower reaches of the Yangtze River, it is found that the attention of enterprises to water-saving work have been significantly improved in recent years, but there is still a lack of professional and scientific water-saving methods. It is mainly reflected that in the unreasonable layout of water treatment system and the lack of pertinence of water-saving technical reform measures. These problems not only reduce the effectiveness of water-saving work, but also increase the economic burden of enterprises. By comparing the high water consumption systems of two power plants, excavation of he water-saving potential of enterprises in the water utilization, and the targeted water-saving measures are putting forward, which can provide reference for water-saving transformation of enterprises.**

Keywords-Once-through Cooling; Coal-fired unit; Water saving technology reform; Reclaimed water reuse; Zero discharge; Flue gas heat recovery

I. INTRODUCTION

The current situation of water resources in China is very serious. Water resources shortage, serious water pollution, water ecological environment deterioration and other problems have become increasingly prominent, which has become one of the main bottlenecks restricting the sustainable development of economy and society. The electric power industry is the basic industry of the national economy, and it also uses a lot of water. Water plays an important role in transferring energy, cooling and cleaning in the process of thermal power generation. With the strict assessment of national and local governments on excessive water intake, how to improve the rationality of water use and scientific management level, and reduce the cost of production and operation of power plants, is an important problem faced by power plant managers.

Once-through cooling thermal power plants are densely distributed in the lower reaches of the Yangtze River Basin. Due to abundant regional water resources, water saving is not fully considered in the design of power plants, resulting in low water efficiency and wastewater discharge. Although the power plant adopted the water-saving technical reform in the later period, it failed to achieve the expected water-saving effect due to the lack of scientific and targeted.[1-4]

Based on the water balance test results of two thermal power plants along the Yangtze River, through comparative analysis of water use links and indicators of power plants, according to the characteristics of water use in power plants, this paper proposed the corresponding water saving scheme.

II. WATER BALANCE TESTING THEORY

A. Concept and Basis

Water balance mainly refers to the water balance. Water balance is to study the balance of water supply, consumption, leakage and emission in the process of water use. Therefore, the water balance of the enterprise is the water balance with the enterprise as the assessment object, that is, the sum of the input water of each water system of the enterprise should be equal to the sum of the consumption and output water.

The core of water balance test is the balance of water. The change of water in any period of a certain region must be equal to the difference between the input water and the output water in that period, that is, the water is balanced, which also conforms to the law of conservation of mass.

The basis of water balance is the continuum equation in hydraulics :

$$\frac{\delta\rho}{\delta t}+\frac{\delta(\rho u)}{\delta x}+\frac{\delta(\rho)}{\delta y}+\frac{\delta(\rho\omega)}{\delta z}=0\,. \tag{1}$$

Further, it can be obtained:

$$Q_{\mathrm{IN}} = Q_{\mathrm{OUT}} \tag{2}$$

The problems in various links of water are studied through water balance, and a targeted improvement scheme is established. A scientific and reasonable water use strategy is proposed to tap the potential of water conservation and improve the utilization efficiency of water resources, so as to implement the purpose of water conservation. In the process of water balance test, the main application basis is: "General rules for enterprise water balance test", "Water-saving enterprise evaluation guidelines", "General Rules for Preparation of Water Quota for Industrial Enterprises", "General rules for

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equipment and management of energy measuring instruments in energy consumption units" and so on.

B. Main content and purpose

The main purpose of water balance test is to strengthen the management of water resources utilization by enterprises through water balance test, improve the utilization efficiency of water, and create greater economic value with limited water quantity, so that enterprises can use water more reasonably, use water more efficiently, and create better economic and social benefits. The main contents of water balance test are as follows.

- The water supply and drainage network is clarified and the layout of water supply and drainage network is optimized.
- Determine the different water systems, and determine the test cycle.
- Collect relevant parameters and water consumption information.
- Testing various amounts of water.
- Summarize the test data.
- Comprehensive equilibrium, reasonable water analysis and rectification.

C. Methord

In the optimal allocation of water resources in modern enterprises, the main methods of water balance test are pipeline leakage test and water balance test.

- The pipeline leakage test method is through the static test of enterprise water, closing all the water meter valves in the enterprise, opening the total water supply valve, and observing the operation of the total water meter after 2 hours of static. If the total water meter is not running, it means that the leakage of water management is zero. If the total water meter is running, it is necessary to find out the leakage pipeline or leakage point, and take corresponding remedial measures to ensure that the pipeline does not leak. Another dynamic test method of pipeline leakage is to meet the water balance test needs of continuous production enterprises. It is to make the total water meter and all water meters of the enterprise in operation. After 2 hours of water accumulation, the values of the total water meter and each water meter are read respectively. The change value of all water meters should be equal to the total water meter value. If you do not want to wait, the error of the meter itself and the leakage of the pipeline are considered.
- Water balance test method. Enterprise production is different in nature and size, the test method is different, the time spent is also different. At present, in principle, no matter what kind of test method is used, it should be based on the test of pipeline leakage, the test results and mathematical statistics calculation are effectively combined, and the water balance of the enterprise is comprehensively analyzed. At present, there are first-level balancing method, stepwise balancing method and comprehensive balancing method. The first-level balance method is to complete the instantaneous test of all water use systems of enterprises. This test method only satisfies the enterprises with relatively simple forms of water use and relatively stable total water use. The step-by-step balance test method is to complete the water use test of various water facilities in enterprises. This test method should reduce the human resources involved in the test and optimize the test organization activities. The comprehensive balance test method generally takes direct cooling water, indirect cooling water, production water, domestic water, supplementary water and recycled water as clues, and balances according to the production water system, auxiliary production water system and auxiliary production water system. Water balance test involves a wide range, high technical content and rich knowledge. It is a comprehensive balance of a multi-level and multi-view complex system.

III. WATER BALANCE TEST OF THERMAL POWER PLANT

A. Unit Overview

Power Plant A: 2×660MW coal-fired generating unit. The water balance test was conducted from August 28 to October 8, 2013. During the test period, the generating load of the whole plant was 80-85%.

Power plant B: 2×630MW coal-fired generating unit. The water balance test was conducted from July 10 to August 10, 2019. During the test period, the power generation load of the whole plant was 80% to 90%.

B. Results of water balance tests

During the test, the water balance of the power plant is shown in Table 1.

TABLE I. THE RESULTS OF WATER BALANCE TESTS

Power Plant	Water intake	Water use	Water consumption	Water discharge	External water supply
A	10668.28	12802.43	8140.4	2338.88	189
B	7900.32	8043.36	7900.32	0	0

The **unit** in the table is. m^3/d

By comparing the water use situation of power plant A and power plant B, it is found that the unit size of the two plants is similar, but the water intake of the two plants is quite different (the difference is 2767.96m3/d). The reasons are as follows:

1) Power plant B basically realizes no waste water discharge. In addition to the once-through cooling water and plant rainwater discharged into the Yangtze River, the rest of the production and domestic wastewater is treated and reused. In power plant A, in addition to the once-through cooling water and plant rainwater, industrial cooling water, water purification station sludge sewage, overflow water and part of the site flushing water are discharged.

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2) In the daily water use process of power plant B, in addition to the Yangtze River water, also uses part of the city reclaimed water. The replacement rate of unconventional water resources was 6.29%. Urban reclaimed water enters the industrial wastewater treatment and reuse system of the power plant and is mixed with the treated in-plant reuse water. It is mainly used in desulfurization system of power plant B and coal yard. According to the relevant policy requirements, the amount of urban water used by power plants does not count the water intake.

Compared with power plant B, the loss of desulfurization process and moisture control water in power plant A are obviously larger. As A result, power plant A consumes more water than power plant B. This is due to differences in water process control and equipment.

C. *Indexes of water use*

According to the results of water balance test, the main water consumption indexes of the two power plants are shown in Table 2.

TABLE II. INDEXES OF WATER USE

Power Plant	Water intake per unit generating capacity m^3/（MW.h）	Reuse rate	Steam-water loss rate	Total discharge rate	Yield of desalinated water
A	0.37	99.16%	1.3%	3.4%	66.38%
B	0.26	99.49%	0.93%	0	70.24%

In this paper, the water intake per unit generating capacity is taken as the core index to evaluate the advanced water consumption level of power plants. According to the Guideline to Water Use Efficiency in Key Industries, the advanced value is 0.33 m^3/(MW.h) and the average value is 0.43 m^3/(MW.h) for the single machine capacity of 600MW class and above. The comparison of water use levels in power plants is shown in Figure 1.

As is shown in the figure, the water use level of power plant A is better than the industry average in the Guideline to Water Use Efficiency of Key Industries. But there is still a gap between the advanced value of the industry. The water use level of power plant B is better than the industry advanced value in the Guideline to Water Use Efficiency of Key Industries.

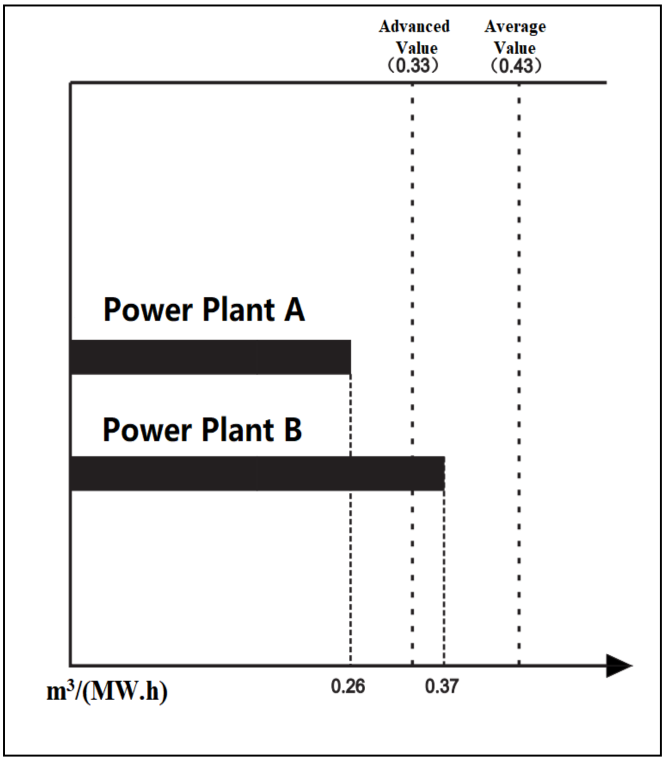

Figure 1. Comparison of water use levels in power plants

IV. DISCUSSION OF WATER SAVING SCHEME

According to the above comparative analysis of the system water use of the two power plants, power plant A has a gap with power plant B in the use of urban reclaimed water, recycling of wastewater and water loss from desulfurization. Its water saving potential is large. In this paper, according to the characteristics of water use in A power plant, combined with the successful water-saving case of once-through cooling thermal power plant[5], the water-saving scheme is proposed as follows.

A. *Improve the reclaimed water reuse system*

According to relevant policy requirements, to promote the use of reclaimed water, industrial production should give priority to the use of reclaimed water. Taking power plant B as an example, a new biological aerated filter was built to pretreat the urban reclaimed water. After reducing the concentration of ammonia nitrogen, it was put into the wastewater treatment system for further treatment and finally used in the desulfurization system and coal water system for reuse. This scheme combines the new reclaimed water treatment system with the original sewage treatment system, although the transformation cost is low, but the water saving effect is significant.

With the maturation of membrane treatment technology and the reduction of cost, ultrafiltration technology will be widely used as a reclaimed water treatment process[6,7]. Immersion ultrafiltration technology has gradually become the mainstream. The turbidity of reclaimed water treated by ultrafiltration technology can be removed up to 90%, which can meet the

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requirements of industrial water and desalting water system of power plant.

B. Optimize the wastewater treatment system

For thermal power plants, the ultimate goal of waste water treatment is no waste water discharge. The technical difficulty of non-discharge of wastewater is the concentration and solidification disposal of terminal wastewater [8-12]. According to the results of water balance test, the wastewater treatment system of power plant B has basically realized no discharge. The terminal waste water produced by wastewater treatment system of power plant B is all used in desulfurization system and coal water system. Desulphurization system and coal-water system have limited capacity to terminal wastewater. In order to realize no discharge of wastewater, it is necessary to optimize the wastewater treatment system and reduce the amount of terminal wastewater.

According to the current situation of the wastewater treatment system in yanjiang power plant, this paper puts forward an optimized scheme. The produced wastewater was divided into sludge wastewater, salt wastewater, domestic wastewater and high-quality wastewater according to pollutant composition. The supernatant of sludge containing wastewater is of good quality after being pretreated by concentration and pressure filtration process and can be reused directly. High quality waste water (such as boiler steam condensate, industrial cooling water) can be collected and reused. Saline wastewater and domestic wastewater are complicated in composition, which is difficult and costly to treat. These two types of wastewater are collected and treated for use in water systems with low water quality requirements, such as desulfurization systems and coal-water systems.

C. Set up desulfurization flue gas waste heat utilization system

Set up flue gas waste heat recovery system, can use closed water cycle, reduce the original flue gas temperature, improve desulfurization efficiency, reduce desulfurization water consumption. Increase the temperature of the purified flue gas, eliminate the white smoke phenomenon, meet the requirements of environmental protection. The flue gas waste heat recovery can be combined with the boiler feed water system to improve the condensing water temperature into the deaerator, further saving energy and reducing consumption. It can also be combined with heat pump system to provide cooling and heating for thermal system or office area. At the same time, the flue gas condenser can also be set up to condense and recover the water in the flue gas, the latent heat of the flue gas can be recovered, and the recovered condensed water can be used as desulfurization and water replenishment after treatment to further reduce the water consumption of desulfurization.

V. CONCLUSION

In recent years, thermal power plants are facing more severe challenges in both water use and drainage. With the increasingly stringent assessment index of water use, thermal power plants will face great pressure in water saving and emission reduction.

In this paper, by comparing the water consumption index and system water consumption of two power plants along the Yangtze River, feasible water saving schemes are proposed:

- Improve the reclaimed water reuse system. According to the quality characteristics of urban reclaimed water, the pretreatment is carried out and combined with the wastewater treatment system of the power plant to reduce the cost and save the amount of water.
- Optimize the wastewater treatment system. Plant waste water is classified according to water quality, high-quality waste water and single waste water are treated on site and reused. After the wastewater with complex water quality is collected and treated uniformly, the rest of the wastewater is used in the system with low water quality requirements.
- Set up the flue gas waste heat recovery system. Thus, the desulfurization efficiency of power plant can be improved, the consumption of desulfurization water can be reduced and the phenomenon of white smoke can be eliminated. The flue gas waste heat recovery system is connected with the boiler feed water system to achieve the purpose of saving water and energy.

It is a long-term task for thermal power plants to save water and reduce emission. With the policy updating and the improvement of water treatment technology, thermal power plants should continuously improve the water saving plan scientifically.

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