Analysis on Water Saving Effect of “Zero Discharge” Wastewater from 4×300MW Coal-fired Power Plants

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Abstract. The contradiction of water resource shortage is increasingly prominent in the process of electric power production. In order to fully understand the implementation of water-saving strategy in a power plant, this paper takes a coal-fired power plant as an example to analyze and evaluate the water-saving effect of “zero discharge” of waste water in the whole plant through the water balance test. The results show that the coal-fired power plant not only protects the water environment, but also saves about 38 % of the cost of production water by implementing special water modification such as “zero discharge” of waste water in the whole plant.

1. Introduction
China is a country with extremely scarce water resources. With the rapid development of China's power industry, the shortage of water resources and water quality has become a key factor restricting China's power production. In 2017, China's National Development and Reform Commission issued the “13th Five-Year Plan for Water-Saving Society Construction” and requested the water-saving reform of the coal-fired power generation industry: “By 2020, the water consumption of coal-fired power plants will be reduced to about 1 kg / (kW h), and the water consumption (excluding DC cooling water) will be reduced by about 8 % compared with 2015 [1]. Therefore, it is of great significance to carry out water-saving research in coal-fired power plants and to explore the water-saving potential of coal-fired power plants. Based on the water balance test of a 4×300MW unit in a coal-fired power plant, this paper analyzes and evaluates the water-saving economic benefits and energy-saving and environmental-protection benefits of the special water improvement measures such as “zero discharge” of waste water from the power plant..

2. General situation of water system and wastewater treatment measures in typical thermal power plants
A typical thermal power plant water system takes water from a fixed water source, reasonably distributes water through the first, second and third water systems, and produces different wastewater through each water system process and discharges it to the wastewater treatment center. The water system of the thermal power plant includes condenser cooling circulating water, steam turbine condensate polishing system, chemical water treatment, boiler water treatment (adding chemicals to soften or dissolve scale in the boiler and discharge it through boiler blowdown, but also adjusting the ratio between the PH value and components of boiler water), industrial cooling water system, domestic water system, fire water system, dust removal, ash removal system water, drainage and production backwater treatment, and
wastewater treatment system. The typical tertiary water system of thermal power plant is shown in fig. 1.

Typical thermal power plant wastewater treatment process is relatively simple, mainly due to the constraints of backward process equipment, improvement degree of energy-saving technology, improvement level of energy-saving measures and technical experience of water-saving management in thermal power plants. Generally, power plants adopt water-saving measures with low technical investment and relatively simple operation and management, such as using waste water from desulfurization system directly to ash flushing system with low water quality requirements. Production (including corrosion products and oil) and domestic wastewater are used in desulfurization process make-up water and plant greening water through the wastewater treatment system. Although some water-saving benefits are achieved and a certain amount of water and drainage are reduced, it is of great significance to the water environment and environmental protection if the wastewater of each system is classified, collected, treated and comprehensively utilized to achieve "zero discharge" of wastewater from the whole plant [2].

3. Measures for water-saving transformation of target power plants and their implementation benefits

3.1. The type and amount of wastewater in the target power plant

A 4×300MW coal-fired power plant in North China implemented a "zero discharge" environment-friendly comprehensive water-saving project in 2009. The wastewater of the target power plant includes continuous wastewater and discontinuous wastewater, among which the continuous wastewater includes reverse osmosis concentrated water of boiler make-up water system, desulfurization wastewater, concentrated brine of flash evaporation system, production wastewater, coal-containing wastewater and domestic wastewater. Discontinuous wastewater includes all kinds of test drainage, unit pickling wastewater, boiler cold and hot start-up wastewater, boiler flue gas side flushing wastewater and air preheater flushing wastewater. There are many kinds of waste water and a large amount of waste water, and the production waste water contains salts, petroleum, fluoride, iron, heavy metals and suspended dirt, etc.

The target power plant uses the seawater open-cycle cooling system and seawater flash evaporation water production system to conduct actual analysis from the perspective of water balance. Due to the influence of unit load, season and actual management level of the power plant, the actual quantity balance of the power plant is constantly changing. For convenience of analysis, the water balance of...
more than 80 % load is selected as an example for preliminary analysis, and seawater circulating cooling water is not used as water consumption statistics. See Table 1 for the results of wastewater and water consumption of each system in the water balance test of the target power plant.

Table 1. Statistics of Unit Water Consumption of Target Power Plants

| Projects                                      | water demand | Amount of waste water | water consumption |
|-----------------------------------------------|--------------|-----------------------|-------------------|
| Domestic system water                         | 16           | 8                     | 8                 |
| Desulfurization system water                  | 198          | 22                    | 176               |
| Slag removal system water                     | 40           |                       | 40                |
| Water for coal conveying flushing water       | 8            | 7                     | 1                 |
| Dry ash mixed with wet water                  | 23           |                       | 23                |
| Reclaimed water for condensate polishing      | 3            |                       | 3                 |
| HVAC system water replenishment               | 7            |                       | 7                 |
| Spray greening of plant area                  | 4            |                       | 4                 |
| Other systems discharge sewage                | 30           | 30                    | 30                |
| Water for chemical flash system               | 304          | 177                   | 127               |
| Total                                         | 633          | 247                   | 386               |

As can be seen from Table 1 above, the total water consumption (excluding circulating cooling water) of the units in the target power plant is 633 m³/h, and the wastewater amount is 247 m³/h, of which the chemical flash 177 m³/h concentrated brine is returned to the sea, and the wastewater generation rate is 39.02 %, which is 123.5×10⁴ m³ of wastewater per year based on the annual utilization hours of 5000h.

3.2. The systematic strategy of “zero discharge” of wastewater from the target power plant

3.2.1. Industrial Wastewater Treatment System and Comprehensive Utilization. According to the different salt content and suspended solids content in the wastewater, the wastewater treatment system adopts the corresponding process to carry out classification treatment, and is finally treated to meet the water quality requirements of each system for reuse [3 - 5]. See Table 2 for the designed effluent quality indexes of the wastewater treatment system of the target power plant.

Table 2. Water quality index of industrial wastewater treatment plant after treatment

| Projects                              | Standard                  |
|---------------------------------------|---------------------------|
| Appearance                            | Clear                     |
| Smell                                 | No                        |
| pH                                    | 7.5 ~ 8.5                 |
| Chemical oxygen consumption (mg/L)    | ≤100                      |
| Sulfide (mg/L)                        | ≤1                        |
| Volatile phenol (mg/L)                | ≤0.5                      |
| Cyanide (mg/L)                        | ≤0.5                      |
| Mercury (mg/L)                        | ≤5                        |
| Oil (mg/L)                            | ≤4                        |
| Chlorine (mg/L)                       | ≤300                      |
| Suspension (mg/L)                     | ≤200                      |

See Figure 2 for the main system flow of wastewater treatment in the target power plant.
The design output of the wastewater treatment system is 2×50 m³/h, divided into two columns. The wastewater treatment capacity of the target power plant is about 70 m³/h, which can produce $35 \times 10^4$ m³ of reclaimed water per year according to the annual utilization hours of 5000h. According to the 5 Yuan /m³ of water used by the local industrial enterprises of the target power plant, plus the sewage treatment fee of 2.2 Yuan /m³ and the total water price of 7.2 Yuan /m³, it can save 2.52 million Yuan of water cost per year.

3.2.2. Desulfurization wastewater treatment system. Desulfurization system is used as the end water point, and wastewater discharge directly affects the wastewater discharge level of the whole plant. Generally, the way of removing desulfurization wastewater in power plants is for ash storage agitation. However, desulfurization wastewater cannot be removed during the comprehensive utilization of dry ash, and the wastewater discharge of wet cooling units is relatively large, so it is particularly important to increase desulfurization wastewater treatment system. See Figure 3 for the main system of desulfurization wastewater treatment system in this plant.

The desulfurization wastewater treatment system of the target power plant adopts the technical route of “clarification and softening + ion exchanger + reverse osmosis + normal osmosis membrane concentration” to treat and concentrate chlorine, fluorine, sulfate, sulfite, calcium and magnesium plasma and suspended solids, reuse the wastewater after treatment to the desulfurization system and coal
conveying flushing water for water replenishment, and send the concentrated wastewater to the ash yard for spraying. Waste water is discharged continuously and treated continuously. Table 3 is the statistical calculation table of water saving for the desulfurization wastewater treatment system of the plant.

**Table 3. Water quality index of industrial wastewater treatment plant after treatment**

| Parameter                                      | THA |
|------------------------------------------------|-----|
| Sewage treatment capacity (t/h)                | 27.5|
| Desulfurization wastewater treatment capacity (t/h) | 12.9|
| the expense of sewage processing /Yuan (t·h)^{-1} | 2.2 |
| Water rate/Yuan (t·h)^{-1}                     | 5.0 |
| Water saving cost /Yuan (t·h)^{-1}             | 125 |

The wastewater treatment capacity of the desulfurization wastewater treatment system of the target unit is 27.5 t/h and the water production capacity is 12.9 t/h, which can save about 625,000 Yuan of production water cost per year based on 5000h hours of annual utilization.

3.2.3. **Seawater flash desalination system.** In order to alleviate the shortage of fresh water resources in recent years, the target power plant adopts a multi-stage flash seawater desalination system, in which heated seawater is sequentially evaporated in several flash chambers with gradually reduced pressure, and steam is condensed to obtain fresh water. The water yield of seawater flash desalination system is about 130m³/h. According to the calculation of 5 Yuan/m³ of water used by local industrial enterprises, the water intake fee for deep wells can be saved by about 650 Yuan per hour. According to the calculation of 5000h hours of annual utilization, the water cost investment can be saved by 3.25 million per year.

3.2.4. **Seawater direct cooling water.** The target power plant is located in the coastal area of China. The unit uses a direct-current cooling water system. The cooling water only passes through the unit condenser circulating water system, and the circulating water temperature rises slightly. The contents of various substances and ions in the water remain basically unchanged. The direct-current cooling water system has no losses such as evaporation, wind blowing and sewage discharge. It consumes much less water than the circulating water of the same type of unit, and has relatively less investment and simple operation.

3.2.5. **The flushing water of the coal conveying system is recycled in closed circuit.** The diversion of clean-up water is a common method used by water users, and the heavily polluted wastewater should not be mixed with the lightly polluted water in order to reduce the treatment difficulty and the treatment cost. There are many kinds of pollutants in coal yard waste water, and the pollution is heavy. It is uneconomical to reuse the waste water after treatment in other water systems. The general economic measure is to recycle the coal yard waste water after simple treatment. The flushing water of the coal conveying system is discharged to the coal settling tank, and the coal can be recycled. The clarified water is discharged to the clean water tank and enters the coal conveying system for recycling. At the same time, the water treated with desulfurization wastewater is used as the supplementary water of the flushing water of the coal conveying system.

4. **Implementation Benefit of “Zero Discharge” System of Waste Water in Object Power Plant**

According to the water balance measurement results of the power plant, the energy-saving economic benefits and environmental benefits after the implementation of "zero discharge" of wastewater in the whole plant are analyzed and calculated.

At present, the total water consumption of the whole plant of the coal-fired unit is 633 m³/h, the water yield of the seawater flash desalination system is about 130 m³/h, the reuse water consumption of the industrial wastewater treatment system is about 70 m³/h, and the water consumption saved by direct
seawater cooling water and washing of the coal conveying system is about 50 m³/h. Through the implementation of water-saving measures, the whole plant can save 250 m³/h of water consumption. According to the calculation of 5 Yuan /m³ of water used by local industrial enterprises, it can save about 1250 Yuan per hour of water consumption for deep wells, and 6.25 million Yuan of water cost investment per year according to 5000h hours of annual utilization. In addition, the wastewater volume of the whole plant is 70 m³/h, and according to the “zero discharge” technical renovation project of the whole plant, the wastewater treatment cost can be reduced by 77000 Yuan per year.

The amount of waste water in power plants is large, the quality deviation of all kinds of waste water is large, different waste water contains different pollutants, and a large amount of waste water causes great damage to the environment. Through the implementation of the “zero discharge” environmental protection water-saving project of the whole plant waste water, the waste water is collected by classification according to the type of waste water produced and treated by classification and classification, which has very important environmental protection significance for social development.

5. Conclusion
The coal-fired power plant not only protects the water environment, but also saves about 38 % of the cost of production water by implementing special water modification such as “zero discharge” of wastewater in the whole plant, classifying, treating and recycling all kinds of wastewater in the power plant.

The “zero discharge” of waste water from coal-fired power plants is a complex systematic project. It is necessary to strengthen water-saving management, rationally utilize water resources, adopt water-saving measures according to local conditions, and take into account water control, water management and water conservation to ensure the sustainable development of “zero discharge” of waste water from coal-fired power plants.

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