



## Analysis and research on comprehensive utilization of seawater of Huangdao Power Plant of Qingdao

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### ABSTRACT

In this paper, it takes Huangdao Power Plant as the research background, according to the location as well as the environmental characteristics of power plant to decide the four comprehensive utilization schemes of seawater desalination, seawater corrosion, marine organism pollution, and direct current cooling water drainage. Through research and demonstration, it can reduce the operating cost and improve the surrounding environment, which can explore a new way for the comprehensive utilization of seawater in power plant.

*Keywords:* Seawater desalination; Pollution control; Power plant

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### 1. Introduction

For electric power industry, energy and water are two essential resources in electric power production. With the development of electric power industry, the average annual water consumption of thermal power plants is increasing by about 10%, and the coefficient of water elasticity (the ratio of annual water consumption increasing rate to annual electricity generating rate) is about 0.68. It can be seen that the supply of freshwater cannot meet the needs of the growth of power construction, and the water shortage problem of thermal power construction in China is quite serious [1].

As a technology of increment of freshwater resources, water desalination has the advantages of no seasonal impact, stable water production, good water quality, and so on, which has become the main way to solve the problem of water shortage in some countries and regions, especially in coastal areas [2]. According to the statistics from International Desalination Association, at present the global desalination water per day has reached 81.4 million tons, which has solved the problem of drinking water for more than 200 million people. The seawater desalination project is a project involving water and

discharge process of seawater [3], during the period of construction and operation of water supply and drainage. The disorder and unscientific process may cause potential impacts on the coastal and marine environment; therefore, it needs to establish a perfect legal system to regulate the activities of the desalination industry, so as to ensure the harmonious and sustainable development of desalination and environment [4].

The traditional power plant usually takes coal as energy, and its power generation process is: coal—steam—power generation. This paper discusses the economic analysis of power plant's power support scheme for seawater desalination, that is, the same power plant supplies energy to the desalination plant in different ways, under the condition that the physical quantity is not changed; it can provide energy in different ways, resulting in different energy prices [5]. This is very meaningful for people at present to reduce the price of energy in seawater desalination, in the case of power generation to access the net, users purchase the electricity from the grid and increase electricity price due to the cost and profit of the power grid. Taking a power plant the North Network in Hebei as an example, this power plant is a  $2 \times 300,000$  kW coal-fired heating generator set, and its desulfurization and gentrification network electricity price (after tax price) is

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0.4323 Yuan. In addition to paying the basic electricity bill, the peak electricity price of the large industry is 0.7619 Yuan, the top price of electricity is 0.3076 Yuan. Calculated by 3 kWh/m<sup>3</sup> of water desalination by membrane method, the gap between the cost of tons of hydropower is 1.0629 Yuan.

Shandong Huangdao Power Plant is located in the west coast of Jiaozhou Bay, the Economic and Technological Development Zone of Qingdao. At present, the total installed capacity of the enterprise is 2,050 MW, which is a large power generation enterprise in China [6]. Among them, in Period I, the two sets of 125 MW dual internal water cooled generator were, respectively, put into operation in 1980 and 1981, which had shut down already; in Period II, two sets of 210 MW hydrogen cooled generators were put into operation, respectively, in 1988 and 1989; from 2002 to 2003, four units of machines had carried out large-scale technology renovation, which can make the enterprise total installed capacity reach 730 MW; the project of Period III had enlarged two sets of 660 MW grade super critical power generation units, which were built and put into operation in 2006 and 2007, respectively [7]. How to rely on the advantages of geographical location and the comprehensive utilization of sea water resources has become an urgent problem for enterprises to solve. In this paper, it takes the comprehensive utilization of seawater in Huangdao Power Plant as the goal, exploring the comprehensive utilization plan of seawater in Huangdao Power Plant, which can explore a new way for the improvement of the surrounding environment and the reduction of operation cost.

## 2. Comprehensive utilization of seawater

After considering the geographical location, surrounding environment and technological process of Huangdao Power Plant, the four identified problems to be solved for seawater comprehensive utilization are as follows: seawater desalination, seawater corrosion treatment, marine organism pollution control, and direct current cooling water drainage scheme.

### 2.1. Seawater desalination

The water desalination system of Huangdao Power Plant needs to consider how to further improve the primary energy utilization rate and reduce the cost of freshwater, according to the advantages and disadvantages of the separate thermal method, membrane method, and chemical method of seawater desalination technology, through economic and technical analysis of the technical scheme comparison, analyzing various reasonable combination of technical scheme, so as to reduce the core problem of the cost of freshwater products of Huangdao Power Plant. The seawater desalination system of Huangdao Power Plant is a two-stage reverse osmosis system. The simple working flow is shown in Fig. 1.

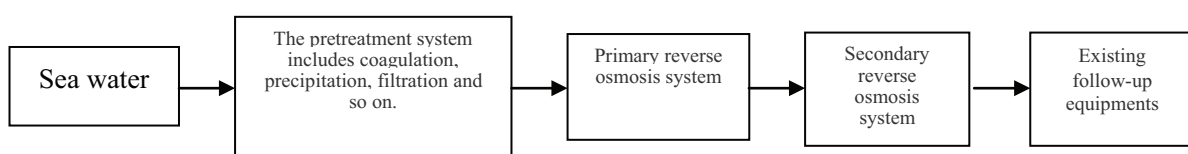


Fig. 1. Working flowchart of seawater desalination system in Huangdao Power Plant.

### 2.2. Seawater corrosion treatment

Seawater is a strong electrolyte solution with high salt content, which can have serious corrosion effect on the rack, filter, cooling water pump, cooling water pipe, condenser, heat exchange, valves, and other equipment of the power plant. The corrosion rate of seawater on carbon steel can reach 0.07–0.18 mm/a, because seawater can affect the cooling pipe of condenser of stainless steel, brass, copper nickel alloy to cause pitting corrosion, hole corrosion, stress corrosion, as well as abrasion, it can eventually leak and force the power plant to shut down.

### 2.3. Marine organism pollution control

Sea creatures grow and propagate in the condenser of Huangdao Power Plant, as well as the sea creatures that flow off into the pipe upstream, which can cause pipeline blockage, both the flow and heat transfer efficiency are reduced, resulting in great economic losses. And the local corrosion of the attached parts of the organism reduces the reliability of the equipment. In addition, the adhesion and reproduction of tiny fouling organisms, the mucus secreted by them is easy to adhere to inorganic substances such as organic matter and sediment in the water, and the thickness is gradually increased, forming sticky mud, which can result in the increase of friction coefficient and the increase of system resistance. At present, the methods of preventing marine organism pollution mainly include mechanical physical control method and chemical oxidant control method, etc.

### 2.4. Warm drainage of direct current cooling water system

The influence of warm drainage of Huangdao Power Plant direct current cooling water system is mainly reflected in the following aspects: (1) influence on the power plant, the temperature of intake water is increased due to the increased water temperature, thereby it can reduce the cooling efficiency of the power plant; (2) influence on the water environment, the saturated dissolved oxygen in water is decreased due to the increase of water temperature, which is easy to lead to red tide, resulting in the changes of aquatic organisms (algae, plankton, and benthic organism); having influence on migration, growth, and reproduction of fish that is sensitive to temperature, may even leading to death.

## 3. Solution plan

### 3.1. Seawater desalination plan

Seawater desalination is the process of obtaining freshwater by removing salt and impurities through desalination device. There are three main types of seawater desalination methods: thermal method, membrane method, and chemical

method. The thermal method mainly adopts multi-stage flash (MSF) and multi-effect distillation (MED). The membrane method mainly adopts reverse osmosis (RO) and electro dialysis. While chemical method mainly adopts ion exchange. Due to the defects of MSF technology, such as high operation temperature, equipment corrosion and fast scaling, huge power consumption, low operation flexibility, and so on, in the aspect of equipment investment and operation cost, it is all higher than that of MED process. At present, MSF process has been basically not used in the process of distilled water desalination, which has been built or being built in Huangdao Power Plant. Electro dialysis usually uses as fine desalination, which often uses RO process that has higher requirements on the softened water, and the water quality is good, meanwhile the degree of automation system is high, there is no acid wastewater, with small occupied area. Besides, the project cost and unit cost of RO process is lower than that of MED process, thus, RO process is often used as a priority seawater desalination process.

### 3.2. Seawater corrosion treatment scheme

#### 3.2.1. Selecting anti-corrosion materials

The equipment and piping material of Huangdao Power Plant that is susceptible to corrosion can use Q235A and Ni–Cr alloy steel, alloy steel, 10CrMoAl 316L and 317LN stainless steel, titanium, steel sleeve concrete pipe (PCCP), glass steel pipe, plastic pipe, steel skeleton plastic composite pipe, and so on. The material Al in 10CrMoAl can form  $Al_2O_3$  film when it has chemical reaction with oxygen in the air, both Cr and Mo can automatically add the space that is formed by Cl ions on the steel corrosion in seawater, forming a dense protective layer to prevent corrosion to develop in depth; PCCP tube can have advantages of pressure resistance, impermeability, and corrosion resistance; while the inner wall of the plastic tube is smooth, with small resistance and good sealing performance, plus the advantages of having corrosion resistance and convenient connection; steel skeleton plastic composite pipe has strong corrosion resistance, having good impact resistance, good elasticity, with resistance to uneven settlement of the terrain, but there is no large diameter pipe, when it adopts welding connection, it needs to use the special tools.

#### 3.2.2. Joint protection of cathodic and anti-corrosion coating

Cathodic protection means to protect the protected metal by a certain direct current, so as to make the protected metal have, which can be divided into sacrificial anode protection method and impressed current protection method. The sacrificial anode protection method does not need power supply, no need for personal management, no need to worry about the interference to the unprotected objects, plus the construction method is simple, however the protection range of the single anode is small, the range of self-adjusting protection is poor, plus one-time investment is also high. While the impressed current protection method needs power supply, it also need for personal management, and payment is required during the operation of the electricity network, in metal intensive areas, it is prone to occur the stray current interference, but range of the single anode protection is large,

the range of self-adjusting protection is strong, one-time investment is also low.

At present, the commonly used coating is zinc rich in epoxy, epoxy coal asphalt, epoxy mortar coating, and so on. The quality of construction quality has great influence on the antiseptic effect, surface rust is the first step of coating construction, which is also a key step, without good quality, even the best coating is also difficult to achieve the desired effect. The diameter of direct current cooling water pipe of Huangdao Power Plant usually reaches more than DN2000. Due to the inevitable defects and aging problems of the coating, cathodic protection and anti-corrosive coating are often combined to deal with these problems.

### 3.3. Marine organism pollution

#### 3.3.1. Mechanical and physical control

At the sea, direct current cooling water intake position sets the trash rack, and filter, as well as the secondary filter before entering the condenser. This method is low cost and easy to operate. It can effectively prevent larger marine organisms from entering the direct current cooling water system, but it will easily cause the flow rate to decrease or even block the pipeline, which will not play a role in preventing microorganism, larva, eggs, and so on. At the same time, the flow velocity of direct current cooling water can be properly improved, which can prevent the adhesion of large sea creatures and control the attachment of sea creatures effectively [8]. In addition, regular manual scraping and draining as well as dewatering method is simple and environment friendly, but it must stop the systematic operation and have underwater operation, which needs a lot of manpower and material resources.

#### 3.3.2. Chemical control

Chemical control includes coated layer protection and bactericide treatment. Copper, mercury, lead, and other heavy metals in the coated layer is easy to cause environmental pollution, which can destruct marine ecology, thus the condenser cannot be protected, which needs repairing or re-coating, so far, the direct current cooling water system of Huangdao Power Plant usually adopts the method of bactericide to control according to its sterilization mechanism, which can be divided into oxidizing bactericide and non-oxidizing bactericide.

The direct current cooling water system in Huangdao Power Plant often adopts the electrolysis of seawater to make chlorine method to prevent marine organism pollution. This scheme has not existed transportation, storage, and other problems. The electrolysis seawater chloride production method has high investment in the initial stage, which has the advantages of low operation cost, simple maintenance, easy operation, and management. It has a significant economic benefit in the application of the direct current cooling water system of Huangdao Power Plant. Non-oxidizing fungicides have the characteristics of broad spectrum, high efficiency, low toxicity, and friendly to the environment. Its biggest advantage is special killing effect on pollution target sea organisms such as clams, shellfish, algae, very small

effects on non target species such as fish, shrimp etc. The reagents have no corrosion effect on to equipment, thus the equipment is simple, and the investment is less. Different from oxidizing fungicides, aquatic organisms are less sensitive to non-oxidizing fungicides. They can be controlled intermittently and medicated with less dosage.

### 3.4. Warm drainage of direct current cooling water system

#### 3.4.1. Deciding the sewerage position

The layout of the intake and drainage outlet of the direct current cooling water system plays a leading role in the operation of the Huangdao Power Plant, which is related to the investment and operation cost of the power plant. The direct current cooling water system of Huangdao Power Plant usually uses the hydrodynamic mathematical model and mathematical model of temperature in its area to simulate the diffusion of warm water drainage, which also should consider the influence of the two thermal regression effect and the heat exchange between water and air interface. Through the analysis of different schemes under different typical tidal outfall near the temperature of diffusion, according to the calculation and analysis of temperature field, combined with the trend characteristics of the project area, through analysis and comparison to optimize the form and position of water intake and outlet, so as to reduce the heat recovery effect of warm drainage on the intake of water, reducing the amount of construction, as well as the operation cost, so as to save the investment of project.

#### 3.4.2. Influence of warm drainage on water environment of receiving water

The thermal capacity is huge when the warm drainage of Huangdao Power Plant is discharged into the surrounding waters, which has serious impact on the water environment. It not only changes the temperature of the water field and the flow field of the water area itself, but also can cause the thermal pollution. Therefore, it is necessary to compare the influence range of the different layout of the water outlet with the water environment, and choose the small influence one on the water environment. Secondly, the oxidizing bactericide in warm drainage is the main factor that can damage phytoplankton. The photosynthesis and respiration of plants near the outlet are inhibited, while the thermal shock of warm drainage has little effect on phytoplankton.

#### 3.4.3. Prevention and cure of foam in the outlet of warm drainage

Warm drainage of Huangdao Power Plant can fall down through the siphon well and overflow weir during the period of falling, a large amount of adsorption air will have violent collision with the downstream water, the aerated water will

occur the fluctuation and shattered churning to form a large amount of bubbles, the higher the drop aeration is, the more intensive the mixing phenomenon is, the more the foam will form. These bubbles increase the surface tension due to the surface active agent or microorganism, protein and other substances, which can increase the surface tension and form a stable foam that is difficult to spread and disintegrate. In order to avoid the generation of warm drainage foam, we need to add the appropriate energy dissipation facilities in the siphon well. Therefore, the siphon well in the drainage outlet of Huangdao Power Plant should be optimized, so as to compare the various plans with reduce the generation of foam.

## 4. Conclusion

Under the increasing pressure of current energy and environment, developing seawater desalination by adopting recycling economy mode is the trend of seawater desalination industry in the future. In this paper, it studies the scheme of seawater utilization in Huangdao Power Plant, through the preliminary analysis, it explores the methods of dealing with the following four aspects, namely, seawater desalination, seawater corrosion, marine organism pollution abatement, as well as the project of direct current cooling water drainage to provide a preliminary reference for the feasibility of seawater utilization by adopting circular economy mode.

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