Study on Cooling Water Source Seawater Filtration System of Nuclear Power Plant

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Abstract. Littoral nuclear power plants at home and abroad use seawater as cooling source, which is the cooling system of nuclear island and conventional island. In recent years, many marine organisms such as jellyfish, phaeocystis globosa, hyacinth melon and prawn have affected the safety of water intake of nuclear power plant, and even led to the event of unit load reduction operation, machine trip and even reactor trip. In this paper, by analysing the existing problems of cold source seawater filtration system in nuclear power plant, the plane layout of water intake project is optimized, and the sea biological interception filtration system is established. Relying on the large offshore platform, online monitoring of the incoming sea creatures and the status of interceptors can realize the mechanized automation of intercepting and cleaning, and improve the reliability and efficiency of intercepting and cleaning. Reduce manual intervention and temporary network layout, reduce the risk of marine personnel operation, and improve the ability to withstand severe weather and large-scale outbreak of marine organisms. It ensures the safe operation of nuclear power plant.

1. The cold source seawater filtration system of nuclear power plant needs to be improved and optimized

After several cooling water source events, at present, domestic nuclear power plants are equipped with multi-channel plane trash screen and interception pocket net at the water intake and open water intake channel[1-2] to strengthen the interception and filtration of marine organisms and sundries and reduce the pressure of the back-end filtration system. However, there are still many problems in the application of the trash raking in the water intake open channel of nuclear power plant in recent years, mainly as follows [3]:

Too large aperture of the trash net cannot effectively intercept micro sea creatures, such as seaweed debris, shrimp, jellyfish, etc. too small aperture of the trash net is easy to cause sea creature debris to block the mesh, affecting the flow area of the trash net, and the contradiction between the reduction of the trash net aperture and the increase of water resistance, the blockage of sea creatures attachment, and the increase of cleaning investment. It is very difficult to clean and replace the biological and sediment on trash raking [4].
The layout and daily cleaning of trash raking net need manual work, lack of automatic and mechanized trash raking replacement and cleaning means, unable to realize rapid replacement of trash raking net, low efficiency of manual cleaning, high risk of diving operation, unable to work at sea in extreme weather, limited response capacity in large-scale outbreak of marine organisms or extreme weather.

The material of the trash net is easy to be attached and corroded by sea creatures. The whole net should be repaired or replaced every 3-6 months with high maintenance cost. There is no on-line condition monitoring means for the trash rack, so it is unable to effectively monitor the attachment, stress and damage of the trash rack. Although the trash rack has good interception and filtration effect, it is also a high risk source. The trash concentrated on the trash rack will cause impact load to the downstream under the condition of the trash rack fracture and breach, which will bring huge risk.

2. **Key technologies of cooling water source protection in nuclear power plant need to be developed**

The safety protection of cooling water source in nuclear power plant is a new subject. Due to the diversity and complexity of cooling water source protection objects, there are still many problems in cooling water source safety protection which are not solved by mature technical methods. For example, sediment deposition at water intake, biological attachment of water intake culvert, automatic and mechanized cleaning of interceptor, ecological defense, etc. Through technological research and development and technological innovation, combined with the existing problems in the safety protection of cooling water source, we need to integrate the technology and scientific research achievements of relevant disciplines, and study and use the safety protection technology of cooling water source applied in the project [5].

3. **Optimization of interception and filtration system of seawater filtration system**

According to the external risk characteristics and operation experience of the cooling water source, comprehensively considering the improvement of efficiency and reliability of seawater interception, filtration and clean-up, as well as the demand of operation and maintenance, the interception and filtration system of the seawater filtration system of nuclear power plant is optimized and improved by optimizing the plane layout scheme of the water intake project, establishing a new interception and filtration system [6], optimizing the relevant system and equipment of the cooling water source, etc.

The safety protection of cooling water source of nuclear power plant is composed of water intake structure and seawater filtration facilities. Based on the current operation feedback, application practice, current technology mature conditions and scientific research achievements, it is necessary to consider in the optimization and promotion of seawater filtration system interception and filtration system:

1) Feature setting based on general protection object and specific plant site object
2) Consider long-term, forward-looking, appropriate excess filtration capacity.
3) Optimize and improve based on operation experience and scientific research achievements.
4) Take the safety of unit cooling water source as the core, and consider the economy.
5) Improve the effect of automatic cleaning, reduce manual intervention, reduce the potential safety risk of personnel cleaning, and enhance the ability of filter system to cope with severe weather.
6) Follow the principle of cascade filtration.
7) Meet the operation and maintenance requirements.

Optimize the plane layout of the water intake project, adopt the encircling water intake, effectively resist the waves and reduce the flow rate, which is conducive to the layout of the sea biological interception facilities and the salvage cleaning.

A new intercepting and filtering system for marine organisms at the water intake is established. The system is mainly composed of self-cleaning intercepting net, copper alloy net or grid plane intercepting, large-scale integrated intercepting platform at sea, intercepting net pocket, double-layer bottom net, etc.

The self-cleaning trash raking is arranged outside the water intake, which is arranged along with the flow field. The key point of the trash raking is to stretch the net in large size. By using the back flushing
function of the rising and falling tide, the trapped organisms in the trash raking are cleaned to achieve the effect of automatic cleaning. The first barrier is formed by arranging self-cleaning screen at the entrance, which can greatly reduce the number of sea creatures and floating objects entering the entrance, and reduce the interception load and cleaning pressure entering the downstream.

A large offshore platform shall be built at the intake gate or open channel section. Copper alloy net or grid shall be arranged at the front end of the platform according to the characteristics of the plant site and the protected objects to intercept large marine organisms and floating debris. The copper alloy mesh has the advantages of full section interception, small mesh size, small-scale interception of marine organisms and marine garbage, and with self-antifouling function, it is not easy to attach fouling organisms; maintenance and replacement are convenient, without considering lifting facilities. The advantages of the intercepting grid are high strength, which can effectively intercept marine organisms and marine garbage, and it is convenient to arrange grab type cleaning equipment for cleaning. The platform is equipped with mechanical equipment to realize the mechanization and automation of trash interception and cleaning. For example, Brunswick power plant in the United States replaced the intercepting network with grid intercepting structure, and cleaned the interceptors on the grid through the grab type trash remover mechanization, which greatly improved the ability of trash interception and cleaning. A net bag is hung at the back end of the grid to intercept the small sea creatures that cannot be intercepted by the copper alloy net at the front end or the grid. A net bag mechanized cleaning platform is arranged on the platform to timely clean up the sea creatures intercepted by the net bag through the cleaning platform.

Relying on the large offshore platform, the monitoring equipment of marine organisms and interceptors are arranged on the platform to monitor the situation of incoming marine organisms and the status of interceptors on line in real time. When a large number of marine organisms are attacking, the automatic alarm will be sent out, and the automatic cleaning equipment will be started to clean up the pollutants, or the automatic alarm will be sent out when the blocking status is abnormal, and the automatic cleaning will be started. The new water intake sea creature interception and filtration system has the ability to intercept and clean up a large number of sea creatures under severe weather. Realize the mechanical automation of interception and clean-up, and improve the reliability and efficiency of interception and clean-up. Reduce manual dredging intervention, permanent and temporary network layout, and reduce the risk of offshore personnel operation. Improve the ability to cope with severe weather and large-scale outbreak of marine organisms.

Figure 1. The automatic cleaning equipment

At the same time, considering the situation of jam outbreak in different seasons, reserve the conditions of installing temporary blocking net on the basis of fixed interception and filtering facilities, so as to adopt more targeted interception, such as placing small-diameter shrimp net in high occurrence period of hairy shrimp, placing corresponding jellyfish net in high occurrence period of jellyfish, etc. Finally, the high-strength double-sided blocking is set in the open channel section. When the sea creatures break through the front-end blocking measures or the front-end blocking breaks through the
network, the bottom supporting is carried out to prevent the sea creatures in the front-end blocking network from suddenly entering the pump station and bringing the risk of impact load.

4. Establish ecological protection and solve the problem of cooling water source from the source

Research and develop ecological means, solve the safety problem of cooling water source from the source, and build ecological nuclear power before the disaster.

On the basis of grasping the typical biological ecological dynamic process of disaster causing cooling water source near domestic coastal nuclear power plants, the species and quantity of cooling water source organisms are controlled by effective technical means such as ecological environment restoration and biological species regulation. Break through many key technologies such as ecological prevention and control and safety assurance, establish a reliable ecological barrier and safety defense system, and gradually eliminate the potential impact of cooling water organisms on the safe operation of nuclear power plants from the source. Through the research and application of ecological regulation technology in the surrounding sea area of nuclear power plant, the ecological safety of cooling water source is realized.

5. Strengthen basic scientific research investment and key technology research and development on cooling water source safety

Strengthen the technical support of cooling water source management equipment, optimize and integrate the scientific and technological resources of various disciplines, promote the scientific and technological innovation of cooling water source management, rely on science and technology to improve the scientific, intelligent and refined level of cooling water source management, strengthen the research and development of key technologies of cooling water source, and improve the response and disposal capacity of cooling water source safety management.

According to the demand of cooling water source safety protection, nuclear power operation enterprises need to increase the research investment in the topic of cooling water source safety improvement. Combined with relevant scientific research institutes and departments, research has been carried out in the following aspects: the law of marine biological explosion, key technologies of marine ecological defense in the water intake area, prediction and analysis of sudden erosion and deposition of sediment at the water intake, dredging technology, marine biological monitoring and early warning technology, interception network status monitoring and automatic cleaning technology, marine biological migration mechanism and anti-blocking technology in the open water intake channel of nuclear power plant. To explore and study new technologies, equipment and methods for improving the safety of cooling water sources.

At the same time, integrate nuclear power safety, marine engineering, marine ecology and big data analysis technology and other disciplines, combine the research of cooling water source safety and related disciplines, and provide technical guarantee for optimizing cooling water source safety protection scheme through technical research and innovation.

6. Conclusion

This paper analyzes the existing problems of seawater filtration system of cooling water source in nuclear power plants at home and abroad, and considers the difficulties of upgrading and optimizing the filtration system of cooling water source in many aspects. This paper summarizes the key problems of optimizing the filtration system, and puts forward the establishment of a marine biological interception filtration system. Based on the large-scale offshore platform, the monitoring equipment of sea creatures and interceptors are arranged on the platform to monitor the status of the incoming sea creatures and interceptors in real time and online, so as to realize the automatic alarm when the sea creatures attack, so as to ensure the safe operation of the nuclear power plant.
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