Research on Security Defence System of Cooling Water Source in Nuclear Power Plant

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Abstract. Nuclear safety is the lifeline of nuclear power development, the premise and foundation of nuclear power development. The safety of cooling water source is an important part of nuclear safety. The safety of cooling water source of nuclear power plant is related to nuclear safety, and it is the final heat sink of nuclear power plant, which undertakes the safety function of reactor residual heat export. Littoral nuclear power plants take seawater as the cooling water source. When the solid suspended solids, floating objects and marine organisms in the seawater exceed the filtering and cleaning capacity of the cooling water filtering equipment, the water intake or filtering equipment will be blocked and unable to provide the required cooling water, which will cause the cooling water source safety event. In view of these problems, this paper proposes to optimize the cooling water source security defence system in depth, improve the cooling water source risk monitoring and early warning system, establish the cooling water source overall status monitoring platform, and improve the emergency response and unit control capacity of the power plant.

1. Composition of seawater filtration system for cooling water source of nuclear power plant

At present, the cooling water source systems of the world's mainstream in-service second generation PWR littoral nuclear power plants are slightly different in site layout and design due to different plant sites, but the overall principle and thinking are basically the same. Taking China's in-service pressurized water reactor nuclear power plant as an example, the cooling water source system and facilities generally consist of an open intake channel, intake structure, intake tunnel, forebay, and sea water filtration facilities [1-2], etc. the sea water filtration facilities include trash raking, coarse screen, fine screen, chlorination equipment, grid decontamination machine, drum screen and backwash device, etc. shellfish traps are also set in the important service water system and so on.

Littoral nuclear power plant takes seawater as cooling water source [3], which is physically filtered by seawater filtration system and then sent to nuclear island and conventional island cooling system to derive core residual heat, condenser exhaust steam in thermal cycle and sensible heat of equipment. Cooling water source refers to a series of systems that can realize the heat generated during the operation of unit equipment to be discharged into the sea through layer by layer heat exchange. Taking CPR1000
unit as an example, the heat generated by the core is finally discharged to the environment through the cooperation of multiple systems.

When the floating matter, solid suspended matter and marine organism mixed in the sea water exceed the filtration and cleaning capacity of the sea water filtration system, it will cause the water intake or filtration equipment to be blocked and unable to provide the required cooling water, thus causing the cooling water source event. Cooling water source is the final heat sink of nuclear power plant. The failure of cooling water source will lead to the unavailability of condenser to trigger shutdown and reactor shutdown [4-5], and the loss of final heat sink will lead to nuclear safety risk.

2. Existing problems

In the design of cooling water source water intake system facilities of nuclear power plant, only to meet the water intake requirements is considered, and the prevention of external disasters of cooling water source is not taken as the design input. Due to the lack of relevant specifications and requirements, the scope and depth of investigation are limited, so the potential external disaster risk identification of cooling water source in different plant sites is insufficient in the early cooling water source protection scheme, which leads to the completion of the existing in service The nuclear power plant has limited filtration and interception capacity, and the efficiency of interception equipment is not high, which cannot be applied to multiple marine organisms and cope with the dual impact of severe weather superimposed on the influx of marine organisms, causing frequent safety incidents of cooling water source [6].

The main performance is: the original design of the water intake open channel does not have any interception facilities; after the operation of the general nuclear power plant, the oil fence and the boat net (intercepting ships and large-scale floating objects) are added; the trash net with larger aperture size intercepts the floating objects, garbage, large fish, jellyfish, aquatic plants, etc.; the coarse grid intercepts large-scale incoming objects, and does not have the automatic cleaning function, generally during the overhaul period Clean up; the interception capacity of the fine screen is increased, but the size is also large, and the trash remover has the ability of automatic fishing, but the fishing efficiency and capacity are low; the diameter of the coarse / fine screen is 200 / 50mm, which directly enters the diameter of 3mm of the rotary screen. In actual operation, the rotary screen must bear most of the incoming materials. In the case of a large number of marine organisms entering in a centralized way, the rotary screen will inevitably block and trip After filtering through the 3mm rotary filter screen, the filter of downstream users is seldom blocked under normal conditions, but the 2mm diameter of the nuclear island cooling water filter of some nuclear power plants will be blocked due to the influence of sediment shells; the water intake marine engineering design is simple, without considering the safety protection of the cooling water source, for example, the open channel of Hongyan river is a short dike to block the sea ice, unable to play the role of wave dissipation, blocking foreign intrusion, and diversion It is easy to cause sea creatures, sundries, sediment, etc. to gather and inhale at the water intake and cause blockage.

Although the water quality monitoring buoy, sonar, underwater video and other methods have been initially established at the water intake of domestic nuclear power plants to monitor the marine organisms at the water intake, the above mentioned physical detection methods are not strong enough to establish the relevant parameters and the law of marine biological explosion due to the current detection means and technical limitations, as well as the insufficient identification of the mechanism of marine biological explosion It can't accurately predict the species, flux density and moving track of the incoming sea creatures, such as the water quality parameters near the water quality monitoring buoy intake and the law of plankton outbreak, the sonar monitoring signal can't accurately predict the sea creature identification, and the effective sonar monitoring range of the underwater sea creatures is about 100-150 meters, and the sea creatures are basically found near the intake, Insufficient early warning time for back-end interventions. In addition, the monitoring of the sea area around the nuclear power plant has only been carried out for a few years. The accumulated data is small and the monitoring parameters are limited. The monitoring parameters cannot be effectively integrated with the mechanism
of marine biological disaster, and an effective early warning model can be established to provide accurate early warning information.

In addition to the monitoring of marine biological debris, the monitoring of cooling water source status should also include the monitoring of interception facilities and the monitoring of key equipment parameters of cooling water source system. The key equipment parameters of the cooling water source system have been monitored by relevant instruments during the initial design of the system, but the front-end interception measures such as the newly added barrage at the water intake, such as the status of the barrage, have not yet established effective monitoring, the attachment of the barrage, the damage and aging of the barrage are basically based on the observation of divers, and the accuracy and real-time performance of the monitoring are not high.

Marine biological debris monitoring, interception facility monitoring and key equipment parameter monitoring of cooling water source system are important aspects to characterize the health status monitoring of cooling water source.

3. Security defence system of cooling water source

3.1. Optimize the defence system of cooling water source safety in depth.

Based on the initial cooling water source of the original nuclear power plant, the in-service power plant improves the protection ability of cooling water source through many technical improvements. Meanwhile, based on the above considerations, the optimization and promotion scheme for the safety protection of cooling water source of nuclear power plant is composed of four links: monitoring early warning, displacement, interception and salvage, and operation pre-warning. The monitoring early warning includes three-dimensional accurate monitoring of marine organisms at the water intake and marine ecology Coupled with marine dynamic prediction, monitoring of key parameters of cooling water source related systems, and establishment of comprehensive monitoring and early warning platform for cooling water source status; meanwhile, the development of marine biological displacement means, such as air curtain and acoustic wave displacement, is applied under the conditions of mature technology, and currently the improvement of cooling water source safety protection scheme is not considered; optimization of interception and salvage system, establishment of a new type of marine biological interception and filtration. The system can realize automatic and mechanized cleaning, improve the reliability and efficiency of sea water interception and filtration system, reserve corresponding external emergency fishing force on the premise of limited monitoring and interception at the front end, and improve the emergency response and unit control ability of the power plant.

3.2. Establish the overall status monitoring platform of cooling water source

On the other hand, improve the early warning system of cooling water source risk monitoring and establish the overall status monitoring platform of cooling water source.

For the monitoring and early warning of marine organisms, because the current detection means are basically based on acoustic, optical and other means, limited by the accuracy and scope of detection means and project operation and maintenance, it is impossible to achieve large-scale and long-term accurate monitoring and prediction in a short term, but facing the severe challenge of the current stage of cooling water source, relying on the existing technical conditions, the short-term improvement is to achieve accurate monitoring of water intake gate. Through the arrangement of high-definition water and underwater cameras, sonar, infrared detection, multi-functional buoys and other monitoring and early warning equipment at the water intake gate, the precise monitoring and early warning of marine organisms entering the water intake area are realized, the types of marine organisms entering the water intake area, the marine biological flux and location track are defined, and the emergency rescue of marine organisms entering the water intake is effectively guided. The precision fishing is realized, the fishing efficiency is improved, and the pressure of blocking and downstream drum net is reduced. At the same time, it provides accurate judgment basis for unit control.
The long-term improvement is to strengthen the research and application of monitoring and early warning technology, and improve the capacity and monitoring scope. We will strengthen cooperation with relevant meteorological and marine departments. By analyzing the data of large-scale marine ecological disasters, long-term marine monitoring and marine biological detection over the years, all the external environmental data related to the possible initiating events are identified and analyzed, and the trend of these data is analyzed to establish the marine ecological model based on the mechanism of marine biological development. Combined with the high-resolution sea air wave coupled forecasting system which is currently mature and applied, a coupled monitoring and early warning system of marine ecology and marine dynamics is established, which can accurately monitor and early warn the outbreak and invasion of marine organisms at a certain time (1-2 days) in advance, realize the intelligent prediction of marine organisms at the far end of the water intake, and provide sufficient early warning response time for taking intervention measures.

Establish a monitoring method for the status of water intake intercepting facilities, and establish a monitoring model for the status of the intercepting facilities through the deployment of tension meter, network position meter, current meter, underwater high-definition video screen, underwater sonar imaging, etc. at the pile foundation offshore platform, to monitor the force and damage of the intercepting network or grid online in real time. It can automatically alarm when a large number of sea creatures come or the blocking status is abnormal, accurately monitor the attachment of sea creatures, guide the fishing and cleaning of the blocking, improve the cleaning efficiency, reduce the underwater operation of divers and ensure the safety of personnel.

Identify the key parameters (such as drum net pressure difference, coarse grid pressure difference, water level after drum net, marine biological catcher pressure difference, etc.) that characterize the safety status of cooling water source in the cooling water source related system, and formulate monitoring and alarm standards to effectively monitor the health status of cooling water source related system.

Research and develop the status monitoring data and information of the far end of the water intake, the water intake gate and the open water intake channel, the intercepting and cleaning device, the water intake tunnel, and the filter equipment of the pump station, establish the status monitoring of the whole process equipment and facilities of the cooling water source, and realize the real-time work and risk of the whole process filter system of the feedback cooling water source. By means of web, app, large screen and other visualization methods, the whole range safety monitoring, data analysis and virtual reality representation of business scenarios of cooling water source can be realized, providing comprehensive, complete and intuitive cooling water source whole process status and monitoring and early warning information for cooling water source management and technical personnel. Build a monitoring and early warning platform for the overall state of cooling water source, promote the modernization of emergency management with informatization, and improve the monitoring and early warning ability, auxiliary command and decision-making ability and emergency response ability.

4. Conclusion

By investigating the important events of cooling water source in nuclear power plants at home and abroad in recent years, the causes of cooling water source problems are analyzed. This paper proposes to optimize the defense system of cooling water source safety in depth, and establish a monitoring platform for the overall state of cooling water source. The condition monitoring platform can realize the whole range safety monitoring of cooling water source, provide comprehensive, complete and intuitive monitoring and early warning information for cooling water source management and technical personnel, improve the monitoring and early warning ability, effectively improve the safety of cooling water source of nuclear power plant, and ensure the safe and stable operation of nuclear power plant.

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