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Research on Water Intake, Usage and Drainage Impact Demonstration for Coastal Nuclear Power Plants

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Abstract. Nowadays, all nuclear power plants including constructed ones and those under construction are coastal plants in China. Water resources assessment of coastal nuclear power plants in China is based on the *Guidelines for Water Resources Assessment of Construction Projects* (SL 322). However, the specific guideline for water resources assessment of coastal nuclear power plant projects, the *Guidelines for Water Resources Assessment of Coastal Nuclear Power Plant Projects*, has not yet issued at present. According to the plans for intake, usage and discharge of water proposed by the owner of coastal nuclear power plants, it was proposed that the general requirements for water resources assessment by considering characteristics of intake, usage and discharge for water. In this study, Tianwan nuclear power plant was chose as the case study. Researches on yields of intake and usage of water, and the impact of water discharge for this nuclear power plant could provide the reference for water intake and usage rationalities, as well as the impact analysis caused by water discharge of coastal nuclear power plants.

1. Introduction

Nuclear power is a kind of new energy which is safe, economic and clean. Development of nuclear power plays an important role in energy conservation and emission reduction, optimizing the power structure, as well as responding to global weather changes. [1, 2]. Safety is the primary factor in the development of nuclear power in China. Nuclear power is closely related to the use of water resources, conservation, and protection. With the accelerating construction and development speed of the nuclear power industry, the safety of nuclear power plants and some water problems are also receiving much attention from the public [3, 4]. At present, nuclear power plants constructed and under construction in China are all coastal nuclear power plants. The coastal areas can provide favorable conditions for the construction and operation of nuclear power plants [5, 6]. In view of the fact that nuclear power plants use fresh water for production and domestic with high water security requirements. Meanwhile, nuclear power plants construct continuously and the nuclear reactors have a greater impact on the allocation of regional water resources. Therefore, water supply and protection are very important considerations for nuclear power plant projects (NPPPs), which is important to safeguard the safety of nuclear power.

Water resources assessment (WRA) of a coastal NPPP mainly refers to analyze the water intake and drainage from the perspective of water resources management and protection. At present, foreign countries in the field of nuclear power water management mainly involve water intake and usage management, water drainage management, public participation, water resources emergency



management under nuclear accidents and emergency situations, as well as the construction of management department [7, 8].

From the current point of view, WRA of the coastal NPPs in China have been prepared in accordance with the requirements of *the Guidelines for Water Resources Assessment of Construction Projects* (SL322). However, SL322 has conducted macroscopic guidance on the water resources assessment of construction projects. There is no specific requirements for the key work of WRA for the coastal NPPs [9, 10], such as *the Guidelines for Water Resources Assessment of Coastal Nuclear Power Plant Projects*. Furthermore, it was found that there are widespread problems on the rationality analysis of water intake and usage, the research on the impact of water drainage, as well as other key issues [11]. The objective of this research is to provide support for the “Water Intake Rationality Analysis”, “Water Usage Rationality Analysis” and “Drainage Impact Demonstration” chapters of *the Guidelines for Water Resources Assessment of Coastal Nuclear Power Plant Projects*. It is significant for the formulation of the “Guidelines” and the WRA work for the coastal NPPs.

2. Method

Based on the characteristics of water for a NPP during the construction and operation periods and water scheme prospected by the owners, WRA regulations for the water intake rationality analysis, water usage rationality analysis, and drainage impact demonstration could be put forward.

2.1 Water intake rationality analysis

Water intake rationality for the coastal NPP should be explained based on the analysis of the regional water resources and their development and utilization, the industrial policies and related documents for the development of the national nuclear power, as well as the related planning of the river basin or the area. In addition, the functions of water intake body, the requirements of environment protection, and different water usage crafts and requirements in the construction and operation periods are also the references for water intake rationality analysis. Furthermore, in view of the water intake scheme proposed by the owners, water intake rationality would be analyzed with comprehensive consideration of the construction scale, water quantity, water quality, and so on. When the coastal NPP needs to intake water from multiple water sources, each water source should be analyzed with comprehensive consideration of the amount of water intake, water quality, the location of the source, the method, the transport scheme, etc. According to the economic applicability, all the scheme would be compared to acquire the most reasonable one.

2.2 Water usage rationality analysis

For the water usage rationality analysis, water usage craft and the design parameters related to the water treatment process would be analyzed on the basis of the designed water supply scheme for the construction and operation periods. In addition, water usage indicators, water balance diagrams, and water usage level would be used to analyze the rationality of water usage scale. According to the local water resources conditions, water efficiency indicators, as well as clean production or other management requirements, water-saving potential of the project and the reasonable volume of water usage should be explained against the advanced level of the industry. For an expansion project, the data of water intake, usage and drainage should be collected together with approval documents and water saving measures. Then, based on the water balance test or analysis of a constructed project, the difference between the designed and actual volume of water usage for the constructed project could be indicated. Water balance diagram of the project could be drawn by combining the relationship between the project and a constructed project in water intake, usage and drainage to obtain the water-saving potential.

2.3 Drainage impact demonstration

For the drainage impact demonstration of the coastal NPP, the impacts of water drainage on water function zones, pollutant carrying capacity, water ecology environment, and other stakeholders should

be described based on the analysis of the regional water resources and their development and utilization conditions, the volume of water drainage, as well as the type and concentration of major pollutants. The relevant conclusions on the impacts of warm water and low-level radioactive liquid effluents drainage would be proposed based on the existing results or conclusions of environmental evaluation and marine environmental impact assessment in the condition that the water is not discharged into the areas of the competent department of water administration.

3. Case Study

Take the Tianwan Nuclear Power Plant as an example to discuss the analysis of water intake/usage rationality and water drainage impact demonstration. It could provide reference for *the Guidelines for Water Resources Assessment of Coastal Nuclear Power Plant Projects*. The Tianwan Nuclear Power Plant is located in Lianyungang City, Jiangsu Province, as shown in Figure 1. Tianwan Nuclear Power Plant No. 1 and No. 2 units are Russia's VVER (Water-Water Energetic Reactor) reactor type with $2 \times 1060\text{MWe}$ PWR nuclear power units, which are currently in operation. In addition, No. 3 and No. 4 units are VVER reactor type $2 \times 1126\text{MWe}$ PWR nuclear power units, which are currently in the installation phase. This case only discusses the conditions of Tianwan Nuclear Power Plant No. 1 and No. 2 whose production and domestic water are taken from the Rose River during the construction and operation periods which is the surface fresh water source.

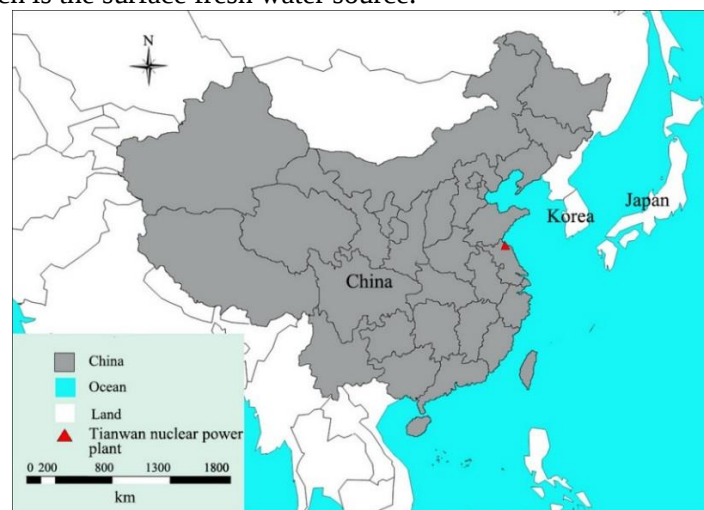


Figure 1. Location of Tianwan Nuclear Power Plant

3.1 Analysis of water intake rationality

3.1.1 Design value of water intake. Cooling water is generally taken from sea water and supplied by direct current. Other use of water is taken from rivers, reservoirs or desalinated water near the plant. Taking Tianwan Nuclear Power Plant No.1 and No.2 as an example, Russia's AES-91 PWR unit with an installed capacity of $2 \times 1060\text{MW}$ is located at Tianwan. There is a wide silt shoal in the vicinity. The average slope of the riverbed is about one thousandth. There is a -8m deep sea area within 5km of the plant site. The best water intake point is the water depth of -5.5m outside the original military harbor. The design value of water intake of Tianwan Nuclear Power Plant No. 1 and No. 2 units are shown in Table 1.

Table 1. Design value of water intake for No. 1 and No. 2 units

No.	Operating conditions	Production water (m^3/d)	Domestic water (m^3/d)	Construction water (m^3/d)	Fire demand (m^3/d)	Total water intake (m^3/d)	($10^4\text{m}^3/\text{a}$)
1	One reactor construction	1026	1350	7608	549	10533	384.5

2	One reactor operation; another reactor construction	4200	2951	7608	549	18000	657.0
3	Two reactors construction	6600	1601	1539	549	10289	375.5
4	One reactor operation; another reactor fire	7000	1601	1609	549	10759	392.7

3.1.2 Suggested value of water intake. According to the literature survey, this research suggests that the freshwater design value of water intake should not exceed $0.05\text{m}^3/(\text{s GW})$ in the condition that the unit capacity of the coastal nuclear power plant is not more than 600MW. Meanwhile, the freshwater design value of water intake should not exceed $0.04\text{m}^3/(\text{s GW})$ in the condition that the unit capacity greater than 600MW. Since the unit capacity of Tianwan Nuclear Power Plant is more than 600MW, the proposed design value of water intake is $0.04\text{m}^3/(\text{s GW})$. However, the actual design value of water intake is $0.085\text{m}^3/(\text{s GW})$ which is much larger than the suggested. This is because the design value of water intake of the Tianwan Nuclear Power Plant is based on “*the Guidelines for the Water Resources Assessment of Construction Projects*” which applies to various types of construction projects. There are no specific requirements for the coastal NPP, so the requirements are relatively broad.

3.2 Analysis of water usage rationality

3.2.1 Water usage in construction period. Data for the construction period of No. 1 and No. 2 units of the Tianwan Nuclear Power Plant was from 1999 to 2007, and the maximum annual water consumption was 2.345 million m^3 in 2002.

3.2.2 Water usage in operation period. Tianwan Nuclear Power Plant No. 1 and No. 2 units’ construction time is earlier. On-site investigation shows that the actual water intake quantity from 2007 to 2013 was 168.08 to 406.7 million m^3/a , and the average water intake was 303.96 million m^3/a . In general, from 2007 to 2013, the annual water usage had gradually declined. The production and domestic water usage of the whole plant as well as the power generation water intake quantity of No. 1 and No. 2 units during the period from 2007 to 2013 were all declining year by year. The reason may be related to continuous improvement in management of nuclear power operation.

3.3 Demonstration of drainage impact. Drainage in the operation period of a nuclear power plant includes non-radioactive waste water and low-level radioactive waste water. Among them, non-radioactive wastewater mainly includes drainage of circulating cooling water system, desalinated wastewater, domestic wastewater, and oily wastewater. In addition, the main sources of low-level radioactive waste water are nuclear island equipment (drainage and leakage of the first circuit coolant), ground flushing, personnel showers and laundry water of worker, process drainage, as well as decontamination fluids. The complex components of wastewater as well as the large changes of concentration and the volume, which are related to the types of reactors in the nuclear power plant, the level of management, and the water chemistry conditions.

3.4 Summary

This section discussed the water intake craft, design value of water intake in the construction and operation periods, drainage system and components, as well as the design drainage situation of Tianwan Nuclear Power Plant based on the suggestion of “water intake rationality analysis”, “water usage rationality analysis”, and “drainage impact of demonstration” of *the Guidelines for Water Resources Assessment of Coastal Nuclear Power Plant Projects*. The result shows that the actual unit power generation capacity is much less than the design value which is $0.085\text{m}^3/\text{s GW}$, and close to the proposed unit power generation capacity of $0.04\text{m}^3/\text{MW h}$. Therefore, the proposed design value of

water intake is more scientific and accurate than the original basis that *the Guidelines for Water Resources Assessment of Construction Projects*.

4. Conclusion

On the basis of summarizing the related researches in recent years, this research had analyzed the water intake craft and drainage characteristics of the coastal NPPP. Meanwhile, water usage and intake rationality analysis as well as drainage impact demonstration for the major parts of WRA of coastal NPPPs had been proposed. The main conclusions are as follows:

(1) The rationality analysis of a coastal NPPP mainly includes the analysis of the conformity of the industrial policy, the analysis of the conformity of the water resources conditions, planning and management, the rationality analysis of the water source configuration, as well as the rationality analysis of the craft technology.

(2) Water usage rationality analysis of a coastal NPPP mainly includes technical analysis of water usage during construction and commissioning periods, analysis of water usage during operation period, and rationality of water usage total amount.

(3) Drainage impact demonstration of a coastal NPPP could include the impacts of drainage on water functional zone, the third parties, groundwater, nearby sea areas, as well as marine life.

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