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Studies on Environment Safety and Application of Advanced Reactor for Inland Nuclear Power Plants

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Abstract

To study environment safety assessment of inland nuclear power plants (NPPs), the impact of environment safety under the normal operation was researched and the environment risk of serious accidents was analyzed. Moreover, the requirements and relevant provisions of site selection between international nuclear power plant and China's are comparatively studied. The conclusion was that the environment safety assessment of inland and coastal nuclear power plant have no essential difference; the advanced reactor can meet with high criteria of environment safety of inland nuclear power plants. In this way, China is safe and feasible to develop inland nuclear power plant. China's inland nuclear power plants will be as big market for advanced reactor.

1. Introduction

Since reform and opening of China, energy industry has been rapidly developed with the economic development. In recent years, energy structure has been transformed cleaner and more efficient in order to reduce the carbon emission and energy consumption.

China's energy policy clearly defines that nuclear power is a kind of clean, efficient and high quality modern energy. The 12th five-year plan, which was recently released by State Council of China, reiterates that it is needed to develop nuclear power in safe and efficient way. As of the end of 2012, the total installed capacity was 1.145 gigawatts of China, with an increase of 7.8%, but nuclear power installed capacity merely shared 1.1% of that, which was 12570 megawatts. In accordance with China's medium and long-term planning of nuclear power development, the installed capacity of nuclear power will be 58 million kilowatts, and 30 million kilowatts under construction plus by 2020. It is expected that there will be a large room for nuclear power, in order to meet with the goals of energy, environment, and economy in the future.

China's relevant government departments have been taking a very cautious attitude for inland nuclear power plants. Especially after the Fukushima nuclear accident, the public concern for construction of inland nuclear power plant increased significantly. To meet with the safety requirement and economical efficiency, the new nuclear power plants will be applied by advanced reactor technology. This research was focus on the environmental effects of radiation when the NPPs are under normal operation, and the environmental risk of the serious accident. Meanwhile, the siting requirements and relevant regulatory of NPPs construction were

comparatively studied. The application of advanced reactor for inland nuclear power plants to reduce the environmental impact of radiation was discussed. Finally, the recent development of NPPs of China National Nuclear Corporation (CNNC) in Sichuan province is introduced.

2. Environmental-Safety assessment of current operating NPPs in the United States and France

The sites of NPPs are divided into coastal and inland sites. Statistics show that the units of riverside and lakeside NPPs are more than the coastal in the United States and France.

2.1 Basic situation of the NPPs

There are 39 sites of NPPs with 64 units, which take up 61.5% units in the United States. Although the per capita of water resource is relatively high, the distribution of that is definitely uneven. Figure 1 shows that the NPPs are almost located to the side of Mississippi River and Atlantic coast region.



Figure 1. Distribution Diagram of NPPs in the U.S.

In France, there are 19 sites of NPPs with 59 units, and 69% of these units are riverside, whose quantity is 40. The distribution of NPPs in France is shown in Figure 2.



Figure 2. Distribution Diagram of NPPs in France

Based on the reasonable distribution, although the installed capacity of inland NPPs is more than the coastal NPPs, there is no shortage of water in NPPs, neither nor conflict of usage between the NPPs and residents.

2.2 Important Environmental-Safety Assessment of the inland NPPs under normal operation

The important environmental issues of NPPs under normal operation are mainly about the effects of radioactive effluent.

(1) The situation of the U.S.

Environmental characteristics of NPPs are diversity. There was an operating feedback of more than 2000 reactor years with inland sites till 2010.

To control the radioactive effluent, the Nuclear Regulatory Commission (NRC) sets the dose constraint value of radioactive-effluent emissions with the ALARA (As Low As Reasonably Achievable) principle in the 10 CFR 50 Appendix I, as following table 1.

The annual report of radioactive effluents of inland PWR nuclear power plant showed that the emissions were controlled in the ARALA levels. The environmental effects of radiation were fluctuated in the range of average radiation background in the U.S.

Table 1. 10 CFR 50 Appendix I List of Design Goals and Dosage Guidelines

| Type of Effluent | Exposure Pathway | Organ | Dose Limit (per year per unit) |
|------------------|------------------|------------------|---------------------------------|
| Liquid | All the way | Whole body | 3 mrem(0.03 mSv) |
| | All the way | Any single organ | 10 mrem(0.1 mSv) |
| Gas | All the way | Whole body | 5 mrem(0.05 mSv) |
| | All the way | Skin | 15 mrem(0.15 mSv) |
| Radioiodine | All the way | Any single organ | 15 mrem(0.15 mSv) |
| Gas | γair dose | | 10 mrad(0.10 mGy)* |
| | βair dose | | 20 rad(0.20 mGy)* |

NRC concluded that the environmental effects of radioactive effluent emissions belonged to the small effect in common, which means the environmental effects are undetectable, or too small to change the critical attribute of resources.

(2) The Situation of France

EDF has an operating feedback of more than 1200 reactor years with inland sites. The emissions were controlled in the ARALA level, which is internationally recognized. The environmental effects of radiation were fluctuated in the range of average radiation background in France.

The main specificity of inland sites is the design of heat sink. Wet cooling towers are generally required to reduce thermal discharges. Additional devices may be necessary in case of low flow rate: discharge cooling, safety cooling tower. Environmental effects of these towers are reduced,

and manageable. Management of liquid wastes (radiological or not) needs more anticipation, but this does not constitute a challenge. Studies of hazards show some difficulties, different from those for coastal sites, but none of them introduce serious challenges, especially for a new site. The feedback led to several improvements, and enables to confirm that the safety of inland sites is comparable to coastal sites.

2.3 Environmental-Risk Assessment of inland NPPs under serious accident

NPPs under operation and construction of the United States have been proposed to carry out a three level environmental assessment of probabilistic risk based on severe accident. It can be concluded: 1) there is no trend difference of the environmental risks on the severe accidents between inland sites and coastal sites; 2) the frequency of core damage and radioactive substances can be reduced by advanced PWR, so it can be significantly lower than the value of safety requirements for the severe accident, which is according to the American social risk levels.

3. The basic situation and safety assessment of proposed plants in China

3.1 Criteria for inland plant selection in China

The safety-related regulation and guidelines for the nuclear power plant selection is reference to International Atomic Energy Agency (IAEA).

In the plant selection, it needs consider the extreme events (Including probable maximum earthquake, probable maximum precipitation, maximum possible tornado, probable maximum storm surge, etc.) in this area to determine the suitable design requirement.

All 30 priority candidate plants which are selected in inland area are located in the crustal stable region where the seismic activity level is very low. Earthquake with tsunami like Fukushima would not occur in these candidate plants.

For the flood control of the inland nuclear power plants, China's inland nuclear power plants will use natural bedrocks as the foundations of the nuclear island beside considers the previously extreme events. This is difference with the operation in France and the US. The methodology in China is to choose the right mountain first, and then to scoop this mountain as the foundation of the nuclear island. This method makes inland nuclear power plants in China can be designed as “dry site”, and the safety margin is also higher.

Table 2. Flood control design of proposed plant in China

| Plant Name | Flood | | |
|-------------------------|------------------|---------------------------------|-------------------------|
| | Location | Basic design level of flood (m) | Elevation for Plant (m) |
| Xianning City (Dafan) | Fushui reservoir | 65.93 | 88.00 |
| Xishui City (Hujiashan) | Xishui River | 32.23 | 62.00 |
| Yiyang (Taohuajiang) | Zijiang River | 73.67 | 85.00 |
| Huarong (Xiaomoshan) | Yangtze River | 37.97 | 42.00 |
| Pengze(Maozishan) | Yangtze River | 22.93 | 31.30 |

Ji'an(Yanjiashan)

Ganjiang River

71.54

80.00

3.2 Safety assessment of proposed inland plants in China

China has drawn up rigorous requirements for the radioactive liquid effluent emissions of inland nuclear power plants. It can ensure that the water about 1km away from the outfall in downstream meets the radioactive indicator of drinking water standards.

The average flow rate and water dispersed conditions of receiving water in China are quite similar with the ones in the United States and France. Some of the proposed plants have better conditions compared in the United States and France. So the water dispersed conditions could be easily checked for the inland nuclear power plant in China.

Another negative factor for safety assessment of inland nuclear power plants in China is low wind speed. But the estimates of long-term and short-term atmospheric dispersion factor indicate that it is acceptable to all the proposed plants.

3.3 The application of advanced reactor technology for inland NNPs

The inland NPPs of China will be applied by advanced reactor technology. The construction and designation are trying to take a lot of engineering solutions to reduce the environmental impact of radiation.

- One stronger radioactive water treatment system for inland nuclear power plants than the coastal nuclear power plants can ensure the concentrations of nuclide except tritium less than 100Bq/L, sometimes can even reach to 37Bq/L level.
- For radioactive liquid effluent, it uses diffuser to enhance attenuation near the outfall.
- Another solution is increasing the capacity of the storage tank to avoid the emission in dry season for small rivers near inland nuclear power plants.
- Adding steel cladding for the radioactive fluid storage tank is also one of the engineering solutions to contain the radioactive fluid water in the steel cladding when storage tanks happened on leaking. And it can help prevent the nuclide leak into groundwater.

4. The latest progress about the CNNC Nuclear project in Sichuan

CNNC had completed the plant selection in the eastern and southern Sichuan. The candidate sites are Jinguang plant and Huilong plant in Guang'an city, Xiaogu plant in Leshan city, and Beijiang plant in Yibin city. Currently, six special investigations for all the plants were completed. The Power Planning and Design Institute issued the review comments on the two projects. And the proposals for these two projects have been submitted to the National Development and Reform Commission. In 2011, the Vice Premier Li Keqiang signed important instructions for the Guang'an project.

In 2010, CNNC and Sichuan Provincial Government signed one Strategic Cooperation Framework Agreement. The Guangan, and Southern Sichuan projects have been listed as the key project of The "Twelfth Five-year" Plan of Sichuan province.

5. Conclusion

According to the previous analysis, we can draw the following conclusion:

- (1) There is no essential difference between inland nuclear power plant and coastal nuclear power plant. The distribution of nuclear power plant is also the same in inland and coastal area. In the United States, about 61.5% nuclear power plants were built in inland area. Compare with it, this percentage hit 69% in French.
- (2) According to the data which get from the normal operation nuclear power plants, the radiation levels around the nuclear power plants only varied with the local natural background fluctuation. And it's far less than limit of the National Standard.
- (3) In China, the criteria of plant selection are in the same level with International requirements. With the high criteria, the plant is very safe for environment. The impact of the radiation can be significant decreased by using engineering solution. Fukushima nuclear incident won't happen in China.
- (4) The inland NPPs of China will be applied by advanced reactor technology, which can reduce the environmental impact of radiation.
- (5) According to the Strategic Cooperation Frame Agreement signed by CNNC and Sichuan Provincial Government, the nuclear power plant projects which were initialed by CNNC have already documented in energy development section of The "Twelfth Five-year" Plan of Sichuan province. Nuclear Power plant will be built in Sichuan in soon according to the plan.

6. References

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