Introduction of Nation-wide Inspection and Reassessment to Chinese Research Reactors after Fukushima Accident

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Abstract: Briefly introduce the nation-wide comprehensive inspection to NPPs and research reactors performed by regulatory body after Fukushima accident, as well as the inspection results to research reactors. Afterwards, reassessment of safety conditions of research reactors was carried out by experts, focus on the following aspects: Anti-flooding capability evaluation, Evaluation on seismic response and anti-seismic capability, reliability of external and internal electrical power supply, evaluation on nuclear accident emergency management, etc. Based on the reassessment results, some improvement measures were proposed by regulatory body, which require operators of research reactors to implement in few years, for instance evaluating seismic margin of some old reactors, increasing waterproof blocking of nuclear island facilities and buildings as well as interim waterproof measures adopted in key buildings, improving power supply capability of storage battery and installation of mobile EDG, and so on. Finally, some additional safety requirements are described for several reactors with potential risk.

Keywords: NNSA, research reactor, Fukushima accident, national inspections

1. Introduction of Chinese nuclear facilities

1.1 Chinese nuclear power plants

There are 56 unit NPPs in China now, among which 38 units are operating and 18 unit are under construction [1]. All of these 56 units are located in 13 coastal sites, operating NPPs list referring to Table 1.

TABLE 1 Chinese NPPs list

Name of NPP		Unit No	Reactor type	Power (MWe)	First fuel-loading
Qinshan NPP	Unit 1	CN-01	PWR	310	1991.08.02
Qinshan Phase II NPP	Unit 1	CN-04	PWR	650	2001.10.09
	Unit 2	CN-05		650	2004.01.29
	Unit 3	CN-14		650	2010.05.30
	Unit 4	CN-15		650	2011.10.21
Qinshan Phase III NPP	Unit 1	CN-08	PHWR (CANDU)	720	2002.07.18
	Unit 2	CN-09		720	2003.03.16
Daya Bay NPP	Unit 1	CN-02	PWR	984	1993.06.01
	Unit 2	CN-03		984	1993.11.26
LingAo NPP	Unit 1	CN-06	PWR	990	2001.12.08
	Unit 2	CN-07		990	2002.07.15
	Unit 3	CN-12		1080	2010.04.21
	Unit 4	CN-13		1080	2011.01.05

Tianwan NPP	Unit 1	CN-10	PWR	1060	2005.10.18
	Unit 2	CN-11		1060	2007.03.16
	Unit 3	CN-45		1060	2017.08.23
Ningde NPP	Unit 1	CN-18	PWR	1080	2012.09.29
	Unit 2	CN-19		1080	2013.11.08
	Unit 3	CN-34		1080	2015.01.29
	Unit 4	CN-35		1080	2016.01.03
Hongyanhe NPP	Unit 1	CN-16	PWR	1080	2012.11.26
	Unit 2	CN-17		1080	2013.09.03
	Unit 3	CN-26		1080	2014.09.18
	Unit 4	CN-27		1080	2016.01.18
Yangjiang NPP	Unit 1	CN-22	PWR	1080	2013.10.25
	Unit 2	CN-23		1080	2015.01.25
	Unit 3	CN-40		1080	2015.10.11
	Unit 4	CN-41		1080	2016.11.19
Fuqing NPP	Unit 1	CN-20	PWR	1080	2014.06.05
	Unit 2	CN-21		1080	2015.05.15
	Unit 3	CN-42		1080	2016.04.04
	Unit 4	CN-43		1080	2017.06.15
Fangjiashan NPP	Unit 1	CN-24	PWR	1080	2014.10.22
	Unit 2	CN-25		1080	2014.12.03
Fangchenggang NPP	Unit 1	CN-38	PWR	1080	2015.09.06
	Unit 2	CN-39		1080	2016.05.25
Changjiang NPP	Unit 1	CN-36	PWR	650	2015.08.28
	Unit 2	CN-37		650	2016.05.12

1.2 Chinese civil research reactors and critical installations

There are 18 civilian-use research reactors and the critical devices uncle supervision of National Nuclear Safety Administration (NNSA) [2]. Among them, the China Institute of Atomic Energy has eight, respectively, heavy water reactor, swimming pool reactor, prototype micro-reactor, China experimental fast-breed reactor and four critical devices; within the same site there is a Beijing Kai Baxter Technology Co., Ltd. owned hospital Neutron irradiator. China Nuclear Power Research and Design Institute has five, respectively, high-flux engineering test reactor, the Chinese pulse reactor, Minjiang test reactor and two critical devices. Tsinghua University has three reactors, respectively, shielding test reactor, low temperature nuclear heating reactor and high temperature air-cooled reactor. Shenzhen University has a micro-reactor. Refer to table 2.

TABLE 2 Chinese research reactors

Reactor Operator	**Reactor type**
China Institute of Atomic Energy	heavy water reactor
	swimming pool reactor
	prototype micro-reactor
	China experimental fast breed reactor

China Nuclear Power Research and Design Institute	high-flux engineering test reactor
	Chinese pulse reactor
	Minjiang test reactor
Tsinghua University	shielding test reactor
	low temperature nuclear heating reactor
	high temperature gas-cooled reactor
Shenzhen University	micro-reactor

1.3 Brief of nuclear regulatory body

China has established a set of supervision and management system of nuclear safety applicable to its national condition and also in line with international practice, which plays an important role in resisting major accidents effectively and ensuring safe utilization of nuclear technology. Ministry of Environmental Protection (National Nuclear Safety Administration (NNSA)) is the national nuclear safety regulatory body, which carries out unified supervision on nuclear safety of national NPPs and exercises the right of supervising nuclear safety independently.

With the headquarters in Beijing, Ministry of Environmental Protection (National Nuclear Safety Administration) has regional offices established in six areas of the country, which are located in areas with concentrated nuclear facilities such as Shanghai, Shenzhen, Chengdu, Beijing, Lanzhou and Dalian. Regional office is responsible for nuclear facilities and utilization of nuclear technology as well as daily supervision on nuclear safety, radiation safety and radiation environment of relevant nuclear activity in its area. To better fulfill supervision function, Ministry of Environmental Protection (National Nuclear Safety Administration) set up Nuclear and Radiation Safety Center as its main technical support and service organization.

2. Comprehensive nation-wide nuclear safety inspection after Fukushima accident

Serious nuclear accident occurred at the Fukushima I Nuclear Power Plant on March 11, 2011 due to the 2011 Tohoku earthquake and the induced tsunami has resulted in great loss to local environment and society. It is a serious multi-reactor accident with common-cause led by station blackout (SBO) which resulted from the overlay of extreme external natural event and its secondary disasters [3], and also one of the most severe accidents in the world so far, thus it has a broad and profound impact on the global nuclear energy industry.

Implement of nation-wide nuclear safety inspection

Just after Fukushima accident, Ministry of Environmental Protection (National Nuclear Safety Administration), National Energy Administration and China Earthquake Administration conducted a comprehensive safety inspection on China’s civil nuclear facilities including NPPs in operation and under construction, research reactors and nuclear fuel cycle facilities in accordance with the “Implementation Plan for Comprehensive Safety Inspection on Nuclear Facilities” [4] approved by the State Council. The comprehensive safety inspection, taking nine months from March 2011 to December 2011, was carried out in six stages including scheme determination, NPP operators or owners self-inspection, safety reevaluation, field inspection and verification, expert review and improvement measures submission. The review methods such as safety self-inspection, communication and dialogue, technical discussion, document review, field inspection, thematic research and expert consultation were adopted during these inspections.

In the comprehensive nuclear safety inspection on nuclear facilities, the nuclear safety regulations used during previous approval, the current nuclear safety regulations, the latest international safety standards and lessons learned from Fukushima nuclear accident so far were taken as datum reference and the safety of NPP was analyzed and assessed. The inspection area mainly focused on eleven factors of three aspects, including:

1) the resistance to extreme external events,
2) the prevention and mitigation of severe accidents,
3) radiation monitoring and emergency preparedness and response, specifically including the appropriateness of external events assessed
4) flood prevention planning and flood control capacity
5) anti-seismic planning and anti-seismic capability
6) the effectiveness of quality assurance system
7) firefighting and protection system
8) the prevention and mitigation of overlying of muti-natural events
9) analysis and evaluation on station-black-out (SBO) accident
10) the measures for prevention and mitigation of severe accidents and their reliability evaluation, the public communication and information release
11) the effectiveness of environment monitoring system and emergency system

3. Inspection conclusions and proposed improvements by NNSA[5]

3.1 Positive conclusions of inspection

The comprehensive safety inspection took nine months and got main positive conclusions as follows:

a) China's nuclear safety regulations fully adopted IAEA safety standards and the system of nuclear safety regulations and standards reached the international level.
b) During siting, NPPs conducted a thorough argumentation on earthquake, flood and other external events and confirmed that the possibility of occurrence of extreme natural events similar to Fukushima nuclear accident is extremely small. NPPs took full account of the prevention and mitigation of severe accidents and conducted effective management in all stages including design, manufacturing, construction, commissioning and operation, thus the overall quality was under control.
c) From the beginning of the construction, China's experimental fast breed reactor, hospital neutron irradiation device, low temperature nuclear heating reactor and high temperature gas-cooled reactor and other reactors, have been under the effective supervision of the National Nuclear Safety Administration and meet China's current nuclear safety regulations. Although some old reactors and critical installations built prior to the establishment of the National Nuclear Safety Administration, they have been conducted a retroactive safety review and periodic safety reviews. According to the review results, great efforts were paid and corrective actions have been already implemented, the safety level of old research reactors and the critical installations are guaranteed completely.

3.2 Proposed safety improvements

However, this inspection also found some problems which may affect the safety operation of civilian nuclear facilities. Therefore, NNSA proposed some generic improvement requirements, including engineering and technology improvement measures and management improvement measures as following [6]:

The measures for engineering and technology improvement mainly include:

a) Accomplish the modification of flood control capacity against tsunami and mountain torrent of some NPPs and research reactors respectively, via building wave walls, and taking other flood prevention and drainage measures. Investigate and complete waterproof sealing for doors and windows, air vents, cable penetration, process pipeline penetration, etc.
b) Install more mobile power supply, moving pumps, etc. to meet the safety requirements in case of station blackout (SBO).
c) Strengthen the maintenance and management of instruments and meters for seismic monitoring and recording to ensure the effectiveness of monitoring and recording system. Improve the post-earthquake actions of corresponding operators in combination with field conditions to improve the seismic response capacity.

The management measures mainly include:

a) Perfect the emergency plan and improve nuclear accident emergency response capacity. Increase the environment monitoring capacity in severe accident condition, perfect the functions of emergency control center, formulate multi-unit emergency planning, establish and improve a sound external emergency support capability.
b) Formulate and perfect information release procedures to reassure the public timely and effectively.
c) Accelerate the outward transport of the spent fuel and treatment and processing of radioactive waste.

3.3 Additional requirements for several research reactors

Except for above generic improvements, some significant requirements were proposed to several research reactors with potential risk.

a) In the site of China Nuclear Power Research and Design Institute

This site should be equipped with more equipment to improve the emergency rescue capacity to deal with mountain landslides, road congestion and other natural disasters; Built the second emergency road of the site to improve the emergency state of road transportation capacity; Improve the emergency control center, strengthen the emergency environmental monitoring capabilities;

b) High-flux engineering test reactor

High-flux engineering test reactor was built in the 1970s, adopting low standards of seismic design. Since seismic check and modification have been carried out several times under the requirements of retroactive safety review and periodic safety review, the seismic capacity has been improved. However, due to the intensity of earthquake was increased in this area, seismic reassessment and reinforcements are necessary to perform in some safety structures to meet its safety margin.

Besides, necessary reliable uninterrupted battery power, mobile EDG power, fire-fighting vehicle, emergent water source, mobile pumps and post-accident monitoring equipment are required to install.

c) In the site of China Institute of Atomic Energy

The history of tornado disaster situation in the site should be verified to assess the impact on plant structures. Fulfill preparatory work of decommissioning or long-term closure for several reactors. Study multiple reactors of one site entering into the emergency response at the same time. Speed up the China Atomic Energy Research Institute, China Nuclear Power Research and Design Institute and Tsinghua University of spent fuel outward transportation and radioactive waste disposal work.

4. References

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