Convention on Nuclear Safety

Extraordinary Meeting on Fukushima Nuclear Accident

The People's Republic of China National Report

April 2012

Beijing

TABLE OF CONTENTS

0. Introduction

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, 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.

Fukushima nuclear accident aroused great attention among the international community and showed the paramount importance and impact universality of nuclear safety. Human beings must fully learn from this setback to utilize nuclear energy more safely, effectively and peacefully.

0.1 China's response actions

Chinese government paid much attention to Fukushima nuclear accident, and related functional departments and nuclear energy industry took relevant response actions quickly.

The State Council of China held an executive meeting on March 16, highlighted the importance and urgency of nuclear safety, discussed and allocated the response actions of Chinese government to Fukushima nuclear accident and put forward four requirements:

- Instantly organize a comprehensive nuclear safety inspection on nuclear facilities. Carry out comprehensive and detail safety evaluation to identify potential safety hazards and take appropriate measures to ensure safety.
- Strengthen safety management of nuclear facilities in operation with concrete measures. The operating organization must improve and complete their management system, follow the operation instructions and procedures strictly and strengthen operation management. The regulatory authorities are required to reinforce the supervision and inspection and direct the enterprises to identify and eliminate the hidden dangers in a timely manner.
- Conduct a comprehensive review on the NPPs under construction. Carry out a safety evaluation on all NPPs under construction based on the most advanced standards, eliminate the hidden dangers with a firm hand and immediately stop NPP construction if the safety standards are not satisfied.
- Review and approval the new NPP projects strictly. Prepare nuclear safety planning in a timely manner, adjust and perfect the medium-term and long-term plans for nuclear power development, and suspend the approval of new NPP projects before the approval for nuclear safety planning.

In addition to the active fulfillment of the State Council's requirements, related government departments also took a series of timely and effective response actions according to the progress and impact of Fukushima nuclear accident, mainly including:

(1) Emergency response and emergency monitoring

China National Nuclear Accident Emergency Coordination Committee initiated the national nuclear emergency coordination mechanism, actively studied the countermeasures, closely followed, studied and judged the evolution of the accident and strengthened radiation monitoring on the environment, atmosphere, food, drinking water and ports according to the "National Nuclear Emergency Planning".

As the nuclear safety regulatory authority and environment protection authority, Ministry of

Environmental Protection (National Nuclear Safety Administration) initiated the emergency planning on March 11 and urgently enabled the departments concerned and local environmental administration into emergency condition. On March 12, the local administrations was requested to carry out emergency monitoring of radiation to the environment, submit monitoring data and launch a special column on the public website of Ministry of Environmental Protection to release and update these data timely. The emergency monitoring involves the air-absorbed dose rate of γ radiation and the radio-nuclides in the atmosphere, ground settlement, water, soil, leaf vegetables, milk, and marine organisms. On April 22, the condition was adjusted into Emergency Standby, and emergency condition was terminated on May 22.

At the same time, Ministry of Environmental Protection (National Nuclear Safety Administration) also set up the specific technical team to closely follow, study and judge the evolution and consequence assessment of Fukushima nuclear accident, adopted the multi-specialized expert consultation mechanism to discuss the important technical issues, estimated the diffusion trend of radioactive substances via analog calculation, studied the causes of Fukushima nuclear accident and the possible lessons learned, and prepared and updated the "Report on Experience Feedback of Japan Fukushima Nuclear Accident" and "Assessment report on Impact of Japan Fukushima Nuclear Accident on China's Environment" in real time to provide technical base for scientific decision making.

(2) Public communication

China National Nuclear Accident Emergency Coordination Committee released information on the evolution of the accident, its impact on China and relevant information in a timely manner to the public through press conference, TV media interviews, expert interview, questions and answers and other methods, made clarification on issues of public concern, put off the public doubts and fears and made them rationally face this accident with a scientific attitude.

Ministry of Environmental Protection (National Nuclear Safety Administration) also released the information through monitoring data announcement and interpretation news release, answering journalists' questions, science popularization and other forms, and also compiled and published the books on popular science. Besides, the Ministry issued the "Notice on Further Strengthening Information release by Operating Organizations of NPP" and "Program of Ministry of Environmental Protection (National Nuclear Safety Administration) on Release of Regulatory Information concerning Nuclear and Radiation Safety (Trial)" in April to direct and standardize the information release by NPP operators and nuclear safety regulatory authorities.

Operating organizations of NPP also reinforced information release and public communication.

(3) Comprehensive nuclear safety inspection

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" approved by the State Council. The comprehensive safety inspection on NPPs, 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.

(4) Preparation of nuclear safety planning

Ministry of Environmental Protection (National Nuclear Safety Administration) organized the

preparation of nuclear safety planning as required by the State Council. The preparation team composing of government departments concerned, enterprises and institutions, research organizations, colleges and universities and many other organizations carried out extensive research and investigation, and generated 12 thematic reports through in-depth analysis on China's nuclear energy, nuclear technology and corresponding safety and security situation. Upon serious discussion and argumentation and integrated the comments from nuclear energy industry, the team spent 10 months in preparing the "Planning on Nuclear Safety and Radioactive Contamination Prevention & Control for the Twelfth Five-Year Plan Period and Long-Range Objective through the Year 2020", which analyzes in-depth the situation of nuclear safety in China, arranges a serious tasks and works guaranteeing nuclear safety during the twelfth five-year plan and also specifies corresponding guarantee measures.

In addition, National Energy Administration organized the preparation of the "Nuclear Power Safety Planning", adjusted and perfected the "Medium and Long-term Development Planning of Nuclear Power", and speed up the process of research and formation of "Regulation on Nuclear Power Management".

The issuance and implementation of the aforementioned planning are in favor of further improving China's nuclear safety level and can provide a solid and powerful support for safe, sound and sustainable development of nuclear energy.

(5) The structure adjustment of related government departments

The general response of the international community after Fukushima nuclear accident was to reinforce the functions of nuclear safety regulatory authority. China's government departments also intensified the efforts to manage nuclear power industry and nuclear sector and supervise the nuclear safety by taking the measures like adjusting organization structure of the government departments, increasing the size of personnel force and financial budget. Specifically, Ministry of Environmental Protection set up three divisions responsible for nuclear and radiation safety regulation based on the original Department of Nuclear Safety, National Energy Administration set up a new division of Nuclear Power and China Atomic Energy Authority set up the department of Nuclear Emergency.

(6) International cooperation and communication

During Fukushima nuclear accident, Ministry of Environmental Protection (National Nuclear Safety Administration) kept close contact with NISA to get the accident information timely and collected relevant information in many ways. Meanwhile, relevant actions and results of other countries and organizations like Japan, America, France and IAEA were tracked which provided a sound technical base for the organization of comprehensive nuclear safety inspection and the preparation of general technical requirements for safety improvement actions.

China assigned technical experts actively to join fact-finding group of International Atomic Energy Agency (IAEA) and participate in important activities of IAEA and OECD/NEA; widened the cooperation with European Union on nuclear safety and capacity building, and communicated in-depth with international peers through bilateral nuclear safety cooperation and exchange mechanism such as Sino-U.S, Sino-France, Sino-Japan, etc... The regulatory bodies of China, Japan and Korea conducted more deep and practical communication and cooperation activities utilizing the existing regulatory top management conference, and signed a cooperation proposal on nuclear safety among these three countries.

China nuclear industry circle has conducted wide technical exchange and shared experience with international organizations such as IAEA, WANO and WNA as well as nuclear industry peers from America, France and Japan, thus promoting the improvement of NPP safety together.

0.2 Comprehensive nuclear safety inspection on NPPs

In the comprehensive nuclear safety inspection on NPP, the nuclear safety regulations used during approval of NPP, 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. Meanwhile, close attention was paid to eleven factors of three aspects, such as the resistance to extreme external events, the prevention and mitigation of severe accidents, radiation monitoring and emergency preparedness and response, specifically including the appropriateness of external events assessed, flood prevention planning and flood control capacity, anti-seismic planning and anti-seismic capability, the effectiveness of quality assurance system, fire fighting and protection system, the prevention and mitigation of overlying of muti-natural events, analysis and evaluation on station-black-out (SBO) accident, the measures for prevention and mitigation of severe accidents and their reliability evaluation, the public communication and information release, the effectiveness of environment monitoring system and emergency system and other possible weakness.

NPP operating organization conducted safety self-inspection according to related guidance documents and submitted the self-inspection report. Design organization submitted the analysis report on the consistency of concrete reactor design with the regulatory requirements. Technical support organization of Ministry of Environmental Protection (National Nuclear Safety Administration) raised some questions concerning safety reevaluation according to datum reference and conducted an in-depth discussion with operating organizations through direct dialog. Ministry of Environmental Protection (National Nuclear Safety Administration took the lead in organizing all NPPs to conduct field inspections, checking the important structures, systems and equipment, interviewing operating personnel or engineering management personnel and preparing a field inspection report.

Ministry of Environmental Protection (National Nuclear Safety Administration), China Earthquake Administration and State Oceanic Administration also conducted a joint research to reassess the influence of earthquake and tsunami to NPP with emphasis on rechecking the influence from the tsunami induced by earthquake of distant origin in plate subduction zone.

Main conclusions drawn from the comprehensive nuclear safety inspection are as follows:

- China's nuclear safety regulations fully adopted IAEA safety standards and the system of nuclear safety regulations and standards reached the international level.
- 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.
- NPPs had sound operational performance and their performance indicators for safety operation ranked forefront in the list of the World Association of Nuclear Operators (WANO). So far, no level-II and above accidents as specified in International Nuclear Event Scale (INES) occurred in these NPPs.
- Ministry of Environmental Protection (National Nuclear Safety Administration) conducted independent and effective safety review and supervision on NPPs.

The inspection results show, the existing NPPs in China meet the requirements of nuclear safety regulations adopted during license review and issuance, and also basically meet the requirements of current nuclear safety regulations and the latest IAEA safety standards. They possess certain

capability of preventing and mitigating the accident, the safety risk is under control and the safety is guaranteed However, the NPPs in China still have some aspects to be improved in light of the lessons learned from Fukushima nuclear accident as well as the principles of defense in depth and continuous improvement.

The concrete inspection results of the technical issues will be illustrated in later sections.

0.3 Requirements on safety improvement

Based on the enlightenment from Fukushima nuclear accident and the results of comprehensive nuclear safety inspection , China's government identified some potential fields to be improved and determined some short-term and mid- and long-term plans for rectification and improvement in respect of management and technology. Related departments and organizations are implementing them gradually in order to further improve the safety level of NPPs in China.

The measures for engineering and technology improvement mainly include:

- Investigate and complete waterproof sealing for doors and windows, air vents, cable penetration, process pipeline penetration, etc. one by one in combination with the evaluation on water out behavior that may occur in NPPs.
- Install more mobile power supply, moving pumps, etc. to meet the safety requirements of the NPPs in case of station blackout (SBO).
- Accomplish the modification of flood control capacity of some NPPs via heightening sea wall, building wave walls, and taking other flood prevention and drainage measures.
- Strengthen the maintenance and management of the NPPs' 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 of the NPPs.

The management measures mainly include:

- Perfect the guidelines for severe accident management of NPPs, evaluate and improve the usability and reliability of equipment and system for mitigating severe accidents. Assess the possible hydrogen explosion, and add or modify hydrogen recombiner according to evaluation result to prevent hydrogen accumulation and explosion under severe accident.
- 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.
- Formulate and perfect NPP information release procedures to reassure the public timely and effectively.
- Accelerate the outward transport of the spent fuel and treatment and processing of radioactive waste of NPPs.
- Conduct a deep and detail evaluation on the seismic tsunami risk, accomplish the analysis and verification on the capacity of anti-tsunami by the NPPs, and take necessary measures accordingly. Promote and perfect the probabilistic safety analysis on external event of NPP or the evaluation on anti-seismic margin.

In addition, related departments of China's government are working together to study the national nuclear emergency capability building, urge nuclear-power enterprises and utilities to improve their emergency capabilities, achieve the sharing of emergency resources and capabilities throughout the

country or region through effective coordination and organization, and standardize and strengthen the management of planning restricted zone of NPP. Refer to Appendix I for details.

0.4 Main works in implementation and to be carried out

Related government departments organized a series of activities and formulated the work plan for certain period in the future according to the result of comprehensive nuclear safety inspection and in combination with development status and trend of China's nuclear power. The NPPs are also carrying out short-term, medium-term and long-term safety improvement measures. The main works include:

(1) Formulate general technical requirements for safety improvement of NPPs after Fukushima nuclear accident

Ministry of Environmental Protection (National Nuclear Safety Administration) is studying to formulate the "General Technical Requirements for Improvement Action of NPPs" to put forward the technical requirements that shall be followed in safety improvement. According to the technical requirements, nine subject domains were mainly investigated and studied, including waterproof sealing for nuclear island facilities and power house, installation of moving pumps and water injection pipelines, mobile power supply and their installation, spent nuclear fuel pool monitoring, improvement of hydrogen recombiner, habitability and functions of emergency control center, improvement of measures for environment monitoring and emergency monitoring, improvement of emergency preparedness and exterior disaster warning.

The General Technical Requirements shall be issued and implemented after extensive soliciting of the opinions from nuclear industry circle and technical consultation of Nuclear Safety and Environmental Expert Committee.

(2) Carry out safety margin evaluation on important external events of NPPs in operation

Ministry of Environmental Protection (National Nuclear Safety Administration) has formulated and issued the "Scheme for Safety Margin Evaluation on Important External Events of NPPs in Operation" and required the NPPs in operation to further evaluate the NPPs' safety margin in the response of NPPs to beyond design basis external events, optimize and implement improvement measures and improve their effectiveness. The detail evaluation contents include the following: the emergency response of NPPs in extreme external events, the effectiveness of preventive measures and accident consequence mitigation, especially investigate the NPPs' possible weakness and steep side effect, so as to evaluate the soundness and safety margin of defense-in-depth of NPPs as well as the appropriateness of current accident management measures and propose the improving actions and measures in respect of technology or organizational system.

At present, the NPPs in operation carried out comprehensive analysis and evaluation on the margin of important external events according to site features and will accomplish them by the end of April 2012. Ministry of Environmental Protection (National Nuclear Safety Administration) shall conduct an independent review on the results of evaluation.

(3) Prepare safety requirements and review principles for new NPP

In order to ensure the NPPs to be built in the future in China has a much higher level of design safety, Ministry of Environmental Protection (National Nuclear Safety Administration) initiated to prepare safety requirements and review principles for new NPPs aiming at the Twelfth Five-Year Plan Period and the Thirteenth Five-Year Plan Period respectively, and currently gives priority to the preparation of relevant requirements for NPPs to be built in the Twelfth Five-Year Plan Period.

Considering the experience feedback of Fukushima nuclear accident and the improvement of nuclear safety level are long term processes, besides tracking and implementation of safety

improvement measures described in the comprehensive nuclear safety inspection, Ministry of Environmental Protection (National Nuclear Safety Administration) plans to carry out the following efforts in certain period in the future:

- Vigorously promote the effective implementation of Nuclear Safety Planning prepare concrete work plans and establish mechanism for coordination and supervision..
- Vigorously promote the construction of regulations and standards system, accelerate the legislation of Nuclear Safety Law closely follow and actively participate in the formulation of international nuclear safety standards.
- Vigorously promote the fundamental capability building, including the construction and capability building in terms of environment monitoring system, accident emergency system and public communication system.
- Vigorously promote the technical capability on nuclear safety, especially independent analysis capability, experimental verification capability, etc.
- Vigorously promote the establishment and continuous improvement of the systems for experience feedback, safety culture and quality assurance system.

0.5 Lessons and inspirations from Fukushima nuclear accident

Through deeply analyzing the occurrence and evolution of Fukushima nuclear accident as well as response actions by the international community, China's related departments summarized lessons and inspirations from Fukushima nuclear accident in management and technique based on the principle of defense in depth and in combination with current situation and characteristics of China's nuclear power industry as well as results of comprehensive nuclear safety inspection of NPPs. Lessons and inspirations concerning the management mainly cover the follows:

(1) Further deeply understand the paramount importance and basic rules of nuclear safety, and improve the literacy and level of nuclear safety culture.

(2) Further improve the requirements of nuclear safety standards, and ensure their effective implementation, especially the defense for external events as well as prevention and mitigation of severe accidents.

(3) Further perfect the emergency response mechanism, improve emergency response capability and genuinely implement the requirements for defense in depth.

(4) Further improve the managing and technical capabilities as well as resource support capacities of operating organizations so as to possess certain capabilities for "isolated island fighting"

(5) Further improve the independence, authoritative and effectiveness of nuclear safety regulatory body to enable them have appropriate resource guarantee and technical capabilities, thus being able to make decisive and correct decisions and take scientific and reasonable actions in various situations.

(6) Further strengthen R&D of nuclear safety technology and promote sustainable improvement of nuclear safety level relying on scientific and technical innovation.

(7) Further enhance the sharing of domestic and international experiences and capabilities on nuclear safety, establish effective mechanisms and platforms, and share the experiences and capabilities within a wider range in a friendlier manner.

(8) Further strengthen the public communication and information release, improve the public's cognition of nuclear safety and acceptance of nuclear power so as to create a good social environment for the development of nuclear power.

Lessons and inspirations in technical field mainly involve:

(1) Constantly improve the ability to defense extreme external events based on the improvement of cognition so as to ensure the beyond design basis accidents of little probability and serious consequence are appropriately taken into consideration in siting and design and appropriate safety margin is maintained.

(2) Improve and strengthen the management of severe accidents, perfect Severe accident Management Guidelines (SAMG), effectively prevent and mitigate severe accidents through systematical management and technical measures, and provide necessary data monitoring, functional verification, resource allocation, personnel training, etc.

(3) Adopt appropriate system configuration and technical measures, improve the reliability, diversity and flexibility of final heat sink and emergency power supply, thus ensuring the cooling function of reactor core and spent fuel pool.

(4) Consider emergency response capacity and mutual assistance mechanism when accidents happen to multiple units under extreme natural conditions, including environment monitoring, communication channels, emergency rescue, personnel qualification and training, reservation and distribution of emergency materials, etc.

0.6 Nuclear facilities concerned in this Report

Nuclear facilities concerned in this Report include NPPs under construction and in operation in China. Relevant information of NPPs in Taiwan is unavailable temporarily.

At present, China has 15 nuclear power units in operation with total installed capacity of 12.54GWe; and 26 nuclear power units under construction with total installed capacity of 29.14GWe. Except that reactor in Third Qinshan Nuclear Power Plant is heavy water reactor (CANDU-6), all the others are of light-water type pressure water reactor, including self-reliance nuclear power units in pressure water reactor type, AP1000 units, EPR units, etc. Please refer to Appendix II for detailed list of China's NPPs under construction and in operation.

China has formed three nuclear power bases in operation, including Qinshan of Zhejiang Province, Daya Bay of Guangdong Province, and Tianwan of Jiangsu Province. Moreover, a number of nuclear power units are being built in Hongyanhe of Liaoning Province, Haiyang of Shandong Province, Sanmen of Zhejiang Province, Fuqing and Ningde of Fujian Province, Yangjiang and Taishan of Guangdong Province, Fangchenggang of Guangxi Province, Changjiang of Hainan Province, etc.

0.7 Subject and structure of this report

This Report is compiled based on the requirements in Guidelines for National Report on 2012 Special Session based on "Convention on Nuclear Safety" issued by IAEA. It illustrates Chinese government and NPPs' current requirements, current situation, weaknesses and problems recognized in self-inspection and corrective actions adopted, being implemented or planned to be implemented for the weaknesses and problems in terms of external events, design improvement, severe accident management and recovery (inside the site), national organization, emergency preparedness and response and post-accident management (outside the site) as well as international cooperation.

1. External events

1.1 Management requirements and current situation of external events

Since 1982, China has collected extensively and studied carefully the laws and regulations on nuclear safety used in nuclear power developed countries, consulted the nuclear safety codes and guides of the IAEA and established the Chinese nuclear safety regulation system step by step.

As for NPP siting, Chinese laws and regulations on nuclear safety conform to IAEA-related safety standards. China is capable of learning other countries' experience in formulating laws, regulations and standards for nuclear power siting as well as related siting evaluation criterion since its nuclear power construction starts relatively late, thus corresponding laws, regulations and standards for siting are gradually perfected and strictly implemented. Main laws and regulations on nuclear safety related to NPP siting are as follows:

- “Code on the Safety of Nuclear Power Plant Siting”(HAF101)
- “Earthquakes and Associated Topics in Relation to Nuclear Power Plant Siting”(HAD101/01)
- “Atmospheric Dispersion in Relation to Nuclear Power Plant Siting”(HAD101/02)
- “Siting Selection and Evaluation for Nuclear Power Plant with Respect to Population Distribution”(HAD101/03)
- “External Man-induced Events in Relation to Nuclear Power Plant Siting”(HAD101/04)
- “Hydrological Dispersion of Radioactive Material in Relation to Nuclear Power Plant Siting”(HAD101/05)
- “Nuclear Power Plant Sitting - Hydrogeological Aspects “(HAD101/06)
- “Site Survey for Nuclear Power Plants” (HAD101/07)
- “Determination of Design Basis Floods for Nuclear Power Plants on River Sites” (HAD101/08)
- “Determination of Design Basis Floods for Nuclear Power Plants on Coastal Sites “(HAD101/09)
- “Evaluation of Extreme Meteorological Events for Nuclear Power Plant Sitting” (HAD101/10)
- “Design Basis of Tropical Cyclone for Nuclear Power Plants” (HAD101/11)
- “Safety Aspects of the Foundation of Nuclear Power Plants” (HAD101/12)

With the implementation of revised planning for IAEA regulations, China is revising “Code on the Safety of Nuclear Power Plant Siting ” and its subsidiary guidelines in combination with China’s practices.

The following factors are mainly taken into account in siting of NPP in China:

(1) Impact of the possible external natural events or man-induced events in the area of certain plant site on NPPs.

(2) Site characteristics that may cause the emitted radioactive substances to move to human body and environment.

(3) Site characteristics related to the feasibility of implementation of emergency planning, including population density, population distribution, transport and communication conditions and

other characteristics.

Criteria of Defining Design Basis for External Natural Events:

(1) Proposed sites are adequately investigated with respect to all site characteristics that could affect safety in relation to design basis natural events.

(2) Natural phenomena that may exist or can occur in the region of a proposed site should be identified and classified according to the potential effects on the safety operation of the nuclear power plant. This classification is used to identify the important natural phenomena from which design bases are derived.

(3) Historical records of the occurrences and severity of the above mentioned important natural phenomena in the region are collected and carefully analyzed for the reliability, accuracy and integrality.

(4) Appropriate methods are adopted to establish the design basis for natural events for some important natural phenomena. The methods should be proved to be compatible with the characteristics of the region and the current state-of-the-art.

(5) The size of the region that should be studied in determining design basis natural events by certain method shall be large enough to cover all the features and areas which could contribute to the determination of the design basis natural events and their characteristics.

(6) Important natural phenomena are expressed as input in inferring the design bases in relation to natural events for NPPs.

(7) In the ascertainment of design basis events, specific data of the site are used unless such data are unavailable. In this case, the data from other regions that are similar to the region may be used.

Evaluation criterion of external events:

Attach great importance to the influence of extreme external events during siting of NPPs, try to keep away from the areas where extreme external events may occur from the perspective of facility siting. For example, siting of NPPs mostly proceeds in the areas of low seismic intensity. From design protection perspective, the methodologies of certainty and probability are usually adopted to evaluate extreme external events, and the maximum possible value is chosen as the design basis for the site of NPP. Moreover, as for the determination of ground motion parameter of design basis for the site of NPP, China adjusted 0.1g, the threshold limit value of SL-2 recommended by International Atomic Energy Agency (IAEA) into 0.15g in combination with seismic activities in China.

Natural Events Affecting the NPPs Safety:

During the siting, the natural factors affecting the safety are investigated and evaluated in detail, and the engineering design bases are determined according to the investigation results and the related safety requirements. The natural factors affecting the safety of the NPP are as follows.

- Floods due to precipitation and other causes,
- Waves caused by earthquake,
- Floods and waves caused by burst of dam and dyke, etc.,
- Surface faulting,
- Slope instability,

- Site surface collapse, subsidence or uplift,
- Earthquakes,
- Soil liquefaction,
- Tornadoes,
- Tropical cyclones(typhoon), and
- Other important natural phenomena and extreme conditions.

Basic situation of siting of NPPs:

At present, China has totally 13 sites for NPPs in operation and under construction, which are all costal NPPs. Hongyanhe NPP in Liaoning Province is located in Liaodong Gulf, and Fangchenggang NPP in Guangxi Province and Changjiang NPP in Hainan Province are close to Beibu Gulf while the others are located in open sea area with wide coastal continental shelves in Eastern and Southern China. China has considered keeping away from capable faults during siting of existing NPPs, which have stable seismic geological structure and most are in weak seismic areas. Certain safety allowance has been taken into account in seismic design and a series of detailed solutions have been formulated in operation management.

During siting of NPPs, extreme external events possibly affecting site safety have been investigated and evaluated. Meanwhile, the evaluation on siting procedure and external events has been carried out in light of regulations on nuclear safety, and audited and confirmed by the Ministry of Environmental Protection (National Nuclear Safety Administration). In siting of NPPs, design input is determined according to geology, hydrology, meteorology and other extreme external event conditions of plant sites. Design basis events considered meet the requirements of China's laws, regulations and guide rules on nuclear safety. NPPs are designed to be able to defense various external risks within design scope as well as control and mitigate severe accidents beyond design basis. Evaluation on external events during siting is appropriate.

After Fukushima nuclear accident, aiming at initial event inducing Fukushima nuclear accident and problems in following accident disposal, Chinese government investigated the changes of natural disasters and industrial activities around the sites since the construction of various domestic NPPs in operation, analyzed the possible extreme natural disasters in sites and the possible combination, and compared them with the original design codes and the latest IAEA standards. Moreover, Chinese government rechecked the NPPs under construction and planned to be built correspondingly.

1.2 Rechecking evaluation on flood control capacity of NPPs

Criterion for determination of design basis flood:

Based on the requirements of Chinese laws and regulations on nuclear safety, design basis flood of offshore site should be defended by a NPP as designed. Flood factors considered include floods from the ocean and land precipitation. Following combinations are considered in floods from the ocean:

- Datum of tidal level;
- Extreme flood events (storm tide, seiche and tsunami);

- Wind and waves;
- Flood in rivers (estuary site).

The role of wind and wave can be considered alone or together with the combinations of floods mentioned above.

Based on ocean hydrologic characteristics of coastal NPPs in China, the specific combination factors considered during determination of design basis flood include: 10% high astronomical tide level, storm tide, influence of wind and wave, and flood in rivers. The probable maximum storm tide of extreme flood events is evaluated mainly through deterministic methodology, i.e. extreme conditions concerning surge and reduction of storm tide are calculated by assuming the least favorable typhoon parameters and routes, which will be regarded as the basis for design of flood control in NPP site. As for offshore site at estuary, design basis flood level will be the superposition of the flood levels of land rivers.

According to the requirements of Chinese laws and regulations on nuclear safety, item important to NPP safety must be able to defend the design basis flood. NPPs shall determine the appropriate flood control measures upon the comparison of static effect and dynamic effect of design basis flood according to the position and elevation of related safety facilities.

Flood control design and measures of NPPs:

At present, NPPs in operation and under construction in China are located offshore. Except that Hongyanhe NPP in Liaoning Province (Liaodong Gulf), Fangchenggang NPP in Guangxi Province and Changjiang NPP in Hainan Province (Beibu Gulf) are located in gulf, all the others are located in open sea area with wide coastal continental shelves in Eastern and Southern China. The most important flood factor of coastal NPPs in China refers to storm tide generated by tropical cyclone (typhoon). Typhoon frequently happens in summer and autumn in coastal areas of Eastern and Southern China and often induces flood disaster. Therefore, the design basis of flood control of NPPs in such areas is higher than that in other coastal areas.

According to the requirements of Chinese laws and regulations on nuclear safety, and based on historical disasters in coastal areas in China and existing experiences in engineering practices, NPPs mainly adopted the measures below in design to defend design basis flood:

(1) Maintain a dry site design to ensure site elevation is higher than design basis flood level and consider the influence of wind and wave.

(2) Build the permanent external shield, such as flood dike, wave wall and other flood control structures, and regard the sea wall as safety related item.

(3) Consider the possible local overtopping in design of flood control and the local flood effect generated by the probable maximum precipitation, including appropriate drainage facilities, corresponding emergency measures for flood control, etc.

(4) Formulate and perfect corresponding flood prevention planning, management system and execution procedure, and conduct flood control exercise on a regular basis.

Safety inspection of flood control and recheck evaluation:

After Fukushima nuclear accident, the NPPs adopted the latest hydrological data to recheck design basis flood. The result showed that the overwhelming majority of NPPs had made appropriate evaluation on extreme flood. Moreover, the adopted flood synthesis and determined design basis flood level conformed to current laws and regulations on nuclear safety. All plants set up flood control measures in land and sea areas, which could meet the requirements of design basis for the maximum basis flood level and the probable maximum precipitation.

In the comprehensive nuclear safety inspection, the appropriateness of flood control design of NPPs

was mainly reviewed. Meanwhile, in combination with the experience from Fukushima NPP in Japan and flooding accident of BLAYAIS NPP in France, the evaluation was conducted to confirm whether the position of important safety equipment and anti-flooding measures can ensure the availability of the equipment, the leakproof capability of pipe drains, corridors, doors & windows and penetration assemblies, the access to early flood warning information, the appropriateness of flood prevention planning, etc.

Due to the reclamation in Hangzhou Bay in late stage, the rechecked and evaluated flood level of Qinshan NPP had exceeded the flood control capacity of the original flood dike. Ministry of Environmental Protection (National Nuclear Safety Administration) requested it to finish flood control planning as soon as possible and improve flood control capacity so as to ensure flood control safety of the NPP. At present, the improved flood control planning has been completed and approved and confirmed by Ministry of Environmental Protection (National Nuclear Safety Administration). Meanwhile, flood control project is put into effect.

Moreover, to further improve the ability of NPPs to withstand extreme flood, especially the influence of the possible super typhoon, the coastal NPPs are required to strengthen the real-time communication with the meteorological and maritime departments, perfect emergency planning for flood control, take the stoppage or waterproof measures for the possible water passageway and maintain the physical separation and diversity of key safety system.

1.3 Rechecking evaluation of anti-seismic capability of NPPs

Criterion for determination of design basis earthquake:

Siting of NPP shall keep away from “capable fault” and strong earthquake zone in the requirements of laws and regulations on nuclear safety. Seismic survey and assessment of NPP mainly revolves around engineering anti-seismic design basis and identification on surface fault motility in plant site. In detail, assess seismic and geological conditions within the region, collect prehistoric, historical and instrument-recorded seismic data to determine earthquake-related risks, survey region scope, type of data collected, survey scope and level of specificity according to complexity and nature of seismic tectonic environment. Wherein, the surveyed scope of plant site shall not be less than 150km. Design basis seismic assessment of the NPP site adopts risk analysis of deterministic and probability. The probability risk level of NPP SL-2 is 10^{-4}, and anti-seismic design basis of the NPP site takes the larger value of the two assessment analysis methods. No matter how low the seismic motion level in NPP site region is, horizontal peak acceleration in SL-2 anti-seismic design basis of NPP site level shall not be less than 0.15g (corresponding to peak value acceleration in null cycle).

Anti-seismic design of NPP:

China has relatively more earthquake disasters with uneven distribution, and the strong earthquakes are mainly in western China and North China. As for coastal area where the NPP is located, seismic activities are more active in southeast coastal area near Taiwan Strait, in which the strongest seismic magnitude in history reached M7.5; however, the seismic magnitude is relatively low in other coastal areas, and the seismic magnitude is basically moderate-strong. China lies inside the Eurasia plate, so the frequency and intensity of earthquakes are significantly lower than that in Japan which is located on the plate collision zone. In China, the main destructive earthquakes are shallow focus earthquake inside continental plate; since the energy of deep focus earthquake is mainly consumed in upper mantle and earth’s crust, it will not affect earth’s surface generally.

Currently, anti-seismic design of NPP in China is divided into two types. One is Qinshan NPP, Daya Bay NPP and CPR1000 nuclear power unit continuously improved based on the two plants above. The anti-seismic design SL-2 of such unit is 0.2g. The anti-seismic design of Tianwan NPP (WWER) and Third Qinshan NPP (heavy water reactor) is at the same level. The other is newly

introduced AP1000 and EPR units. The anti-seismic design SL-2 of AP1000 and EPR nuclear power reactor type is respective 0.3g and 0.25g. The design seismic response spectrum adopts smoothly extended RG1.60 standard spectrum.

Anti-seismic safety inspection and recheck evaluation:

After the Fukushima nuclear accident, appropriateness of anti-seismic design basis of NPPs was reviewed and confirmed in combination with the latest earthquake record data, including anti-seismic classification and anti-seismic appraisal result of items important to safety, setting of seismic instruments and appropriateness of post-earthquake measures (anti-seismic planning), design and assessment of items which may interact with items important to safety and cause seismic secondary disaster.

Inspection results show that determination of design basis earthquake motion, anti-seismic classification and appraisal of items important to safety and setting of seismic instruments of NPP in China can satisfy the requirements of current laws and regulations on nuclear safety and the latest nuclear safety standard of IAEA. The actual anti-seismic design of each NPP can cover the assessed seismic ground motion of plant site. Some plant sites even have a relatively larger anti-seismic safety allowance compared with the seismic ground motion parameters in plant site. Each plant has formulated relatively complete anti-seismic planning and improved the emergency action plan of nuclear accident.

Considering lessons from Fukushima nuclear accident, each nuclear power plant shall fully perceive the uncertainty of seismic motions, respond to possible extreme earthquake event, and improve earthquake emergency planning. Anti-seismic allowance analysis of NPP shall be developed to find possible existing weakness and implement corresponding safety improvements.

1.4 Review and assessment of tsunami influence on NPPs

Requirements of laws and regulations

In “Code on Safety of Nuclear Power Plant Siting” (HAF101) and Safety Regulations for Assessment on Nuclear Facility Site newly issued by IAEA, it is required to develop assessment on possible earthquake-produced tsunami. Moreover, in the attached nuclear safety guideline “Earthquakes and Associated Topics in Relation to Nuclear Power Plant Siting” (HAD101/01), it is required to identify the strongest tsunami source based on seismic and geological data and estimate the potential impact; In nuclear safety guideline “Determination of Design Basis Flood for Nuclear Power Plants on Coastal Sites” (HAF101/09), the flood-control design basis of plant site shall be based on the possible largest extreme flood, and tsunami, among the flood-combined factors considered, is included into the possible extreme flood events. Siting assessment of coastal NPP shall consider some flood control factors, including: benchmark water level (astronomical tide level, unusual sea level, etc.), extreme flood events (storm surge, tsunami, false tide, etc.) and wave effect corresponding to storm surge and tsunami. As for offshore sites in estuary, floods at upstream of rivers shall also be considered.

In the combinations above, extreme flood event is the most concerned factor in flood control design of NPP, and is closely related to natural conditions of plant site. As for a region, the extreme flood event can be tsunami, storm surge or seiche, which depends on the features of neighboring water body of plant site and seismic or meteorological conditions. In coastal area of China, typhoons occur frequently in summer due to the influence of southwest pacific tropical monsoons, so the storm surge resulting from typhoon is highly concerned. According to nuclear safety guides, the combined influence of different extreme flood events may not be considered in siting assessment since the ratio of simultaneous occurrence of different flood events is quite low.

Assessment on tsunami effect to coastal NPPs in China

According to historical siting assessment of coastal NPPs in China, the possible tsunami effect can be analyzed in three aspects:

The first is historical data analysis. In related historical data concerning coastal area of China, especially eastern and southern coastal area, a lot of flood disasters such as “tidal water” “tsunami”, etc. were recorded over one thousand years ago; however, upon verification, the recorded floods in coastal area were mainly related to storm surge resulting from typhoons. There was no exact disastrous tsunami effect resulting from earthquake.

The second is seismic activity assessment. The seismic activity in coastal area of mainland in China is not as strong as that in Japan which is located at plate boundary. There are seismic activity records in Bohai Sea, Huanghai Sea and southeast coastal according to historical seismic distribution records of coastal area. The highest seismic magnitude reaches M7.5, most referring to moderate-strong earthquake. According to study of regional seismic tectonic stress field, seismic geology and sea geophysical prospecting, since most of those earthquakes are established by strike-slip movement of faults resulting from horizontal tectonic stress, the vertical displacement is relatively small. Since those seismic magnitudes are low and fault movements are strike-slip dominated, these earthquakes were not accompanied with significant tsunami.

The third is to analyze and calculate possible tsunami effect through models, including tsunami source estimation around coastal area of China and the calculation results of effect on NPP site from those tsunami sources. Upon model calculation, the water increase value of coastal NPP site in China resulting from tsunami is much lower than that resulting from storm surge.

It is mainly broad shallow water continental shelf terrain in the coastal sea area in China. There are arc-shaped ring formed by many islands and cays in offshore sea area, and Kyushu Islands, Ryukyu Islands as well as Philippine Islands outside offshore sea area, forming two natural barriers to defend tsunami. As recorded, tsunami driven by earthquake had almost no effect on offshore sea area of China. According to seismic geological background, marine hydrological condition, and historical earthquake-produced tsunami assessment results of NPP siting, coastal area in China does not possess conditions of large-scale earthquake-produced tsunami.

Recheck evaluation of tsunami effect:

After Fukushima nuclear accident, recheck evaluation on tsunami were developed in comprehensive nuclear safety inspection and data about international historic large-scale tsunamis were collected. Those tsunamis have a common characteristic, that is, tsunamis happened in circum-Pacific and circum-Atlantic plate tectonic boundary, which were in line with seismic zone distribution and belonged to seismic source of plate subduction zone type.

The recheck study pays much attention to the effect of large-scale earthquake-produced tsunami in plate subduction zone around coastal area on coastal NPP. The nearest plate subduction zone from coastal area of China is Ryukyu trench outside Donghai Sea, and the other plate subduction zone is Manila trench at east of Nanhai Sea.

Main conclusions of recheck evaluation are as follows:

(1) The coastal sea area of China belongs to continental shelf type sea area, whereas eastern Japan belongs to subduction zone of Pacific plate toward beneath Eurasian plate, so that the sea areas in China are quite different from that in Japan in tectonic setting, and the earthquake-produced tsunami similar to Earthquake & Tsunami in Japan March 2011 will not happen in coastal area of China.

(2) NPP siting assessment in coastal area of China demonstrates that flood in coastal area of China is basically under control of storm surges. Storm surge is decided as the extreme event in design basis flood-combined factors, which is in line with seismic and hydrometeorology conditions in coastal area of China.

(3) Survey of historical tsunami sediment in coastal area of China reveals that was no large-scale tsunami in coastal area of China in history.

(4) The study at present shows that tsunami risk in China mainly originates from strong earthquake happening in Manila Trench, which will influence NPP in coastal area of Guangdong Province. Generally speaking, tsunami risk is so small that safety of NPP can not be menaced directly. Considering weakness in tsunami research, related departments of China are developing a profound research and discussion to further analyze climbing effect of tsunami, effect of tsunami wave strikes on flood control structure and protection ability of existing embankment facilities of related NPPs.

1.5 Improvement measures of external events

Based on problems found in comprehensive nuclear safety inspection, main improvement measures of external events are as follows:

(1) Based on possible submerging situations of all NPPs, inspect and complete plugging or waterproof measures of pipes ditches, corridors, doors, windows, penetrations, etc. , improve the waterproof ability and the ability against submerging of important plant buildings and equipment, keep the physical separation, diversity and availability of key safety system and meanwhile strengthen information exchange and real-time communication with meteorological, ocean and seismic departments.

(2) Complete risk assessment of existing flood control facilities and improve flood control ability by heightening sea wall, increasing wave wall, adding waterproof and drainage facilities in safety plant buildings, timely warning and other measures.

(3) Reinforce the maintenance and management of seismic monitoring and recording instruments and devices to ensure the effectiveness of monitoring and recording system, improve the post-earthquake operation specification of operators in combination with the field condition to improve anti-seismic response ability.

(4) Develop probabilistic safety analysis on external event and assessment on anti-seismic allowance, study the effect of important natural disasters and extreme external events superposition beyond the design basis on NPP safety, and fulfill risk prevention and safety improvement tasks.

(5) Further improve the emergency planning of extreme natural disasters, follow up and study variation trend and industrial practice of nuclear safety requirement about external events in international nuclear energy circle and revise Chinese laws and regulations on nuclear safety in time.

2. Design Issues

2.1 Design requirements related to severe accidents

In April of 2004, the MEP (NNSA) promulgated the amended "Code on the Safety of Nuclear Power Plant Design", which stipulated that countermeasures against severe accidents shall be considered in the design of newly-built NPPs. Although high-reliability design is provided for current nuclear power plants to cope with the design-basis accidents (DBAs) so as to prevent the core from severe damage and to inhibit the releases of radioactive substances, it is still possible to cause severe damage of the core by certain extremely low probability events. Hence, the newly built nuclear power plants shall be required in design to take following measures into considerations for severe accidents based on the operating experience and combined with the results of safety analyses and safety studies.

- Identify the important events sequences which can lead to severe accidents by combining the probabilistic and deterministic methods with rational engineering judgments.
- Determine which severe accidents shall be considered in the design according to a set of review criteria.
- For the selected event sequences, evaluate the modifications of design and the changes of procedures which may decrease the events' probabilities or mitigate their consequences if occurred, these measures shall be taken if they are reasonable and feasible.
- The whole designed capabilities shall be considered, including using certain systems (safety systems and non-safety systems) and additional temporary systems under the conditions beyond predefined functions and anticipated operating conditions, to make the NPP return back to the controlled status and/or to mitigate severe accident consequences. The condition is that these systems and equipment can fulfill their functions in the anticipated situation.
- For the multi-unit NPPs, applications of available means and/or supports from other units shall be considered provided that the safety operation of other units is not jeopardized.
- Accident-management procedures shall be formulated for the representative and predominant severe accidents.

2.2 Design of NPPs to prevent and mitigate severe accidents

Operation NPPs:

All Chinese NPPs are provided with engineered safety features as safety injection system, containment spray system, containment hydrogen concentration control and air monitoring system, auxiliary feedwater system of the steam generator, containment isolation system etc. Engineering safety features are used to limit the consequences caused by damaged radioactive product shielding of hypothetical events. The performance of engineered safety features is verified by periodic testing.

In Chinese nuclear power plants, there are containments to enclose radioactive material releasing from the core, and to reduce to minimum the discharge of radioactive material to the environment so as to protect the public and the environment.

In order to realize units status control of post-accident, Chinese NPPs establish the post-accident monitoring system. The instrument and equipment of the post-accident monitoring system can work under severe environment and provide correct information of post-accident unit status.

Chinese NPPs are provided with the accident management procedure which covers from anticipated transient events to design basis accidents of the unit. The accident management procedure of some NPPs even extends to beyond-design basis accidents (e.g. plant blackout, steam generator deprived of all feedwater) to take precautions against and mitigate accidents with lower probability of occurrence.

A series of improvement measures on design have been taken for the construction NPPs in China, including equipping perfect flammable gas control system and adopting depressurization extension of voltage stabilizer to further improve the safety and reliability of NPPs and strengthen the ability of accident prevention and mitigation.

Construction NPPs :

As for the construction NPPs , the design and safety improvement shall follow the principles as follows:

- Satisfy requirements of Chinese laws and regulations on nuclear safety;
- Meet demands on progress of nuclear power technology;
- Consider experience feedback from the same type construction and operation units of home and abroad;
- Consider improvement requirements on weakness from probabilistic safety assessment;
- Refer to appropriate design requirements of AP1000, ERP and other international advanced NPPs.

Currently, technology for most construction NPPs in China has been improved based on mature million-kilowatt pressurized water reactor NPPs, and standard design has been formed. Moreover, a batch of safety improvement items have been studied and implemented according to operation experience and safety research of NPPs and changes of nuclear safety requirements, including: digital control and protection system, passive hydrogen recombiner in containment, depressurization extension of pressurizer safety valve, wet pressure relief and filtration system, improving the fire protection system design, increasing volume of auxiliary water supply tank and refueling water tank, improve the configuration of emergency feed water system, modify emergency diesel generator set, etc.

Sanmen NPP and Haiyang NPP now have two AP1000 units under construction respectively; Taishan NPP has two ERP units under construction. As for AP1000 and ERP reactor type, Ministry of Environmental Protection (National Nuclear Safety Administration) exchanges with other countries and international organizations actively to share the study achievements and supervision practice, strengthen safety supervision as independence of EPR safety instrument control system, AP1000 shield building design, design verification of explosion valve, etc.

2.3 Re-evaluation of related design of NPPs

After Fukushima nuclear accident, NPPs in China performed re-evaluation on power plant design relating to external events, prevention and mitigation of severe accident, nuclear accident emergency, etc. Moreover, inspections on power supply reliability, cold source reliability, hydrogen control and fire protection system design were emphasized in comprehensive safety inspection according to lessons from Fukushima nuclear accident.

The results reveal that the design of NPPs in China can satisfy the requirements of current laws and regulations on nuclear safety as well as the latest standards of IAEA. The safety design level of NPPs in China has been improved greatly through introducing, digesting and absorbing mature technology, learning operation experience and safety research achievements of the same type units

at home and abroad as well as continuous design improvement. Some of the lessons from Fukushima nuclear accident have been concerned in modification of operation units and design of construction units.

Self-review and comprehensive safety inspection of NPPs have also identified some potential safety improvement fields, including: improvement on station blackout (SBO) event, containment filtration system, spent nuclear fuel pool exhaust heat removal and cooling, fire protection system, etc.

According to safety importance and availability, those improvements can be further divided into short-term, medium-term and long-term improvements as well as the improvement requiring special study. For different NPPs, corresponding plans will be made and corresponding improvement measures will be implemented in combination with respective characteristics and with reference to nuclear safety study achievements and practice of same type units at home and abroad.

2.4 Improvement measures related to design

According to comprehensive safety inspection results, the design improvements completed or planned to be completed are as follows:

(1) Formulate solutions for station blackout (SBO) accident, improve emergency water supply ability in the condition beyond design basis to ensure cooling of reactor core and spent nuclear fuel pool, prevent small break loss-of-coolant accident of shaft seal of reactor coolant pump.

(2) Keep necessary monitoring and response abilities post-accident. Configure portable source, portable pump, water-injection pipeline and matched interfaces, and improve the application procedures on water source of plant site in case of accidents.

(3) Set monitoring equipment of liquid level and temperature of spent nuclear fuel pool during long cooling period after accident, and improve redundant measures of monitoring and water supply of spent nuclear fuel pool.

(4) Increase diesel engine fuel oil reserve, prepare guarantee planning of emergency diesel engine set and study specific measures for supporting emergency power sources among sets to respond to blackout of multiple units offsite power sources.

2.5 R&D of advanced pressurized water reactor in China

To further improve the safety of newly built NPPs in future, China is committed to independent R&D of large-scale advanced pressurized water reactor NPPs to comprehensively promote the ability of handling extreme external events and severe accidents, ensure stability of core molten debris and integrity of containment, and protect the public as well as the environment. Currently, the projects in progress mainly include CAP1400, AC1000, ACPR1000, etc.

R&D of CAP1400 is based on design of AP1000, in which the rated electric power is increased by about 20% on the premises of ensuring the safety. Through experience feedback of localized support projects of AP1000 of China, the design organization develops design analysis for key equipment such as nuclear steam supply system, passive safety system, steam generator, pressure vessel and reactor internals, auxiliary system in NPP and plant building arrangement. After Fukushima nuclear accident, the design organization also plans to take measures to strengthen the abilities as external submerging prevention beyond design basis, guarantee of power and water source for 72h and liquid level monitoring of spent nuclear fuel pool.

R&D of ACP1000 is based on existing million-kilowatt pressurized water reactor NPPs in China, in

which mature technology and equipment are adopted to greatly prevent and mitigate severe accident upon system reconstruction and modification and to meet the requirement of performance indicators of advanced pressurized reactor. The main safety design improvements are as follows: in-core neutron flux monitoring through the top of pressure vessel, active-passive reactor cavity cooling system, passive residual heat removal system of secondary, passive containment heat discharging system are set; in-containment refueling water storage tank, double containment are adopted; and emergency boron-injection system is set.

R&D of ACPR1000 is based on relatively mature CPR1000+. In detail, triple series engineered safety system and double containment design are adopted and solutions to severe accidents are systematically considered to improve anti-seismic design basis, reduce liner heat generation rate of core and improve safety margin of reactor core. As a technical transition, the design organization is working for the design of ACPR1000-P, and the important design improvements to be taken include: increase water injection in reactor cavity, temporary water supply at secondary and spent nuclear fuel pool; add special processing cabinet and storage battery for severe accidents; increase auxiliary emergency power supply, online oil supply function of hydrostatic test pump power supply system, etc.

3. Severe accident management and recovery (on-site)

3.1 Management Requirements and current situation of severe accidents

Ministry of Environmental Protection (National Nuclear Safety Administration) formulated and issued "Technology Policy of Several Important Safety Issues for Design of newly-built NPP" in 2002, with 14 requirements proposed to prevent and mitigate severe accidents to be considered in NPP design.

In 2004, Ministry of Environmental Protection (National Nuclear Safety Administration) released new versions of "Code on Safety of NPP Design" and "Code on Safety of NPP Operation" and extended the beyond design basic accident operation procedures to the field of severe accident. It also proposed specified requirements for severe accidents management by combining international practices, as shown in Chapter 2.1 of the Report.

"Code on Safety of NPP Design" indicates that "the code involves accidents which are unlikely to happen, such as severe accidents that may lead to a great quantity of radioactivity release, prevention and mitigation measures provided in the design are appropriate and applicable for such accidents." Comprehensive safety analysis is required for NPP design to meet the specified safety goal, which shall also take into account the sequence of events that may result in severe accidents apart from normal operation, anticipated operational occurrence and design basis accidents of the NPP. As the fourth layer of defense-in-depth to ensure the safety of NPP, "Code on Safety of NPP Design" requires that radioactivity release shall be maintained low as practical as possible in the severe accidents that design basis may have been exceeded.

"Code on Safety of NPP Operation" requires that "personnel of NPP shall be educated on dealing with beyond-design basis accidents and the training of operators shall guarantee them a good familiarity with the signs of beyond-design basis accidents and accidents management procedures." Meanwhile, periodical safety review must cover accident management. "Code on Safety of NPP Operation" defines "accident management" as a series of taking actions during the progress of beyond-design basis accident, involving preventing incidents from upgrading to severe accidents, mitigating consequences of severe accidents and realizing stable safety state for a long time. National Nuclear Safety Administration has also organized to prepare "Technical Policy of Severe accident Management for Operating NPP", which played an active role in promoting works concerning severe accident management of NPP in our country even it was not formally issued.

To better guide and standardize severe accident management of China's NPPs, Ministry of Environmental Protection (National Nuclear Safety Administration) has also revised "Design of the Reactor Containment Systems for NPPs" and formulated "Management on Severe accident of NPPs", which shall be released in the form of nuclear safety management guide and technical document.

"Code on Safety of NPP Design", "Code on Safety of NPP Operation", "Design of the Reactor Containment Systems for NPPs" and "Management on Severe accident of NPPs", which are all based on corresponding documents of IAEA, own internationally equivalent safety level.

Although the abovementioned requirements are raised for newly-built NPPs, the operation NPPs, with reference to the above requirements, have actively tracked and studied the advanced experience of international nuclear power industry and conducted research on relevant severe accidents to take reasonable and applicable actions in preventing and mitigating severe accidents by combining actual conditions, thus continuously improving the management of severe accident in NPPs, with the major measures as follows:

(1) Adopt systematic methods to perform self-evaluation on weaknesses of severe accidents, and

propose reasonable and applicable improvement measures;

(2) Adopt probabilistic safety analysis method and select representative and dominate severe accident sequences to analyze accident sequence process., then, select appropriate management strategies of severe accident based on various severe accident phenomena;

(3) Investigate the latest tendency of severe accident study in international nuclear power industry, launch the research and formulation work of procedures and guides for severe accident management, establish organization for severe accident management and conduct personnel training and exercise on severe accidents;

(4) Perform engineering evaluation on instruments, equipment, systems, and facilities of preventing and mitigating severe accidents, demonstrate the applicability and capacity under conditions of severe accidents, and perform design improvement and engineering modification to enhance the capacity of preventing and mitigating severe accidents as necessary.

(5) Large quantity of research and improvement has been done to prevent high-pressure core melt and anti hydrogen explosion of power plant.

3.2 Inspection and evaluation of severe accidents

After Fukushima nuclear accident, comprehensive safety inspection, based on currently valid and latest regulations and standards, involves prevention and mitigation measures of severe accidents as well as reliability as the focal points of inspection.

The inspection result shows that China has taken necessary prevention and mitigation measures into consideration of power plant design and operation management at present, which can resist various risks within the scope of design basis accident and have acquired the capacity of controlling and mitigating beyond-design basis accident. However, there is still much room for improving the severe accident management of NPP based on the lessons from Fukushima nuclear accident, thus more adequate and effective technical and management measures shall be applied. Main weaknesses in severe accident management include:

(1) The formulation of Severe accident Management Guidelines (SAMG) for some operating NPPs has not been completed yet, only some specified procedures are applied to prevent and mitigate certain specific beyond-design basis accidents.

(2) Operating NPPs which have finished formulation of SAMG are still lack effective training and exercise to ensure the effectiveness of SAMG.

(3) Some NPPs in operation and under construction lack necessary measures to prevent and mitigate severe accidents due to early design.

(4) Demonstration of equipment availability under severe accident condition still witnesses deficiency of clear goal and specific acceptance criteria;

(5) Research and analytical work of level II PSA should be carried out to consider the containment response to different severe accidents sequence.

3.3 Improvement measures related to severe accidents

To improve the ability of preventing and mitigating severe accidents, the following measures are mainly adopted:

(1) Research to improve the reliability, diversity, redundancy and independence of equipment, power supply and communication channel based on site condition of power plant and considering the potential danger which may lead to extreme natural events, meanwhile, meet the demands of

seismic resistance and water resistance, thus improving the availability of key equipment and instruments in severe accidents.

(2) Perform on-line monitoring, regular maintenance, in-service inspection and test on key safety equipment and facilities of NPP. Meanwhile, timely and effectively conduct periodical safety review and probabilistic safety analysis to recognize and correct defects of equipment as early as possible, thus ensuring the equipment to exercise safety function in severe accidents.

(3) Evaluate the applicability of equipment and systems used for mitigating accidents in severe accidents. Then improve and optimize relevant systems and equipment based on assessment result, and take adequate material and personnel preparation into consideration to guarantee that power plant is able to coping with accidents for a long period when off-site rescue is unavailable.

(4) Determine the main accidents sequence which may result in severe accidents by combining relevant safety research and the practice of similar power plant based on PSA. On the above basis, adopt reasonable and feasible prevention and mitigation measures, such as control measures of flammable gas in severe accidents, measures of preventing high-pressure retention ejection, measures of preventing containment bypass, etc.

(5) Perfect and maintain necessary monitoring system of post-accident core status and improve the monitoring capacity of spent nuclear fuel pool. Meanwhile, carry out effectiveness research on waste treatment of severe accidents and further improve the radioactive waste processing system. Then analyze and evaluate the reliability of safety class digital control system and seek the weaknesses for improvement.

Human resource and training:

After Fukushima nuclear accident, human resource and training situation enjoyed more attention from China's NPPs in severe accident management, with the following major measures taken:

(1) Perform overall review on severe accident management, relevant technical document system, regime, etc., and conduct self-evaluation on manning, training, qualification and authorization of important safety posts.

(2) Strengthen the training of personnel in power plant on severe accidents management, esp. beyond-design basis accident. Meanwhile, enhance the targeted training, field simulation exercise and simulator exercise for accident procedure operators and supporting crews.

(3) Adjust the training and exercise planning of beyond-design basis accident for operators with training planning and refreshment training period of Severe accident Management Guideline (SAMG) reformulated.

(4) At the level of enterprise group, research the unity of SAMG management and maintenance as well as training materials through resource integration and unified input.

Severe Accidents Management Guidelines:

China's NPPs which have been put into commercial operation are further perfecting Severe Accident Management Guideline (SAMG) and related procedures based on the experience feedback of Fukushima nuclear accident. NPP under construction shall complete SAMG preparation before initial loading as required by regulatory body, with the main measures as follows:

(1) Formulate and optimize severe accident management guideline and strengthen the severe accidents management and recovery ability of nuclear power base and multi-unit with regard to various complex accident conditions and condition of common cause failure in multiple-reactor site.

(2) Overall review and optimize on existing accident procedures and consider safety management on spent fuel storage facilities under severe accident conditions. All power plants shall evaluate and modify accident procedures based on system update and reconstruction, regular safety review and

probabilistic safety analysis, use experience of accident procedure, research of accident evolution, etc.

(3) Analyze the power supply reliability of NPP, analyze and evaluate long-term plant blackout accident, thus formulating corresponding preventive measures and emergency planning;

(4) Improve and perfect environmental monitoring ability and function of emergency control center under severe accident conditions.

4. National organizations

4.1 Supervision and management of nuclear safety

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):

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. Additionally, it has established a long-term and stable partnership with other technical support units.

Ministry of Environmental Protection (National Nuclear Safety Administration) set up Nuclear Safety and Environmental Expert Committee and Expert Committee of Nuclear and Radiation Safety Regulations, so as to play advisory role in significant technical decision, important supervision activity, preparation of nuclear safety rules, technological development of nuclear safety and other aspects.

Ministry of Health

Ministry of Health is in charge of preventive treatment of occupational diseases in NPP and medical emergency rescue of nuclear accident. It is responsible for formulating hygienic codes and standards related to the health of personnel working in NPPs and general public; monitoring exposure dose of personnel working in NPPs and general public; the health management of personnel working in NPPs and the evaluation of adverse impacts on human body due to nuclear contamination; the prevention and cure of radiation injury; sanitation censoring, and final acceptance of construction for siting and design of newly constructed, expanded and transformed nuclear power projects.

China Atomic Energy Authority

China Atomic Energy Authority (CAEA) is the nuclear industry administration in China. It is responsible for researching and drafting out policies and regulations for peaceful utilization of atomic energy in China; researching and establishing developing program, planning and nuclear industry standard for peaceful utilization of atomic energy in China; organizing demonstration, reviewing and approval of relevant science and technology research project on peaceful utilization of nuclear energy; surveillance and coordination of the implementation of science and technology projects; taking control of nuclear materials and physical protection of nuclear installations; review and management of nuclear export; communication and cooperation in nuclear energy field among governments and also among international organizations; taking part in the IAEA and its related activities on behalf of the Chinese government; undertaking emergency management of state

nuclear accidents and leading on organizing the National Coordinating Committee for Nuclear Emergency; developing, preparing and implementing national nuclear accident emergency plan; the decommissioning of nuclear installations and the treatment of radioactive waste.

National Energy Administration

The National Energy Administration is the administrative department of energy resource industry of China. It is in charge of leading on drafting out laws and regulations related to nuclear power; drafting out and implementing developing program, conditions for access and technical standards of nuclear power; putting forward the layout of nuclear power and opinions about review of significant project; organizing coordination and guidance of scientific research of nuclear power; organizing the emergency management of the NPPs; international cooperation and communication among governments in the field of nuclear power.

4.2 Linkage between departments and enterprises after Fukushima nuclear accident

After Fukushima nuclear accident, Chinese government has made corresponding deployments immediately and developed comprehensive safety inspection for nuclear facilities across the country. Ministry of Environmental Protection (National Nuclear Safety Administration), National Energy Administration and China Earthquake Administration have jointly formulated “Comprehensive Safety Inspection Implementation Planning of Civil Nuclear Facility” and inspected all the NPPs in operation or under construction in China together.

Ministry of Environmental Protection (National Nuclear Safety Administration), National Energy Administration, China Earthquake Administration and State Oceanic Administration People’s Republic of China organized information collection regarding earthquakes in costal areas and analyzed and assessed the information to reassess the influence of tsunami on NPPs. Moreover, Ministry of Environmental Protection (National Nuclear Safety Administration), State Oceanic Administration People’s Republic of China and China Meteorological Administration reassessed based on the evaluation of storm surge and maximum precipitation.

Member departments of China's National Nuclear Emergency Coordination Committee, Ministry of Foreign Affairs, Ministry of Industry and Information Technology, Ministry of Environmental Protection, Ministry of Health, General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China, China Meteorological Administration, State Oceanic Administration People’s Republic of China and National Energy Administration held an emergency meeting to initiate immediately the emergency planning, follow, study and judge the latest progress of nuclear accident, actively study and take countermeasures by way of regular consultation system, strengthen the radiation monitoring of environment, meteorology, oceans, food, drinking water and port and release the latest information timely.

The National Nuclear Accident Emergency Office organized experts and authoritative institutions in related fields in China to make analysis, study and judgment on tendency and influence of radioactive substance on environment and the public of China of Fukushima nuclear accident so as to provide technical reference for important policy decision, organized related departments to hold a consultation every day and release the latest authoritative information to stabilize the public.

All nuclear power utilities followed the accident progress closely, initiated related emergency planning, released corresponding instructions to the NPPs subordinated and carried out support and advice.

4.3 Related improvement measures after Fukushima nuclear accident

Adjustment of national organization

In order to further strengthen the construction of nuclear safety regulation and improve the nuclear safety regulation after Fukushima nuclear accident, the central government of China decided to revoke Department of Nuclear Safety Management (Department of Radiation Safety Management) of Ministry of Environmental Protection (National Nuclear Safety Administration), and set up Department of Nuclear Facility Safety Supervision, Department of Nuclear Power Safety Supervision and Department of Radiation Source Safety Supervision to take charge of nuclear and radiation safety supervision of China.

Department of Nuclear Emergency was added for China Atomic Energy Authority to be responsible for national nuclear accident emergency preparedness management, construction of a nuclear emergency response capability, organization and coordination of accident rescue work.

Department of Nuclear Power was set up for National Energy Administration to take charge of the development and management of nuclear power energy in China.

Construction of technical capacity

After Fukushima nuclear accident, Chinese government strengthened the political guidance further, formed the nuclear safety technology innovation mechanism led by national investment and dominated by enterprise investment, increased the researching funding, set up nuclear safety technology R&D project and listed it into national technology development and management system to be implemented by the national nuclear safety regulatory body.

Chinese government adjusted the supervision and management organizations and further strengthened the construction of nuclear safety regulation on the basis of increasing human resource and funds. In addition, Chinese government emphasized the construction for R&D base of the national nuclear safety regulation technology, organized nuclear safety analysis and evaluation, verification & calculation, construction of experiment ability, basic ability of supervision and reinforcement, and radiation monitoring ability, reinforce comprehensively the nuclear safety regulation review, supervision, monitoring, education and international operation abilities.

After Fukushima nuclear accident, Chinese government and all power group corporations, operating organizations of NPP as well as related supporting organizations have developed multidirectional and profound exchanges and cooperation in the industry, held seminar regarding Fukushima nuclear accident for several times to deeply exchange and analyze related experience and lessons. Based on experience and lessons from Fukushima nuclear accident, they study and analyze the safety and potential problems of NPPs operated in China and for the NPPs under construction, put forth the solutions to provide important references for the formulation and management decision of nuclear safety planning and also point out the direction for operating organizations and technical support organization (TSO) ability construction.

Construction of laws, regulations and standards

China has established a set of complete system of laws and regulations on nuclear safety. After Fukushima nuclear accident, Chinese government analyzed the accidents profoundly and led to a conclusion in 26 aspects. The conclusion covers nuclear safety management system mechanism, siting safety, design safety, operation management and accident emergency response and puts into consideration at different levels of nuclear safety regulations system.

On the basis of following and studying the development tendency of international nuclear safety laws, regulations and standards continuously and participating in the regulation revision of IAEA actively, China sufficiently analyzed the gap between the technical requirements in different fields of current nuclear safety laws and regulations in China and the improved nuclear safety requirements after Fukushima nuclear accident and organized revision of and improvement in current nuclear safety laws and regulations as well as standards step by step in different stages.

Establishment of long-acting linkage and coordination mechanism

In order to guarantee the coordination and uniformity of nuclear energy development and safety, Chinese government shall establish the check and balance mechanism in making industrial development strategy, planning and in early project approval, as well as the cooperation and coordination mechanism in construction of major projects between nuclear safety regulatory body and nuclear industry development departments. Nuclear safety requirements shall be taken as the important basis for making development decisions of relevant industries.

The natural disaster warning and emergency linkage mechanism and optimization management mechanism for the competent department of nuclear industry, nuclear safety regulatory body, meteorology, ocean, earthquake and other departments will be established to improve the management and control efficiency; The nuclear safety licensing system is to be improved in the principle of balance between responsibility and rights to guarantee that all nuclear power utilities hold the nuclear facility safety permit; The nuclear safety responsibilities among nuclear power utilities, owners and specialized companies will be further refined.

Furthermore, “Opinions of the State Council on Strengthening Major Environmental Protection Work” was issued on October 2011. It indicates that China will regard the operation of nuclear facilities as the regulatory emphasis, strengthen the safety review on newly-built and expanded nuclear facilities, perfect radiation environment monitoring and supervising system, promote the construction of R&D base for national nuclear safety regulatory technology, and establish regulatory technology supporting platform, thus ensuring nuclear safety.

5. Emergency preparedness and response and Post-accident management (off-site)

5.1 Requirements and present situation of emergency preparedness and response management

To improve the government's ability to guarantee public safety, dispose public emergency, prevent and reduce public emergencies and its damages aroused to the largest extent, guarantee life and property safety of the public and maintain the national security and social stability, Chinese government released master national emergency planning, a series of special national emergency planning, emergency planning of administrations of the State Council and local emergency planning. Along with the development of nuclear power in China, nuclear accident emergency management of China has gone on the track of systematism, standardization and institutionalization.

Major laws, regulations and implementation rules regarding nuclear emergency mainly include:

- "Act of Protection and Remedy of Radioactive Contamination of the People's Republic Of China"
- "Act of Emergency Response of the People's Republic of China"
- "Emergency Management Regulations for Nuclear Accidents of Nuclear Power Plant"
- "The State Nuclear Emergency Planning (the State Council, 2005)"
- "Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China (HAF001)"
- "Rules for the Implementation of Regulations on Emergency Management of Nuclear Accident for Nuclear Power Plant — Part One: Emergency Preparedness and Response for Operating Organization of Nuclear Power Plant(HAF002/01)"
- "Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China — Part Two: Safety Surveillance of Nuclear Installations(HAF001/02)"
- "Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China — Part Two Appendix One: The Reporting System for Operating Organization of Nuclear Power Plant(HAF001/02/01)"
- "Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China — Part Two Appendix Two: Reporting System for Research Reactor Operating Organization (HAF001/02/02)"
- "Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China — Part Two Appendix Three: Reporting System for Nuclear Fuel Cycle Facility (HAF001/02/03)"
- "Rules for the Implementation of Regulations on the Safety Regulation for Civilian Nuclear Installations of the People's Republic of China — Part Three:- Application and Issuance of Safety License for Research Reactor(HAF001/03)".

International conventions relating to nuclear emergency are as follows:

- "Convention on Early Notification of a Nuclear Accident"
- "Convention on Emergent Assistance of Nuclear Accident or Radiation"
- "Convention on Nuclear Safety"

In addition, there are a series of rules, guidelines and standards of departments relating to nuclear emergency.

Classification and response of emergency state

Emergency state of nuclear accident in NPPs of China is divided into four classes according to the influence of actual radiological consequence or the expected radiological consequence of the accident or incident: on standby, plant emergency, site area emergency and off-site emergency.

(1) On standby. In case of specific cases or external event that may endanger the safety of NPP, personnel concerned of the NPP shall be on alert.

(2) Plant emergency. In case the incident only affects local area in NPP, personnel of NPP takes action of nuclear accident emergency response according to requirements of site nuclear accident emergency planning and informs relevant nuclear accident emergency response organization offsite.

(3) Site area emergency. If the incident affects the whole plant area, personnel of the area takes action of nuclear accident emergency response and informs the department designated by the government at the provincial level. Moreover, some offsite nuclear accident emergency response organizations may develop nuclear accident emergency response.

(4) Off-site emergency. Influence of the incident has crossed the site boundary; hence offsite and onsite emergency planning of nuclear accident shall be implemented.

The emergency response responsibilities of nuclear emergence organizations at all levels are regulated in Article XXII of “Regulations on Emergency Measures for Nuclear Accidents at NPPs of the People’s Republic of China”.

When NPP is on standby, nuclear accident emergency organizations of a NPP shall report the condition timely to competent department of the NPP and nuclear safety departments of the State Council and decide whether to report it to the department designated by the government at provincial level on condition. If radioactive substances have been or are possible to be released, depending on the circumstances, determine to prepare in plant emergency or site area emergency state and report it immediately to the competent department of NPP, nuclear safety department of the State Council and department designated by the government of principal level. In case the radioactive substances are possible or have been spread outside NPP, propose to enter off-site emergency state and to take emergency protective measures to the department designated by the government at provincial level.

After receiving the report of nuclear accident from nuclear accident emergency organization of the NPP, the department designated by the government at the provincial level shall take corresponding nuclear accident emergency countermeasures and emergency protective measures immediately and report it to the department designated by the State Council timely. If off-site emergency state is to be entered, approval from the department designated by the State Council must be obtained. In special cases, the department designated by the government at the provincial level can decide entering off-site emergency state first and then make report to the department designated by the State Council immediately.

Nuclear accident emergency organization of NPP and the department designated by the government at the provincial level shall develop forecast and evaluation of nuclear accident consequence as well as environment radioactivity monitoring to provide basis for taking nuclear accident countermeasures and emergency protective measures.

The department designated by the government at provincial level shall take such measures in time as hiding, taking stable iodine, controlling channel, controlling foods and water source, withdrawing, moving, decontaminating the area affected and so on.

Nuclear accident emergency organization of the NPP and the department designated by the

government at the provincial level shall do well on rescue, decontamination, transfer and medical disposal for personnel suffered from nuclear radiation on accident site.

In the off-site emergency state of nuclear accident, the department designated by the State Council shall dispatch personnel to come to the site timely to give guidance on nuclear accident emergency response and the suggestions on assigning rescue personnel if necessary. Regional blockade can be implemented if it is necessary to take nuclear accident emergency response. Regional blockade in single administrative division of provincial, autonomous region and municipality directly under the Central Government level shall be decided by respective province, autonomous region and municipality directly under the Central Government; regional blockade crossing provinces, autonomous region and municipality directly under the Central Government and causing interrupted arterial traffic shall be decided by the State Council.

Emergency report system:

In case of nuclear accident in an NPP, operating organization shall make report to Ministry of Environmental Protection (National Nuclear Safety Administration), local supervision station and superior competent department timely, including nuclear accident emergency notification and nuclear accident emergency report. The report system is as follows:

(1) Nuclear accident emergency notification:

Operating organization shall send out emergency notification by telephone and telefacsimile to the Emergency Center of Ministry of Environmental Protection (National Nuclear Safety Administration), local supervision station and the superior competent department within 15 minutes after the occurrence of accident and entering on standby or higher emergency states.

(2) Nuclear accident emergency report (including initial report and sequent report)

Operating organization shall send out emergency report by telefacsimile to the Emergency Center of Ministry of Environmental Protection (National Nuclear Safety Administration), local supervision station and the superior competent department, departments designated by the provincial government, the national nuclear accident emergency response office within 45 min after the occurrence of accident and entering plant emergency or higher emergency states.

After sending out initial report, operating Organization shall send out sequent report by telefacsimile to the Emergency Center of Ministry of Environmental Protection (National Nuclear Safety Administration), local supervision station and the superior competent department, departments designated by the provincial government, the national nuclear accident emergency response office hourly.

In case of alteration of accident source item or emergency state class, operating organization shall send out sequent report by telefacsimile to the emergency center of Ministry of Environmental Protection (National Nuclear Safety Administration), local supervision station and the superior competent department, departments designated by the provincial government, the national nuclear accident emergency response office immediately and then deliver a sequent report hourly.

After the nuclear accident is controlled, operating organization shall send out sequent report by telefacsimile to the Emergency Center of Ministry of Environmental Protection (National Nuclear Safety Administration), local supervision station and the superior competent department, departments designated by the provincial government, the national nuclear accident emergency response office every 4 hours till exiting the emergency state.

(3) Final evaluation report

Operating organization shall submit the final nuclear accident evaluation report to Ministry of Environmental Protection (National Nuclear Safety Administration), local supervision station and the superior competent department, departments designated by the provincial government, the

national nuclear accident emergency response office within 30 days after exiting the emergency state.

Emergency radiation environment monitoring

Under nuclear accident emergency circumstance, the operating organization of NPP and local nuclear and radiation environment monitoring departments shall undertake the responsibilities of monitoring nuclear and radiation environment, which shall be guided and coordinated by off-site emergency committee (the provincial government generally) so as to fully coordinate the resources and activities of all parties and unify the action.

In early stage of nuclear accident, operating organization of NPP takes charge of nuclear and radiation monitoring near site relying on the site area emergency nuclear and radiation monitoring resource and power. In later stage, the operating organization develops nuclear and radiation monitoring relying on the offsite monitoring resource and power because the involvement of the recovery in large area. In middle stage of the accident, environment monitoring is undertaken jointly by the site and offsite parties.

Present situation of emergency preparedness and response

As for nuclear accident emergency, China has established three-class nuclear accident emergency organization systems, including national nuclear accident emergency organization, nuclear accident emergency organization of the province, autonomous region and municipality as well as nuclear accident emergency organization of the NPP operating organization. To be specific, they are the National Nuclear Accident Emergency Coordination Committee set by the State Council, Local Nuclear Accident Emergency Coordination Committee set by the government of the province (autonomous region and municipality) where the NPP is located and Emergency Command Department founded by NPP operating organization. The three-class nuclear accident emergency organization systems are respectively responsible for the emergency management of nationwide, local and organizational nuclear accidents. The organization structures and functions are regulated in “Regulation on Emergency Measures for Nuclear Accidents at NPPs of the People’s Republic of China (HAF002)”.

China’s National Nuclear Emergency Coordination Committee is composed of relevant departments under the State Council; it is responsible for implementing national policies to deal with public emergencies, drawing up national nuclear emergency response policy, and organizing to formulate national nuclear emergency planning. In case of emergency, China’s National Nuclear Emergency Coordination Committee uniforms the command decisions to coordinate national nuclear emergency rescue action; meanwhile, it is responsible for fulfilling related international conventions, bilateral or multilateral cooperation agreement, reviewing the scheme on international aid for nuclear emergency, and organizing its implementation.

In addition, related member organizations of the National Nuclear Accident Emergency Coordination Committee prepared/revised emergency planning, relevant people’s government at the provincial level improved the NPP accident emergency planning and implementation procedure and organized emergency exercise at regular base according to relevant laws and regulations, the nuclear safety regulatory body developed supervision and improved the supervision continuously. It is shown from years of practices that the effective nuclear emergency system in China guarantees the health development of Chinese nuclear power industry.

With the policy of “unremitting always, adapting actively, commanding uniformly, cooperating strenuously, protecting the public and the environment”, nuclear accident emergency preparedness and response in China has witnessed continuous improvement and optimization. At present, Chinese government is organizing to revise National Nuclear Accident Emergency Planning.

5.2 Off-site emergency response

According to “Regulations on Emergency Measures for Nuclear Accidents at NPPs of China”, the army, public security, fire protection, health, civil administration and other departments concerned will carry out corresponding rescue in case of off-site emergency. All departments of China have prepared emergency planning for response to ensure division of responsibilities and task cohesion in response to off-site emergency accident as well as rapid and effective response mechanism.

China has established a complete system for nuclear accident emergency in terms of radiation protection, environmental monitoring, medical rescue, transportation, decontamination and other technical support abilities. Ministry of Health has established Medical Emergency Center for Nuclear Accident that is divided into three clinical medical departments, and set up 17 radiation injury treatment bases. It has also established National Medical Rescue Team for Nuclear and Radiation Emergency with equipment provided, and conducted training and exercises, so as to rapidly carry out rescue in case of sudden nuclear and radiation accident. Medical Emergency Center for Nuclear Accident of Ministry of Health has established medical emergency communication system and technical support system of medical emergency for nuclear accident, and opened up communication with National Nuclear Emergency Office and other departments, thus providing effective guarantee for medical emergency processing of nuclear accident.

In case of severe accident, competent transportation department of province, autonomous region and municipality shall organize transportation team to take charge of implementing unified organization and leadership on transportation by combining support forces of other districts and departments under the leadership of Local Nuclear Accident Emergency Commission. Preparation and organization of transportation resource and forces are multilevel and multipath. Transportation department of province, autonomous region and municipality shall transfer and organize transportation forces for emergency response jointly with departments concerned. Emergency transportation forces shall mainly rely on local transportation forces. Provincial, autonomous and municipal governments shall instruct and transfer the forces of transportation departments in other areas near power plant for rescue when these forces are insufficient, and request the handy army to appoint transportation force for rescue when necessary. Water and air transportation forces can be transferred and appointed locally or by army.

Possible tasks undertaken by the army during nuclear accident emergency response involve: participating in radiation monitoring, decontamination, medical emergency rescue and engineering emergency rescue, providing support in terms of transportation, health, weather, communication, guard, protection and other aspects, and offering assistance in directing public protection locally.

5.3 Emergency response action after Fukushima nuclear accident

After Fukushima nuclear accident, National Nuclear Accident Emergency Office launched nation nuclear emergency coordination mechanism in the first time, coordinated nuclear emergency organizations at all levels to cope jointly, organized relevant experts inland to closely track the trends of the accident, timely and accurately collect information relating to various nuclear emergencies of Japanese and international nuclear community, organized relevant scientific research institutions and experts for analytical calculation and deep judgment, and submitted special information of nuclear emergency to departments concerned, thus providing scientific support for emergency decision. National Nuclear Accident Emergency Coordination Committee organized representatives of departments such as Ministry of Foreign Affairs, Ministry of Industry and Information Technology, Ministry of Environmental Protection, Ministry of Health, China Meteorological Administration, State Council Information Office of the PRC, State Oceanic Administration of the PRC, Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), etc. and relevant experts to hold a consultation and broadcast authoritative information on

CCTV for correctly guiding public opinion. Besides, it also coordinated nuclear emergency organizations at all levels to organize for comprehensively strengthening emergency work and maintaining social stability. Moreover, it fulfilled international obligations carefully in accordance with stipulations of "Convention on Assistance in Case of a Nuclear Accident".

After Fukushima nuclear accident, Nuclear and Radiation Safety Center, Radiation Monitoring Technical Center, local nuclear and radiation safety monitoring station, local department (bureau) of environmental protection and its radiation environmental monitoring organization, etc. took immediate action, launched radiation emergency monitoring procedure, developed nationwide radiation environment monitoring and released national radiation environment monitoring data everyday. Meanwhile, Ministry of Environmental Protection (National Nuclear Safety Administration) also set up "Relevant Issues on Nuclear Safety of Japan Earthquake" column on its official website and answered the public's questions by news conference and organizing experts for interview, etc.

Since March 13, National Automatic Radiation Environment Monitoring Station has performed real-time measurement on continuous variation of the air-absorbed dose rate of γ radiation in environment, to give warnings on any unexpected increase in ambient level. Ministry of Health has launched monitoring on food and drinking water, with the results released to the public timely. Some cities have also conducted continuous sampling measurement on isotope of inert gas xenon, monitoring on China-Japan round-trip flight, etc. It entered into normal monitoring till May 22.

After Fukushima nuclear accident, little radioactive substance was directly blown to China and no obvious abnormality was discovered in environmental radiation monitoring. However, certain radioactive sewage discharged to Pacific Ocean by Fukushima nuclear accident may generate certain influence on marine organism. China will continue tracking, monitoring and evaluating its long-term effect on environment and marine ecology.

5.4 inspection and evaluation on nuclear accident emergency management

After Fukushima nuclear accident, comprehensive safety inspection aimed at the problems during Fukushima nuclear accident emergency response and focused on inspecting the design and configuration of NPP environment monitoring system, conditions of emergency organization, habitability of main emergency facilities, provision and maintenance of emergency device, site area emergency communication system facilities, etc. based on self-check of all power plants.

The inspection shows that operation condition of the existing emergency management system is good; emergency document structure is integral with complete varieties of data; emergency training and exercise have been executed in NPP as required by emergency plan, with periodical inspection and test performed on emergency facilities and equipment. Through years of working practices, nuclear emergency working guidelines of "always on the alert, positive and compatible, central command, vigorous coordination, protecting the public and environment" have been implemented. However, Chinese government also realizes that emergency response mechanism and ability shall be further improved to make emergency organizations at all levels possess clear division of work, seamless connection, responsibility in place, adequate preparation, always on alert, quick response and resolute decision.

5.5 Relevant improvement measures for emergency preparedness & response and post-accident management (off-site)

To learn lessons from Fukushima nuclear accident, improvement measures determined for emergency preparedness and response by combining problems discovered in safety inspection are as follows:

(1) Research the response program of NPP after several units enter into emergency condition simultaneously in nuclear base, and evaluate emergency command capability as well as allocation and coordination planning for emergency rescue personnel and materials, so as to perform unified emergency management on nuclear base.

(2) Research to prepare emergency planning for nuclear emergency rescue, strengthen the emergency linkage between power plants and allocate emergency resources, manpower and material resources under serious natural disasters, thus ensuring effective handling even in case of a solitary-island-situation.

(3) Urge power enterprises or groups to improve emergency capability and bring it into the management scope of national nuclear emergency rescue and handling capability. Moreover, realize sharing of emergency resources and capability nationwide or regionally through effective coordination and organization.

(4) Evaluate the rationality of off-site environmental monitoring stationing of nuclear facilities, improve and perfect the function of NPP emergency control center, and strengthen the ability of accident diagnosis and predictive assessment on accident consequence as well as the ability of environmental emergency monitoring and predicting environmental radioactive consequences.

(5) National nuclear emergency management department, nuclear safety regulatory body, competent department of nuclear energy industry, ocean department and earthquake department shall strengthen information exchange and real-time communication, establish warning mechanism and emergency planning for preventing earthquake and tsunami, and further perfect national nuclear emergency system.

(6) Track and study management measures after off-site emergency accident taken by Japan after the Fukushima nuclear accident and used for improving China’s nuclear accident management system, thus preparing more effective long-term countermeasures.

(7) Track and study the trends of international nuclear safety codes and standards, and revise relevant Chinese nuclear safety codes and standards timely, so as to promote the synchronization of Chinese nuclear safety codes and standards with international ones and continuously improve the safety level of civil nuclear installations.

6. International Cooperation

6.1 Current situation of international cooperation in the field of nuclear safety

China attaches great importance to the international cooperation in nuclear safety and has signed, ratified or approved Convention on “the Physical Protection of Nuclear Material, Convention on Early Notification of A Nuclear Accident”, “Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency”, “Convention on Nuclear Safety”, “Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management” and other international conventions and conscientiously fulfills the obligations under the convention. During Fukushima nuclear accident, China’s government departments kept close contact with Japan, America, France and other international counterparts, exchanged and shared the information and experience with each other and timely reported relevant information to IAEA.

China holds that the active developing of international cooperation in nuclear safety is an important component of ensuring nuclear safety and the multilateral, bilateral and regional international cooperation in nuclear safety is very beneficial for ensuring nuclear safety by all cooperative parties. Over the past few years, outstanding achievements were obtained in the multilateral, bilateral and regional international cooperation in nuclear safety and made contributions to the improvement of China’s nuclear safety level.

Fulfillment of international conventions on nuclear safety:

China completed the preparation of national reports concerning all previous “Convention on Nuclear Safety” and “Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management” and fulfilled its duties, thus it obtained the unanimous recognition of the contracting parties and presented a good international image as a responsible nuclear power.

Multilateral cooperation:

The Integrated Regulatory Review Service (IRRS) provided by IAEA for China’s nuclear and radiation safety has been completed, and China was fully recognized by International Atomic Energy Agency (IAEA) and experts around the world. China actively took part in the Ministerial Conference on the Nuclear Safety of IAEA, the general assembly of agency in September, Senior Officials' Meeting on Nuclear Safety Supervision, the activities organized by Safety Standards Commission, etc., made full use of TC technology cooperation projects of the agency and peer review on expert service and consulted and carried out the nuclear safety action plan stipulated. Besides, it also actively participated in many important international cooperation projects like Multinational Design Evaluation Programme of Nuclear Energy Agency (NEA) of Organization for Economic Cooperation and Development (OCED), Generation IV Forum for Nuclear Energy Cooperation, International Thermonuclear Experimental Reactor (ITER) and Global Nuclear Energy Partnership (GNEP) and developed the cooperation with European Union in nuclear safety research and capacity building.

Regional cooperation:

Take full advantage of the mechanism of China–Japan–South Korea Senior Officials' Meeting on Nuclear Safety Supervision to pragmatically develop the international cooperation in nuclear safety and sign China–Japan–South Korea Nuclear Safety Cooperation Initiative to provide guidance for enhancing the nuclear safety cooperation in Northeast Asian region after Fukushima nuclear accident.

Bilateral cooperation:

Steadily promote the bilateral nuclear safety cooperation with America, France, Japan, Russia, Brazil, Spain and other countries, strengthen the interaction and training of personnel and sharing of information and experience, push forward the overseas supervision on nuclear safety equipment and absorb the advanced nuclear safety technology and supervision experience from foreign countries, make contributions to improving nuclear safety supervision ability of China and guaranteeing the evaluation and supervision on the domestic nuclear power projects in operation and under construction.

6.2 Response actions taken after Fukushima nuclear accident

After Fukushima nuclear accident, Chinese government immediately took corresponding countermeasures, actively developed the international cooperation in nuclear safety, pushed forward the preparations for the review on international conventions on nuclear safety through fulfilling the declaration in the Ministerial Conference on the Nuclear Safety of IAEA, participated in the revision of IAEA's nuclear safety standards and guide rules, developed the exchanges in terms of nuclear emergency, information notification, research and development of nuclear safety technology, etc., strengthened the cooperation and experience sharing with the international community in the field of nuclear safety, earnestly fulfilled the responsibilities and obligations given in the international conventions and made efforts to further improve the global nuclear safety level.

Exchange and cooperation with international organizations:

(1) China attended the Fifth Review Conference of Convention on Nuclear Safety held in Vienna, stressed that nuclear safety is borderless and all contracting states should learn profound lessons and reinforce the supervision on nuclear safety, and, as the presiding country, exchanged the positions and viewpoints on Fukushima nuclear accident with IAEA, Russia, America, France, Japan, Britain, Brazil and other countries.

(2) China attended the Ministerial Conference on the Nuclear Safety of IAEA's Members held in Vienna and advocated conscientiously sum up the experience and lessons, further perfecting nuclear safety standards, strengthening the sharing of nuclear safety information and giving full play to the leading role of IAEA.

(3) After Fukushima nuclear accident, China was invited by IAEA to send experts to join Fukushima Nuclear Accident Investigation Team to firsthand investigate the accident.

(4) China regularly accepted the peer review by IAEA, OSART and WANO, actively carried out the peer review among domestic nuclear sector and power groups, actively tracked the changes in peer review by WANO and IAEA after Fukushima nuclear accident and improved the domestic peer review system.

(5) China took part in all activities in the framework of NEA Multinational Design Evaluation Programme (MDEP) of OCED, especially the activities organized by AP1000 work group, EPR work group, digitized instrument control work group and MDEP Steering Committee (STC), communicated with the international counterparts in terms of the specific reactor and concrete technical matters and shared the achievements gained from the response actions taken after Fukushima nuclear accident.

(6) As the presiding country, China undertaken the Eleventh Biennial General Meeting of WANO. According to the decision made in the meeting, Unit Startup Peer Review Office would be set up in Shenzhen and the safety construction and review notification would be carried out before first criticality of NPP. China also directly participated in the work of WANO committee and put forward some viewpoints for improving existing business and structure of WANO. based on the Chinese nuclear power plant response activities and improvements.

(7) The government departments, NPPs, related technology supporting agency, IEAE and WANO jointly organized the seminar to study various topics in respect of NPP severe accident management, probabilistic safety analysis technique, the construction of integrated management system, etc., and made full use of various channels to collect, select, analyze and utilize the internal and external experience feedback information obtained after Fukushima nuclear accident.

Regional and bilateral exchanges and cooperation:

(1) Chinese government paid high attention to the process and treatment of Fukushima nuclear accident, timely sent the national rescue team to Japan to conduct rescue work in disaster area and provided the disaster area with disaster relief supplies and assistance many times. The department concerned exchanged with NISA and Japan Nuclear Energy Safety Organization (JNES) many times and jointly held China-Japan Nuclear Safety – Fukushima Nuclear Accident Symposium to discuss the countermeasures for Fukushima nuclear accident, sharing of experience, lessons and information and further cooperation. This symposium was the first meeting held by China and Japan for summing up experience and lessons drawn from the Fukushima nuclear accident after its occurrence.

(2) Upon the communication with French Atomic Energy Commission (CEA), Electricite de France (EDF) and National Assembly of France, they researched and discussed the experience and lessons drawn from the Fukushima nuclear accident and response actions taken by France and China, and shared the information on nuclear safety.

(3) Upon the communication with U.S. Nuclear Regulatory Commission (U.S. NRC), United States Department of Energy, Westinghouse Electric Corporation and Shaw Power Group, China researched and discussed the impact of Fukushima nuclear accident on nuclear safety requirements and strengthened the safety supervision cooperation between China and America in AP1000 NPPs and in-service NPPs.

(4) In May 2011, China, Japan and South Korea held the fourth leaders' meeting and released the *Declaration of the Fourth China–Japan–South Korea Trilateral Summit*. In this meeting, they reiterated the importance of the cooperation among them in disaster management and nuclear safety field and decided to promote the cooperation in respect of information exchange and notification, emergency rescue, experience sharing and nuclear safety cooperation according to the consensus reached at the meeting, etc.

(5) In October 2011, related departments of China, Japan and South Korea held the Fukushima Nuclear Leakage Hygiene Seminar in Beijing. The three parties discussed and communicated with each other in respect of hygienic countermeasures taken, risk assessment, risk communication, nuclear hygiene emergency, etc. conducted for leakage of Fukushima NPP.

(6) At the Fourth China–Japan–South Korea Senior Officials' Meeting on Nuclear Safety Supervision in November 2011, nuclear safety regulators of the three countries jointly signed the nuclear safety cooperation initiative and determined the framework for nuclear safety cooperation among them, thus providing guidance for the nuclear safety cooperation in Northeast Asian region after Fukushima nuclear accident.

(7) In November 2011, China held the Experience Exchange Meeting of Nuclear Safety Supervision with nuclear safety regulator of Russia and communicated with it in detail in respect of safety supervision of VVER type NPP and response actions of Russia and China after Fukushima nuclear accident.

(8) In February 2012, China held the Sixth Pakistan-China Nuclear Safety Cooperation Steering Committee meeting together with Nuclear Regulatory Commission of Pakistan and exchanged and shared the measures taken for and experience & lessons drawn from Fukushima nuclear accident.

(9) In February 2012, China conducted the bilateral exchanges with Nuclear Safety Council of

Spain, focused on NPP safety inspection after Fukushima nuclear accident and signed Spain-China Nuclear Safety Cooperation Agreement.

In addition, during the Fukushima nuclear accident, Ministry of Environmental Protection (National Nuclear Safety Administration) attached great importance to the headway of the accident, kept close contact with NISA to get the accident information timely and collected relevant information in many ways, closely tracked relevant activities and researches organized by the other countries and organizations like Japan, America, France, Russia, Ukraine, Canada, Finland and IAEA, and conducted the technical exchanges of nuclear safety to provide sound technological base for subsequent comprehensive safety inspection. NPP operating organizations and the group companies also developed extensive technical exchanges with nuclear energy circles of France, America, Japan and other countries.

6.3 Improvement plan concerning international cooperation

China will continue the analysis & research on Fukushima nuclear accident and the feedback of experience from the accident together with international counterparts, constantly strengthen the cooperation with the international organizations like IAEA and OECD/NEA, actively participate in the research and formulation of international nuclear safety standards, strengthen the bilateral cooperation with surrounding countries and the countries developing nuclear power, intensify the evaluation and supervision, reinforce technical exchange and experience sharing, improve emergency response capacity, make emergency preparations, strengthen event notification and share monitoring data.

Further strengthen the sharing of nuclear safety experience and capability in the world:

Nuclear safety is borderless. The impact of Fukushima nuclear accident on the environment and policies of the departments of all countries and the losses caused by it show that nuclear safety is a global issue and requires the countries to strengthen the cooperation, help each other and share the experience, lessons and capabilities.

Further strengthen nuclear accident information notification:

Strengthen the accident information notification with IAEA, timely know the accident occurrence and experience feedback of other countries and propose to establish China-Japan-South Korea Accident Information Notification Mechanism in East Asia.

Further strengthen the system and mechanism of international cooperation in nuclear safety:

Strengthen the establishment of the institution for fulfillment of Convention on Nuclear Safety and Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management to improve the fulfillment capability. And further deepen and strengthen the international exchange and cooperation in nuclear safety with the other countries through improving the ability of international exchange of nuclear safety.

Appendix I: List of NPPs Safety Improvement actions in China

Activities		Activities by the Operator			Activities by the Regulator[1]		
		(Item 2.a)	(Item 2.b)	(Item 2.c)	(Item 3.a)	(Item 3.b)	(Item 3.c)
Topic 1 – External Events							
External disaster warning and processing		Ongoing	Long term	N/A	Ongoing	Completed in 2012	Yes
Anti-flooding capability evaluation and improvement of key plants	Waterproof blocking of nuclear island facilities and buildings as well as interim waterproof measures adopted in key buildings	Taken	Completed at the end of 2011	Yes	Ongoing	To be completed in 2012	No
	Modification on flood protection facilities in all power plants of Qinshan Nuclear Power Site	Ongoing	Completed at the end of 2013	Yes			
	Increasing water-retaining wall in Tianwan NPP	Ongoing	Completed at the end of 2013	Yes			
Evaluation on seismic response and anti-seismic capability	Improving seismic monitoring and anti-seismic response capability	Taken	Completed at the end of 2011	Yes			
	Carrying out anti-seismic allowance analysis and safety analysis on probability of earthquake	Ongoing	Completed in 2013				
Evaluating the influence of on-site reservoir on Daya		Taken	Completed at the end of 2011	Yes			

[1] China's nuclear safety regulatory body shall perform supervision and management on important safety improvement measures adopted by power plant through technical review and site supervision. Therefore, the column "Actions taken by regulatory body" puts emphasis on technical requirements to be issued or research activity launched by regulatory body.

Bay Nuclear Power Site							
Evaluating the influence of earthquake and tsunami on power plant	Detailed evaluation on influences of earthquake and tsunami in all power plants of Daya Bay Nuclear Power Site	Ongoing	Completed at the end of 2012				
	Jointly analysis on influences of earthquake of distant origin (plate margin) on China's coastal power plants by several departments				Taken	Completed in 2011	Yes
Evaluation on safety allowance of important external events in operating power plant		Taken	In April 2012	Yes			
Probabilistic safety analysis on external event		Ongoing	In 2015				
Topic 2 – Design Issues							
Fire protection modification		Ongoing	Completed at the end of 2013	Yes			
Monitoring and water filling of spent fuel pool		Ongoing	Operating NPP shall be completed at the end of 2011 NPP under construction shall be completed before first fuel loading		Ongoing	Completed in 2012	
Improving power supply capability of storage battery		Ongoing	Completed at the end of 2013				
Increasing portable source, portable pump and other facilities		Taken	Completed at the end of 2011	Yes	Ongoing	Completed in 2012	
Increasing or modifying hydrogen recombiner		Ongoing	Completed at the	Yes	Ongoing	Completed in	

		end of 2013			2012	
Improving iodine absorber of activated carbon	Ongoing	Completed at the end of 2013	Yes			
Increasing diesel engine generator and improving fire protection system in Qinshan NPP	Ongoing	Completed at the end of 2013	Yes			
Evaluating and strengthening the cooling capacity of reactor core cooling and spent fuel pool under the condition of station blackout (SBO)	Ongoing					
Analyzing and evaluating the reliability of digital control system at security level	Ongoing	Completed in 2015				
Topic 3 – Severe Accident Management and Recovery (On-Site)						
Developing or optimizing Severe accident Management Guidelines (SAMG)	Ongoing	Operating NPP shall be completed at the end of 2013 NPP under construction shall complete phased work before first fuel loading and complete fully before 2015				
Evaluating and improving containment relief and discharge system of operating NPP	Ongoing	Completed in 2013	No			
Evaluating the ability of mitigating severe accident in NPP with two unit layout	Ongoing	Completed before first fuel loading				
Carrying out secondary probabilistic safety analysis	Ongoing	Completed in 2015				
Topic 4 – National Organizations						
Organization adjustment				Ongoing		

Construction of nuclear safety regulation capacity					Ongoing		
Construction of technical capacity		Ongoing	Long term		Ongoing	Long term	
Building of long-acting linkage mechanism		Ongoing	Long term		Ongoing	Long term	
Topic 5 – Emergency Preparedness and Response and Post-accident Management (Off-Site)							
Improving the habitability and functions of emergency control center in power plant under construction		Ongoing	Completed before first fuel loading		Ongoing	Completed in 2012	
Improving environmental monitoring and emergency monitoring measures of NPP		Ongoing	Completed before first fuel loading	Rationality evaluation of site has been completed	Ongoing	Completed in 2012	
Strengthening the ability of emergency preparedness and response	Researching the response program after several units entering into emergency state	Ongoing					
	Strengthening management on the second escape trunk in Daya Bay Nuclear Power Base	Taken	Completed at the end of 2011				
	Strengthening the emergency response capability building as well as capability sharing and mutual rescue mechanism of nuclear enterprises and groups	Ongoing	Long term		Ongoing	Completed in 2012	
Topic 6 – International Cooperation							
Fulfillment of “Convention on Nuclear Safety”		Completed	2011	N/A	Completed	2011	N/A
Ministerial Conference on the Nuclear Safety of IAEA					Completed	2011	N/A
The 11th annual meeting of WANO and the establishment of post Fukushima nuclear accident		Completed	2011	N/A			

Committee						
Expert support and information notification to IAEA				Completed	2011	Yes
the Fourth China–Japan–South Korea Senior Officials' Meeting on Nuclear Safety Supervision				Completed	2011	N/A
Fulfillment of China–Japan–South Korea Nuclear Safety Cooperation Initiative				Ongoing	Long term	N/A
China-Japan Nuclear Safety – Fukushima Nuclear Accident Symposium	Completed	2011	Yes	Completed	2011	Yes
The following and analysis of relevant experience feedback after Europe stress tests and Fukushima accident	Ongoing	Long term	N/A	Ongoing	Long term	N/A

Appendix II: NPPs List

State	Name of power plant		Reactor type	Rated power MW(e)	Commercial operation	Date of first connection to the grid
In operation	Qinshan NPP		PWR	310	1985-03-20	1991-12-15
	Daya Bay NPP	unit 1 unit 2	PWR	2×984	1987-08-07 1988-04-07	1993-08-31 1994-02-07
	Qinshan Phase II NPP	unit 1 unit 2 unit 3 unit 4	PWR	4×650	1996-06-02 1997-04-01 2006-04-28 2007-01-28	2002-02-06 2004-03-11 2010-08-31 2011-11-25
	LingAo NPP	unit 1 unit 2 unit 3 unit 4	PWR	2×990 2×1080	1997-05-15 1997-11-28 2005-12-15 2006-06-15	2002-02-26 2002-09-14 2010-07-15 2011-05-03
	Third Qinshan NPP	unit 1 unit 2	PHWR (CANDU)	2×700	1998-06-08 1998-09-25	2002-11-19 2003-06-12
	Tianwan NPP	unit 1 unit 2	PWR	2×1060	1999-10-20 2000-09-20	2006-05-12 2007-05-14
Under construction	Hongyanhe NPP	unit 1 unit 2 unit 3 unit 4	PWR	4×1080	2007-08-18 2008-03-28 2009-03-07 2009-08-15	

	Ningde NPP	unit 1 unit 2 unit 3 unit 4	PWR	4×1080	2008-02-18 2008-11-12 2010-01-08 2010-09-29	
	Fuqing NPP	unit 1 unit 2 unit 3	PWR	3×1080	2008-11-21 2009-06-17 2010-12-31	
	Yangjiang NPP	unit 1 unit 2 unit 3	PWR	3×1080	2008-12-16 2009-06-04 2010-11-15	
	Extension Project of Qinshan NPP (Fangjiashan Nuclear Power Project)	unit 1 unit 2	PWR	2×1080	2008-12-26 2009-07-17	
	Sanmen NPP	unit 1 unit 2	PWR	2×1250	2009-03-29 2009-12-15	
	Haiyang NPP	unit 1 unit 2	PWR	2×1250	2009-09-24 2010-06-20	
	Taishan NPP	unit 1 unit 2	PWR	2×1700	2009-11-18 2010-04-15	
	Changjiang NPP	unit 1 unit 2	PWR	2×650	2010-04-25 2010-11-21	
	Hongsha NPP in Fangchenggang	unit 1 unit 2	PWR	2×1080	2010-07-30 2010-12-28	