环境保护部核与辐射安全中心
Nuclear and Radiation Safety Center

Safety enhancement of NPPs in China after Fukushima Accident

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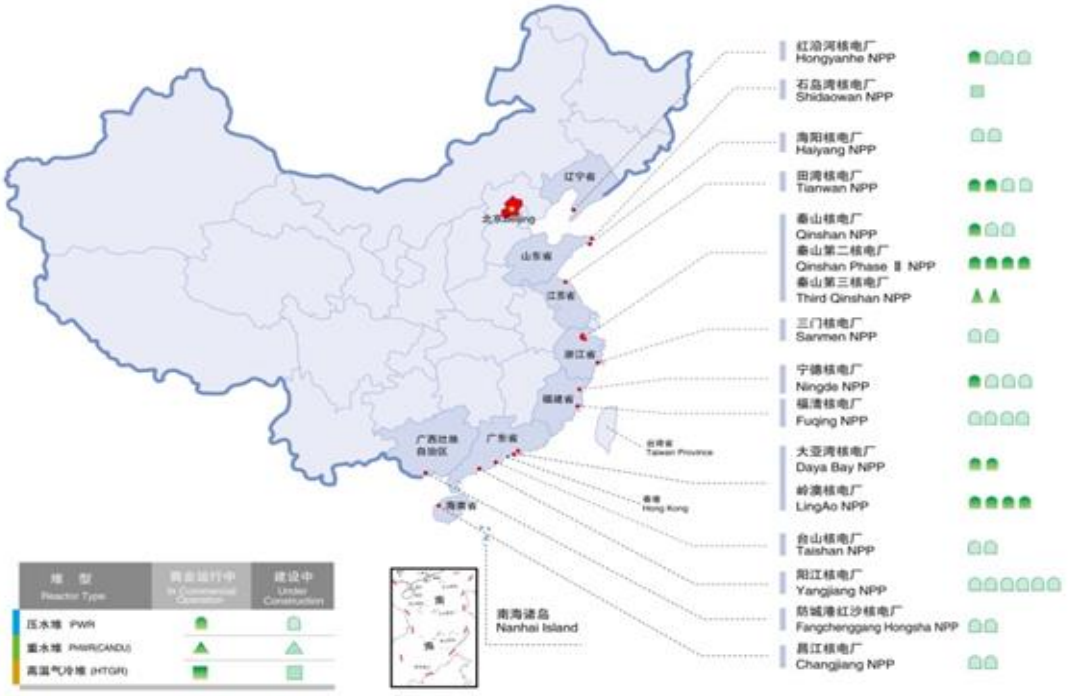
WEBSITE
http://www.chinansc.cn/

Current Development of Nuclear Power

- **Mid of year 2015**
  - 13 sites
  - 26 units in operation
  - 26 units under construction



TianWan
2x1060 MWe

Qinshan Nuclear Power Plant
310 MWe

Qinshan 2nd Nuclear Power Plant
4x650 MWe

Qinshan 3rd Nuclear Power Plant
2x700 MWe

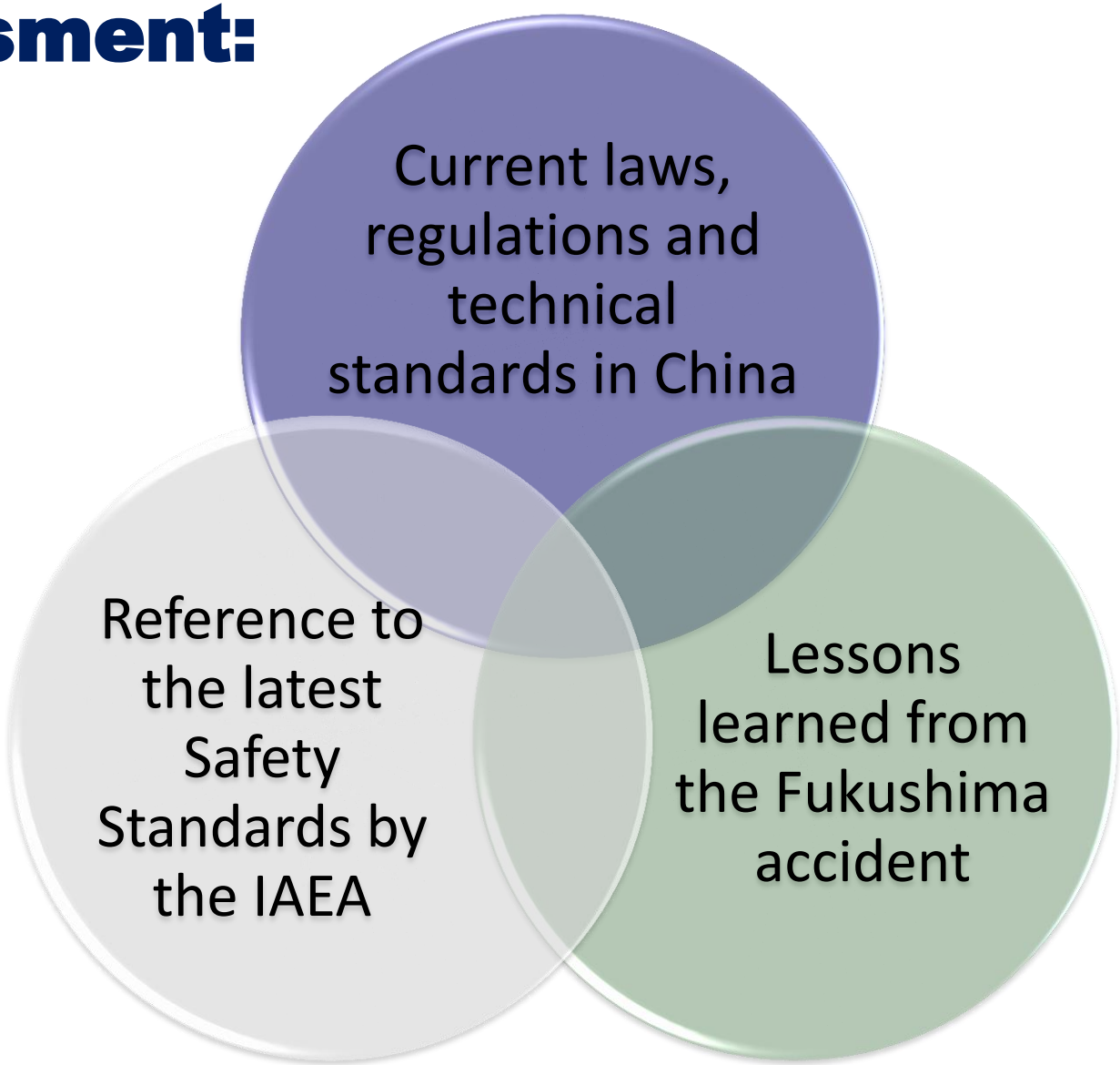
Daya Bay
2x984 MWe

Ling Ao
2x990.3MWe
2x1080 MWe

NPPs under Construction

- **NPP Technology**
- Standardized Enhanced million-kilowatt pressurized water reactor technology: 15 units
    - ACPR1000: 4 units
- VVER-1000/AES-91: 2 units
- AP1000 : 4 units
- EPR: 2 units
- HTR-PM: 1 unit
- Hualong-1: 2 units

Comprehensive Safety Assessment: Basis



Safety Assessment: Content

- Assessed External Events During Siting
- Plans and Measures Against Flooding
- Analysis and Evaluation of the NPP Black-out Incident and Emergency plan
- Plans and Measures Against Seismic
- Measures to Prevent Accidents from Multiple Extreme Natural Disasters
- Prevention & Mitigation Measures for Severe Accidents
- Effectiveness of Environment Monitoring and Emergency Response Systems

Safety Assessment: Conclusion

- NPPs' design, construction and operation satisfy the requirements of Chinese safety regulations, and reach the safety level in IAEA's latest safety standards
- The NPPs have fully ability to prevent DBA, and have the basic ability to prevent severe accidents and, should they happen, to mitigate the consequence
  - Improvement with the consideration of Experience feedback, such as LOT93, VD2, VD3, etc.
  - Additional permanent installed DG for each sites.
  - Diversity turbine driven AFW
  - PARs in the containment
  - Filtered Containment Vent system

Improvement Actions: Operating NPPs

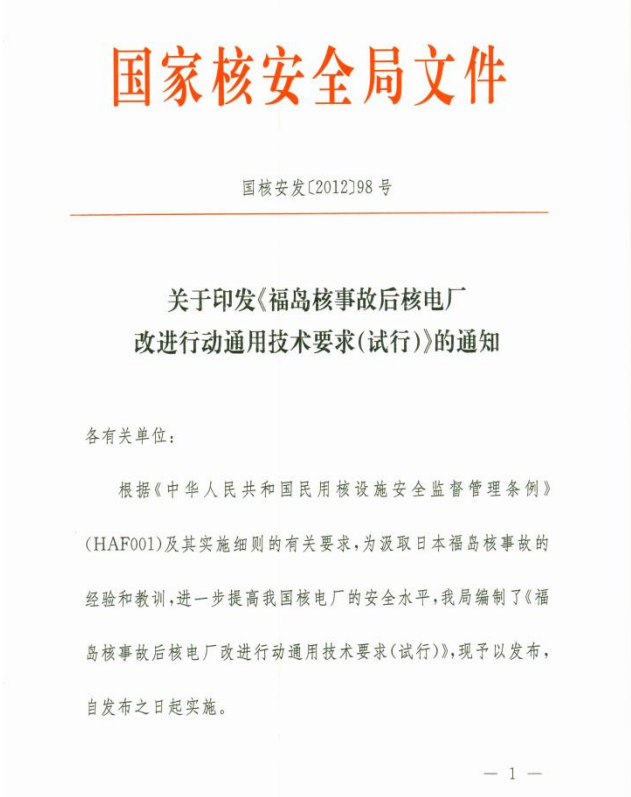
- **9 actions**
- **Short-term actions (to be accomplished before the end of 2011)**
  - Water-proofing seal and blocking
  - Additional mobile power supply and pumps, etc.
  - Effectiveness of NPP's earthquake monitoring systems and anti-seismic and response capacities
- **Medium-term actions (to be accomplished before the end of 2013)**
  - Upgrade of flooding prevention facilities, if necessary
  - Thorough assessment of earthquake and tsunami risks, and safety margin evaluation of external events
  - Improvement of SAMG, and improvement of the hydrogen removal facility if necessary
  - Strengthening of Emergency response capacities;
  - Improve information transparency and public communication
- **Long-term projects**
  - PSA, as PSA for external events, etc.

Improvement Actions: NPPs under Construction

- **10 actions**
- **Actions before first fuel loading**
  - Water-proofing measures
  - Additional mobile power generator and pumps, etc.
  - **Habitability and functions of emergency center**
  - Upgrade of flooding prevention facilities
  - Thorough assessment of earthquake and tsunami risks, and safety margin evaluation of external events
  - Improvement of SAMG, and improvement of the hydrogen removal facility if necessary
  - Strengthening the emergency response capacities
  - **Enhancement of the early warning and response capacities in case external disasters should occur**
  - Improve information transparency and public communication
- **Long-term projects**
  - Implementation of PSA, as PSA for external events, etc.

Improvement Actions: General Technical Requirements

- *Generic Technical Requirements on Improvement Actions for NPPs after Fukushima Accident*, published by NNSA in June 2012



国家核安全局文件

国核安发〔2012〕98号

关于印发《福岛核事故后核电厂改进行动通用技术要求(试行)》的通知

各有关单位：

根据《中华人民共和国民用核设施安全监督管理条例》(HAF001)及其实施细则的有关要求，为汲取日本福岛核事故的经验和教训，进一步提高我国核电厂的安全水平，我局编制了《福岛核事故后核电厂改进行动通用技术要求(试行)》，现予以发布，自发布之日起实施。

— 1 —

- Flood defense capability improvement
- Emergency Water-Injection and related Equipment
- Mobile Power Supply
- Monitoring of Spent Fuel Pool
- Hydrogen Monitoring and controlling system
- Habitability and functions of emergency center
- Radiation environmental monitoring and emergency
- Emergency plan for external natural disasters

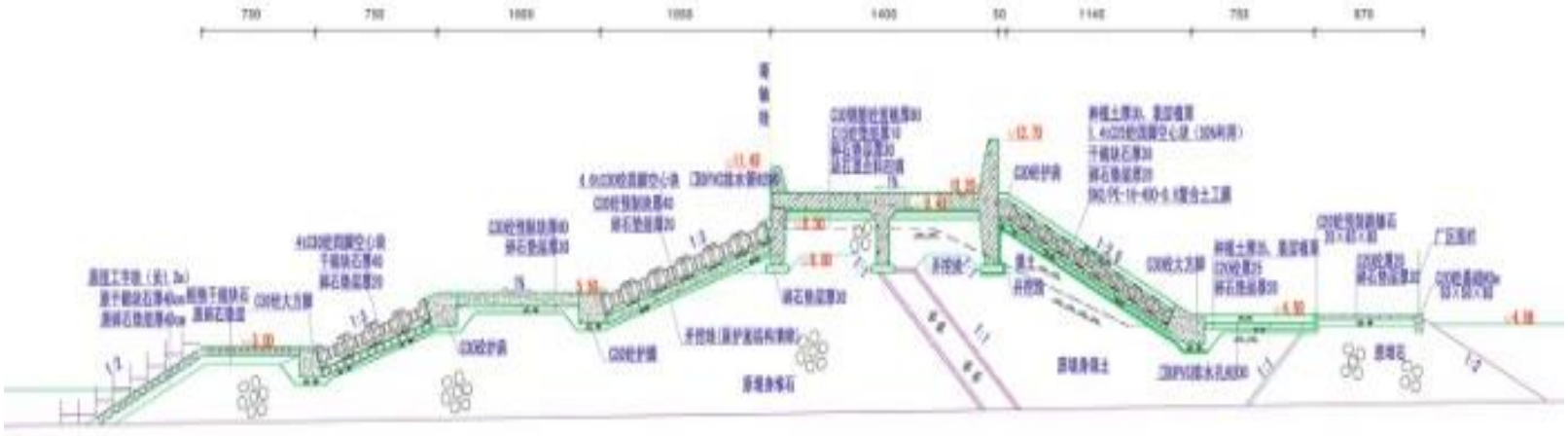
Improvement Actions: Implementation Status

- Short-term actions: accomplished before the end of 2011
- Medium-term actions: all accomplished by now;
- long-term actions: Progress meet the time schedule requirements

- Upcoming lessons learned from Fukushima accident and international good practice will be referred continuously to improve the safety level of NPPs in China

Water Proofing seal and blocking for Safety Important Building

Qinshan NPP, Flood-Prevention Reconstruction



Emergency Mobile Water & Power Supply Equipment

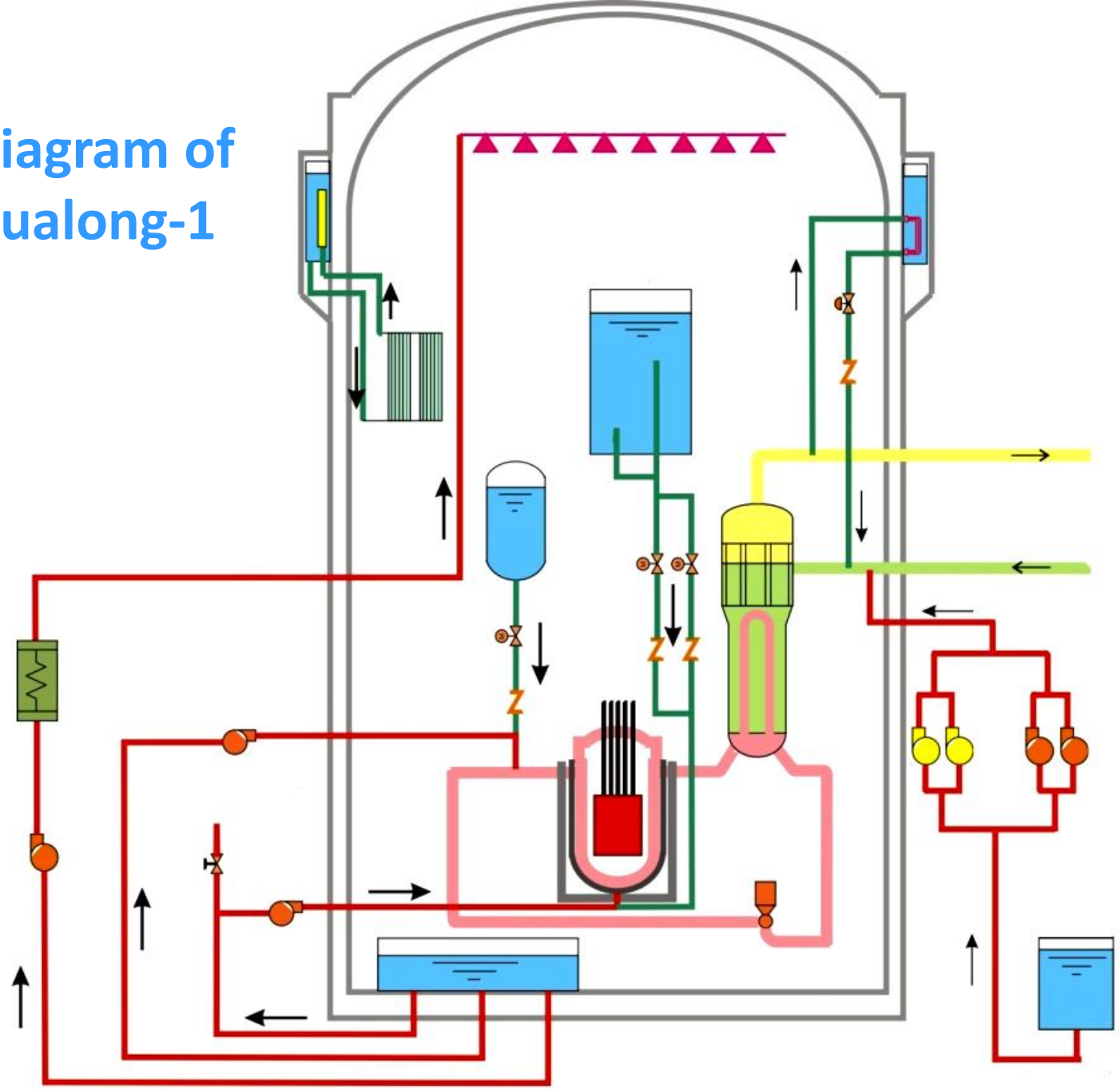
Safety enhancement: New built NPPs: ACPR1000

- **Based on the big amount of CPR1000 under construction and operation, consider the experience feedback from Fukushima nuclear accident, apply the determinate methodology and PSA methods, adopt reasonable and feasible improvement measures, such as:**
  - ✓ **Add DAS (Diversity Actuation System) system;**
  - ✓ **Add instrument control cabinet dedicated to severe accident;**
  - ✓ **Adopt measures to guarantee the integrity of main coolant pump shaft seal;**
  - ✓ **Add the pressure relief valve dedicated to severe accident;**
  - ✓ **Add reactor cavity water injection system ;**
  - ✓ **Add one standby DG for each reactor;**
  - ✓ **Add one filtering device so that each reactor has its individual filtered containment venting system;**
  - ✓ **Add cooling tower as the diversity ultimately heat sink, etc.**
  - ✓ **Passive secondary side heat removal system;**
  - ✓ **Passive reactor cavity water injection system;**
  - ✓ **Passive emergency water supply tank;**

Safety enhancement: New built NPPs: Hualong-1

- Chinese-designed new reactor type, considering the experience feedback from Fukushima nuclear accident, fully considering the measures of preventing and mitigating severe accident:
  - ✓ Equipped with double containments;
  - ✓ Equipped with sealing function for main coolant pump in case of pump shutdown;
  - ✓ Equipped with DAS system which is SSE seismic designed;
  - ✓ A backup DG is equipped for each reactor;
  - ✓ Dedicated SSCs are equipped to cope with severe accident;
  - ✓ Adopt many diversity safety system design (active+passive);
  - ✓ Equipped with rapid pressure release valves during severe accident that can satisfy redundancy requirements;
  - ✓ Adopt IVR cooling function;
  - ✓ Equipped with filtered containment venting system, etc.

Diagram of Hualong-1



Safety enhancement: New design of NPPs: CAP1400

- Chinese-designed new reactor type, expected to be built in China in near future, has made great safety improvements:
  - ✓ Improve the seismic resistance of DAS system and adds earthquake automatic reactor trip signal;
  - ✓ Improve the seismic resistance of SSCs dedicated to mitigate severe accident consequence;
  - ✓ Improve the seismic resistance of standby DG in NPPs;
  - ✓ Improve the seismic resistance of Ignitor, and add some PARs to control hydrogen in containment;
  - ✓ Enhance the seismic resistance of CCWS and SWS which can transfer the residual heat into the sea, so that the sea can be the diversity ultimate heat sink, and perform the function as defense-in-depth (passive+active);
  - ✓ Improve filtered containment venting measures;
  - ✓ Equipped with mobile DG and mobile pump.

Safety improvement: Requirements for new NPPs

- China NNSA and its TSO have prepared a document of *the Safety Requirements for New Nuclear Power Plants*. the first draft was finished in 2013.9
- Based on implementing the current nuclear safety regulations ,the document complements and expends some key issues on nuclear safety
- Enhancing the concepts of the diversification on design, and continuously improving nuclear power safety by using the most up-to-date technologies and research achievements

Safety improvement: Requirements for new NPPs

- Base on the content and form of HAF102, and adopt the most updated *Safety requirements of Nuclear Power Plants: Design Requirements* (SSR-2/1) issued by IAEA and the newest nuclear safety requirements from other countries;
- consider requirements in the documents including *the Safety of New NPP Designs* issued by the Western European Nuclear Regulators Association (WENRA) in March 2013, and the NRC Standard Review Plan (SRP), etc.;
- Reflect *the General Technical Requirements on post-Fukushima Nuclear Accident Improvement Measures for NPPs*.

Safety improvement: Requirements for new NPPs

- **Safety Functions**
  - **Clearly request that under the selected Beyond Design Basis Accident conditions, three fundamental safety functions and post-accident monitoring function must be implemented**

Safety improvement: Requirements for new NPPs

- Safety Analysis
  - The results of deterministic and probabilistic safety analysis must be considered;
  - PSA Level 1 and 2 on internal and external events during the plants states including power operation and outages must be fulfilled. The analysis objects include core, spent fuel pool.

Safety improvement: Requirements for new NPPs

- **Defense in Depth (DID)**
  - **Emphasize the effectiveness of DID and the independence between individual levels. The DID approach is also requested for defensing external events, especially through multi-level defense to prevent and mitigate severe accidents caused by extreme external events.**

Safety improvement: Requirements for new NPPs

- **External events defense**
  - **The site must forbid to settle in high seismicity areas and dangerous surface rupture zone cause by seismic activity. The areas where suppose to have over 0.3g limiting safety seismic motion are not suitable for siting, therefore it must choose in areas with low seismic activity. For new NPPs, the Design Basis Earthquake Motion Level （SL-2, or SSE） should not be lower than 0.30g; the earthquake warning system in NPPs should be able to initiate the reactor trip automatically.**
  - **The Flood defense design of NPPs must consider the impact of extreme flood events and combined flood events. The NPP floor elevation should be higher than the design basis flood level.**
  - **For the NPPs with crash risk by large-size commercial airplanes, the design should consider the effects by large-size commercial airplanes crash..**

Safety improvement: Requirements for new NPPs

- Station Black Out
  - Besides the stationary additional power supply at the plant site, on a multi-units site at least two mobile DGs and mobile pumps should be equipped.
  - The reliability of the offsite power should be enhanced, or appropriate compensatory measures should be considered.

Safety improvement: Requirements for new NPPs

- Safety consideration on severe accidents
  - keep the concept of “beyond design basis accident” (including severe accidents) in HAF102; however, to be consistent with the requirements by IAEA SSR-2/1, adopt the safety consideration related to Design Extension Conditions in SSR-2/1

Safety improvement: Requirements for new NPPs

- **Severe accidents prevention and mitigation**
  - **Place equal emphasis on prevention and mitigation.**
  - **Confirm to formulate and improve the Severe Accidents Management Guideline.**
  - **measures such as responding station blackout , high-pressure core melt, global hydrogen explosion, molten-core concrete interaction, and containment bypass, etc. should be adopted in design.**

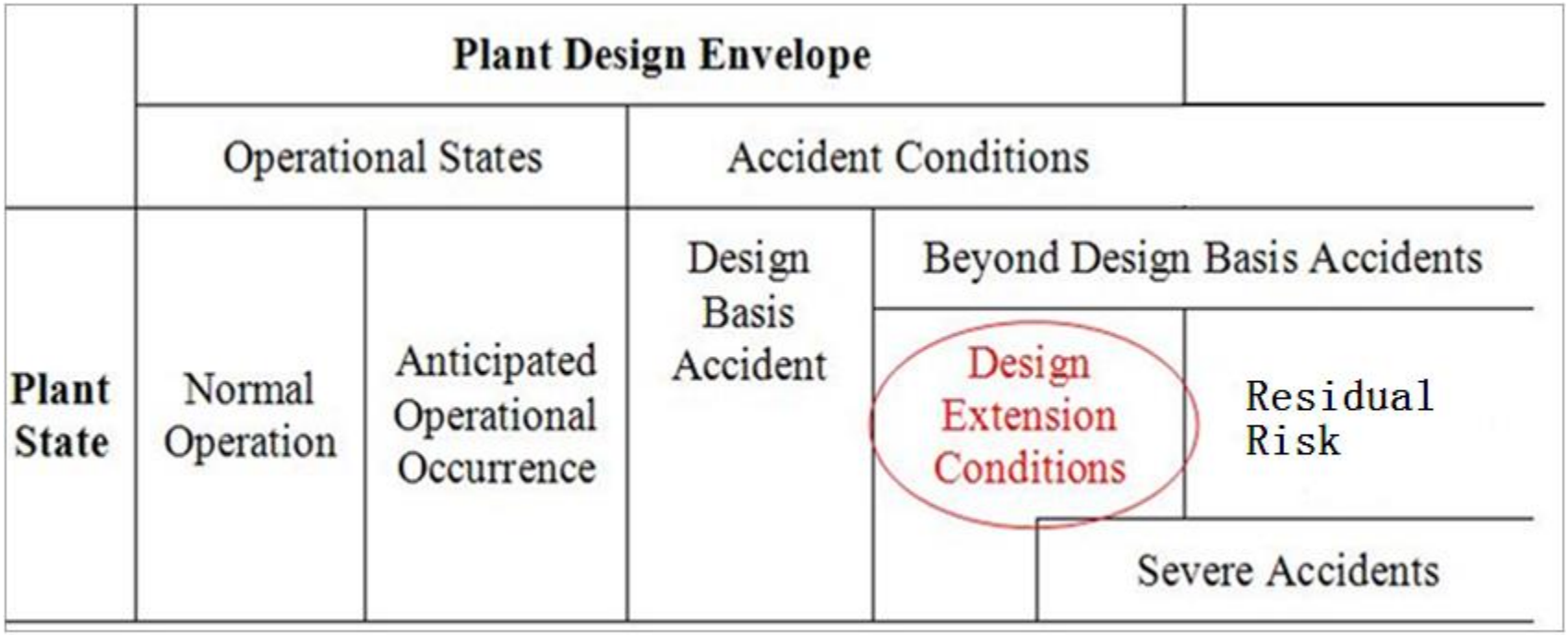
Safety improvement: Requirements for new NPPs

- Reactor coolant system
  - Remove the residual heat from the safety important item of nuclear power plant to the ultimate heat sink with high reliability in all plant operating modes; meanwhile the diversity of heat sink should be considered.

Safety improvement:
Update of requirements for new NPPs

- Planning on Nuclear Safety and Radioactive Contamination Treatment and a Long-term Goal 2020 (Nuclear Safety Plan)
  - New safety objective: practical elimination of large radioactive releases
- Vienna Declaration on Nuclear Safety
- More requirements related to practical elimination of large radioactive releases would be added in follow-up revision in the future.
  - States of Nuclear Power Plants
  - Levels of defense in depth
  - AHARA principal of nuclear safety

States of Nuclear Power Plant



Safety improvement:
Update of requirements for new NPPs

- Design extension condition , includes
  - Selected multiple failure condition, DEC-A
    - ATWS, SBO, total loss of SG feed water, loss of ultimate heat sink, multiple SGTR, etc
    - to prevent core melt
  - Selected severe accident, DEC-B
    - including relevant severe accident phenomena
    - to prevent damage of the containment
  - Selected extreme external events, DEC-A
    - 1.67 times of SSE, 2 times of PMP, DBF+PMP, PMP with 50% blockage of rain drainage system.
    - to avoid Extensive damage state of NPP

Safety improvement:
Update of requirements for new NPPs

- Practically eliminated states (Residual risks), i.e. extensive damage state of NPP caused by extreme external event.
  - Measures have been taken in the design to eliminate such states, and the occurrence of it is very low.
  - beyond the current human's recognition.

Levels of defense in depth

Level of defense in depth	Safety goals	Basic measures	Plant status
1	Prevention of abnormal operation and failure	Conservative design and high quality construction and operation	Normal operation
2	Control of abnormal operation and detection of failures	Control, limiting and protection system and other surveillance features	Anticipated operational occurrence
3	Control of accidents within design basis	engineered safety features and Emergency operating procedures	Design basis accident（single failure postulated initial event）
4	Control of serve accident, including prevention of serve accident（4a）and mitigation of consequence（4b）	Additional safety systems and severe accident management	Design extension condition, including multiple failure（4a）,serve accident（4b）
5	Emergency rescue work on extremely condition, mitigation of offsite radioactivity	safety margins, supplementary safety measures, DiD measures, Extensive Damage Mitigation, offsite emergency response	Practically eliminated states (Rresidual risks), i.e. extensive damage state

Safety improvement: Method to mitigate accident

- Engineered safety features
  - For the design basis accidents, such as ECCS. safety level, seismic category I, conservative analysis
  - Single failure criteria
- Additional safety systems
  - For the design extension condition, such as severe accident rapid Relief Valves. non safety class, functional after SSE, realistic analysis
  - Redundancy for some key functions
- Supplemental safety measures
  - Supplemental safety measures are used to minimize the consequences of residual risk and the engineering rescue of extreme conditions, such as mobile DG, mobile pump and reservoir for mitigating extensive damage state of NPP; flittered containment venting measures, store and treatment features of radioactive waste liquid; the safety storage building for mobile equipment ; offsite assistant team with mobile equipment.

Safety improvement:
AHARA principal of nuclear safety

- Five features of nuclear safety: complexity of technology, sudden of accidents, difficulty for disposal, severity of consequences and sensitivity to social.
- Due to the limitations of human cognition, there is potential uncertainty in nuclear power plant safety.
  -The residual risk. Mainly from the extreme external events which may lead to extensive damage of SSCs of NPP, it's common-cause failure.
- Regarding the extreme importance of nuclear safety, nuclear safety as high as reasonable achievable should be considered in the design of nuclear power plant.
- Promote improving nuclear power safety by using the most up-to-date technologies and research achievements, and experience feedback, so as to increase the safety margin.

Thanks for Attention!

Questions & Comments?