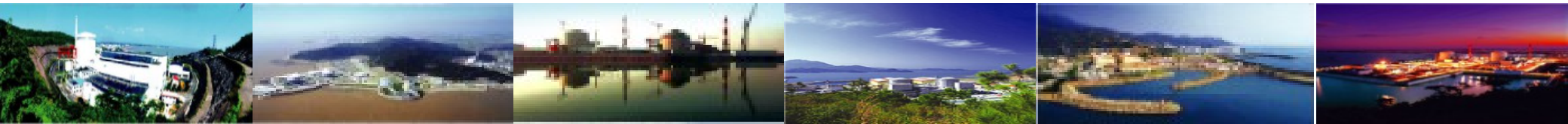
Safety Reassessment for Nuclear Facilities in China

China Atomic Energy Authority

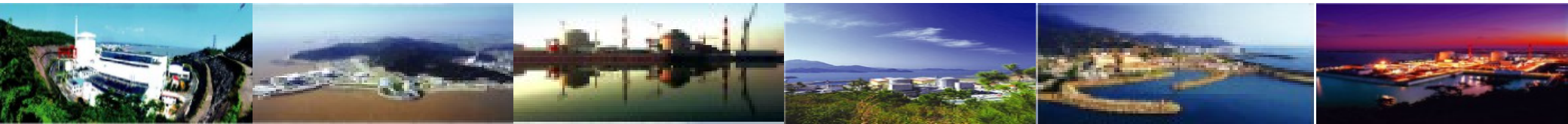
2014.11.5



Nuclear Facilities in China

Status

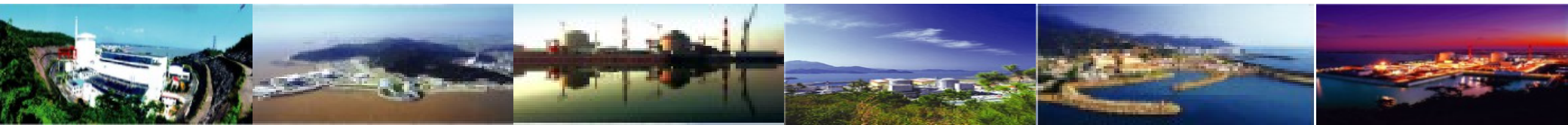
- By now, three major nuclear power bases have been formed in Chinese mainland, namely, Qinshan of Zhejiang, Daya Bay of Guangdong， Tianwan of Jiangsu in China.
- Already has 21 nuclear power units （Total installed capacity of 19.0 GW） commercially operated, and 27 nuclear power units （Total 29.5GW)have been constructed.
- On 12th five year plan(2010 to 2015),10 projects will be approved , capacity 38000Mw, About 6 units may get CP every year from 2016 to 2020.
- A lot of new NPP projects, includes projects of inland NPPs, such as Taohuajiang NPP, Xianning NPP, Pengze NPP are waiting for the permission.



Nuclear Facilities in China

Status

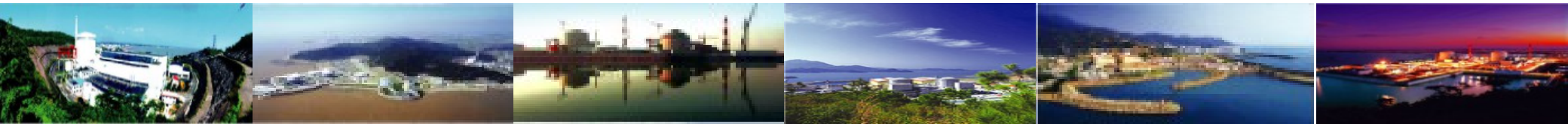
- **NPP project of Fast neutron reactor (FBR) is in plan.**
- **Some new concept design of PWR are being considered.**
- **The State Council readjusts the Mid-Long Term Plan for Nuclear Power Development(2011-2020) in Oct. 2012(After the Fukushima nuclear accident) with the object of total installed capacity in operation reaching 58GW and another 30 GW under construction by 2020.**



Nuclear Facilities in China

Status

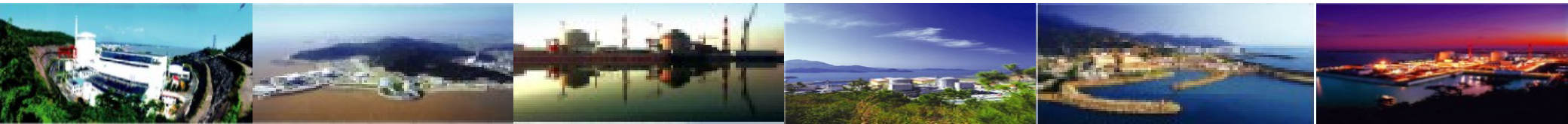
- **There are nearly 10 research/test reactors is in normal operation , such as High Flux Engineering Test Reactor (HFETR) and Ming Jiang Test Reacot (MJTR) .**
- **Nealy 10 types of product lines provides fuel assemblies for NPPs and research reactors.**
- **Also many nuclear technology application facilities have been uesed for medicine or exploring and so on.**



Legislative and Statutory framework

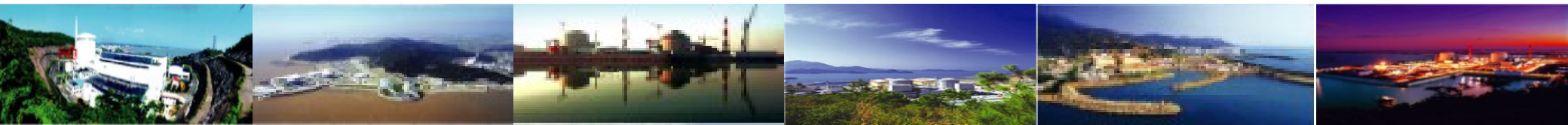
- **China has already established legislative system on nuclear safety and radiation safety by referring the IAEA safety standards. Regulated facilities include:**

- **— NPPs**
- **— Research reactors**
- **— Facilities for fuel cycle**
- **— Facilities for radioactive waste processing and disposal**
- **— Nuclear safety equipment**
- **— Nuclear technology application, e.g. radiation sources**
- **—Uranium (thorium) mining and associated mineral resources exploitation and application**
- **— Transport of Radioactive Material**



Legislative and Statutory framework

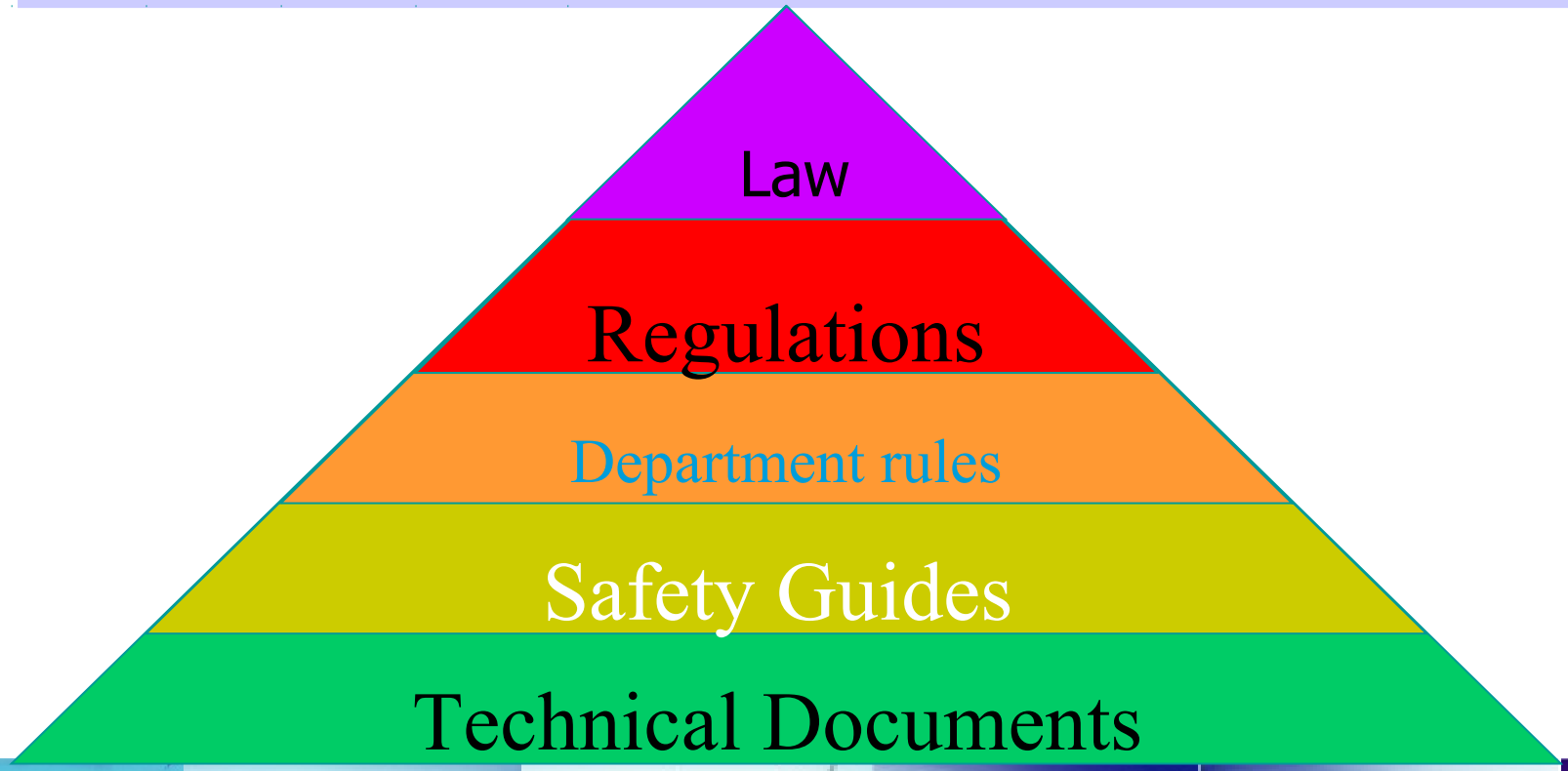
- **China has formed a systematic legislation framework on the safety of nuclear & radiation, which would fit up with the requirements of Chinese nuclear & radiation industry, especially NPP 。**
- **The legislative system cover the siting, design, manufacture, construction, operation and decommissioning, etc. to Maintain a high level of nuclear safety standard accepted internationally.**
- **Also established the legal basis for licensing process.**
- **Will improve continuously Chinese legislative system on nuclear and radiation safety based on domestic and international experience feedback.**

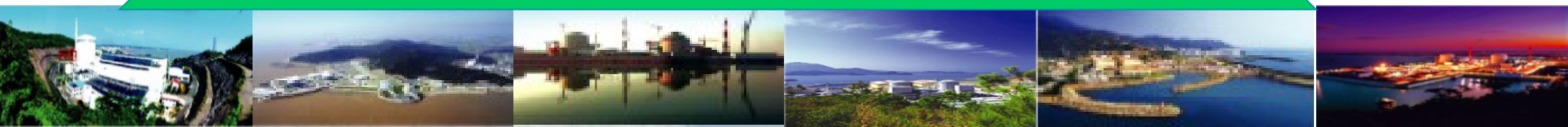


Legislative and Statutory framework

Hiberarchy : Five-level

The legislative system is composed by law,Administrative regulations, Department rules, safety guides and technical documents.





Legislative and Statutory framework

- **Laws/ACT** (including International Conventions)

— Enacted by the National People's Congress (Mandatory).

- Law on Prevention and Control of Radioactive Pollution, 2003

- **Administrative Regulations**

— Promulgated by the State Council (Mandatory).

- **Regulations on Surveillance and Control of Civilian Nuclear Installations, 1986**
- **Regulations on Nuclear Materials Control, 1989**
- **Regulations on Nuclear Accident Emergency Management in NPPs, 1993**
- **Regulations on Surveillance and Control of Civilian Nuclear Safety Equipment, 2007**
- **Regulations on Surveillance and Control of Radioactive Substance Transportation, 2009**
- **Regulations on Radioactive waste Management,2011**

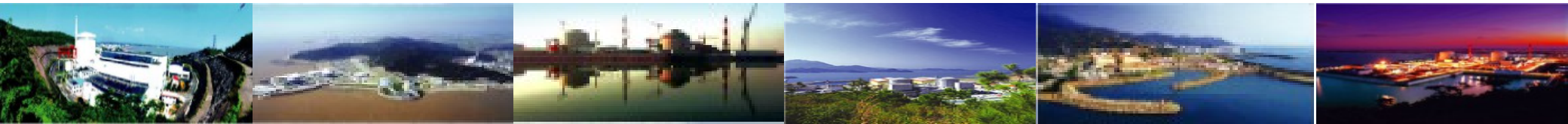
Legislative and Statutory framework

➢Departmental rules and Compulsory Standards

—— Department rules are issued by Ministry of Environmental Protection (National Nuclear Safety Administration-NNSA) (Mandatory). Total:34

--- Compulsory National Standards on nuclear safety and radiation protection are issued jointly by MEP and China Commission of Standards.

- **Code on the Safety of Nuclear Power Plant Siting (1991)**
- **Code on the Safety of Nuclear Power Plant: Design (2004)**
- **Code on the Safety of Nuclear Power Plant: Operation (2004)**
- **Code on the Safety of Nuclear Power Plant Quality Assurance (1991)**
- **Management Rules on Safety and Protection for Radioactive Isotopes and Irradiation Devices (2006)**
- **Basic Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources (GB18871-2002)**



Legislative and Statutory framework

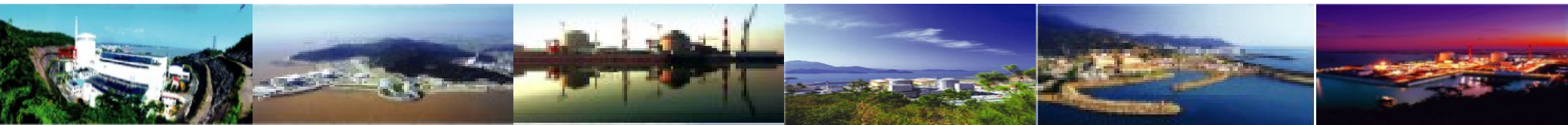
- Safety guides and recommended standards

— Safety guides are issued by Ministry of Environmental Protection (NNSA) (recommendatory,more than 90).

--- Recommended standards are issued by Committee of Standards(GB/T)(recommendatory).

- Technical documents （ more than 180 ）

— Issued by Ministry of Environmental Protection (NNSA) (referential).



Legislative and Statutory framework

2003 Act on Radioactive Pollution Prevention & Control of the People's Republic of China

1986 The Regulations on Safety Regulation for Civilian Nuclear Installations of the People's Republic of China

1987 Regulations on the Nuclear Materials Control of the People's Republic of China

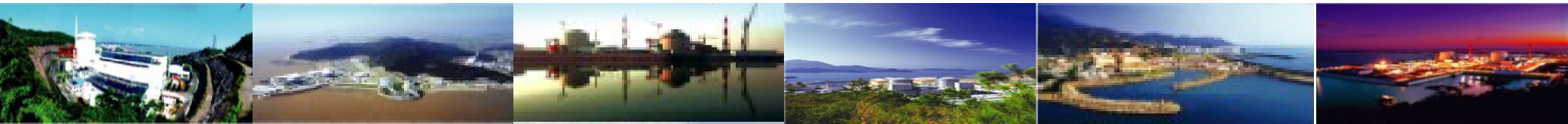
1993 Regulations on Emergency Management for Nuclear Accidents at Nuclear Power Plants

2005 Regulations on Safety and Protection of Radioactive Isotope and Radioactive Ray-Emitting Devices

2007 Regulations on Supervision and Control of Civil Nuclear Safety Equipment

2009 Regulations on Transportation Safety for Radioactive Substances

1985 1990 1995 2000 2005 2010 year



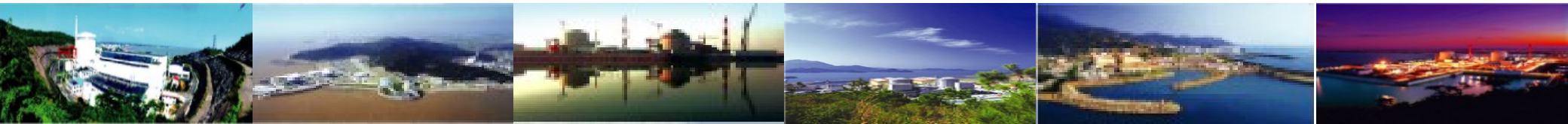
Conditions of Safety Reassessment

- **Safety Reassessment should be conducted under the following primary conditions:**
  - **PSR:** ***Periodical Safety Review(per ten years)***
  - **Modification:** ***Including modifications of structures, systems, components, of operational limits and conditions,and of instructions and procedures***
  - **Event or accdient:** ***After significant event or major accident***
  - **Others:** ***Operating experience （including international)***

    Technical developments ***(for example:analysis sofwares upgraded after identifyicaiton or verification test)***

    Results of Newest Probabilistic Safety Analysis

    Changes of Fuel Management strategy etc.



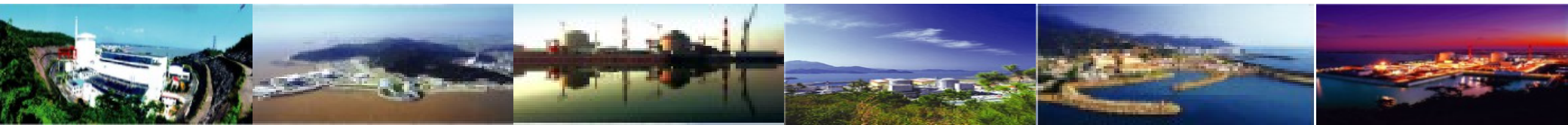
Rules and Guides Related to Reassessment

Rules:

- HAF102:Safety of Nuclear Power Plants:Design (2004)
- HAF103:Safety of Nuclear Power Plants:Operation(2004)

Guides:

- HAD 103/07:Maitenance,Surveillance and In-service Inspection in Nuclear Power Plants(2011)
- HAD 103/11:Periodic Safety Review of Nuclear Power Plants(2006)
- HAD 103/12:Modifications to Nuclear Power Plants(2011)
- HAD102/17:Safety Assessment and Verification for Nuclear Power Plants(2006)

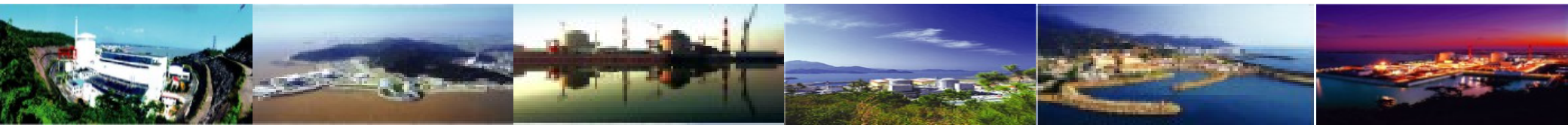


Rules and Guides Related to Reassessment

◆Rules:

➢HAF103:Safety of Nuclear Power Plants:Operation(2004)

- ***Article 3.12:<u>After an abnormal event</u>, the plant shall be brought into a safe operational state, which could necessitate shutting down the reactor. In the event that the operation of the plant deviates from one or more of the established operational limits and conditions, the appropriate remedial actions shall be taken immediately, and <u>the operating organization shall undertake review and evaluation of the case and shall notify the regulatory body in accordance with the established event reporting system.</u>***

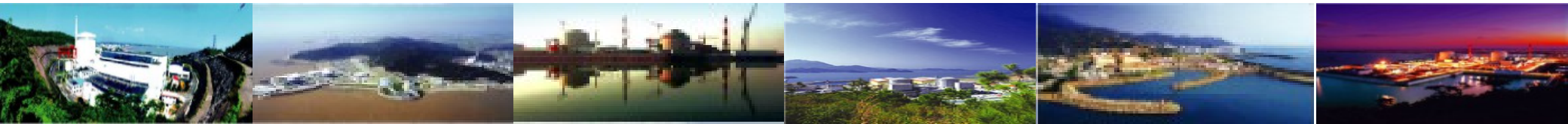


Rules and Guides Related to Reassessment

◆Rules:

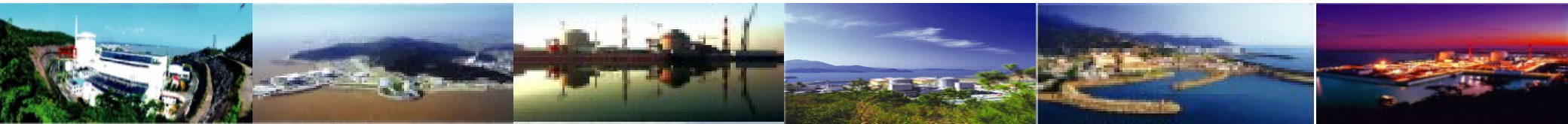
➢HAF103:Safety of Nuclear Power Plants:Operation(2004)

- ***Article 7.2:Proposed modifications to structures, systems and components important to safety, which affect the bases on which the operating licence was issued, to the operational limits and conditions, and to procedures and other documents originally approved by the regulatory body shall be submitted to the regulatory body for prior approval.***
- ***Article 10.1:Systematic safety reassessments of the plant in accordance with the regulatory requirements shall be performed by the operating organization throughout its operational lifetime, with account taken of operating experience and significant new safety information from all relevant sources.***



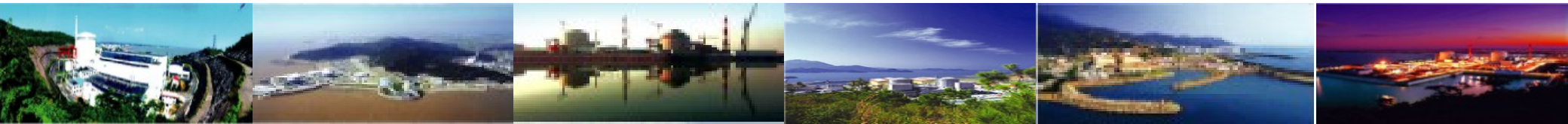
Rules and Guides Related to Reassessment

- **Guides:**
  - **HAD 103/07:Maitenance,Surveillance and In-service Inspection in Nuclear Power Plants(2011)**
    - ***When the results of MS&I for a plant item that is out of service fall outside the acceptance ,then that plant item,unless it is repaired,replaced or modified,should remain non-opreational until the safety aspects have been reviewed.If a review of the safety aspects for such a safety related palnt item shows that its reliability and effectiveness have been affected, and if it is confirmed that a decision wa taken not repair,replace or midify it,then the deviation from the acceptance criteria should be justified in accordance with established procedures as a change to the safety analysis report.***



Rules and Guides Related to Reassessment

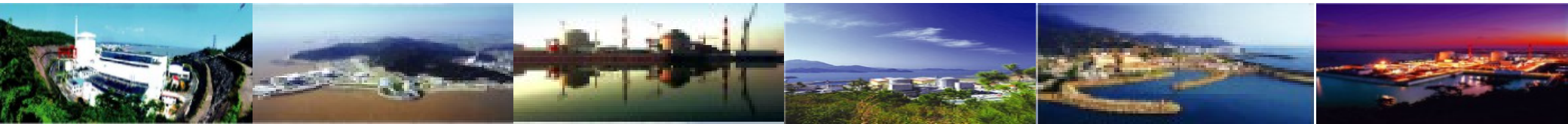
- **Guides:**
  - **HAD 103/11:Periodic Safety Review of Nuclear Power Plants(2006)**
    - ***Article 1.3.1:A PSR is a comprehensive safety review of all important aspects of safety,carried out at regular intervals, typically of ten years.***
    - ***Article 2.2:The objective of a PSR is to determine by means of a comprehensive assessment of an existing nuclear power plant: the extent to which the plant conforms to current international safety standards and practices; the extent to which the licensing basis remains valid; the adequacy of the arrangements that are in place to maintain plant safety until the next PSR or the end of plant lifetime; and the safety improvements to be implemented to resolve the safety issues that have been identified. (An assessment against current safety standards does not imply that all current safety standards have to be met)***



Rules and Guides Related to Reassessment

- **Guides:**
  - **HAD 103/11:Periodic Safety Review of Nuclear Power Plants(2006)**

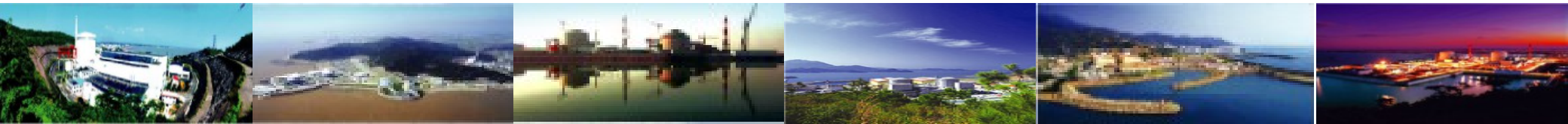
Article 1.1.3:<u>Periodic safety review (PSR)</u> is to assess the cumulative effects of plant ageing and plant modifications, operating experience, technical developments and siting aspects. The reviews <u>include an assessment of plant design and operation against current safety standards and practices,</u> and they have the objective of ensuring a high level of safety throughout the plant's operating lifetime. They are complementary to the routine and special safety reviews and do not replace them.



Rules and Guides Related to Reassessment

- **Guides:**
  - **HAD 103/12:Modifications to Nuclear Power Plants(2011)**

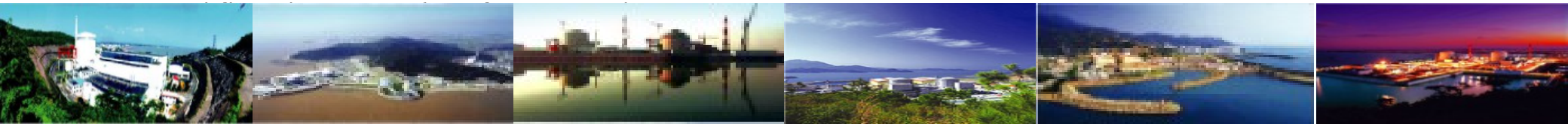
An initial safety assessment should be carried out before starting a modification to determine whether the proposed modification has any consequences for safety and whether it is within the regulatory constraints for the plant design and operation. This initial assessment should be carried out by trained and qualified personnel, taking a systematic approach, and should be reviewed by an independent safety expert. The implementation phase for the modification (including the radiological hazard) as well as plant operation after the modification should be considered in the assessment at this stage. The regulatory body should have access to all intended modifications in order to assess compliance with the proposed categorization.



Rules and Guides Related to Reassessment

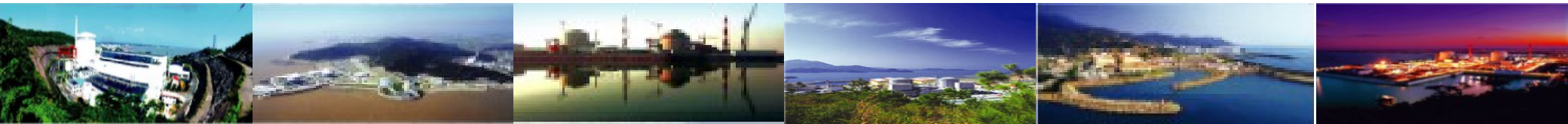
- **Guides:**
  - **HAD 103/12:Modifications to Nuclear Power Plants(2011)**

- ***Depending on the results of the initial safety assessment, a more detailed and comprehensive safety assessment may be needed. The extent and complexity of the additional assessment that is necessary will depend on the nature and extent of the consequences of the modification for safety.***
- ***The comprehensive safety assessment should include an evaluation of the effect of the modification on radiological hazards during its implementation and during subsequent commissioning, testing, maintenance and operation of the modified plant. This evaluation should include the effect of the modified plant item and its associated system on physically adjacent systems and plant items, and on interconnectedsystems or support systems such as electrical power supplies.***
- ***It should be demonstrated by means of the comprehensive safety assessment that the modified plant can be operated safely and complies with the system***



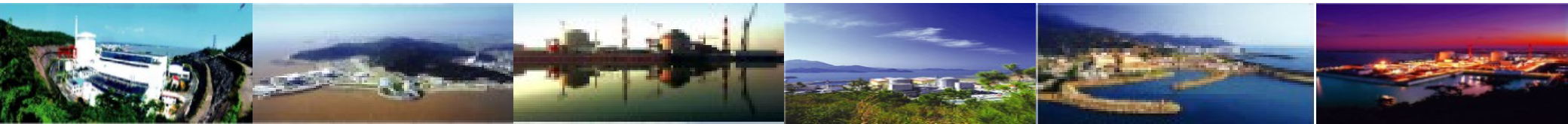
Case： PSR

- The operational NPPs, according to requirement of relevant regulations, will implement periodical safety review once in every ten years af ter beginning of commercial operation. According to operating experience, relevant important safety information, and existing safety standard and practice, the NPP systematically conducts re-assessment of safety. The scope of review covers all aspects of nuclear safety, including 14 safety elements in five categories.
- Duration of periodical safety review shouldn’t exceed three years. In the process of periodical safety review, according to result of review, NPPs identify reasonable and achievable corrective action/safety improvement and the execution plan. NPPs comprehensively assess the weakness which weren‘t reasonably resolved, identify related risks and provide corresponding certificates for sustainable operation.



Case： PSR

- **Qinshan and Daya Bay NPPs have finished the first PSR in 2003. Review conclusion showed both NPPs can continue the safe operation.Now is in progress of second PSR. Qinshan is estimated that second PSR is completed at 2015.Daya Bay will be accomplished at bottom of 2014.**
- **1# and 2# units of LingAo and Qinshan Phase Ⅱ NPP, Third Qinshan and Tianwan NPP will perform PSR in succession.**
- **Some prophase preparations are performed for all NPPs under construction, including studying requirement of Codes,collecting and studying relevant PSR achievement of other NPPs completed in China.**
- **Some research reactors have been reevaluated and renewed the operation licenses， Such as HFETR.**

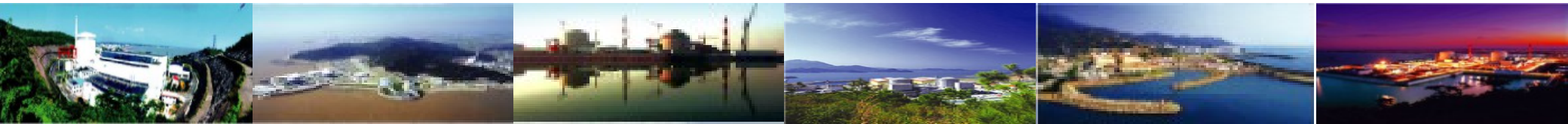


Case： PSR for LingAo1&2 NPP

◆1、 PSR Project

- ✓Jan 2009， Submit PSR Programme
  （ The review methods and safety factors which should be approved by RB ）
- ✓Apr 2009， Establish PSR QA Plan
- ✓Jun 2009， Establish Procedure and Manual
- ✓Jul 2009， Begin PSR
- ✓Jul 2010， Begin to Submit Report to RB
- ✓Jun 2011， Submit General Report
- ✓Sep 2011， Submit Programme of corrective actions

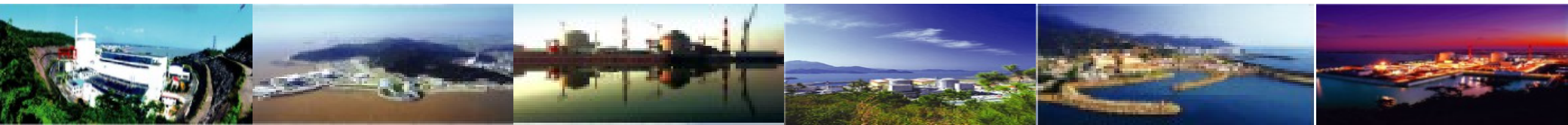
1# and 2# units of LingAo NPP （ LNPS ） , report on all 14 factors of the primary PSR had been completed and had been submitted to MEP (NNSA) in five batches; totally more than 400 problems in four batches of MEP (NNSA) had been answered, and the overall review report and correction action plan had been submitted.



Case： — PSR for LNPS

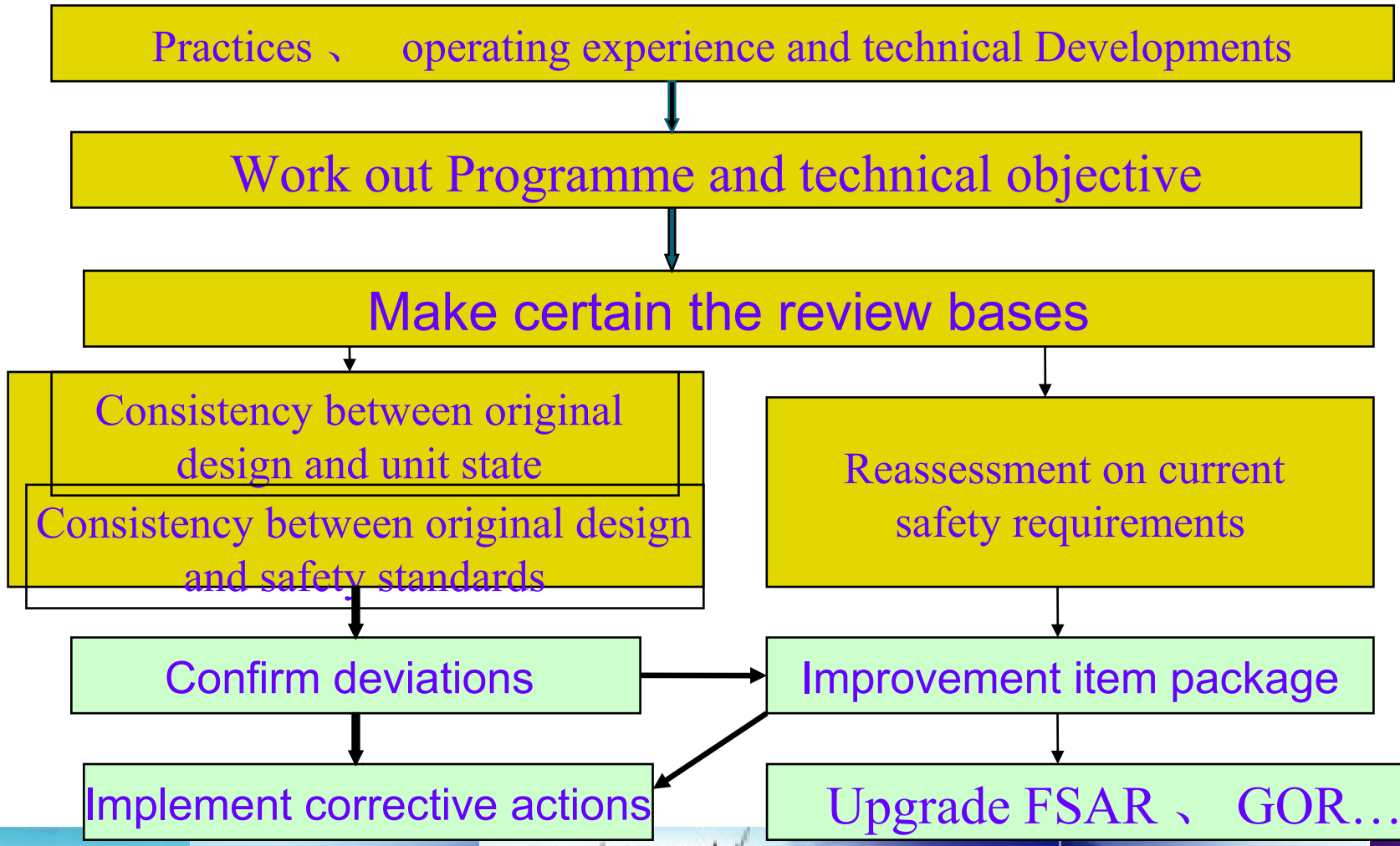
◆2、 PSR Programme of LNPS

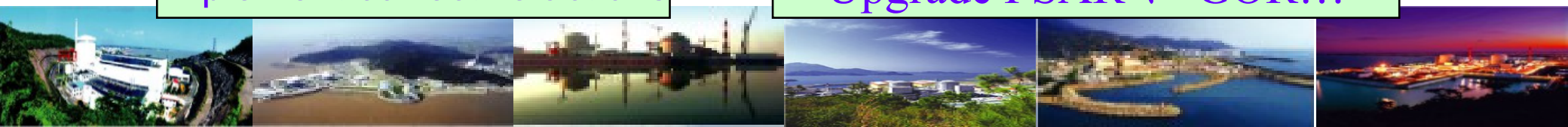
- ✓Introduction （ Objective、 Basis and Scope ）
- ✓Organization and Management （ Body、 Responsibility ）
- ✓Review Strategy and Methods
- ✓Review process and general plan
- ✓Review Documents
- ✓Safety Factors
- ✓Reference



Case of Safety Reassessment—PSR for LNPS

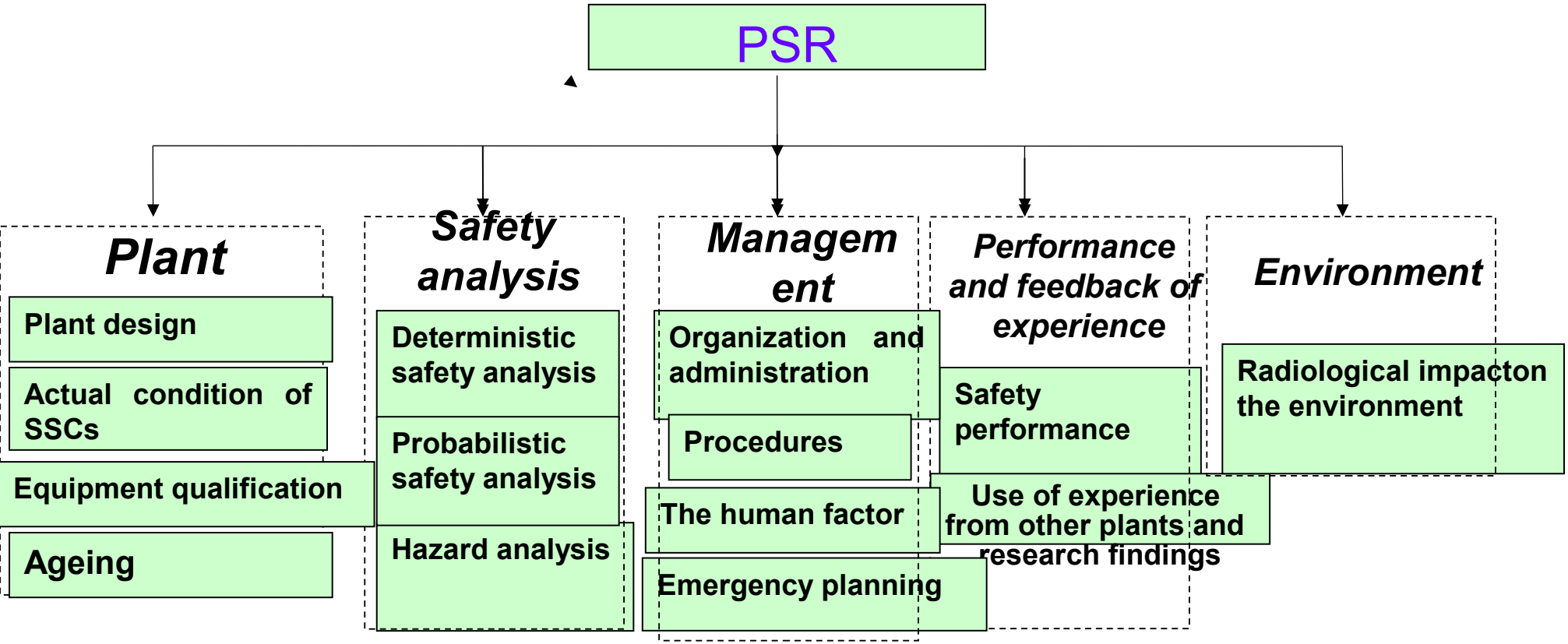
3、 Review strategy and method-Basic route:

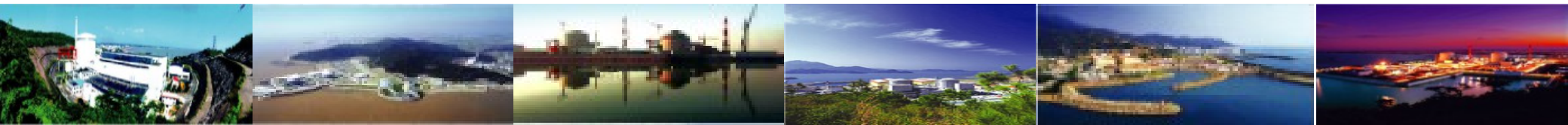




Case of Safety Reassessment—PSR for LNPS

4、 Review Scope: 14 safety Factors （ 5 aspects ）





5.1 Review topics-NPP design

Special topics: （ subtopics ）

- ***Design document***

·**Makeup of design document and its management system**

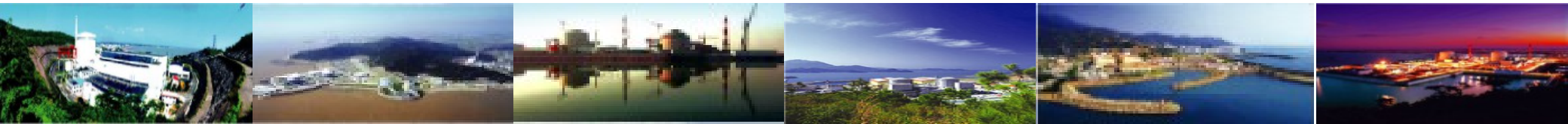
- ***Classification of equipment***

·***Compare to the similar units of EDF， Analysis deviation， amend lists of equipment classification , confirm the classification of new equipment after commercial operation 。***

- ***System and barrier***

·***Review sub-system， compare with current standards and latest design practice of system in current NPP (include feedback , account take of VD3) , find out strengths and weaknesses , implement corrective measures.***

- ***Vibration fatigue of small branch***
- ***Heavy object downfall*** **while earthquake is as an initiating event.**
- ***Severe accident management***



Case of Safety Reassessment—PSR for LNPS

5.2 Review topics-Actual Condition of SSCs

- Total 11 topics :

- ***System and Barrier***

  mainly include： System function、 system makeup、 key parameters、 maintenance and periodic test items after operation。

  Emphases : Analysis of periodic test result、 operational events、 outage records of equipment、 questions focused by supervisor ,and so on. In order to judge the whole functional competence.

- ***Structures***
- ***Limits for switchboard***
- ***Earthquake as initiating event***
- ***Seismic supports of equipment***
- ***Seismic supports of High energy piping***
- ***Thermal fatigue of piping***
- ***Vibration fatigue of small branch***
- ***Potential of modification and replacement***
- ***Status of issues promised by Licensee***
- ***Status of support facilities on or off the site***

5.3 Review topics-Equipment Qualification

3 topics:

- ***Review list of qualification equipment***

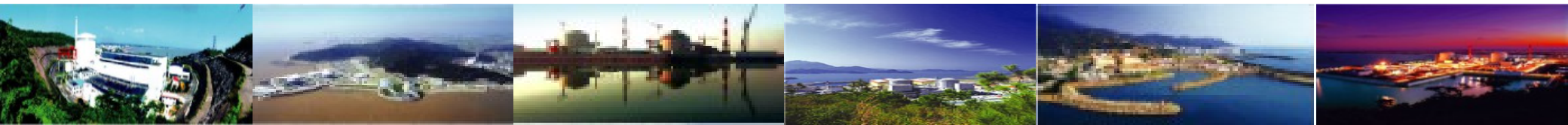
  Integrality and veracity ： Compare with the similar unit of EDF

- ***Review actual condition of qualification equipment***

  Unsolved questions for operation： local inspection and records （including records of preventive maintenance、 periodic test、 verification、 invalidation 、 modification and replacement）

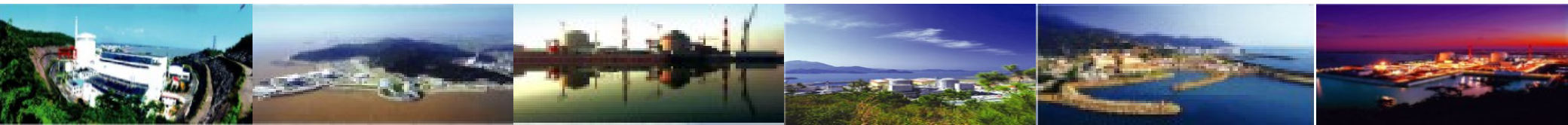
- ***Review maintenance measure of qualification equipment***

  Control to maintain equipment qualification activity： procedure （ on preventive maintenance 、 surveillance 、 modification and replacement）、 local environmental monitoring、 purchase and storage control of standby equipment、 experiences feedback、 training.



5.4 Review topics-Ageing

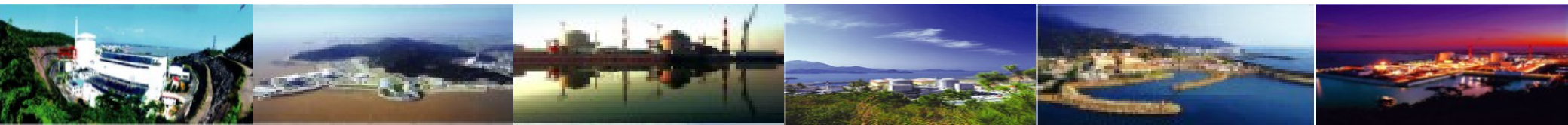
- Main assessment task for first PSR to LNPS ：
  - *Assessment of ageing management programme*
  - *Improvement of ageing management structures*
  - *Collection and Analysis of former ageing information of NPP*
- 10 topics:
  - ***Ageing management system***
  - ***Chemical control***
  - ***Transient statistic***
  - ***In-service inspection***
  - ***Corrosive protection***
  - ***Technology improvement management***
  - ***Spare part management***
  - ***Important ageing SSCs management***
  - ***Important ageing problem management***
  - ***Special management of ageing elements***



5.5 Review topics- deterministic safety analysis

According to elements ,on the basis of assessment for actual condition, screen out 2 topics to be the review important items：

- ***Accident analysis***
- ***Severe accident management***
  - ✓***Establish guide of Severe accident management for LNPS***
  - ✓***Implement appropriate justification and improvement of mitigation measure for severe accident***
  - ✓***Review the accuracy and validation for the prescribed items.***



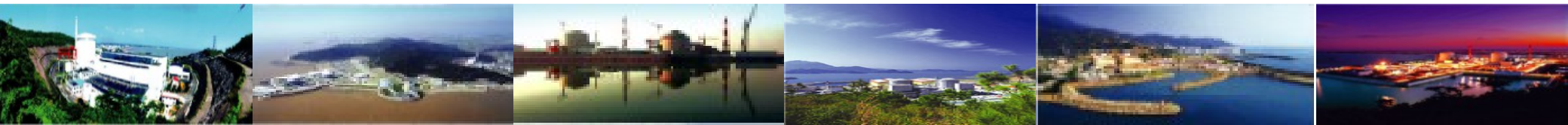
5.6 Review topics- Probabilistic safety assessment

2 special topics：

- **Management for PSA**

Account be taken of modification on design and operation、 technical developments、 current analysis methods and recent operational data， review model of PSA whether it is satisfied with safety requirements and accurately reflect the actual condition and risks level of NPP.

- **Application tools of PSA：** ***weakness analysis.***



5.7 Review topics- hazard analysis

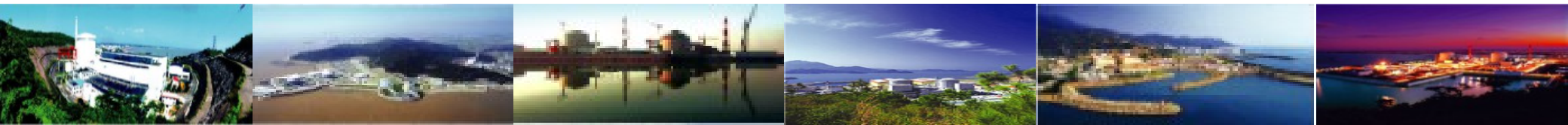
2 topics:

- **Internal hazards:**

  Potential sources analysis, examine local status and management procedure

- **External hazards:**

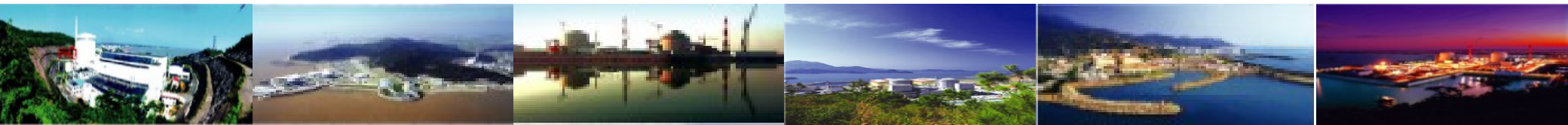
  on the basis the analysis results of Lingao Ⅱ （3&4）, Take account of improvements in safety standards and changes of site characteristics, compare and analyze External hazards:



5.8 Review topics- safety performance

3 topics

- ***Assess status of safety performance indicators***
- ***Assess radiation protection system 、 records of radiation dose and rad-waste products***
- ***Feedback related to safety performance***



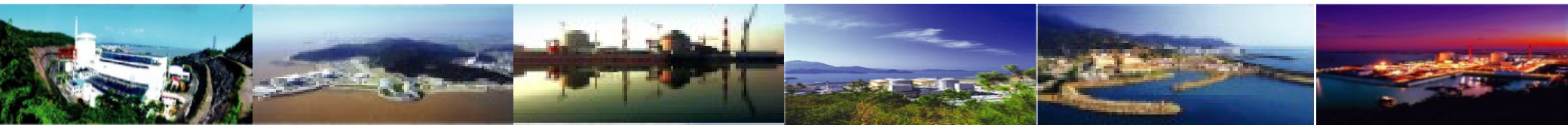
Case of Safety Reassessment—PSR for LNPS

5.9 Review topics-

use of experience from other plants and research findings

3 topics

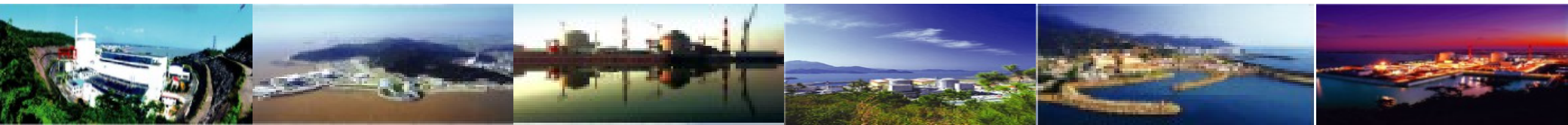
- ***Review of Feedback process from other NPPs***
- ***Review usage of improvement from other NPPs***
- ***Review usage of management experiences from other NPPs***



5.10 Review topics- organization and administration

5 topics

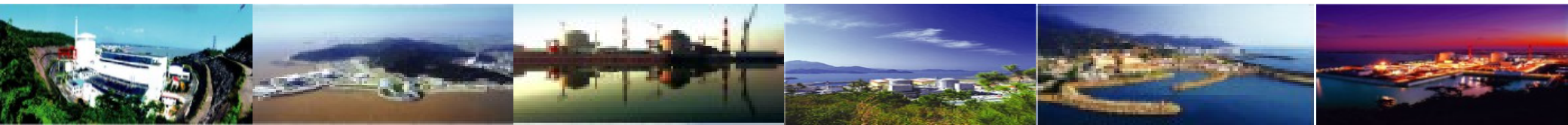
- ***Safety regime of NPP***
- ***safety organization(operational 、 maintenance 、 radiation protection）***
- ***Interaction with RB***
- ***Maintenance of QA system***
- ***Compare with good pratices of international organization***



5.11 Review topics- procedures

8 topics：

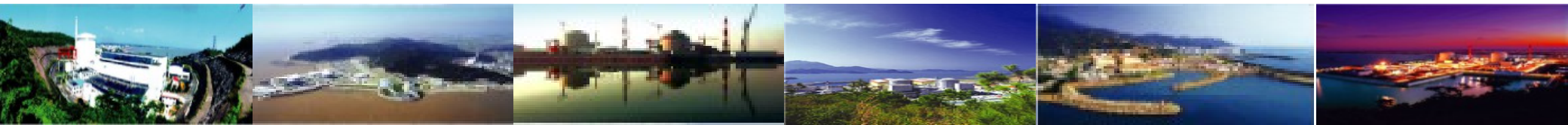
- ***Potential effects to documents , resulted from all modification after operation***
- ***Potential effects in relation to technical documents , resulted from incidents after operation***
- ***Completeness of surveillance programme***
- ***Accident management procedure***
- ***Modification、 maintenance and control in relation to technical procedure on operation、 maintenance、 surveillance、 radiation protection、 in service inspection***
- ***Periodic test surveillance programme***
- ***Usability of latest technical norms***
- ***Special report of 18-month refueling***



5.12 Review topics- human factors

3 topics

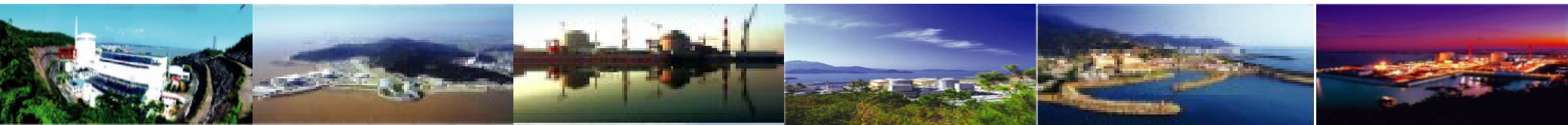
- ***HR***
- ***Training***
- ***Human-machine interface and human error***



5.13 Review topics- emergency planning

5 topics:

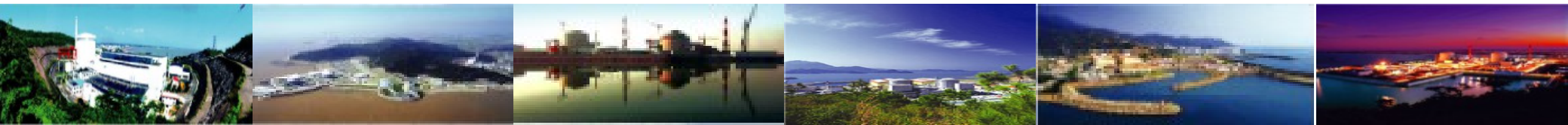
- ***Emergency countermeasure and organiztion***
- ***Emergency plan and procedures***
- ***Emergency facilities、 equipment***
- ***Maintenance of emergency capability***
- ***Interactions of relevant offsite organizations***



Case of Safety Reassessment—PSR for LNPS

6、 Reports related to PSR of LingAo NPP

- ***PSR programme***
- ***Original safety standards***
- ***Current safety standards***
- ***Review report on safety factors***
- ***Special topics review report***
- ***Global report of PSR***
- ***Integrated Corrective Actions plan***

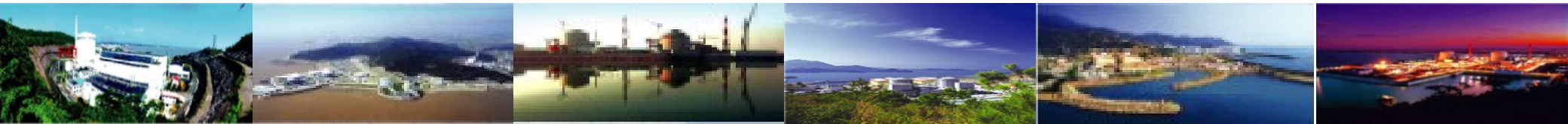


Case ： Reassessment after 3.11 accident

➢1、 Comprehensive Safety Inspection on NPPs

After Fukushima nuclear accident， from March 2011 to December 2011 ,The inspection was conducted mainly on the basis of China's existing and valid nuclear safety laws, regulations and technical standards, by reference to the latest nuclear safety standards released by IAEA and by drawing the lessons and experiences from Fukushima nuclear accident. The content covers 11 fields, incluing:

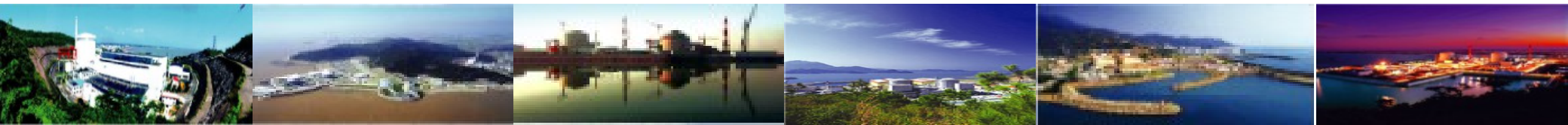
- ✓***Appropriateness of evaluated external events during siting***
- ✓***Capability to prevent and mitigate extreme external event***
- ✓***Measures to prevent and mitigate severe accidents***
- ✓***Effectiveness of environment monitoring and emergency system, etc.***



Case： Reassessment after 3.11 accident

- **1、 Comprehensive Safety Inspection on NPPs**

The detailed requirements refer to technical improvement measures put forward for specific NPPs and mainly cover three aspects: the first one is improving capability to resist external events, the second one is improving capability to prevent and mitigate severe accidents, and the third one is improving nuclear accident emergency and monitoring capability.



Case: Reassessment after 3.11 Accident

➢**1、 Comprehensive Safety Inspection on NPPs**

To be specific, they include eight technical improvement measures as below:

— Improvement on anti-flooding capability of NPPs;

— Selection of emergency water supplement equipment and layout of pipelines;

— Selection of portable power supply and interface setting;

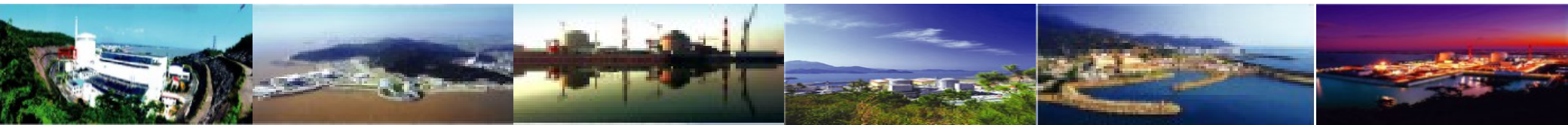
— Monitoring on spent fuel pool;

— Improvement of hydrogen monitoring and control system;

— Habitability and functions of emergency control center;

— Radiation environment monitoring and emergency improvement;

— Response to external disaster.

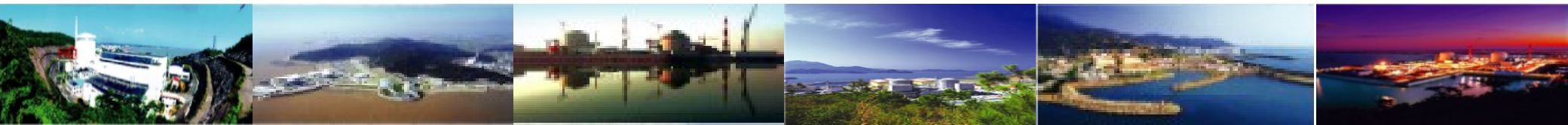


Case: Reassessment after 3.11 Accident

2、 General Technical Requirements for Improvements

In order to normalize improvements of the NPPs in Chinese mainland, the NNSA developed the "General Technical Requirements for Improvements of NPPs after Fukushima Nuclear Accident".

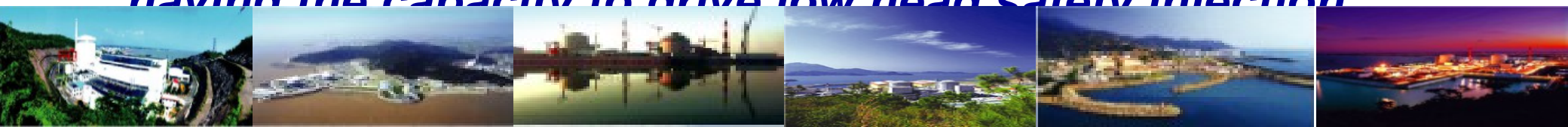
The General Technical Requirements provided technical guide for improvements and include the main contents as follows:



Case: Reassessment after 3.11 Accident

2、 General Technical Requirements for Improvements

- ***a. When implementing waterproof plugging, estimate level of accumulated water according to design basis flood level superposed by thousand -year rainfall, and ensure an available residual heat removal security series before connection of a portable water supplement device.***
- ***b. Design capacity of the portable water supplement device in accordance with connection of it 6 hours after shutdown and equip two sets of such device in each plant site.***
- ***c. Equip two sets of portable power supply, with one set having the capacity to drive low head safety injection***



Case: Reassessment after 3.11 Accident

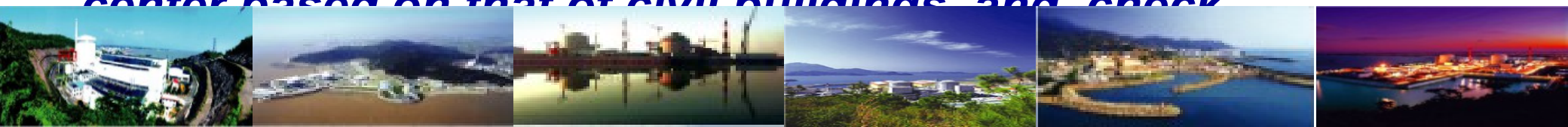
2、 General Technical Requirements for Improvements

✓ ***d. Store portable water supplement devices and portable power supply in the places that can prevent flood 5m higher than design basis flood and are more than 100m . away from safety system, add one degree for structures based on that of civil building, and check according to SL2.***

✓ ***e. Install necessary level and temperature monitoring facilities for spent fuel pool.***

✓ ***f. Assess containment hydrogen in accordance with cladding zirconium-water reaction of 100% active region.***

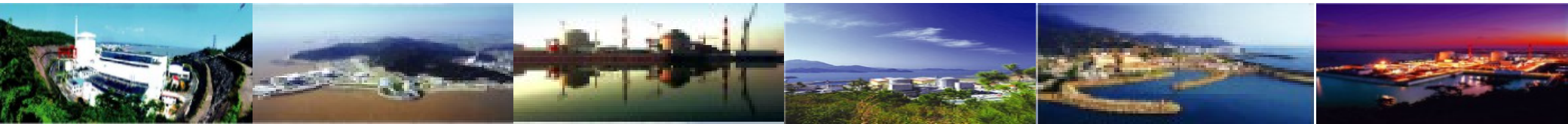
✓ ***g. Add one degree for structures of emergency control center based on that of civil buildings, and check***



Case:Reassessment after 3.11 Accident

- **3 、 Safety Margin Assessment on External Events of NPPs in Operation**
- **3.1 Assessment Coverage and Method**

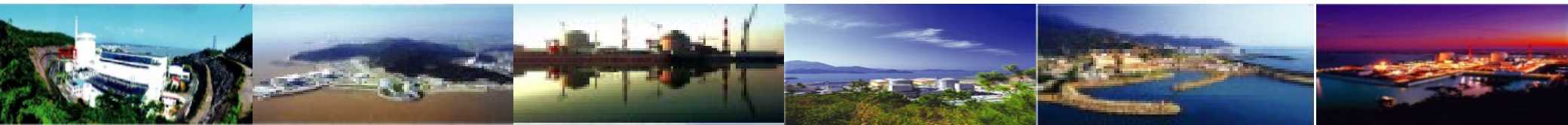
The NNSA promulgated "Notice on Carrying out Margin Assessment on External Events of NPPs in Operation" in March 2012, which requires China's NPPs in operation to further assess safety margin in response to beyond design basis external events so as to optimize and fulfill improvement measures proposed in comprehensive safety inspection. External events selected for assessment include earthquake (initiating event), flood (initiating event) and station blackout (safety system fails afterward), and the assessment covers accident response, defense and consequence of NPPs in case of extreme external events, effectiveness of mitigation measures and possible weakness and steep-sided effect of NPPs.



Case:Reassessment after 3.11 Accident

3.1 Assessment Coverage and Method

As for the assessment method, with deterministic view as the benchmark, supposing defense lines of NPPs lose effectiveness successively during development of extreme natural disasters but failure probability is not investigated, improvements for organization system or technical aspects are put forward through assessment on solidity and safety margin of defense-in-depth of NPPs as well as appropriateness of current accident management measures.

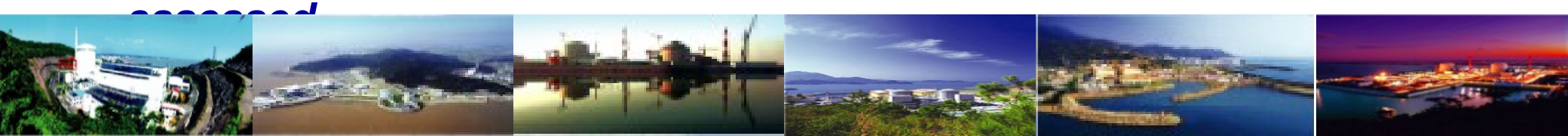


Case:Reassessment after 3.11 Accident

3.1 Assessment Coverage and Method

In this assessment:

- ***In terms of seismic margin, EPRI SMA method was adopted to find out all systems and equipment for accident mitigation, and on this basis, the path to successively make NPPs realize safe and stable shutdown was chosen;***
- ***In terms of flood safety margin, the most likely flooding path was found out according to data of equipment, system and powerhouse, and it was assumed that all systems failed gradually due to rising flood level till reactor core meltdown;***
- ***In terms of station blackout (SBO), considering only battery power supply was used for monitoring main unit parameters and controlling unit status under the accident condition that off-site and emergency diesel power was not restored, the duration of units being kept under controllable state was assessed.***

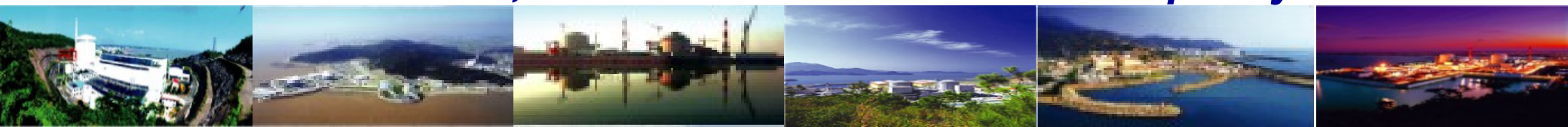


Case:Reassessment after 3.11 Accident

3.2 Assessment Conclusion

According to results of NPP assessment and conclusion of peer review:

- ***All NPPs in operation in Chinese mainland can meet requirements of resistance to earthquake 1.5 times or above design basis earthquake;***
- ***NPPs have the safety margin in response to beyond design basis flood. However, 300MW unit of Qinshan NPP is at a wet site and does not meet requirements of beyond design basis flood level, now some improvements are being implemented, so it also will have the safety margin in response to beyond design basis flood after completion of such improvements;***
- ***All NPPs have taken sound countermeasures for station blackout accident, and the batteries have the capacity of***



Thanks for your attentions.