Development and Related Regulation Practice of SMR in China

Lixin Zhu
P.R. China
CONTENTS

◆ Development of SMR in China

◆ Safety Review Practice of HTR-PM

◆ Safety Requirement of SMR: View of NNSA
Development of SMR in China
1.1 SMRs in China

◆ China General Nuclear Power Corporation (CGN) and CNNC (China National Nuclear Corporation), as two main nuclear industry enterprises in China, are studying their own SMR series of ACPR and ACP.

◆ CSIC (China Shipbuilding Industry Corporation), Tsinghua University are studying offshore SMR and low temperature nuclear district heating reactor plant.
1.2 ACP100 (1/2)

- ACP100 is an innovative PWR based on existing PWR technology, adapting passive safety system and integrated reactor design technology.
- Two reactor modules share electrical building and nuclear auxiliary building. One reactor module can provide 100MWe electric power.
1.2 ACP100 (2/2)

◆ CNNC has signed *General Reactor Safety Review Agreement* with IAEA in 2015.

◆ The demonstration NNP of ACP100 are planned to construct in Chang Jiang, Hainan province.
1.3 Offshore floating reactor by CSIC

◆ China Shipbuilding Industry Corporation (CSIC) is researching and developing its offshore floating reactor, and is preparing for demonstration nuclear reactor power platform construction.
1.4 ACPR50S (1/2)

◆ ACPR50S is a small modular offshore floating reactor, with the electrical capacity of 50MWe per reactor
◆ Supplying power for sea oil exploitation (electricity) and seawater desalination for sea shore areas and islands.

Power supply for sea shore or island
1.4 ACPR50S (2/2)

◆ China General Nuclear Power Corporation (CGNPC) plan to construct a test reactor of ACPR50S.

◆ Preliminary design will be completed in June 2019

◆ CGNPC are discussing with NNSA to identify and resolve some potential licensing issues, such as source term calculation and SSC function test verification.
1.5 NHR200-II (1/2)

- NHR200-II is a lower temperature PWR, was developed by Tsinghua University.
- As early as 1989, the 5MW experimental reactor was successfully constructed and tested for nuclear safety and heating support.
  - Integrated Layout,
  - Natural circulation with full power
  - Passive safety system
1.5 NHR200-II (2/2)

• NHR200-II is looking for suitable sites and users in northern China. The investors hope to use nuclear power to alleviate air-pollution (smog) in winter in northern China, which is caused by burning coal.

• CNNC is developing its Deep Pool Heating Reactor (DPHR) for district heat support. The DPHR is a low temperature and pressure reactor and the capacity of thermal output is 200MW or 400MW.
1.6 HTR-PM(1/3)

- HTR-PM is a high temperature gas cooled reactor demonstration plant for electricity production, designed by Tsinghua University. It starts constructing in Dec 2012.
- At the end of 2015, the Final Safety Analysis Report was submitted to NNSA, and the NNSA was conducting the safety review.
- According to the present schedule, HTR-PM will connect to grid by 2020.
1.6 HTR-PM(2/3)
1.6 HTR-PM(3/3)

- Thermal Capacity:
  - 2*250MW

- Reactor Type:
  - Modular Pebble bed High Temperature Gas-cooled

- Fuel Type:
  - Spherical elements with coated particle fuel

- Coolant: Helium
Safety Review Practice of HTR-PM
2.1 Milestone of HTR-PM Demonstration Project

- April 2008: PSAR review was started
- Sept. 2009: PSAR review was finished
- Dec. 9, 2012: FCD of HTR-PM
- Dec. 2015: FSAR review was started
- At Present: FSAR review is in progress
2.2 Safety Review of HTR-PM(1/6)

- As the first HTGR in China, many challenges in SSC design, and in the safety regulation (analysis, review and licensing).
- Both the NNSA and the designer agreed that current licensing requirements were developed mainly for/from LWR and should be made some changes.
2.2 Safety Review of HTR-PM(2/6)

- Basis and favorable conditions:
  - NNSA has many experiences on different type of plants: LWR for Gen II+, VVER, CANDU, AP1000, EPR.
  - Successful experience from HTR-10 safety analysis and review
- NNSA was early involved into the HTR-PM review process, including HTR-PM Design criteria, Review principle and related guideline
2.2 Safety Review of HTR-PM (3/6)

- This common understanding is reached between licensing authority and designer that current safety requirements are generally applicable to HTR-PM, especially in the level of ministerial rules and regulatory guides.

- Detailed requirements are specified in the Design Criteria Document (More than 40 chapters, various HTR-PM CSC) and have been accepted by NNSA.
2.2 Safety Review of HTR-PM (4/6)

- Guideline for HTR-PM regulatory review is developed and issued in 2008 by NNSA. The associated requirements for Safety goal, Defense-in-Depth concept, General Design basis, Containment, Accident source terms, Emergency Planning, PRA application and Safety related software V&V, are included.
2.2 Safety Review of HTR-PM (5/6)

- The current achievements of HTR-PM safety analysis are embedded in the PSAR and FSAR, e.g. Chapter 15.

<table>
<thead>
<tr>
<th>Classification of Plant Conditions</th>
<th>Occurrence Frequency</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>预计运行事件 AOO</td>
<td>&gt;1E-2</td>
<td>0.25mSv/year</td>
</tr>
<tr>
<td>稀有事故 DBA1</td>
<td>1E-2~1E-4</td>
<td>5mSv for body</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50mSv for thyroid</td>
</tr>
<tr>
<td>极限事故 DBA2</td>
<td>1E-4~1E-6</td>
<td>10mSv for body</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100mSv for thyroid</td>
</tr>
<tr>
<td>超设计基准事故 BDBA</td>
<td>1E-6 (all the accident sequences with a &gt;50mSv consequence)</td>
<td></td>
</tr>
</tbody>
</table>
2.2 Safety Review of HTR-PM(6/6)

- Safety analysis of HTR –PM shows the unique and excellent characteristics of modular HTR in safety. as
  - High performance TRISO fuel
  - High NTC
  - Spontaneous residual decay heat removal
  - No severe accident
Safety Requirement of SMR: View of N
3.1 Work on Regulation and Review

- NNSA published *Safety Review Principles of SMR Demonstration Project* to guide the review work of SMR in China.
- NNSA is now working on the *Source term calculation* and external hazards consideration of offshore nuclear reactor.
3.2 Characteristics of SMR

- Small (minor radiological consequences)
- Advanced (inherently safe)
- Modular (high quality construction)
- Multi-purpose: power supply, heating, desalination, etc. (close to the user requirements)
3.3 Safety Requirement of SMR(1/6)
3.3 Safety Requirement of SMR (2/6)

- The approval process and fundamental safety requirements of SMR are the same as those of large commercial PWR.
- Considering that the characteristics of SMR, some safety requirements may be different, such as site selection, design, construction and operation requirements, nuclear emergency, etc.
3.3 Safety Requirement of SMR(3/6)

- Inherent safety and passive safety systems will reduce the possibility of severe accidents, such as large LOCA, control rod ejection accident, etc.,
- Even the most serious accident, radioactivity will not be released to the environment in large quantities. The accident consequence area is limited to the boundary of Exclusion Area.
3.3 Safety Requirement of SMR(4/6)

- Nuclear power accidents can not be completely eliminated, but even if the most severe accidents happened, the main consequence is the economic losses of nuclear power plants, but not affecting the surrounding environment and the lives of residents.
3.3 Safety Requirement of SMR(5/6)

- Acceptance criteria of post-accident radioactive consequence: Individual effective dose on site boundary shall be controlled below 5 mSv or 10 mSv during whole accident period (generally 30 days) and the equivalent dose of thyroid below 50 mSv and 100 mSv when an infrequent fault or a limiting fault occurs. Individual effective dose on site boundary in BDBA (DEC) shall be controlled below 10 mSv during the whole accident (generally 30 days).
3.3 Safety Requirement of SMR(6/6)

The radiological consequence should be restricted on the site boundary.
3.4 Close to Power User

- High radiation doses or large radioactive release should be ‘practically eliminated’
- The off-site interventions is limited and even unnecessary.
- The size of Emergency Plan Zone (EPZ) is as small as close to the site boundary.
THANKS