Specific Design Consideration of ACP100 for Application in the Middle East and North Africa Region

IAEA Technical Meeting on Technology Assessment of Small Modular Reactors for Near Term Deployment
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CONTENTS

- Background
- Introduction of ACP100
- Design parameters of ACP100
- Technical Aspects
- Safety and licensing strategy
- Testing & Verification
- Proven and Mature technology
- Demonstration project of ACP100
- Application for North Africa & Middle East Region
SMR (less than 300Mwe, IAEA definition) is suitable for small electricity grid, district heating, process heating supply, seawater desalination. Especially suitable for Middle East and North Africa Region.
Background

Main developed and innovated SMRs over the member states
Introduction of ACP100

- CNNC SMR, code ACP100, is an innovative PWR based on existing PWR technology, adapting "passive" safety system and "integrated" reactor design technology;

- CNNC stared R&D on ACP100 from 2010 to 2015

- The modular design technique is used to control the product quality and shorten the site construction period.
Introduction of ACP100

Roadmap of ACP100 development

2010-8
18 Special demonstrations

2010-10
Top design completed

2011-5
Scheme design completed

2011-11
Optimization after Fukushima accident

2011-12
Standard Design PSAR completed

2014-6
Demonstration project preliminary design completed

2015-6
Demonstration project PSAR completed

2016-4
GRSR completed

GRSR passed the review
### Design parameters of ACP100

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal power</td>
<td>385MWt</td>
</tr>
<tr>
<td>Electrical power</td>
<td>~125MWe</td>
</tr>
<tr>
<td>Design life</td>
<td>60 years</td>
</tr>
<tr>
<td>Refueling period</td>
<td>2 years</td>
</tr>
<tr>
<td>Coolant inlet temperature</td>
<td>282 °C</td>
</tr>
<tr>
<td>Coolant outlet temperature</td>
<td>323 °C</td>
</tr>
<tr>
<td>Coolant average temperature</td>
<td>303 °C</td>
</tr>
<tr>
<td>Best estimate flow</td>
<td>10000 m³/h</td>
</tr>
<tr>
<td>Operation pressure</td>
<td>15MPaa</td>
</tr>
<tr>
<td>Fuel assembly type</td>
<td>CF3 shortened assembly</td>
</tr>
<tr>
<td>Fuel active section height</td>
<td>2150 mm</td>
</tr>
<tr>
<td>Fuel assembly number</td>
<td>57</td>
</tr>
</tbody>
</table>
## Design parameters of ACP100

### Main design parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel enrichment</td>
<td>4.45%</td>
</tr>
<tr>
<td>Drive mechanism type</td>
<td>Magnetism lifting</td>
</tr>
<tr>
<td>Control rod number</td>
<td>25</td>
</tr>
<tr>
<td>Reactivity control method</td>
<td>Control rod, solid burnable poison and boron</td>
</tr>
<tr>
<td>Steam generator type</td>
<td>OTSG</td>
</tr>
<tr>
<td>Steam generator number</td>
<td>16</td>
</tr>
<tr>
<td>Main steam temperature</td>
<td>&gt;290 °C</td>
</tr>
<tr>
<td>Main steam pressure</td>
<td>4MPaa</td>
</tr>
<tr>
<td>Main steam output</td>
<td>560t/h</td>
</tr>
<tr>
<td>Main feed water temperature</td>
<td>105 °C</td>
</tr>
<tr>
<td>Main pump type</td>
<td>canned pump</td>
</tr>
<tr>
<td>Main pump number</td>
<td>4</td>
</tr>
</tbody>
</table>
Design parameters of ACP100

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor power-control operation program</td>
<td>primary constant average temperature</td>
</tr>
<tr>
<td>Thermal power plant operation model</td>
<td>Base load operation (Mode-A)</td>
</tr>
<tr>
<td>Plant design life</td>
<td>60 years</td>
</tr>
<tr>
<td>SSE level ground seismic peak acceleration</td>
<td>0.3g</td>
</tr>
<tr>
<td>Predicted Core Damage Frequency (CDF)</td>
<td>&lt;1E-7 Per reactor year</td>
</tr>
<tr>
<td>Predicted Large Release Frequency (LRF)</td>
<td>&lt;1E-8 Per reactor year</td>
</tr>
</tbody>
</table>
The reactor coolant system has been integrated reactor module, which is illustrated in Figure. The reactor module is consisted of reactor vessel, once-through steam generators, canned motor pumps, reactor internals and integrated reactor head package.
(2) Reactor coolant system

- System function and composition
  - 4 main pumps
  - 16 OTSG
  - 1 pressurizer

- System description
  - Operation pressure 15.0MPa
  - Core exit temperature 325°C
(3) Reactor Core

57 CF3S fuel assembly with Gd2O3 solid burnable poison

During refueling 24 4.45% enrichment new fuel assemblies load.
(4) Fully passive safety system

ACP100 adopts fully passive safety system, which is illustrated in Figure:

- passive core cooling system,
- passive residual heat removal system,
- passive containment heat removal system,
- passive inhabitation system,
- automatic depressurization system,
- passive hydrogen control system.
Safety and licensing strategy Aspects

(1) ACP100 Safety design conception

- No active Emergency Core Cooling System
- No active containment spray and recirculation system.
- No active safety system shared between units.
- No need for operator intervention after accident for 72 hours.
- No safety-related emergency AC power.
- NSSS integral design minimizes both the probability and impact of design basic accident (DBA).
- Mitigate DBA without non-safety system. Emergency planning zone is limited inside the site boundary.
Safety and licensing strategy

(2) Special design aspects

- Integral primary system
- Canned motor pump
- Negative feedback coefficient and decreased linear power density
- High capacity of natural circulation in the primary system

Safety enhancing

- Elimination of LB-LOCA
- Reduction of SB-LOCA
- Increased safety margin
- Inherent safety
(3) Passive safety system

- Core make-up tank
- Accumulator
- All injection water with boron
- Multi stages ADS
- Passive residual heat removal
- Submersion of the cavity during accidents
- Natural circulation between core and cavity
- Heat conducted to the large pool outside of containment

Safety enhancing

- Core coverage
- Forbidden the core return to critical
- Core depressurization
- Decay heat removal
(4) Non-residential Area and Planned Restricted Zone Study

Non-residential area (EAB): Less than 300 m; (for large reactor 500m)

Planned restricted zone (LPZ): Less than 800 m; (for large reactor 5km)

Emergency plan zone (EPZ): Internal zone Less than 400 m; (for large reactor 3~5 km) External zone Less than 600 m. (for large reactor 7~10 km)
Safety and licensing strategy

5 Severe accident prevention and Mitigation measures

- Prevention of high pressure core melting
- Prevention of RV failure and melting-through of CV bottom plate
- Prevention of containment over-pressure
- Prevention of hydrogen explosion

- Automatic pressure release system
- Passive hydrogen recombiner
- Reactor cavity flooding by gravity water injection
- Passive containment heat removal
(6) Third party verification (1/2)

Signed a contract of SMR combined research with National Nuclear & Radiation Safety Center (NSC) from 2011 to 2015.
NSC gave the comments on the SMR research report;
NSC perform 3rd party calculation and safety analysis by different codes/software.
NSC perform 3rd party passive integration test research by their own staffs;
IAEA gave the review comments on ACP100 Generic Reactor Safety Review (GRSR) report on April 22, 2016, the 1st SMR completion of GRSR in the world.
Testing & Verification

Seven test research subjects

- Control rod drive line cold and hot test
- Control rod drive line anti-earthquake test
- Internals vibration test research
- Fuel assembly critical heat flux test research
- Passive emergency core cooling system integration test
- CMT and passive residual heat removal system test research
- Passive containment heat removal testing
<table>
<thead>
<tr>
<th>Code number</th>
<th>Name</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>control rod drive line cold and hot testing</td>
<td>2011-2013</td>
</tr>
<tr>
<td>2</td>
<td>passive emergency core cooling system integration testing</td>
<td>2011-2013</td>
</tr>
<tr>
<td>3</td>
<td>internals vibration testing</td>
<td>2012-2014</td>
</tr>
<tr>
<td>4</td>
<td>fuel assembly critical heat flux testing</td>
<td>2011-2014</td>
</tr>
<tr>
<td>5</td>
<td>CMT and passive residual heat removal system testing</td>
<td>2011-2013</td>
</tr>
<tr>
<td>6</td>
<td>control rod drive line anti seismic testing</td>
<td>2012-2014</td>
</tr>
<tr>
<td>7</td>
<td>passive containment heat removal testing</td>
<td>2013-2015</td>
</tr>
</tbody>
</table>
Control rod drive line related testing
Over 3 years, CNNC had constructed the most comprehensive passive engineering safety system testing facility. Core cooling system integration testing, Passive residual heat removal system testing had finished on this facility.
Fuel assembly critical heat flux testing

CHF testing facility

CHF testing tube

CHF heating assembly
Passive containment heat removal testing

The results of the testing indicate the passive containment heat removal system is sufficient to conduct the heat to the ultimate heat sink
Proven and Mature technology

ACP100 with complete independent intellectual property rights

Self-design and manufacture of all main equipment

- Reactor pressure vessel
- once-through steam generator
- Shielded primary pump
- Reactor internals
- CRDM
- Pressurizer, etc.

CF3S fuel assembly with independent intellectual property rights

125 MWe conventional standard turbine generator
Demonstration project of ACP100 in China

Changjiang nuclear power site, Hainan, China, as illustrated in Figure, was chosen to build the first of a kind (FOAK) ACP100 demonstration project.
Demonstration project of ACP100 in China
Three Northeasten Provinces (power and heat supply)

Bohai Sea (Floating NPP)

Zhejiang, Fujian, Hainan Provinces, etc. (power and steam supply, seawater desalination)

Hunan, Jiangxi Provinces, etc. (power and steam supply)
**Application for North Africa & Middle East Region**

![Map of North Africa and Middle East](image)

- **(power or heat supply)**
- **(power and seawater desalination)**
- **(power and steam supply)**

<table>
<thead>
<tr>
<th>No.</th>
<th>parameters</th>
<th>value</th>
<th>remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water and electricity Co-generation output by 1 reactor module</td>
<td>92000t/d+ 60MWe</td>
<td>distilled water by LT-MED</td>
</tr>
<tr>
<td></td>
<td>Steam production only</td>
<td>560 t/h</td>
<td>250 °C, 4MPa</td>
</tr>
<tr>
<td></td>
<td>Electricity only</td>
<td>125Mwe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heat supply area</td>
<td>6X10^6 m²</td>
<td></td>
</tr>
</tbody>
</table>
Application for North Africa & Middle East Region

The corporation between China and North Africa & Middle East are compliance with “one belt one road” Chinese government policy.
Thanks and Questions