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Science and Technology on Reactor System Design Technology Laboratory

Research & Development on Advanced PWR Design Improvement and Innovation in NPIC

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OUTLINE

1. Development of advanced PWR in NPIC
2. Design refinement of advanced PWR in NPIC
3. Research on key issues of advanced PWR in NPIC

1.1 General Introduction

Large Scale Advanced PWR ◆ Small Module Reactor

PWR : ACP1000

Advantages:

- Good Economy
- Technology Maturity Based on Gen II+
- Active & Passive Reliable, efficient + SBO

Testing & verification:

- Reactor integral hydraulic test, by-pass Test, lower plenum mixing test
- Cavity Injection and Cooling System test
- Test for Passive Residual Heat Removal System of Secondary Side(PRS)
- Internals flow induced-vibration test
- Control Rod Drive Line anti-seismic test

First Site: Fuqing 5&6, Fujian, China

SMR: ACP100

Advantages:

- Multi-application
- Flexible site selection
- Inherent Safety

Testing & verification:

- Control rod drive line anti-seismic & control rod drive line cold & hot test
- Fuel assembly CHF testing
- Passive emergency core cooling system integration testing
- Internals vibration testing
- CMT and passive heat removal system testing

Demonstration Site: Putian, Fujian, China

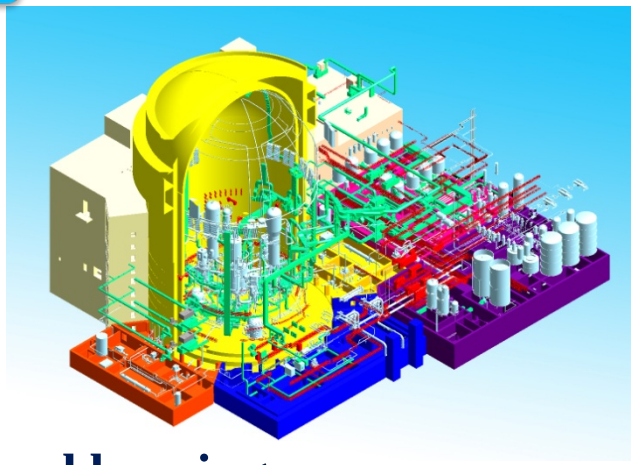
1.1 ACP1000 (Hualong)

Main Parameters

- Core Nominal Thermal Power: 3050MWt
- Nominal Electrical Power: >1100MWe
- TDF flowrate: 22840 m^3/h/loop
- Design Pressure: 17.23 MPa
- Design temperature: 343℃
- Fuel assembly number: 177
- Fuel type: CF3
- Operating Pressure: 15.5 MPa
- Reactor inlet temperature: 291.5℃
- Reactor outlet temperature: 328.5℃
- Core average temperature: 310℃

1.1 ACP1000 (Hualong)

Technical Features



- **Nuclear Design**
  - Loading strategy for 18-month refueling
  - CF3 advanced fuel assembly
- **Advanced in-core measurements (RII)**
  - LPD & DNBR online monitoring system
- **Advanced CRDM (ML-B)**
  - Integrated latch housing & integrated rod travel housing
- **Reactor Coolant System Design**
  - Dedicate depressurization system for severe accident
  - PRV high point venting system
  - LBB technology
  - Passive secondary side heat removal system (PRS): ≥72 hours
  - Core Cavity Injection and cooling system (CIS): IVR, ≥ 72 hours
  - Passive Containment Heat Removal System(PCS): ≥ 72 hours
- **Main Equipment** 60 years

1.1 ACP1000 (Hualong)

Main Features

- Design Lifetime: 60 years
- Cycle Length: 18 months
- DNB margin > 15%
- Operating Mode: Mode G
- Plant Availability Factor ≥ 90%
- Extreme safety ground motion (SL-2): 0.3g
- Core Damage Frequency < 1×10^{-6}
- Large Early Release Frequency < 1×10^{-7}

1.2 ACP100 (Longxing)

Main Parameters

- Core Nominal Thermal Power: 310MWt
- Electricity power: ~100 MWe
- Best estimate flowrate: 6500 m^3/h
- Fuel assembly number: 57
- Fuel enrichment: 4.2%
- Fuel type: CF2 shortened assembly
- Operating Pressure: 15 MPa
- Reactor inlet temperature: 282℃
- Reactor outlet temperature: 323℃
- Core average temperature: 303℃
- SG type: OTSG

1.2 ACP100 (Longxing)

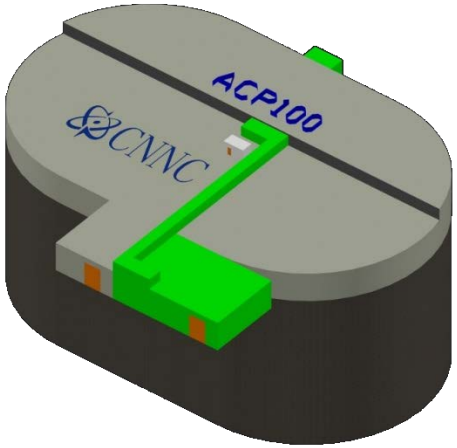
Technical Features

Integral reactor module

- OTSG, Canned motor pump, Integrated reactor head package
- All main components mature

Inherent Safety

- Integrated arrangement
- Canned motor pump
- Small power, small residual heat, small source term
- Low Power Density
- Large Reactor Coolant Inventory
- NSSS Underground



Passive Safety

- Passive core cooling system
- Passive residual heat removal system
- Passive containment heat removal system
- Passive inhabitation system
- Automatic depressurization system

1.2 ACP100 (Longxing)

Main Features

- **Primary system and equipment integrated layout.**
  - The max size of the conjunction pipe is 5-8 cm, whereas the large PWR is 80-90cm
- **Large primary coolant inventory.**
- **Small radioactivity storage quantity.**
  - Total radioactivity of SMR is 1/10 of large PWR's
- **Vessel and equipment layout is benefit for natural circulation**
- **Assurance decay heat removal more effectively**
  - 2-4 times of the efficiency of large PWR heat removal
- **Smaller decay thermal power**
  - 1/5-1/10 times of decay thermal power comparing that of large PWR after shutdown, and is easier to achieve safety by the way of "passive"
- **Reactor and spent fuel pool lay under the ground level for better against exterior accident and good for the reduction of radioactive material release**

2.1 ACP600

10 design refinement of ACP1000

- 24-month refueling capability
- Load following without boron regulation
- Extended scoping time without operator actions
- Refinement of operation flexibility
- New ZH60 SG design
- On-line fatigue monitoring system
- Refinement of reactor vessel structure design
- Enhanced CIS design
- Fuel assembly seismic against 0.3g
- Enlarged pressurizer volume

Better performance, economy, safety and reliability

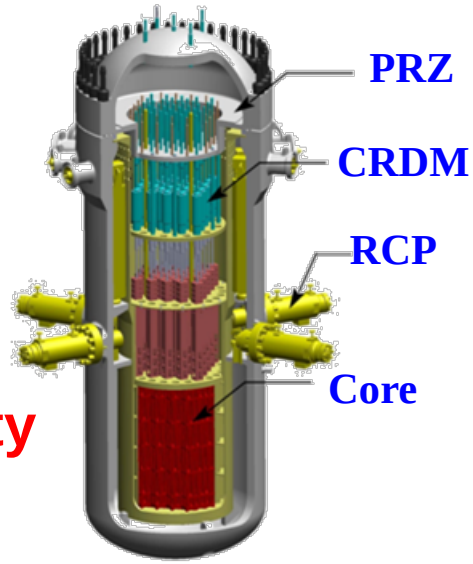
2.2 ACP100+

Brand New SMR Design

Evolutionary improvements on safety

Integrated RCS	✓ Eliminate Large LOCA
internal steam pressurizer	✓ Eliminate Medium LOCA
internal CRDM	✓ Eliminate rod ejection
Control rods for reactivity control	✓ Eliminate boron dilution
Fully flooded containment	✓ Ensure core flooding

The objective of ACP100+ is to meet the multi-function requirement on nuclear co-generation of heat, electricity, pure water and etc. for in-land and/or coast with more inherent safety features.



Better safety & Economics

- Simplified system, Less Devices
- Shortened construction

Site flexibility

- Less site area

Practical elimination of large radioactive release from NPP

Risk Monitoring

Monitor Operation Parameters → Estimate NPP Risk Trend → Online Response & Risk Control

Deterministic Method — Digitized Nuclear Reactor — Multi-Physics/Multi-Scale Coupling Methodology

Probabilistic Method — Risk Monitoring System — Based on living PSA | Point-in-time Risk

ATF

Longer Coping time ⇔ Accident Mitigation ⇔ Safety improvement

- Zr alloy cladding improvement
- Alternative fuel forms

Experience in dispersed/inert matrix fuel & New Zr-based alloy development

- Alternative cladding materials

Research on SiC/SiC composite Cladding

Severe Accident Analysis

- Cladding Oxidation
- Debris Bed Cooling Model
- Hydrogen Behavior

Assure the integrity of Three-Barriers of NPP

Thank you!