Secondary side Passive Residual Heat Removal System
R&D and Engineering Applications

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00. CGN?
01. What is SPRHR?
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China General Nuclear Power Group

A leader in Clean Energy

- Nuclear Power Development
- Nuclear Fuel Supply
- New Clean Energy Development
- Financing
- Nuclear Technology
- Environmental Protection
- Etc.

What We Do 4+X

Nuclear Power Technologies

HPR1000
- China's first nuclear power technology
- Demonstration project: Units 3 & 4 of Taishan nuclear power plant
- The GDA in the UK and EUR assessment of HPR1000 are in progress

ACPR50S SMR
- China's first nuclear power technology
- Electric power of 60 MW, compact reactor design, combined with mature marine engineering technology
- The program design was finished, and the construction is expected to start in 2017

FirmSys
- China's first nuclear-classified DCS product with property rights
- Designed and used in nuclear units under construction in China
- China is the first country to have DCS technology.
- China has become the 4th country to have DCS technology.

CGN: A leader in Clean Energy

- Devoted to nuclear power development and operation since 1979
- As of the end of December 2016, CGN's total assets amounted to over RMB 500 billion
- Focuses on the development of clean energies such as nuclear power, nuclear fuel, wind power, solar power, etc.
- 40,000 employees worldwide
Nuclear power

Daya Bay Nuclear Power Base
- 6 gigawatt-level units
- Total 6120 MW

Guangdong Yangjiang NPP
- 6x1086 MW

Guangdong Taishan NPP
- 2x1750 MW

Liaoning Hongyanhe NPP
- 6x1119 MW

Fujian Ningde NPP
- 4x1089 MW

Guangxi Fangchenggang NPP
- 2x1080 MW
- 2x1180 MW

The largest nuclear power operator in China
The largest nuclear power constructor worldwide

As of the end of Jun. 2017
Units in Operation
- Ranking first in China and entering top 5 internationally (include the units which are available for commercial operation and the in-service units)
- 21.47GW
- 62% of the total installed nuclear power capacity in China

Units Under Construction
- Number of units under construction ranks first in China
- 10.27GW
- 44% of the total nuclear power capacity under construction in China
- Accounting for 16% of the world
What is SPRHR?
• Safe
  • Active & **Passive** safety design philosophy
  • Integrated Severe Accident Prevention & Mitigation Measures
  • Enhanced protection against external hazards
  • Improved emergency response Capability
  • Sufficient Physical Separation Achieved for Item Important to safety

• Maturity

• Economic
• Heat Removal of second side
  • Remove core residual heat from the secondary side of steam generator
  • Active auxiliary feedwater system
  • Passive residual heat removal system of secondary side
• No need of external power
• Use **natural convection** as driving force
• Residual heat removed automatically in case of accidents
• Significant meaning for mitigating accident consequences
02
Why we need it?
After Fukushima accident
  ✓ Higher requirements on mitigating DEC like SBO
  ✓ Reliable and diverse heat sink

Much safer nuclear power with HPR1000
  ✓ Complementary measure for auxiliary feedwater
  ✓ CDF<10^-6
  ✓ LRF<10^-7
03
How to achieve it?
Stage 1: Theory Study
- Research and analysis
- System characteristics
- Principle Experimental
- Determination of overall technical scheme

Exclude disruptive factors, overall technical scheme theoretically feasible
• System Characteristics analysis
  System principle experiments
  • Study on operation law,
  • Study on key factors.
• 7 groups, 33 cases in total
  • Different start features
  • Influence of steam release valves
  • Influence of bare reflux line
  • Cold and hot core level difference
  • Overcooled condenser outlet
  • Non condensable gas
  • Different loop resistance distribution

• Figure out key factors' influence on SPRHR start and operation
• Provide support and reference for functional requirements, system arrangements and operation design
Design and demonstration of preliminary technical project

- Functional requirements and capacity analysis
- System design and demonstration
- Condenser design and demonstration
- Design and demonstration of arrangement and structure
**System function requirements and capacity demonstration**

- safety functions Based on various accident,
- capacity sensitivity analysis Based on safety functions
- Determine the most important design feature: system capacity

Typical accident:
- Heat removal in 72h without water supply

Safety function:
- Action signal analysis

System capacity determination:
- capacity sensitivity analysis

**Graphs:**
- SG level
- System capacity
● **System design and demonstration**

- accomplish the system design according to the functional requirements
- Demonstration of system capacity and features by Modeling by RELAP SCDAPSIM

![System scheme](image1)

![SG level](image2)
• Engineering experiments verification
• Engineering scheme improvements and solidification
• Code applicability analysis

Engineering design with license applied successfully
- Engineering verification experiment
  - SPRHR design verification
  - Code verification

- Experiment purpose ensured by scale modeling and pre-analysis

- SPRHR requirements verified by engineering tests

  Impact of
  - SG level
  - VDA opening
  - Resistance of steam side and liquid side
  - Non condensable gas
RELAP SCDAPSIM is qualified to be applied to SPRHR analysis
- Validated by Chinese authorities
- Validated by third-party independent verification
04
What have we achieve?
1. Secondary passive residual heat removal overall project scheme
2. SPRHR functional requirements and capacity design
3. SPRHR starting, operation stability analysis
4. Evaluation of non condensable gas on natural circulation
5. Passive modeling and code applicability demonstration
6. The first SPRHR applied to engineering Internationally
7. CDF of HPR1000 reduced an order of magnitude $<10^{-6}$
05

About Us and About the Future
Already applied in FCG No.3 No.4 reactors and HongYanHe No.5 No.6 reactors
Will be applied in subsequent HPR100 projects
Dedicated to safer nuclear power
Natural Energy Powering Nature
Developing clean energy to benefit mankind
Thanks