Opportunities and Challenges in SMR and Its Practice in ACP100

INPRO Dialogue Forum on Opportunities and Challenges in SMR
2–5 July 2019 Lotte Hotel Ulsan
Ulsan Republic of Korea

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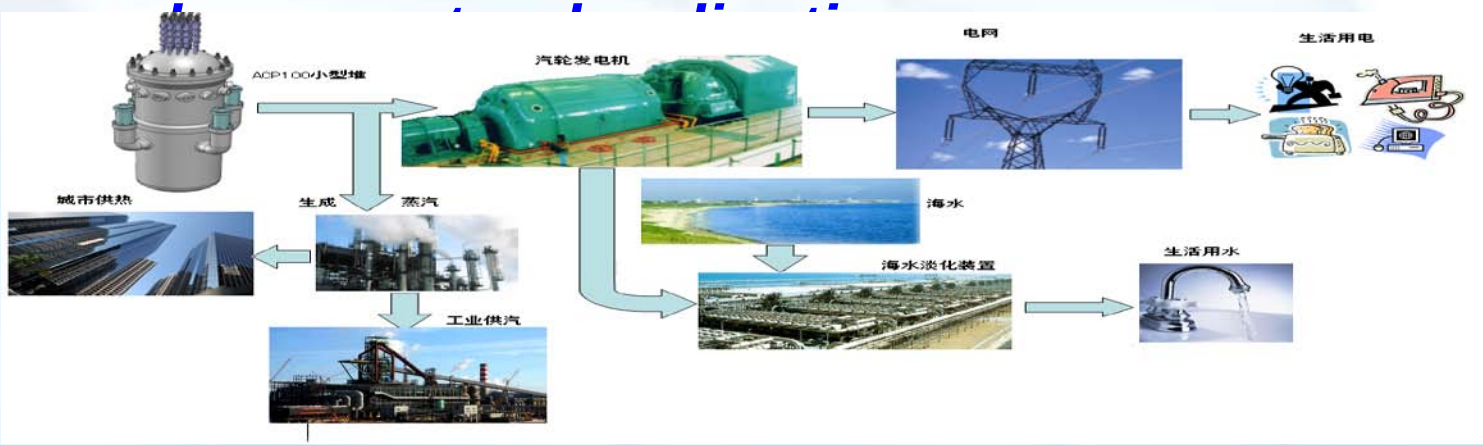
Background

- *SMR (less than 300Mwe, IAEA definition; Small and modular , WNA definition) is suitable for small electricity grid, district heating, process heating*



Background

SMRs Estimated Timeline of Deployment

Immediate Deployable

CAREM — Argentina
HTR-PM — China
KLT-40S — Russian Federation

Under Construction

- **CAREM-25**
  CNEA, Argentina
- **KLT-40S**
  OKBM Afrikantov, Russian Federation
- **HTR-PM**
  INET, China

Near-term Deployable

ACP100 — China
SMART — Republic of Korea
NuScale — USA

Certified or at Advanced Design Stage

- **SMART**
  KAERI, Republic of Korea
- **RITM-200**
  OKBM, Russia
- **PRISM**
  GE-Hitachi, USA
- **PBMR-400**
  PBMR, South Africa
- **BREST300-OD**
  NIKIET, Russia
- **4S**
  Toshiba, Japan
- **ACP100**
  CNNC, China
- **NuScale**
  NuScale Power, USA
- **mPower**
  B&W, USA
- **GTHTR300**
  JAEA, Japan
- **SVBR-100**
  AKME Engineering, Russia
- **ABV-6M**
  OKBM, Russia

Mid to Longer-term Deployable

UNITHERM — Russian Federation
HTMR100 — South Africa
SMR160 — United States of America

Conceptual Design for Future Deployment

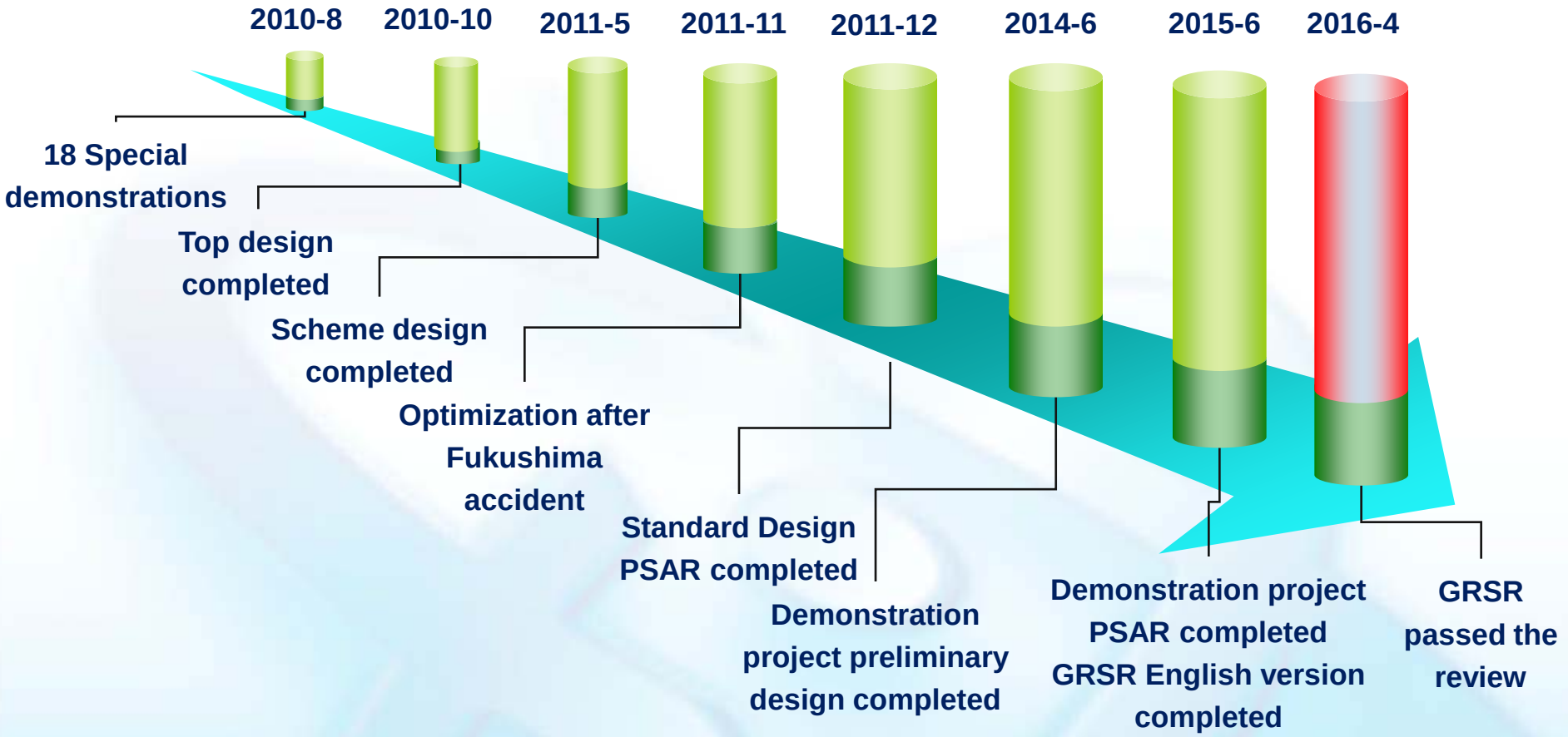
- **AHWR300**
  BARC, India
- **Flexblue**
  DCNS, France
- **IRIS**
  IRIS International Consortium
- **DMS**
  Hitachi-GE, Japan
- **IMR**
  MHI, Japan
- **VVER-300**
  OKB Gidropress, Russia
- **Westinghouse SMR**
  Westinghouse, USA
- **SMR160**
  Holtec, USA
- **VK-300**
  NIKIET, Russia
- **Th-100**
  STL, South Africa
- **SC-HTGR**
  AREVA, France
- **G4M**
  Gen4 Energy, USA

Introduction of ACP100

- *CNNC SMR, ACP100, is an innovative PWR. Based on existing PWR technology , adapting "passive" safety system and "integrated" reactor design technology;*
- *CNNC started R&D on ACP100 from 2010*
- *The modular design technique is used to control the product quality and shorten the site construction period.*

Introduction of ACP100

Roadmap of ACP100 development



Introduction of ACP100

Main design parameters

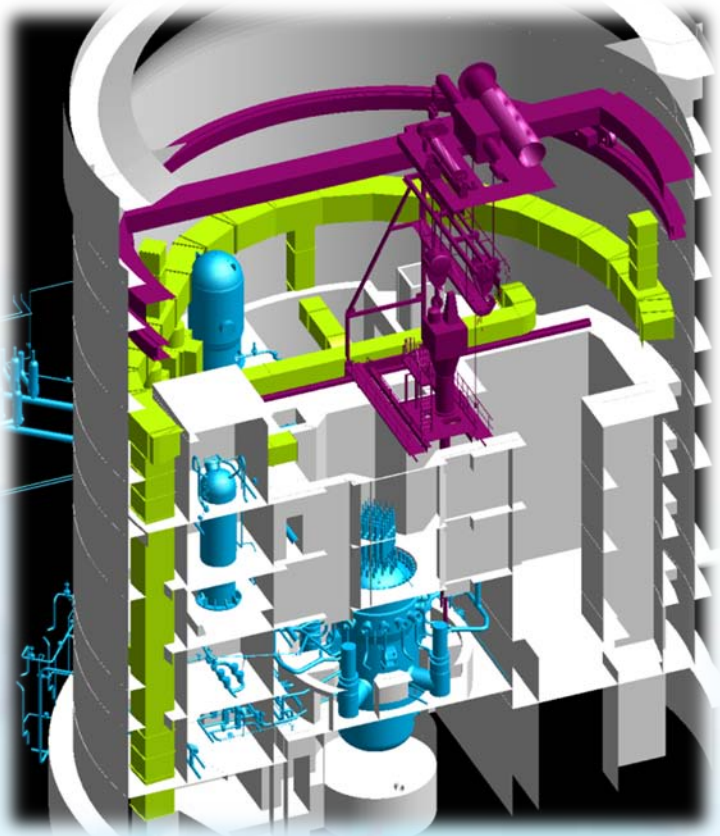
ACP100

Thermal power	385MWt
Electrical power	~125MWe
Design life	60 years
Refueling period	2 years
Coolant inlet temperature	282 ℃
Coolant outlet temperature	323 ℃
Coolant average temperature	303 ℃
Best estimate flow	10000 m^3/h
Operation pressure	15MPaa
Fuel assembly type	CF3 shortened assembly
Fuel active section height	2150 ㎜
Fuel assembly number	57

Introduction of ACP100

Main design parameters

Fuel enrichment	*4.45%*
Drive mechanism type	*Magnetism lifting*
Control rod number	*25*
Reactivity control method	*Control rod、solid burnable poison and boron*
Steam generator type	*OTSG*
Steam generator number	*16*
Main steam temperature	*>290 ℃*
Main steam pressure	*4MPaa*
Main steam output	*560t/h*
Main feed water temperature	*105 ℃*
Main pump type	*canned pump*
Main pump number	*4*



Introduction of ACP100

Main design parameters

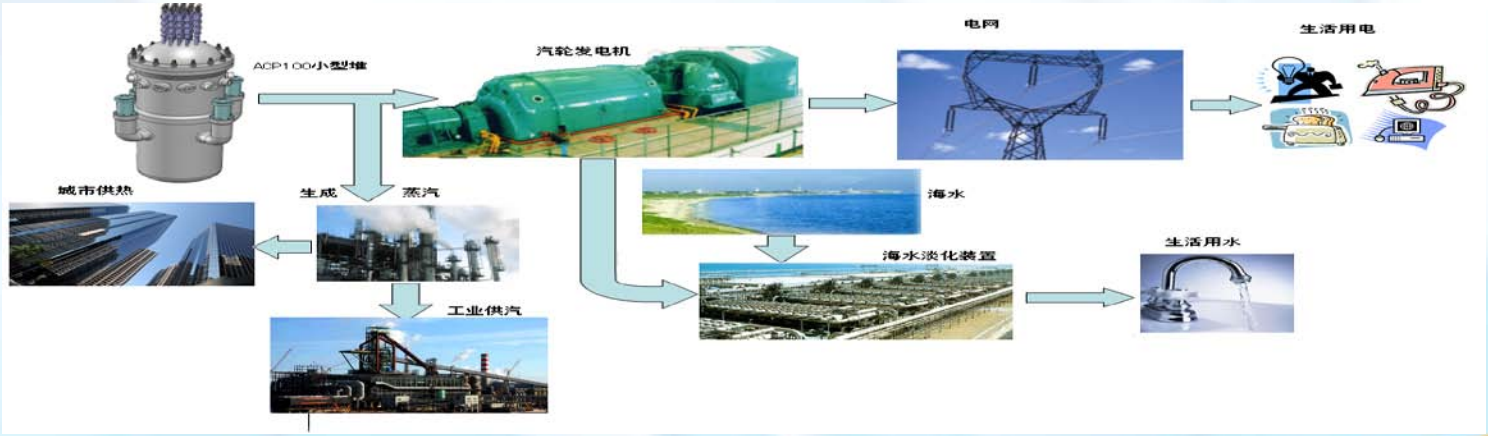
Reactor power-control operation program	*primary constant average temperature*
Thermal power plant operation model	*Base load operation（Mode-A)*
Plant design life	*60 years*
SSE level ground seismic peak acceleration	*0.3g*
Predicted Core Damage Frequency (CDF)	*＜1E-7 Per reactor year*
Predicted Large Release Frequency (LRF)	*＜1E-8Per reactor year*

SMR Opportunities in China

- *Fitness for smaller electricity grids*
  Such as island, remote and isolated area
- *Options to match demand growth by incremental capacity increase*
- *Site flexibility , less site or install on boat*
- *Reduced emergency planning zone, less influence on the neighborhood*
- *Lower capital cost, especial for developing country even affordable by an industry park or one energy consuming industry*
- *Easier financing scheme*

SMR Opportunities in China

- *SMR is suitable for small electricity grid, district heating, process heating supply, seawater desalination. According to different condition, different countries have different goals.*



SMR Opportunities in China

Market Development Situation in China

Three Northeasten Provinces (power and heat supply)

Bohai Sea (Floating NPP)

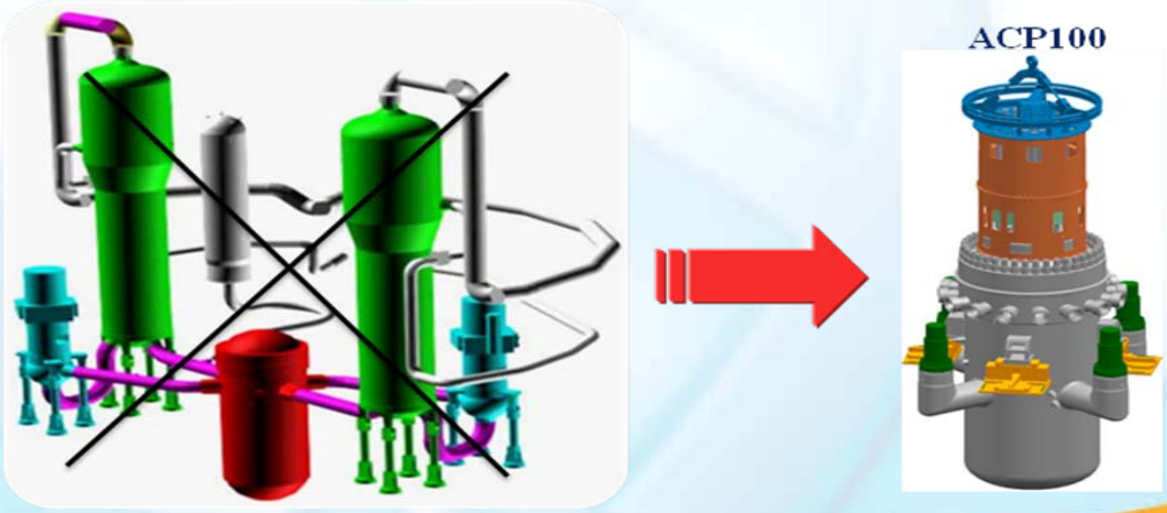
Zhejiang, Fujian, Hainan Provinces, etc. (power and steam supply, seawater desalination)

Hunan, Jiangxi Provinces, etc. (power and steam supply)

Opportunities Benefit from Technology

- ***Shorter construction period (NSSS as a modular)***

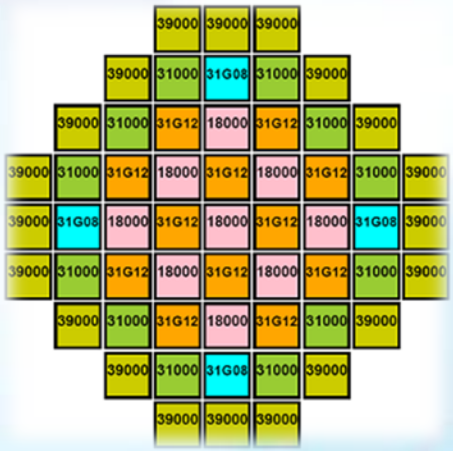
The reactor coolant system can be integrated into reactor module, take an example of ACP100, which is illustrated in Figure. The reactor module is consisted of reactor vessel, once-through steam generators, canned motor pumps, reactor internals and integrated reactor head package.



Opportunities Benefit from Technology

- ***Inherent safety***

Less thermal power, less residual heat, less radiation source achieving higher safety. In case of ACP100, there are 57 CF3S fuel assembly in the core compare that of 157 in the core of a large NPP.



Core layout

57 CF3S fuel assembly with

Gd2O3 solid burnable poison

- ***Easy to achieve Full Passive Engineering***

Safety System: Lower power density, higher coolant volume Vs power ratio.

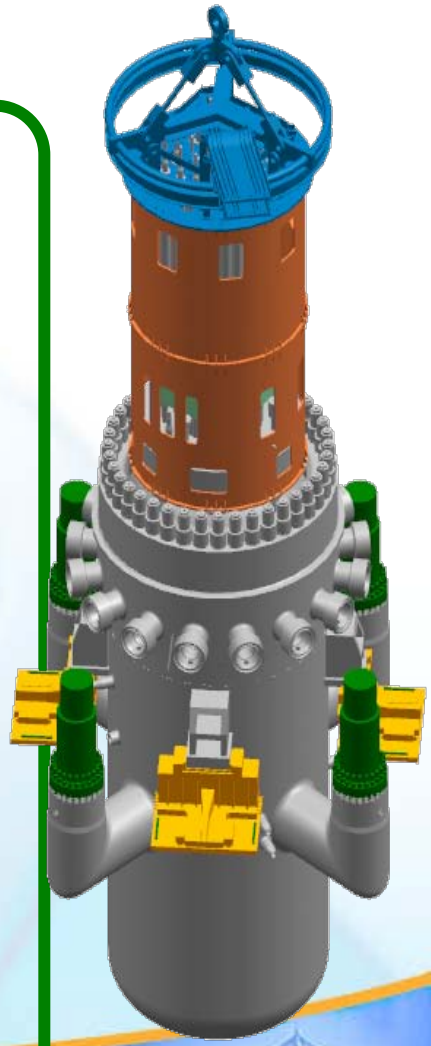
In case of ACP100, safety systems are fully passive.

Opportunities Benefit from Technology

- ***Easy to achieve Safety by design owe to inherent and passive system***

In case of ACP100

- ***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.***



Opportunities Benefit from Technology

Special design aspects	Safety enhancing
Integral primary system	Elimination of LB-LOCA
Canned motor pump	Reduction of SB-LOCA
Negative feedback coefficient and decreased linear power density	Increased safety margin
High capacity of natural circulation in the primary system	Inherent safety

Opportunities Benefit from Technology

Passive safety system

Safety enhancing

- Core make-up tank
- Accumulator

→ Core coverage

- All injection water with boron

→ Forbidden the core return to critical

- Multi stages ADS

→ Core depressurization

- 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

→ Decay heat removal

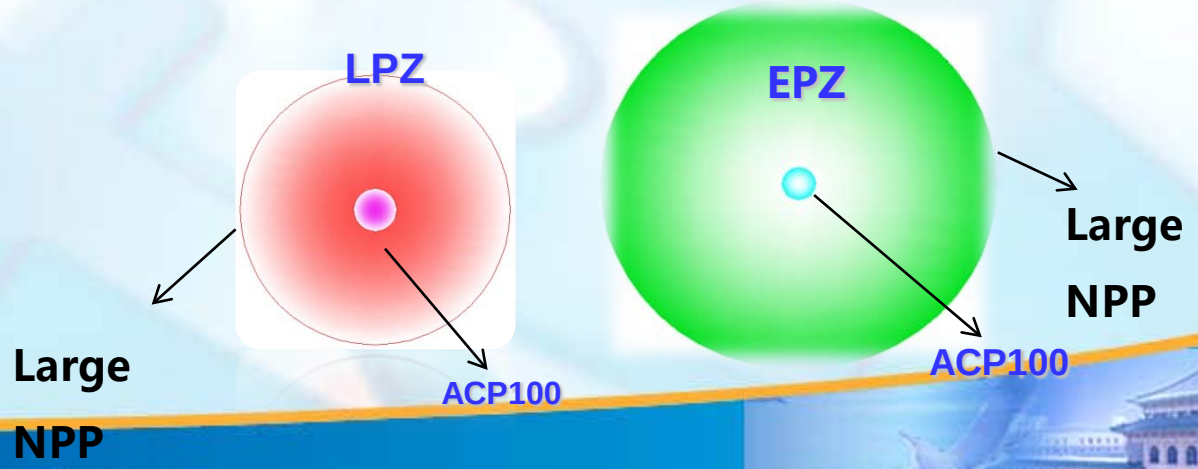
Opportunities Benefit from Technology

Owing to less radiation source and safety features, SMR can achieve small EAB, LPZ, and EPZ.
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)

Eemergency 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)

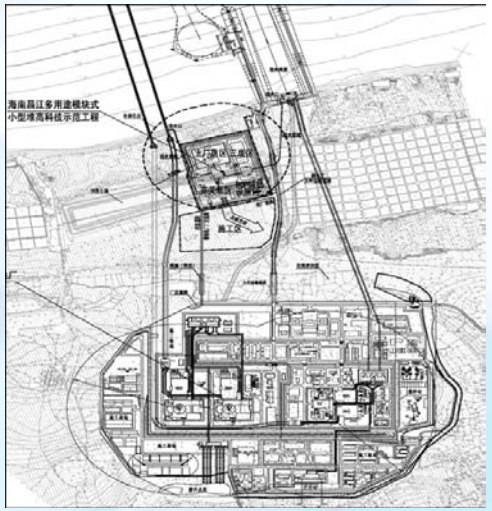


Opportunities Benefit from Technology

- *Utilities of district heating, process heating supply, seawater desalination need adjacent to customer .*
  SMR with smaller EPZ can deploy near customer .

In the case of ACP100,

the customer can establish seawater desalination plant 300 meters away from the reactor building



Challenges in SMR (None Technical)

Economic competitiveness:
SMR with less power output, LCOE（$/kWh) is rather higher than Large NPP according to the scale effect.

In case of ACP100, demonstration project, the price is 1.5 times higher than that of Large NPP. Considering series effect, modular manufacturing and co-generation, the price will decrease in future and in different application scenario.

Challenges in SMR (None Technical)

Construction cost :
SMR with less power output, construction cost of per kW is rather higher than Large NPP according to the scale effect.

In case of ACP100, demonstration project, the cost is 2 times higher than that of Large NPP. Considering different application scenario, ACP100 with 300mX300m footprint can be deployed near population density area.

Challenges in SMR (None Technical)

Supply Chain for multi-modules:
In the beginning stage of the SMR market, different vendor promote different kinds of SMR, it is big challenging and risk investment to supply chain.

In case of ACP100, demonstration project, major component developed by well-known suppliers and sign the corporation agreements in the following project to lower investment risk for supply chain.

Challenges in SMR (None Technical)

Public opinion :
Public opinion support is the same question to the large NPP and SMR, especially for SMR which will be deployed near population density area.

In case of ACP100, we start demonstration project , after 1 or 2 years safety operation then the following project can strength the confidence for public.

Challenges in SMR (None Technical)

Physical Security:
Physical Security may be the most difficult issue now a days due to more and more terrorist attacks.

In case of ACP100, we share the physical security with that of large NPP. In a site without large NPP, the Physical Security is still an big issue to resolve.

Challenges in SMR (Technical)

Regulatory infrastructure:
Regulatory infrastructure is established for large NPP. New regulation or revised regulation should established for SMR.

We are glad to see IAEA Safety REQUIREMENTS ON DESIGN (Ssr-2/1 (Rev.1)) to SMALL AND MEDIUM SIZED MODULAR REACTORS is discussed in member states in the past 2 years and will be published draft document next year.
In China, National Nuclear Safety Authority published SMR licensing guideline in year 2016.
Only guidelines are not enough.

Challenges in SMR (Technical)

Licensability:

Licensability (first-of-a-kind structure, systems and components) New kind of reactor, SMR, need more time in licensing stage because of new technology.

In case of ACP100, Signed a contract of SMR combined research with National Nuclear & Radiation Safety Center (NSC)

IAEA gave the review comments on ACP100 Generic Reactor Safety Review （GRSR）report on April 22, 2016.

Challenges in SMR (Technical)

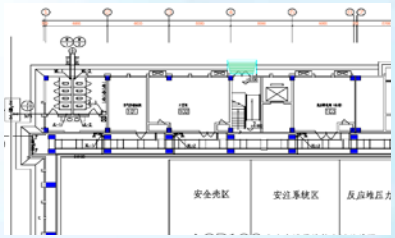
Advanced R&D needs:
In order to achieve higher safety and lower cost, passive safety system, simplified system, new equipment, new technology and new analysis software are used in SMR design.

How to demonstrate the technical readiness for 1st kind of SMR?
In case of ACP100, We conduct major validation testing related to safety.

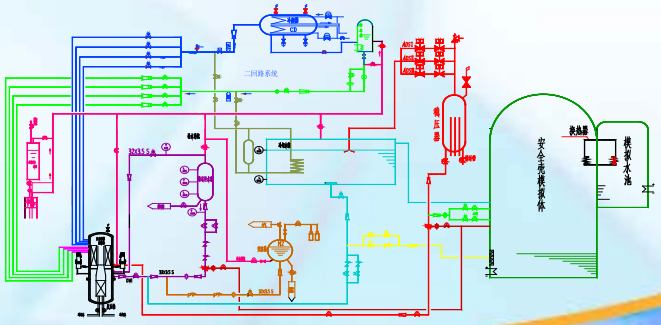
Challenges in SMR (Technical)

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



➢Thermal hydraulic testing hall



Passive emergency core cooling system

Challenges in SMR (Technical)

Proven and Mature technology for major equipment

Summary

SMR concepts have potential benefits in district heating supply, small electrical grid, water desalination and cogeneration markets .

SMR concepts have common technology and non-technology challenges, including regulatory and licensing frameworks.

Demonstration or pilot project is essential important for the SMR.

Summary

Studies needed to evaluate of deploying SMR in the field that large NPP cannot or hard to achieve, such as No EPZ near population density area.

Studies needed to pay more attention on SMR "target costs" in future cogeneration markets, the benefits from coupling with renewable to stabilize the power grid, and impacts on sustainability measures from deployment.

中核集团 CNNC

Thanks and Questions