Progress of SMR

ACP100 Series

UK in SMR; SMR in UK

2014-09-25

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Background

1.1 Background

（1）What is Small Modular Reactor (SMR) ?

- SMR is an integrated pressured water reactor, adopting modular design and construction concepts, passive safety technology.
- It can reach large power by several modular combination.
- It can be used in different places and different condition.

Background

1.1 Background

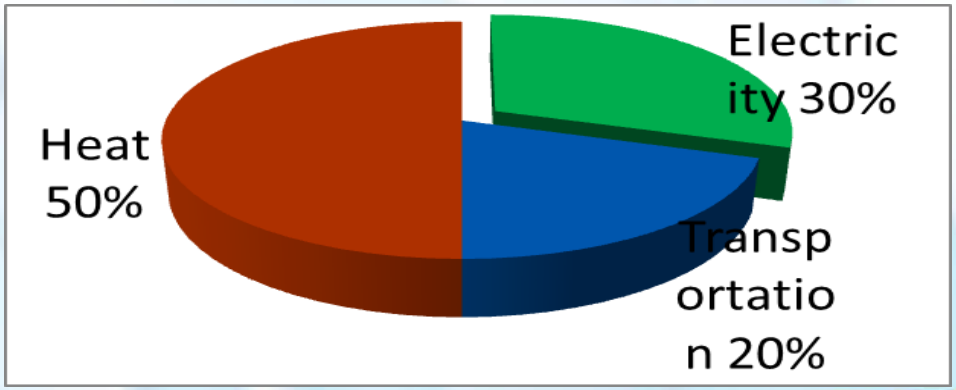
（2）Challenges of Increasing the large NPP power

- Industry capacity and transportation
- Marginal effect of the economy by increasing power
- Difficulty in application of passive technology
- Huge overnight investment
- Not flexibility for different using

1.1 Background

（3）Non electrical application nuclear energy and needs of developing countries for nuclear electricity

In 10 to 20 years，70% of the energy consumption in developing countries is non-electricity application, such as heat and transportation.



Background

1.1 Background

（4）Improving economic by modular design and constriction

- Not like that of large NPP, SMR achieves its economic by simplify modular design and increase number of the modular

（5）Advantage for safety

- SMR with lower power, lower residual heating, suitable for passive safety facilities application.

Background

Main developed and innovated SMRs

Country	Name	Technology	Type	Electric power/thermal power	Date target of business deployment
USA	M-power	PWR	integrated	125MWe	2021
USA	SMR	PWR	integrated	225MWe	2022
Korea	SMART	PWR	integrated	100MWe	2015
Russia	KLT40-S	PWR	compacted	35MWe	2016
China	NHR	PWR	integrated	40MWe	2015
China	ACP100	PWR	integrated	100MWe	2015

Technical Aspects

2.1 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;
- No operator intervention needed in 72 hours of accident ;
- Passive severe accident prevention and mitigation action, such as for containment hydrogen eliminator, cavity flooding etc. to ensure the integrity of pressure containment;
- The modular design technique is easy to control the product quality and shorten the site construction period.

Technical Aspects

Main design parameters

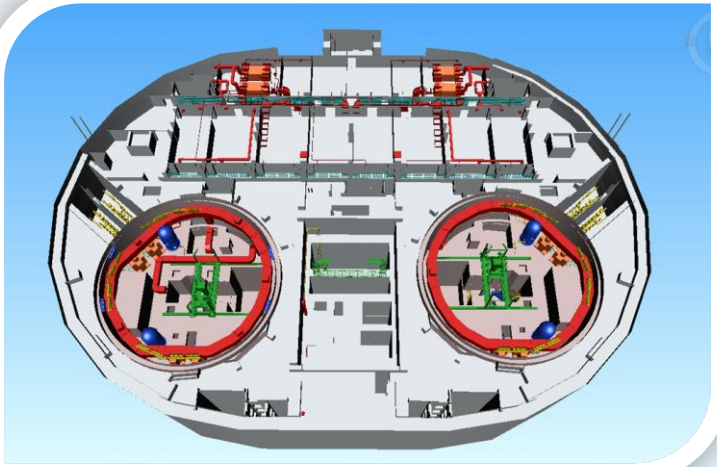
ACP100

Thermal power	310MWt
Electrical power	~100MWe
Design life	60 years
Refueling period	2 years
Coolant inlet temperature	282 ℃
Coolant outlet temperature	323 ℃
Coolant average temperature	303 ℃
Best estimate flow	6500 m^3/h
Operation pressure	15MPaa
Fuel assembly type	CF2 shortened assembly
Fuel active section height	2150 ㎜
Fuel assembly number	57

Technical Aspects

Main design parameters

Fuel enrichment	*4.2%*
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	*450t/h*
Main feed water temperature	*105 ℃*
Main pump type	*canned pump*
Main pump number	*4*



Technical Aspects

Main design parameters

Extraction temperature	235 ℃（reheat）
Extraction loop pressure	0.294MPa
Heating temperature	125 ℃
Heating loop temperature	1.6MPa
Reactor power-control operation program	primary constant average temperature
Thermal power plant operation model	Base load operation（Mode-A)
SSE level ground seismic peak acceleration	0.3g

Technical Aspects

Main characteristics

(1) Primary system and equipment integrated layout. The maximal size of the conjunction pipe is 5-8 cm, whereas the large PWR is 80-90cm.

(2) Large primary coolant inventory.

(3) Small radioactivity storage quantity. Total radioactivity of SMR is 1/10 of large PWR's, meanwhile multi-layer barrier is added to keep the accident source-term at a low level.

(4) Vessel and equipment layout is benefit for natural circulation.

Technical Aspects

Main characteristics(continued)

(5) Assurance decay heat removal more effectively. 2-4 times of the efficiency of large PWR heat removal from the vessel surface.

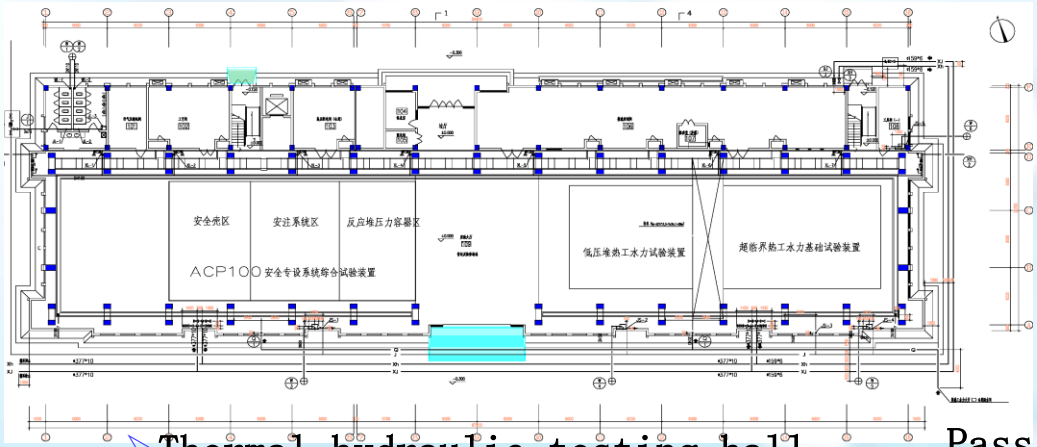
(6) Smaller decay thermal power. 1/5-1/10 times of decay thermal power comparing that of large PWR after shutdown, and is easier to achieve safety by the way of “passive”.

(7) Reactor and spent fuel pool lay under the ground level for better against exterior accident and good for the reduction of radioactive material release.

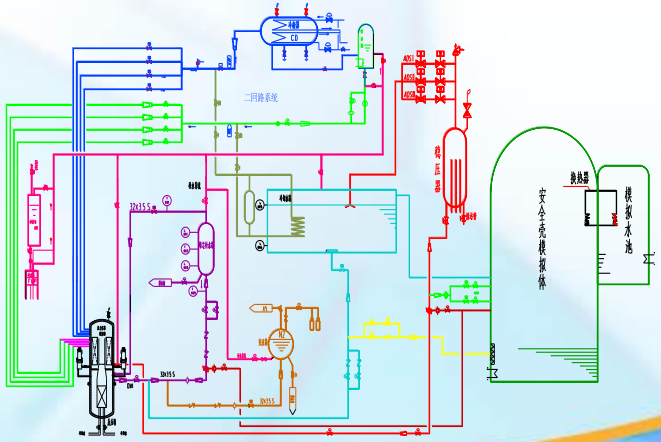
Testing & Verification

Six 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



➢Thermal hydraulic testing hall



Passive emergency core cooling system

Testing & Verification

Code number	Name	Period
1	control rod drive line cold and hot testing	2011-2013
2	passive emergency core cooling system integration testing	2011-2013
3	internals vibration testing	2012-2014
4	fuel assembly critical heat flux testing	2011-2014
5	CMT and passive residual heat removal system testing	2011-2013
6	control rod drive line anti seismic testing	2012-2014

Licensing

- ***Signed a contract of SMR combined research with National Nuclear & Radiation Safety Center in 2011, and developed the following works:***

National Nuclear & Radiation Safety Center gave the comments on the SMR research report of design preparation phase;

Had a technical exchange of SMR containment design after Fukushima nuclear accident;

Passive integration test research technical exchange, and the test program was approved;

Completed the Q1 questions and question reply of concept design stage, and the concept design was approved;

Signed several specific research programmers and standard design safety analysis combined research with National Nuclear & Radiation Safety Center in year 2013. Evaluation report will issue in mid of 2015.

Site Selection

- ***The demonstration ACP100 nuclear power plant , with two 310Mwth reactors, will be located in Putian City, Fujian Province in the east coast area of China.***

ACP100

Demonstration Site

Further R&D on ACP100+

Based on the ACP100 design, in order to enhance its safety, economics and operational flexibility, R&D for next generation SMR, i.e., ACP100+, is carried out by CNNC.

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.

Further R&D on ACP100+

ACP100+ Main design parameters

Type	Integrated PWR
Thermal power	385 MWt
Electrical power	120 MWe
Design life	60 years
Refueling period	2 years
Fuel assembly type	17×17 CF shortened assembly
Number of fuel assemblies	57
Reactivity control	Control rods + Burnable absorber

Further R&D on ACP100+

ACP100+ Main design parameters

Average coolant temperature	305℃
RCS pressurizer	Internal steam pressurizer
Steam generator type	OTSG
Coolant pump type	Internal Canned pump
Control rod drive mechanism	Internal CRDM
Main steam pressure	4MPa（abs）
Main steam temperature	＞290℃
Containment	Submerged steel containment

Further R&D on ACP100+

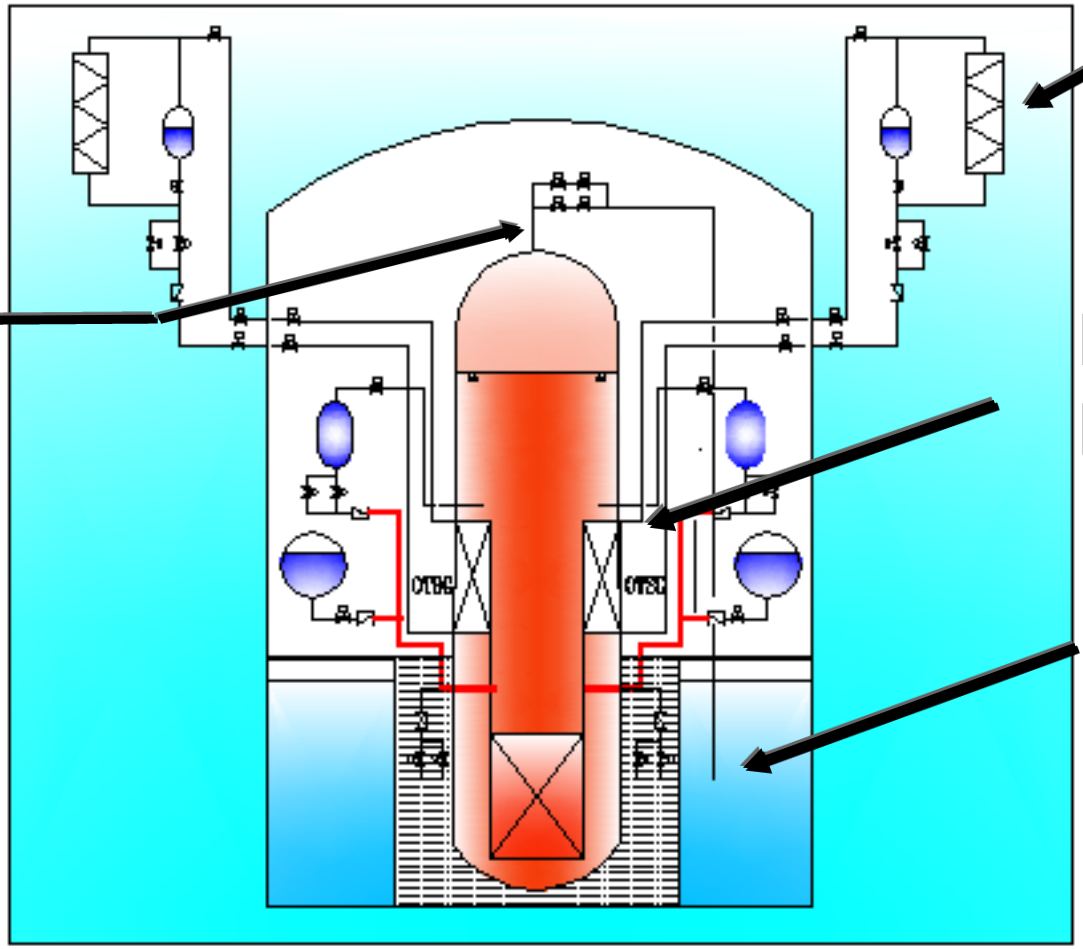
Overall Technical plan

ACP100+ is designed as a forced circulating PWR with integrated RCS to eliminate the primary loop pipes and surge line of pressurizer so as to prevent large and medium LOCA accidents.

The atmosphere as the ultimate heat sink is achieved by a compact steel containment fully flooded in coolant. Passive safety systems are utilized to further limit the CDF.

Further R&D on ACP100+

Overall Technical plan



ACP100+ Overall scheme

Further R&D on ACP100+

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

Simplified system，Less devices

Better safety & economics

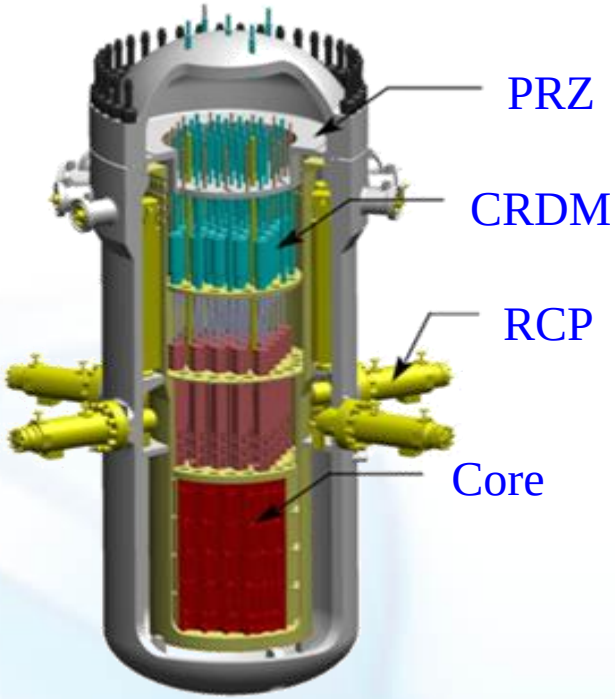
Further R&D on ACP100+

Modular design for Reactor

- The modular design of reactor is consisted of reactor vessel, internals, CRDM, OTSG, primary pumps, fuel assemblies, internal PRZ and etc. based on an integrated RCS.
- The modular design is targeting for manufacture, transportation and installation.

Shortened construction, Less site area

Better economics & site flexibility



General arrangement of modular reactor

Further R&D on ACP100+

Key Technologies

- ***Internal CRDM***
- ***Internal steam pressurizer***
- ***Design, manufacture and installation of canned pump***
- ***Design of flooded compact steel containment***
- ***Severe accident source term analysis***

Further R&D on ACP100+

Prospect for collaboration

CNNC has been devoting to the development of ACP100+ and its key technologies with active sharing and discussion.

CNNC is enjoying to have brief presentations from Great Britain about previous topics and pleased to have your comments and proposals.

It is the long term and bilateral collaboration with Great Britain that is anticipated by CNNC.

Conclusion

- *Nuclear energy is the sustainable energy of the 21 century.*
- *Fukushima accident proves that nuclear industry and research department must improve the safety of nuclear power plant further.*
- *Development of nuclear power must balance safety and economy.*
- *Economy effect of capacity scale is limited.*
- *Single purpose application of nuclear energy to multipurpose application, including thermal, water, electric etc. has already scheduled.*

Thanks for your attention!!