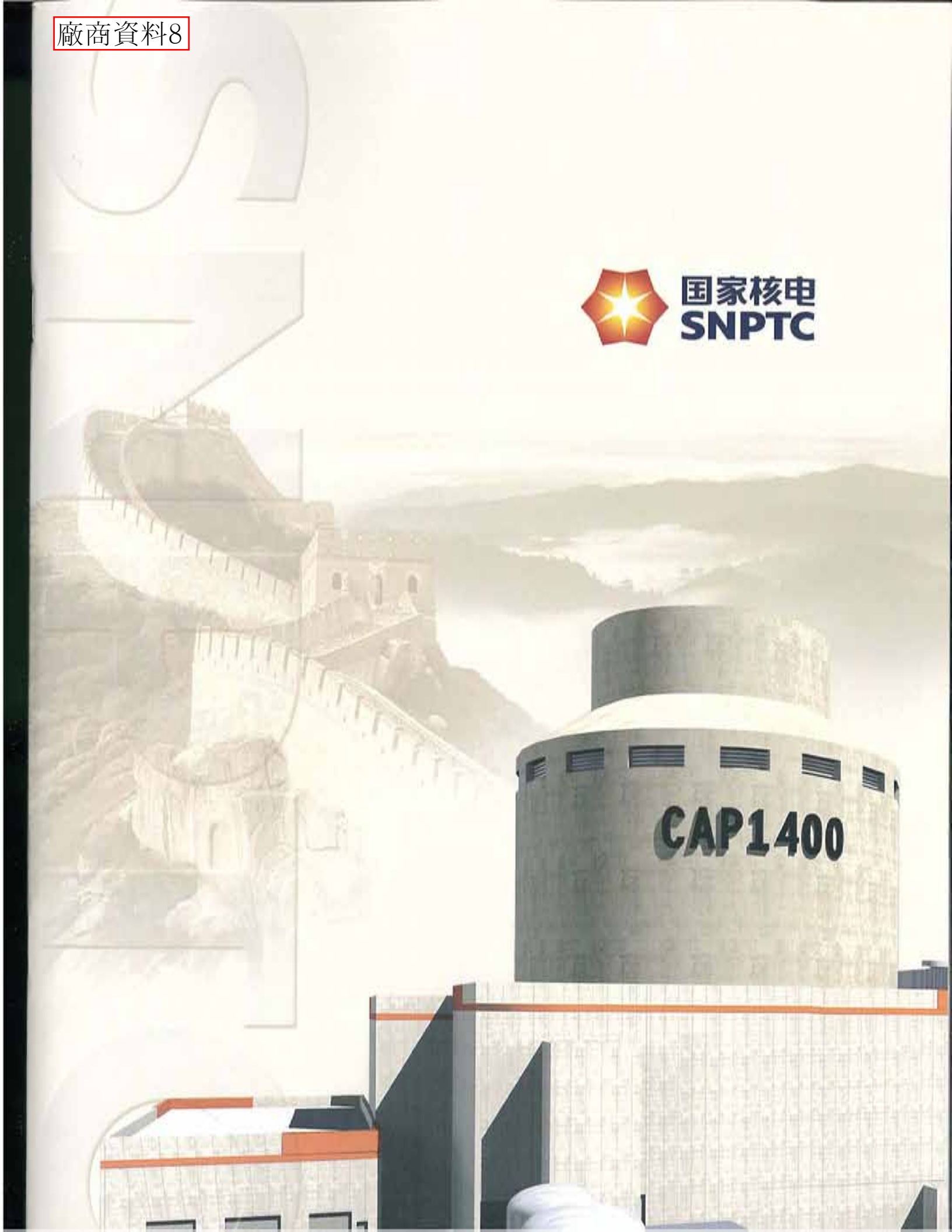
廠商資料8

国家核电
SNPTC



国家核电
SNPTC

Complete nuclear industrial system in China supports nuclear innovation

SNPTC is the organizer of introduction and absorption of advanced AP1000 nuclear power technology, EPC general contractor of self-reliance supporting project and industry leader of China's self-reliant nuclear power technology

SNPTC carries forward China's 40-year nuclear power R&D and designing practice and experience

Pakistan Chashma Nuclear Power Plant exported by China has displayed commercial value and a good record of safe operation

SNPTC is the transferee of AP1000 technology and the executing body of the nuclear power self-reliance supporting project designated by Chinese government

SNPTC is EPC contractor of the world's first AP1000s

CAP1400 inherits advancement and maturity of AP1000

CAP1400 design principle & performance

CAP1400 main indicators

CAP1400's major improvement on AP1000

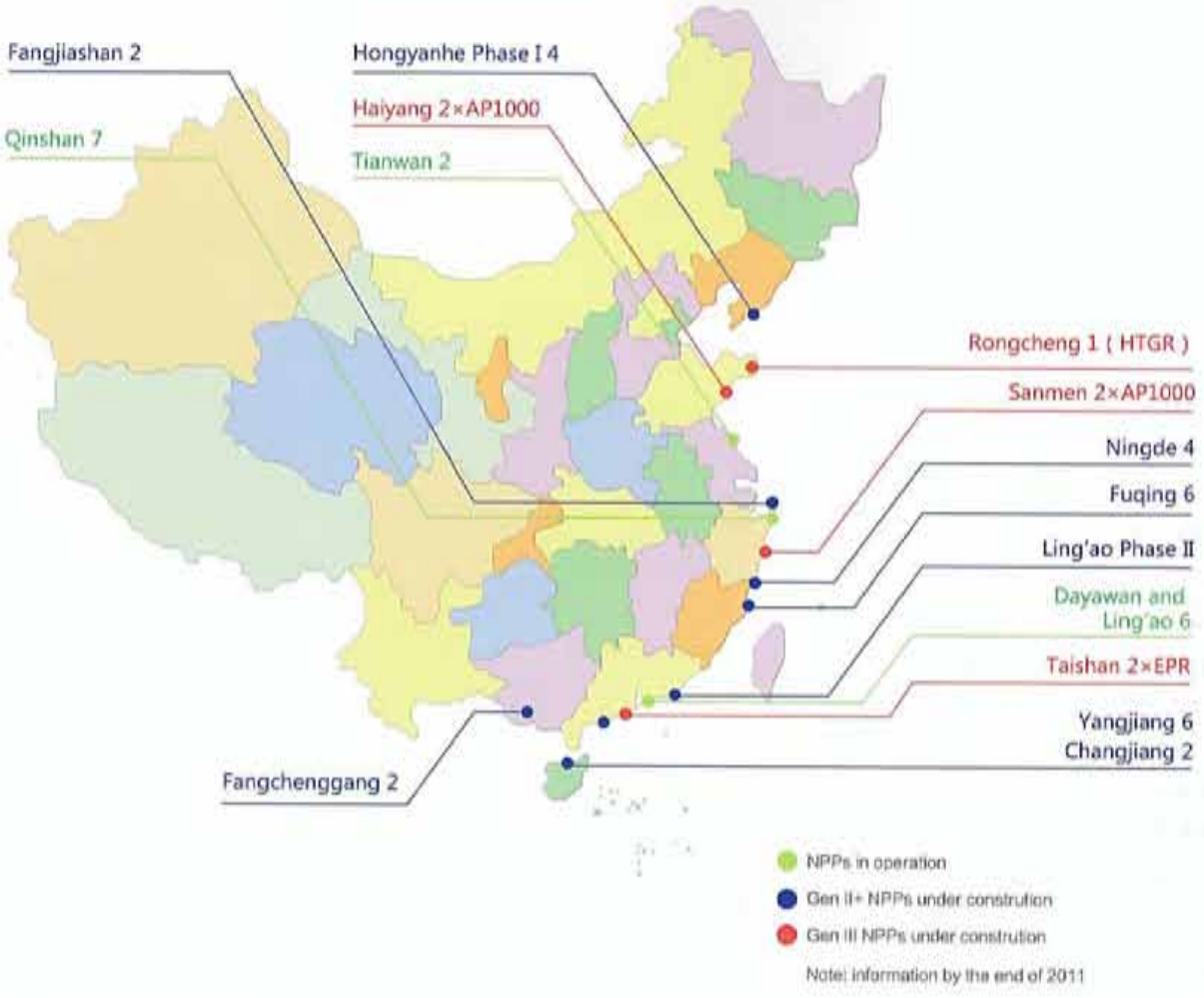
CAP1400 development has gained support from Chinese government and pooled wisdom of global nuclear elites

CAP1400 will start construction in 2014 and begin operation in 2018

Complete Nuclear Industrial System in China Supports Nuclear Innovation.

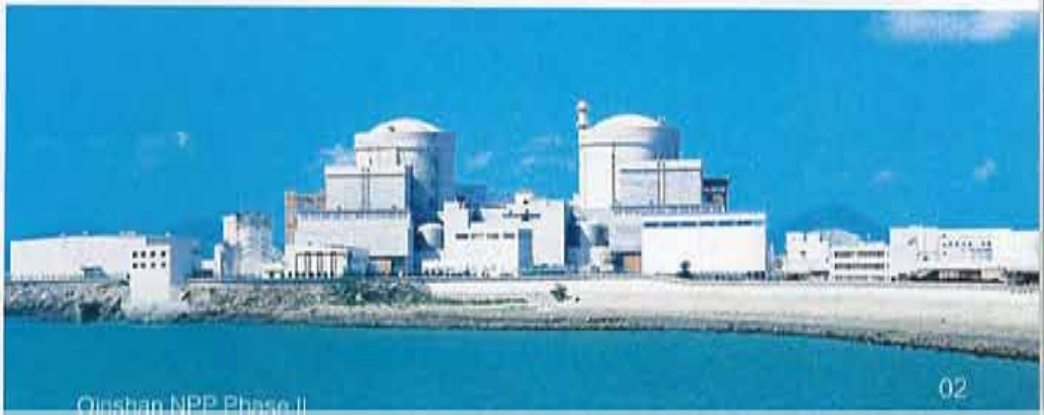
Chinese government has taken nuclear power expansion as a significant tool to improve energy structure, alleviate emission of carbon dioxide and meet national medium and long term demands for energy. From Dec. 15th, 1991, when the independently designed and constructed Qinshan NPP was put into operation, to the end of 2012, there are 16 units connecting to the grid in China's mainland with the total installed capacity of 11688 Mwe (source: IAEA | PRIS), ranking the 8th in the world. They have maintained a good record of safe operation for over 20 years. Currently there are 29 units (30970 Mwe) under construction which tops the world in installed capacity.

To support innovation and development of nuclear power technology, China has established a complete nuclear industrial system, covering technical R&D, engineering design, test verification, equipment manufacturing, project construction, operation and maintenance and nuclear fuel supply.



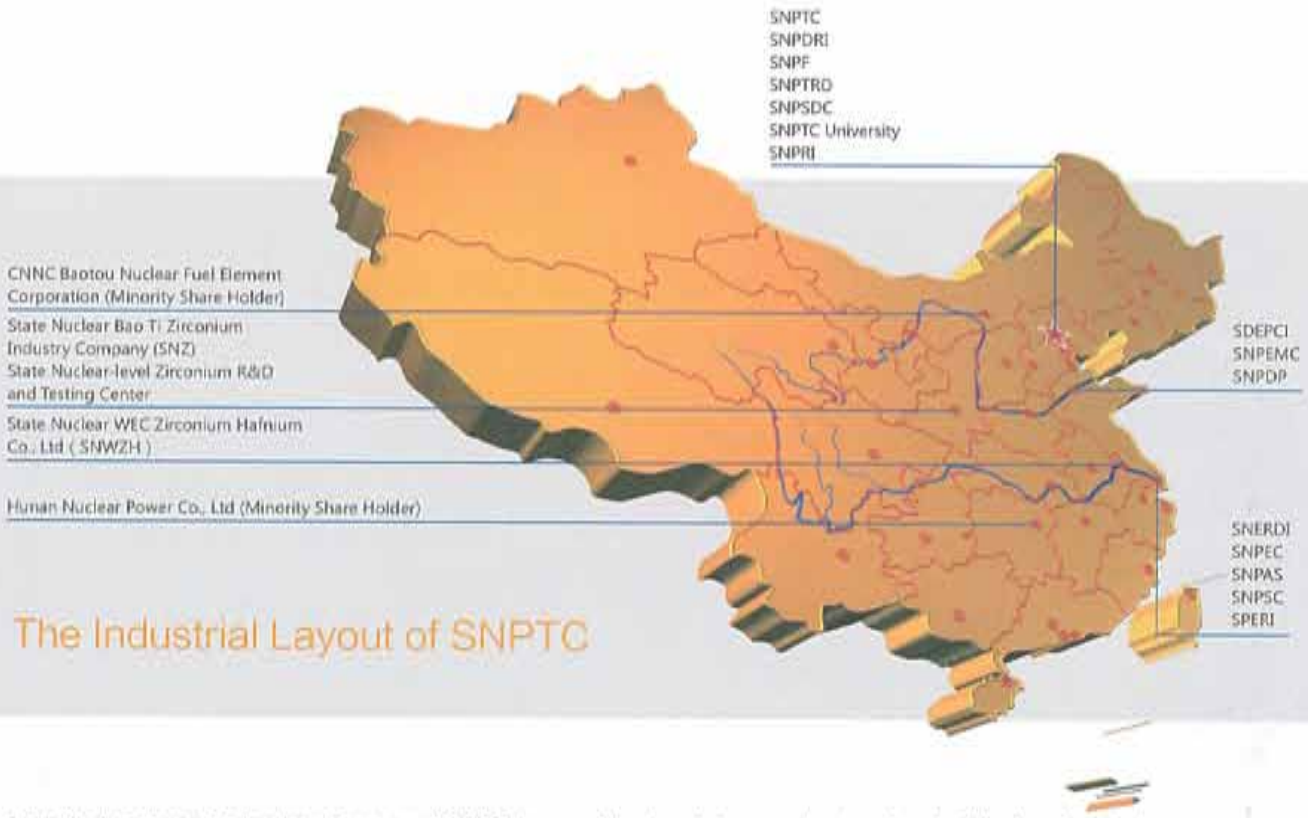
Haiyang NPP Site

Tianwan NPP Site



Qinshan NPP Phase II

SNPTC is the Organizer of Introduction and Absorption of Advanced AP1000 Nuclear Power Technology, EPC General Contractor of Self-reliance Supporting Project and Industry Leader of China's Self-reliant Nuclear Power Technology.



The Industrial Layout of SNPTC

State Nuclear Power Technology Company (SNPTC) is one of the key state-owned enterprises in China's nuclear industry.

SNPTC undertakes the introduction and absorption of advanced AP1000 nuclear technology and serves as the general EPC contractor of China AP1000 Self-reliance Supporting Projects by designing and constructing AP1000 nuclear power plants in China's mainland per contract authorization.

SNPTC is engaging in independent R&D of CAP series NPP brand featuring advanced passive technology, and will design, construct and operate CAP 1400 Demonstration Project.

SNPTC has established a complete industry chain consisting of technical R&D, engineering design, equipment supply, project construction and operating service of nuclear power, conventional and new energy power plants, thus enabling the provision of one-stop and menu-typed service.

——Industry leader of China' s self-reliant nuclear power technology and constructor of Demonstration Project.

——Technology supplier of advanced CAP NPPs.

——EPC general contractor of advanced CAP NPPs.

SNPTC Carries Forward China's 40-year Nuclear Power R&D and Designing Practice and Experience

Shanghai Nuclear Engineering Research & Design Institute (SERDI), a subsidiary of SNPTC, has designed and provided operating support for Qinshan NPP Phase I, a pressurized water reactor of 300MWe. Ever since its commercial operation in 1991, Qinshan NPP Phase I has maintained sound operation and performance for over 20 years.

Due to the safety and economy of Qinshan NPP Phase I, this 300MWe design has been popularized across Pakistan.

Pakistan Chashma Nuclear Power Plant Exported by China Has Displayed Commercial Value and a Good Record of Safe Operation.

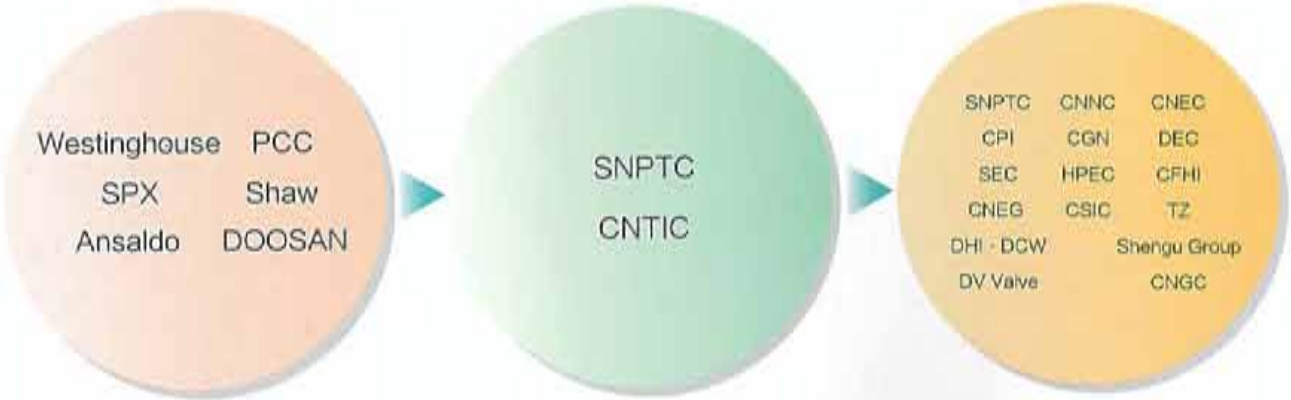
Shanghai Nuclear Engineering Research and Design Institute (SNERDI), a subsidiary of SNPTC, is the designer and the operation supporter of Pakistan Chashma Nuclear Power Plant. CHANUPP Unit 1 with a generation capacity of 300MWe, was initially connected to the gird on Jun. 13th, 2000, and turned over to Pakistan for management and operation from Sep. 25th.

The completion of CHANUPP Unit 1 reflected that Chinese PWR nuclear power technology has been integrated with the international technology and management codes and standards. International Atomic Energy Agency (IAEA) considered that CHANUPP project, with a safe and reliable operation, is in line with the international standards.

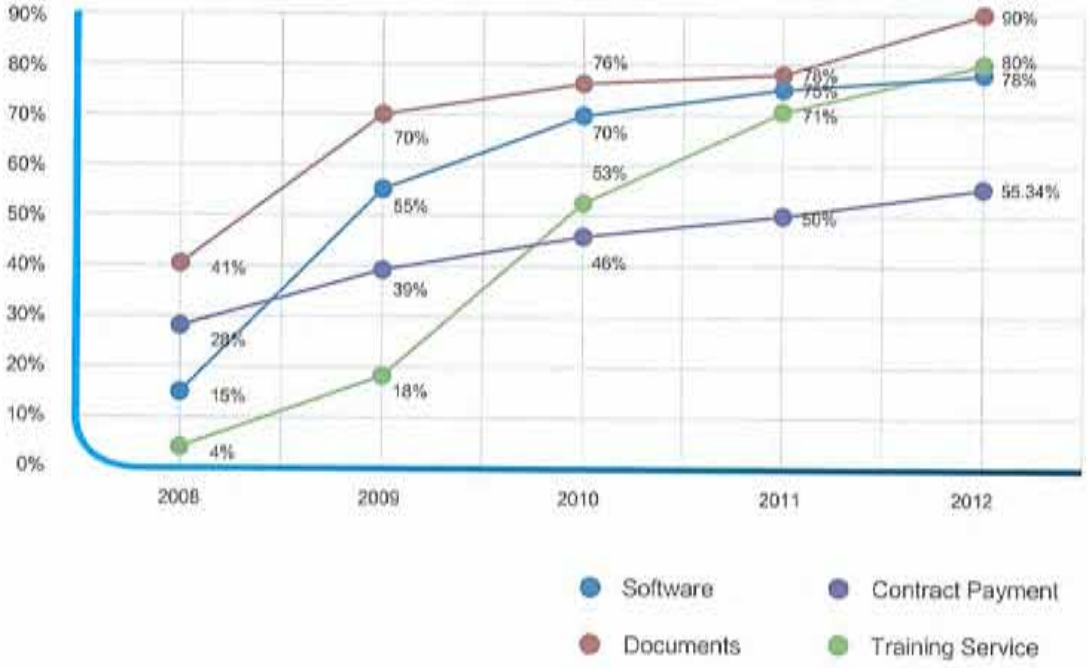
Since CHANUPP Unit 1 has been highly recognized by the Pakistan clients, China has been awarded the EPC Contract for Unit 2, 3 and 4.

SNPTC is the Transferee of AP1000 Technology and the Executing Body of the Nuclear Power Self-reliance Supporting Project Designated by Chinese Government.

Contract Signing Ceremony for Nuclear Power Self-reliance Supporting Project



The Annual Accomplishment of AP1000 Technology Transfer Contract



Authorized by Chinese Government, SNPTC entered into a contract on AP1000 technology transfer with WEC Consortium on Jul. 24th, 2007. The 3rd generation AP1000 nuclear power technology has been successfully introduced, digested, and absorbed by the authorized Chinese enterprises during the 5-year execution of the contract.

SNPTC has been designated as the EPC general contractor for the construction of the world's first 4 AP1000 units, also known as China's self-reliance supporting projects, which are in smooth progress currently.

During the construction of these first 4 AP1000 units, SNPTC has organized a number of Chinese enterprises to promote the localization of AP1000 key equipment.

SNPTC is EPC Contractor of the World's First AP1000s

The world's first AP1000, now under installation of main system, is set to connect to grid in August, 2014. SNPTC has led Chinese enterprises to comprehensively acquire the technology and knowhow for AP1000 design, equipment manufacture and construction work.

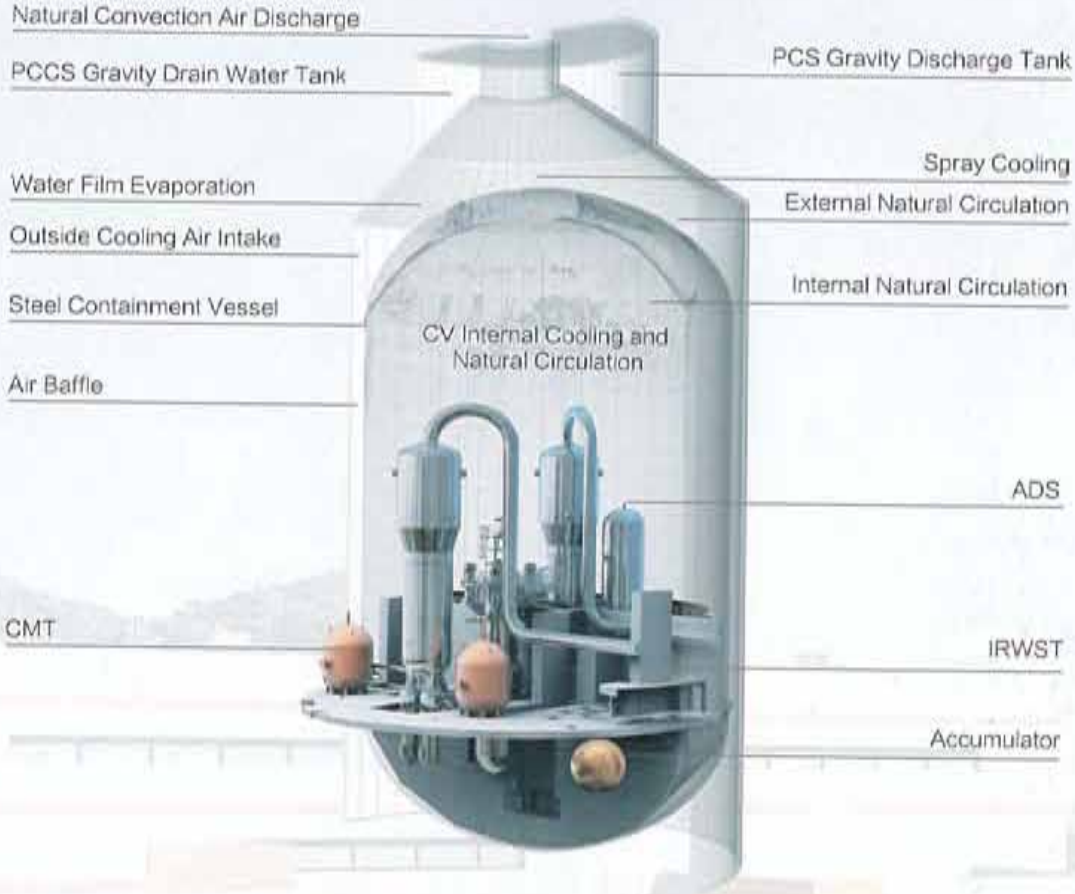
Based on AP1000, SNPTC completed the standardized design of CAP1400 in China which includes not only the best practice and lessons learned from AP1000 Sanmen 1, 2 & Haiyang 1, 2 projects, but PWR technologies and experience accumulated by Chinese experts in the last four decades, thus laying technical foundation for the mass production of follow-up projects. The standardized design covers 80% of the NPP design activities, with the rest 20% involving site-specific design.

The whole international nuclear market will benefit from the globally competitive equipment supply chain established by SNPTC for AP/CAP NPP.

Equipment	Sanmen Unit 1	Haiyang Unit 1	Sanmen Unit 2	Haiyang Unit 2
Canned Motor Pump	EMD	EMD	EMD	EMD/Shenyang Blower Works Group Corporation/Harbin Electric Corporation
Squid Valve	SPX	SPX	SPX	SPX/Sufa
Reactor Pressure Vessel	Doosan	Doosan	CFHI	Shanghai Electric
SG	Doosan	Doosan	Harbin Electric Corporation	Shanghai Electric
RVI	Newington	Newington	Shanghai Electric	Shanghai Electric
CRDM	Newington	Newington	Shanghai Electric	Shanghai Electric
Refueling Machine	WEC	Chinese (TBD)	Chinese (TBD)	Chinese (TBD)
CV	WEC/SNPEMC	SNPEMC	SNPEMC	SNPEMC
Main Pipe	China National Erzhong Group Co /Jilin Zhongyi (backup)	China National Erzhong Group Co.	CSIC	CSIC
Pressurizer	Shanghai Electric	Shanghai Electric	Dongfang Electric Corporation	Dongfang Electric Corporation

The schedule for the localization of the key equipment of 4 units in Self-reliance Supporting Project.


CAP1400 Inherits Advancement
and Maturity of AP1000
CAP1400
国家核电
SNPTC



CAP1400 inherits AP1000 Safety Concept and takes prevention and mitigation of severe events as its design basis. CAP1400 adopts passive safety design concept and essentially improves the safety of nuclear power plants. CAP1400 safety systems take full advantage of natural forces such as gravity, pressurized gas, natural circulation, etc. This passive safety system is used to remove the residual heat independent of active equipment. In case of accidents, the reactor core and containment vessel can be safely cooled without safety-related supporting systems or operators' intervention within 72 hours.

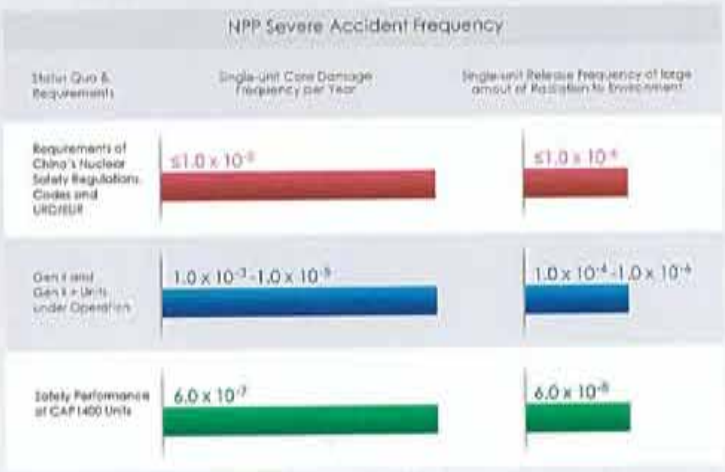
CAP1400 adopts the advanced ROBUST fuel assemblies developed by Westinghouse. Based on AP1000 design, capacity of the major equipment has been boosted and the design has been optimized, enabling it to possess sixty years' design service life, mature application experience and more convenient operation & maintenance.

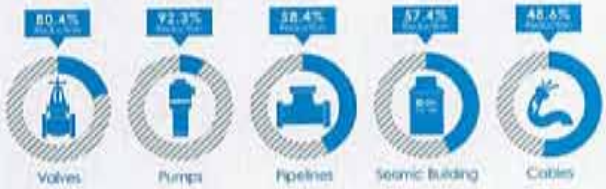
CAP1400 adopts and optimizes the modular construction technology which has been successfully applied in first-of-its-kind AP1000 units, significantly contributing to shortening construction duration, improving construction quality and reducing construction costs.

CAP1400 Design Principle & Performance

CAP1400 Design Principle

1. Adoption of latest nuclear licensing codes and standards (including URD)
2. Simplified system and proven component
3. Passive safety systems and systemic severe accident prevention and mitigation measures
4. Digital I&C and advanced MCR technology
5. Full-scopes PSA
6. Modularization technology
7. Response to Fukushima event





A Comparison of CAP1400 with Gen-II PWR

CAP1400 Performance

Key Items	Target
Thermal power	4040MWt
Electrical power	~1500MWe
Design lifetime	60 years
Plant availability	≥93%
Construction period	~50 months (42 months follow)
Refueling cycle	18 months
Core thermal margin	≥15%
CDF	$<1x10^{-6}$/yr
LRF	$<1x10^{-7}$/yr
Occupational radiation exposure	<1.0 person · Sv/yr
Time period to keep safe without operator action	72 hours
Operation mode	Load follow by MSHIM
RCS pressure	15.5MPa(a)
RCS average temperature	304℃
RCS HZP temperature	291℃
Steam pressure (SG exit)	6 MPa(a)
Fuel type	Improved 17x17XL PFA
No. of fuel assembly	193
Operation Cycle length	18 months
MOX fuel loading	available
Outage duration	≤17 days
Primary system	2-loop configuration, 1 hot leg and 2 cold leg pipes per loop
Safety system	Passive system
Severe accident mitigation	IVR and hydrogen recombiners/igniters
Seismic condition	0.3 g SSE, and 0.5g HCLPF
Public concerns	No long-term emergency planning required
Regulation compliance	Compatible worldwide including US, Europe &CHINA

CAP1400 Main Indicators

Absorbing advanced AP1000 technology, CAP1400 takes reference from 40 years of design experience on pressurized water reactor in China, adopts the best practice and experience feedback from the engineering construction of world first AP1000 units as well as the enhancement measures for nuclear safety margin based on Fukushima Nuclear Accident in Japan.

Through improving installed capacity, optimizing overall parameters, balancing plant design and innovating the design of key equipments, CAP1400 has further enhanced the safety of nuclear plant and environmental compatibility and it is more economical and convenient in terms of operation and maintenance.

CAP1400 power output is around 1500MWe, availability factor over 93% and design life 60 years. Compared with AP1000, it is safer and more economical, with better site utilization rate and less radiation waste.

CAP1400 is the choice for environmental harmony and a typical example of advanced technology, providing a guarantee for future development and vision.

High safety and economy by reliable and proven technologies

High Plant Availability

1. Plant design lifetime is 60 years
2. Less than 17 days for normal refueling outage
3. On-line maintenance capability
4. Reliable and proven technologies and experiences from AP1000 and necessary tests
5. Plant availability ≥ 93%
6. 18 months refueling cycle with the possibility of 24 months

Top-level safety as a generation III plant

1. Passive safety system design
2. Compatible worldwide regulation and URD
3. 72 hours without operator action to sustain intact core and integrity containment
4. Over 15% reactor core thermal margin
5. Resistance of large commercial airplane crash
6. Core damage frequency less than 1×10^{-6} yr
7. Large release frequency less than 1×10^{-7} yr
8. Occupational radiation exposure less than 1.0 person ·Sv/yr
9. Long-term containment integrity after severe accidents kept by IVR and hydrogen control capability
10. Minimization of the radioactive waste, less impact for environment
11. Considering of Fukushima event lessons

Operation flexibility

1. Flexible of 18 to 24 month operation cycle length with less fuel cost
2. MOX fuel loading capacity
3. Load follow by MSHIM mode, and without adjusting the concentration of boron solution

Flexibility for site

1. Standard design of CAP1400 with conservative site conditions
2. Consider 0.3g SSE and 0.5g HCPLE, available for high seismic area
3. Consider both rock and soil geologic conditions
4. Design available for 50Hz, but also can consider 60 Hz

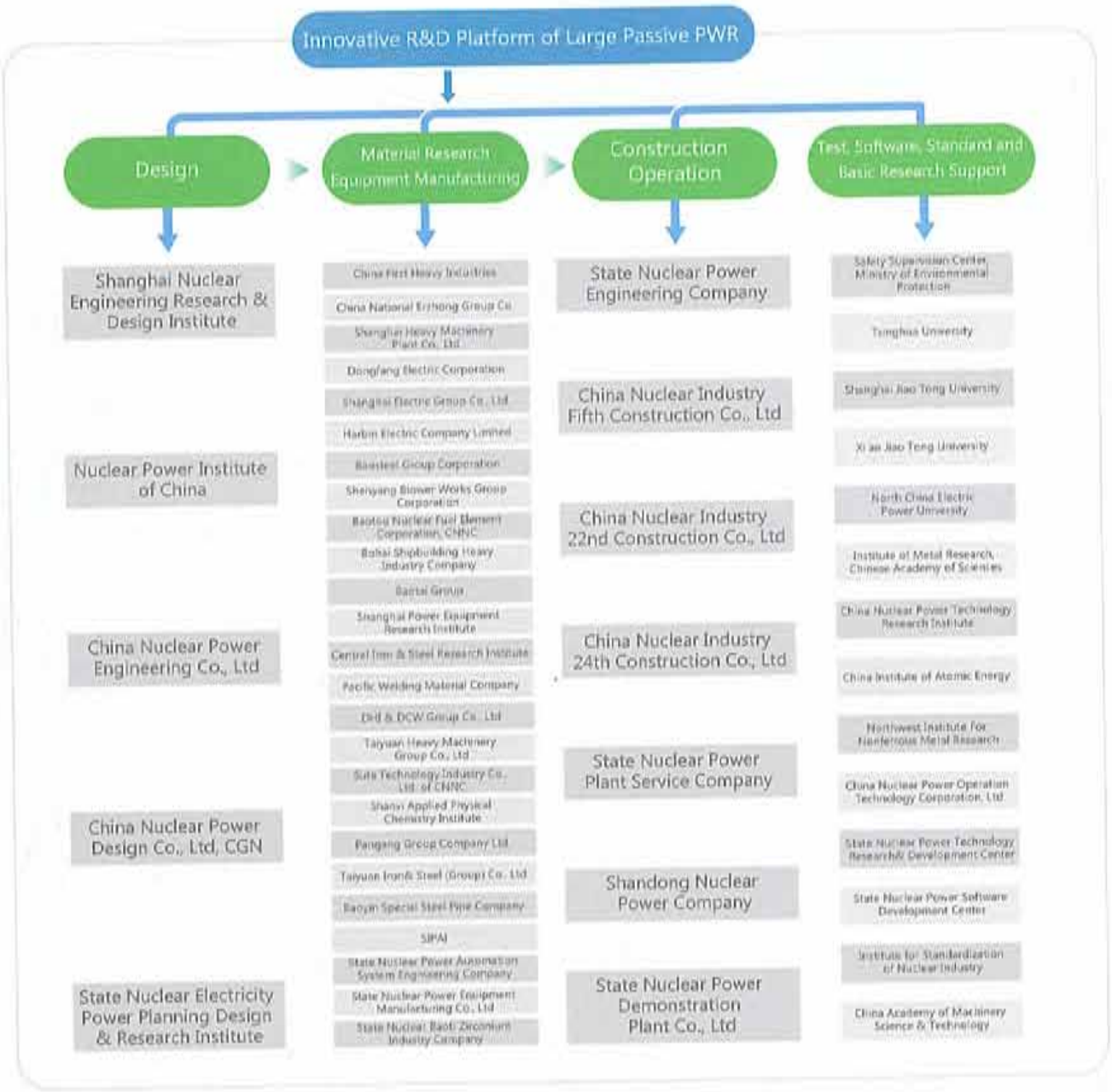
CAP1400's Major Improvement on AP1000

Compared with AP1000, CAP1400 has the following improvements:

1. Improved plant design, reactor power up by 20%
2. Optimized overall parameters, plant efficiency increased by 1%
3. Enhanced overall plant layout, better accessibility and maintainability
4. Reduced weld joints of main equipments, improved equipment reliability and reduced inspection costs for operation
5. Improved module design and modular construction scheme; further increased economical efficiency
6. Improved CV parameters and ADS level 4 design; safety systems with higher safety margin
7. Improved RVI design and higher IVR success rate;
8. Low-leakage reactor design adopted, RV fast neutron fluence rate reduced, neutron shield exempted and risks of loose reactor components reduced;
9. Design for main pipe, main steam pipe and SG improved, and possible flow accelerated corrosion and SG spill rate reduced;
10. FPGA-based reactor protection system adopted to enhance reliability of I & C system;
11. Lessons from Fukushima accident are learned and resistance against earthquakes, floods and other extreme natural disasters is strengthened. The passive safety system has supply capacity after 72 hours to ensure security of the power plant.
12. Radioactive waste dealing system is improved to further reduce discharge thereof.

Comparison of Major Parameters (AP1000/CAP1400)		
Major Parameters	AP1000	CAP1400
Reactor Power Output,MWt	3400	4040
Average Temperature of Cooling, ℃	300.9	304
Pressure of the Reactor Coolant System, MPa(a)	15.5	15.5
Number of Core Fuel Assemblies	157	193
Active Core Height, m	4.267	4.267
Type of Steam Generators	△125	SNP140
DNBR Margin	>15%	>15%
Average Linear Power Density, W/cm	187	181
SG Outlet Pressure,MPa(a)	5.61	6
Flow Rate of Primary Steam Pipe, kg/s	944	1122
Flow Rate of Reactor Cooling System, m³/h	68110	82412
Containment Volume, m³	58380	75000

CAP1400 Development Has Gained Support from Chinese Government and Pooled Wisdom of Global Nuclear Elites.



CAP1400 development has drawn great attention from Chinese government and is a key national science and technology project.

Over 100 parties including Chinese nuclear companies, equipment manufacturers, research institutes and universities participate in CAP1400 technical development.

CAP1400 has also gained international cooperation and support. Scores of companies from US, Germany and Japan are involved, with WEC (US) for design consultation, L&M (US) for development of I & C system, EMD (US)/KSB (Germany) for RCP development, GRS (Germany) for project design verification and OECD lab for test data. Companies from US, Canada and Japan participate in equipment material R & D and verification test.

CAP1400 Will Start Construction in 2014 and Begin Operation in 2018.

With support from partners home and abroad, SNPTC will complete CAP1400 technical R & D in 2013. The first unit is expected to get approval (including safety evaluation) from Chinese government in 2013, start construction in 2014 and begin operation in 2018.


国家核电
中国华能
公司成立

廠商資料9

中核建中核燃料元件有限公司

CNNC Jianzhong Nuclear Fuel Co.,Ltd

公司概要

中核建中核燃料元件有限公司是中国核工业集团公司下属骨干成员单位，是中国目前最大的压水堆核电燃料组件生产基地。

公司通过引进国外先进技术和不断自我创新，具备300MW、600MW、900MW、1000MW及低温核供热堆、试验堆、小堆、快堆转换区组件等系列燃料元件制造能力及全堆芯核燃料元件供应能力。自1987年建成第一条核燃料元件生产线以来，截至目前，公司已为秦山一期、二期核电站、广东大亚湾核电站、岭澳核电站、田湾核电站、宁德核电站、红沿河核电站、阳江核电站等国内多座核电站及巴基斯坦恰希玛核电站提供了7000多组质量优良的燃料组件，为各核电站安全、稳定、经济运行做出了重要贡献。公司在核燃料元件制造领域实现了跨越式发展，被誉为“核电粮仓”。

INTRODUCTION

CNNC Jianzhong Nuclear Fuel Co., Ltd (CJNF), a backbone member company under the jurisdiction of China National Nuclear Corporation (CNNC), so far is the largest base specializing in manufacturing of nuclear fuel assemblies for PWR NPPs in China.

With technologies transferred from overseas partners and in a way of sustaining self-innovations, CJNF is boasted of a capability to manufacture a series of fuel elements for NPPs of 300MW, 600MW, 900MW and 1000MW, as well as low temperature nuclear heat reactors, testing reactors, small reactors and fast reactor conversion zones while supplying nuclear fuel elements for full reactor cores. Having manufactured and delivered over 7000 high quality fuel assemblies for NPPs such as Qinshan Phases Ⅰ and Ⅱ, Daya Bay, Ling Ao, Tianwan, Ningde, Hongyanhe, Yangjiang and Chashma (Pakistan) since the first fuel line set up in 1987, CJNF makes a important contribution to the plant operation in safety, stability and economy. Achieved a great stride of developments in the field of manufacturing fuel elements, CJNF is reputed as “Granary of Nuclear Power”.

沿革

EVOLUTION

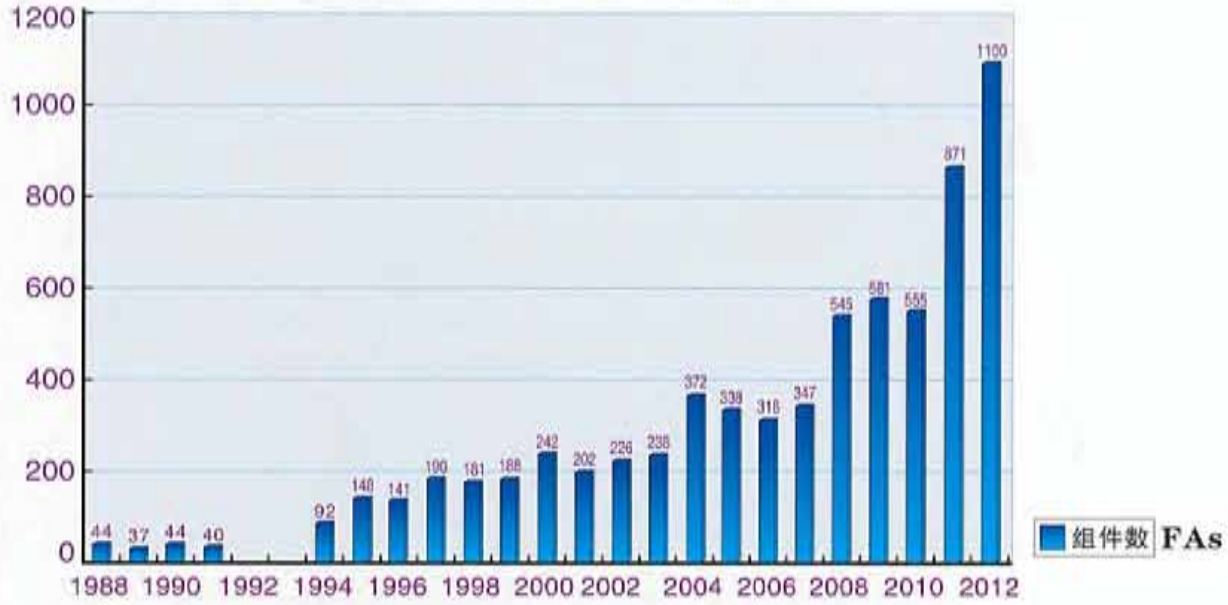
1987年	第一条核燃料元件制造生产线建成
1990年	为秦山核电站提供300MW核燃料组件，填补国内空白
1991年	引进AFA2G组件制造技术
1995年	为大亚湾核电站提供AFA2G换料组件，实现大型核电燃料组件国产化
1998年	向巴基斯坦出口300MW组件
2001年	完成生产线改造升级，成功生产出AFA3G高燃耗组件
2003年	引进VVER组件制造技术并于2011年为田湾核电站提供换料燃料组件
2006年	成功制造出全M5 AFA3G组件
2013年	400吨扩建技改工程建成

1987	The first line to manufacture nuclear fuel elements was set up.
1990	300MW nuclear fuel elements were supplied for Qinshan NPP, ending the history that no fuel elements supplied in China.
1991	Technology transfer of manufacturing AFA2G fuel assemblies was fulfilled.
1995	AFA2G reload of fuel assemblies was delivered to Daya Bay NPP, achieving the localization of fuel assemblies for large NPP.
1998	300MW fuel assemblies were exported to Chashma NPP (Pakistan).
2001	Production line was adapted and upgraded, succeeding in manufacturing AFA3G high burnup fuel assemblies.
2003	Technology transfer of manufacturing VVER FAs and the reload of FAs were supplied for tianwan NPP.
2006	ALL M5 AFA3G fuel assemblies were successfully manufactured.
2013	400tU/a Capacity Increase Project will be completed

公司核品主要发展历程 DEVELOPMENT HISTORY

历年核燃料组件年产数量图

Statistic chart of FA yield over the years



核电站用户分布图

Distribution map of CJNF's customers（NPPs）

UO_2粉末生产 UO_2 POWDER PRODUCTION

公司UO_2粉末生产主要采用IDR工艺，工艺原理是将UF_6原料气化后通入一体化转换炉中进行气相水解和还原，再经稳定化、均匀化处理后制成性能均一的UO_2粉末。IDR工艺具有流程短，自动化程度高，三废排放少等优点。

CJNF具有自主研发的100吨铀/年和200吨铀/年IDR生产线。

UO_2 powder is produced by IDR (integral dry route) process. The process principle is that the raw material UF_6 is directly converted into UO_2 powder by hydrolysis and reduction in the integral rotary kiln after UF_6 is evaporated, and then the UO_2 powder with uniform characteristics is obtained by stabilization and homogenization. The IDR process is featured with shorter route, higher automation and less discharges of three wastes (waste gas, waste water and industrial residue).

CJNF has both IDR lines of 100 tU/a and 200 tU/a, which were independently developed.

气化装置/ Evaporation device

UF_6气化

UF_6 evaporation

干法炉/IDR Kiln

均匀化设备/ Homogenization device

转 化
Conversion

均 匀 化
Homogenization

控制室/Control room

分析检测设备/Analytic and testing device

UO_2芯块制备

UO_2 PELLETIZATION

经过预压、制粒、球化等工序处理后，UO_2粉末在旋转压机中压制成圆柱形的生坯块，然后在高温下烧结成陶瓷级UO_2芯块，再经外圆磨削、检测等工序，制成UO_2芯块。

CJNF目前有三条UO_2芯块生产线，装备有先进的旋转压机、连续推舟式高温烧结炉、外圆磨床等设备。

CJNF还有一条独立的含钆芯块生产线，用于制造含钆燃料棒。

芯块压制设备/ Pellet press

压 制

Pressing

Being pre-compacted, granulated, spheroidized, etc, the UO_2 powder is pressed into cylindrical green pellets in a rotary press, and then the green pellets are sintered into ceramic UO_2 pellets at high temperature. Finally the finished UO_2 pellets are completed after they are ground and inspected.

CJNF has three UO_2 pelletilization lines, which are equipped with the advanced rotary presses, the continuous push-type high-temperature sintering furnaces and the grinders.

In addition, CJNF has a separate production line for Gd-bearing fuel pellet which are used for the Gd-bearing fuel rods.

芯块/ Pellets

芯块烧结设备/ Sintering furnace

芯块磨削设备/ Grinding line

烧 结
Sintering

磨 削
Grinding

芯块外观检查/Visual inspection

芯块称重/Weighing

零部件加工 MACHINING PARTS & COMPONENTS

CJNF具有完整的组件零部件生产线，包括管座、格架、连接柄和小零部件生产线，可以生产燃料组件和相关组件所需的各种零部件。生产线全部采用数字化高精度的机械加工设备和检验设备。

CJNF has the complete lines to machine various parts and component for fuel assemblies and associated core components, including top and bottom nozzles, spacer grids and small parts. The lines are equipped with the digital, high precision machining equipment and testing devices.

定位格架焊接
Welding spacer grids

零部件生产线/
Parts & components machining lines

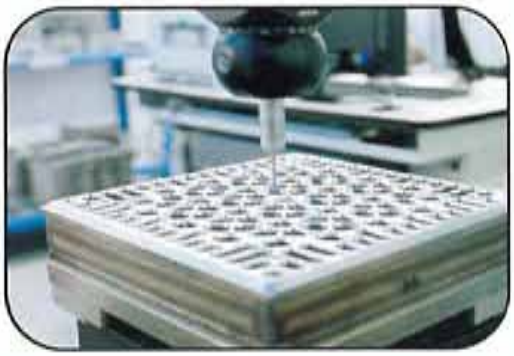
上下管座加工

Machining top and bottom nozzltes

小零部件加工

Machining small parts

轮廓仪/Countourgraph



三坐标检测/3D testing

燃料棒制造 MANUFACTURING FUEL RODS

下端塞压塞机/ Bottom end plugger

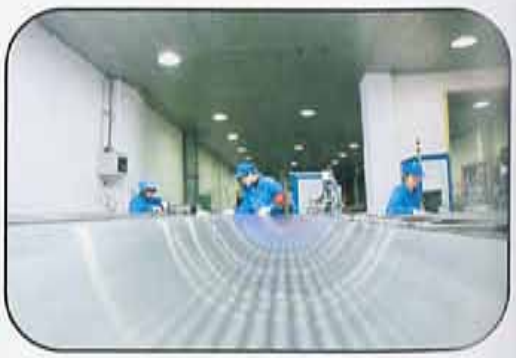
压下端塞
Plugging bottom end plug

将UO_2芯块等装入锆合金包壳管中，并充入氦气，端部采用焊接密封，经过χ-射线、γ-扫描、氦质谱检漏等无损检测后，形成燃料棒。

CJNF目前有两条燃料棒生产线，燃料棒焊接分别采用高真空电子束焊接和TIG焊接工艺。

Fuel rod consists of the zirconium alloy cladding tube inserted with UO_2 pellets and other parts, pressurized with helium and sealed by welding at the ends. The fuel rod is confirmed as a finished rod only after no defect is found by the nondestructive tests of χ-ray, γ-scanning and helium leak.

CJNF has two lines to manufacture fuel rods. The fuel rods are welded by high vacuum electron beam welding and TIG welding processes.



表面检查/Visual inspection

电子束焊接设备/ Electron beam welding machine

芯块自动装管/Automatic pellet loading device

焊 接
Welding

装 管
Pellet loading

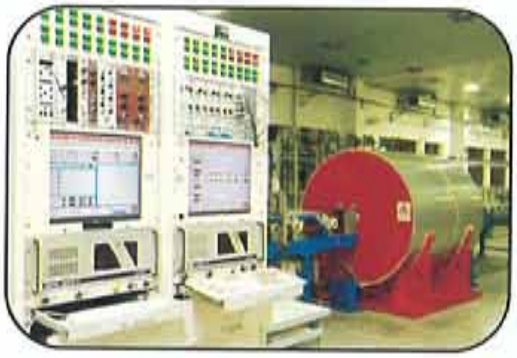
TIG焊接设备/ TIG welding machine

上端塞压塞机/ Top end plugger

焊 接
Welding

压上端塞
Plugging top end plug

X光检测/X-ray examination



丰度检测/Enrichment examination

组件组装 FA ASSEMBLING

将燃料棒装入由定位格加、导向管等焊接而成的骨架中，并装配好上、下管座后，形成燃料组件。CJNF现阶段可生产包括300MW（15×15）、AFA2G（17×17）、AFA3G（17×17）、全M5 AFA3G（17×17）、VVER-1000等不同类型的燃料组件及相关组件。CJNF制造的燃料组件一直保持着良好的堆内运行记录。

Fuel assembly consists of the skeleton welded by guide thimbles to grids and the fuel rods inserted into it. CJNF has the capability to manufacture the various types of fuel assemblies and the associated core components, including 300MW(15 × 15), AFA2G (17 × 17), AFA3G(17 × 17), ALL M5 AFA3G(17 × 17) and VVER-1000 fuel assmblies. The fuel assembilies manufactured by CJNF have been maintaining the good records on in-reactor performances.

骨架焊接/ Skeleton welding

骨架生产
Skeleton spot welding

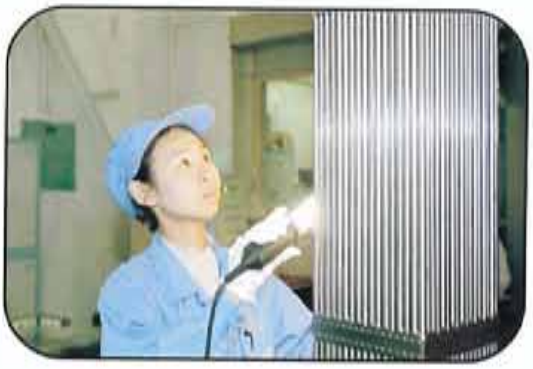
骨架检测/ Skeleton testing

组件组装/ FA assembling

组件清洗/ FA cleaning

组 装
Assemblting

清 洗
Cleaning



组件外观检测/FA visual inspection

组件尺寸检测/FA dimentional testing

组件运输 FA TRANSPORTATION

CJNF组件运输采用铁路为主、公路为辅的运输方式。2012年CJNF开创了我国全公路长距离运输先河。

CJNF拥有专业检车工25人，火车司机3人，调车员8人，管理人员9人，专业技术人员16人，现有各型火车24节，燃料组件运输容器230台，集装箱42个，专用铁路线7条及其它配套设施，年运输能力超过2000组。

CJNF's FAs are transported mainly by railway and supplementarily by road. In 2012, CJNF initiated a precedent that FAs were transported long distance fully by road.

CJNF has 25 professional train inspectors, 3 train drivers, 8 dispatchers, 9 managerial staff and 16 technicians. Having 24 various-type railway cars, 230 transportation containers for fuel assemblies, 42 shipping containers, 7 special purpose railway lines with supporting facilities, CJNF can implement transportation of more than 2000 fuel assemblies per year.

装 箱
Packaging

全公路运输

Full road transport

吊 装
Handling

运 输
Transportation

装有容器捆绑后的集装箱

Shipping container with bundled FA containers

装箱前检查

Examination before packaging

质量管理 QUALITY MANAGEMENT

质量方针：

★ 质量为本，追求卓越，
★ 为顾客提供安全、可靠的核燃料。

Quality Policy:

★ Esteeming quality as foundation,Pursuing super excellence,
★ Delivering customer with safe, reliable nuclear fuel.

质量理念：

★ 质量是企业的生命，
★ 质量是顾客的安全。
★ 质量是提升效率，
★ 质量是创造价值。

Quality Phylosophy:

★ Quality is the life of an enterprise,
★ Quality is the safety of customers.
★ Quality is the enhancement of efficiency,
★ Quality is the creation of value.

质量价值观：

★ 将顾客满意作为质量的最高标准。
★ 培育学习型组织和个人。
★ 促进创新管理。
★ 建立共赢的内外部伙伴关系。

Quality Values:

★ To esteem customers' satisfaction as the highest quality standard.
★ To cultivate the learning organization and individuals.
★ To promote the innovation management.
★ To develop the win-win internal and external partnerships.

荣誉称号

Honorary titles

质量体系：

- 建立了以核安全法规(HAF003)为核心,以ISO9000标准为补充的有特色的质量管理体系，并形成了“以过程控制为主线，三大鉴定为特点，监督放行为原则”的运行模式。
- 1996年在核工业系统率先获得ISO9000标准质量管理体系认证证书。
- 从顾客的需求出发，以实现“核燃料元件制造零破损”为终极奋斗目标，践行质量承诺，并通过经验反馈，实现持续改进。
- 继承传统并创新发展，不断积淀、拓展和升华，形成了具有丰富内涵的建中质量文化，突出“我们的质量，顾客的安全”的主题，并通过专题讲座、业务培训、质量月（年）、群众性的QC小组等多样化的活动，不断提高员工的质量意识和业务水平，为质量管理体系的有效运行提供了保障。

Quality System

- The quality management system with the nuclear safety code (HAF003) as core and the standard ISO9000 as supplementarity has been created and the operation mode with “the process control as mainline, the three qualifications as specialties and the supervision release as principle” has been developed.
- 1996, the first one of CNNC industries was awarded the certification by ISO9000 standard quality management system.
- Starting from the demands of customers and taking into consideration of the final effort to realize the “zero failure in manufacturing of nuclear fuel elements”, fulfilling the commitment for quality, and implementing the feedback of experiences, CJNF accomplishes the sustaining improvement.
- Inheriting tradition and innovating to develop, continuously depositing, expanding and sublimating, CJNF forms her abundant-connotation quality culture and highlight the motive “Our Quality, Customer's Safety”. To guarantee the effective implementation of quality management system and continuously raise the staff’s quality consciousness and operation levels, CJNF frequently hold the specialty lectures and the operation training, and develop the various activities of quality month (year), mass QC groups, etc.

质量行为准则

- 一切按程序办事
- 一次把事情做对
- 凡事有章可循，凡事有人负责，凡事有人监督，凡事有据可查
- 质疑的工作态度，严谨的工作作风，相互交流的工作习惯

CRITERIA OF QUALITY ACTIONS

- Everything handled as per procedure.
- Everything implemented at a time.
- Everything rule-based, everything be in charge, everything supervised and everything documented.
- Questioning work attitude, precise work style and mutual-exchange practice.

安全环保 SAFETY AND ENVIRONMENT PROTECTION

CJNF实施安全、环保、清洁的核燃料元件生产，在取得良好生产业绩的同时，致力于污染预防和污染防治，努力降低生产过程中的职业健康安全风险，公司承诺保证核设施、环境和工作人员的安全。CJNF核设施设计具有良好的固有安全性，对核设施、核材料实施三道屏障管理，并安装现代化的监控设备，在严格的核安全监管体系和“核安全至高无上”的核安全文化氛围下，执行严谨的运行控制及操作，保证核设施安全、稳定、可靠地运行。

CJNF核设施运行放射性气、液态流出物归一化排放量仅为国家标准的1%，长期监测数据表明，厂区周边地区的环境放射性水平与本底水平相比，没有发生异常变化。

CJNF implements the manufacture of nuclear fuel elements in the conditions of safety, environment protection and cleanliness. While getting good production achievement, CJNF dedicates herself to the prevention and control of contaminations, and makes efforts to reduce the occupational, healthy and safe risks to guarantee the safety of nuclear facilities, environment and personnel. With the inherent safety of nuclear facilities, the three-shelter management for nuclear facilities and nuclear materials and the modern monitoring devices, CJNF strictly implements the operations and the operational controls under the rigorous nuclear safety supervision system and at the atmosphere of nuclear safety culture “Nuclear Safety Supreme”, to guarantee nuclear facilities operating safely, stably and reliably.

The normalized emission of active gaseous and liquid effluences from CJNF's nuclear facilities is only 1% of the national standard. The long-term monitoring data show the radioactivity level in the environments around the CJNF facilities keeps unchanged in comparison with the background level.

★ 2003年通过ISO14001环境管理体系认证

★ 2003, CJNF, the first one in CNNC, passed ISO14001 environment management system certification

★ 2008年通过GB/T28001职业健康安全管理体系认证

★ 2008, CJNF passed the certification of occupation, health and safety management system GB/T28001

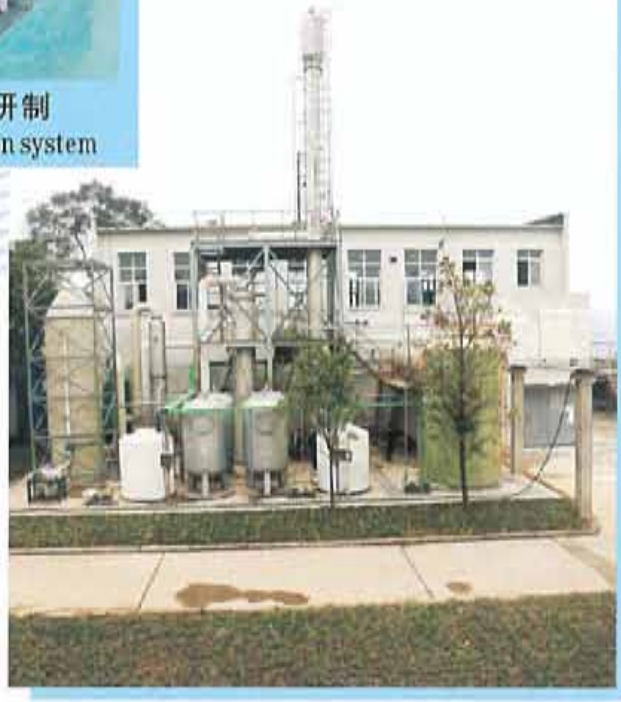
科研创新 SCIENTIFIC RESEARCH AND INNOVATION

CJNF建有国家级企业技术中心，同时也是首批国防科技工业认定企业技术中心。公司已在核燃料制造和相关领域取得了150多项科研成果，其中，参与秦山300MW核电站研制和建造项目荣获国家科技进步特等奖；百万千瓦级大型燃料组件国产化及制造技术创新、含钆燃料棒国产化技术研究、AFA3G燃料组件国产化制造技术创新等三个项目分别获得了国防科学技术进步奖一等奖。

CJNF Technology Center is a state-level enterprise center and also one of the first batch of enterprise technology centers qualified by the National Defense Sci-Tech Industry. CJNF has had more than 150 scientific research achievements in the manufacture of nuclear fuels, of which the project of Qinshan 300MW NPP development and construction was awarded as National Top-grade Prize of Sci-Tech Advancement; and the three projects (Localization of 1000MW Large-size Fuel Assemblies and Innovation of Manufacturing Technology; Technology Research on Localization of Gadolinium Bearing Fuel Rods; and Manufacturing Technology Innovation of Localization of AFA3G Fuel Assemblies) are awarded as the First Prize for Technology Progress of National Defense Sci-Tech Industries.

N36特征化组件/
N36 characterized FAs

200吨铀/年干法转换系统研制
Development of 200tU/a IDR conversion system



含氟含氨废水处理项目研制/
Development of treatment system for wastewater bearing fluorine and ammonia

展望未来 FUTURE PROSPECT

全球提倡低碳环保、绿色能源，核电的发展处于难得的机遇期。积极发展核电是国家重要的能源战略，我国核电事业迎来了新的发展。

公司将积极致力于核燃料元件制造技术、装备及产能的提升，丰富技术路线，提升产品质量，树立产品信誉，同步满足国内核电发展及核电出口需要，建成管理科学、装备先进、产品多样、制造柔性、技术领先、质量优良、安全可靠、清洁高效的集科研、生产于一体的现代化、园林式核燃料工厂，努力朝着建成国际一流核燃料元件制造基地的战略目标迈进！

The low carbon environmental protection and green energy is advocated to use in the world, it is a just opportunity to develop nuclear power. Positively developing nuclear power is an important strategy of energy in China, our nuclear power is facing a new development.

CJNF commit herself to upgrade the technology of manufacturing nuclear fuel elements, the equipment and the productive capacity, amplify the technical routes, improve the product quality and establish the product creditability, meeting the demands for the in-home nuclear power development and the export of nuclear power. CJNF makes effort to build itself into a modernized garden nuclear fuel factory integrated in scientific management, advanced equipment, diversified products, flexible manufacturing, advanced technology, as well as high quality, reliablesafety, green and high efficiency. CJNF will stride forward to the strategy target-to be a global top class base to manufacture nuclear fuel elements.

廠商資料10

INEST·FDS Team

FDS Software

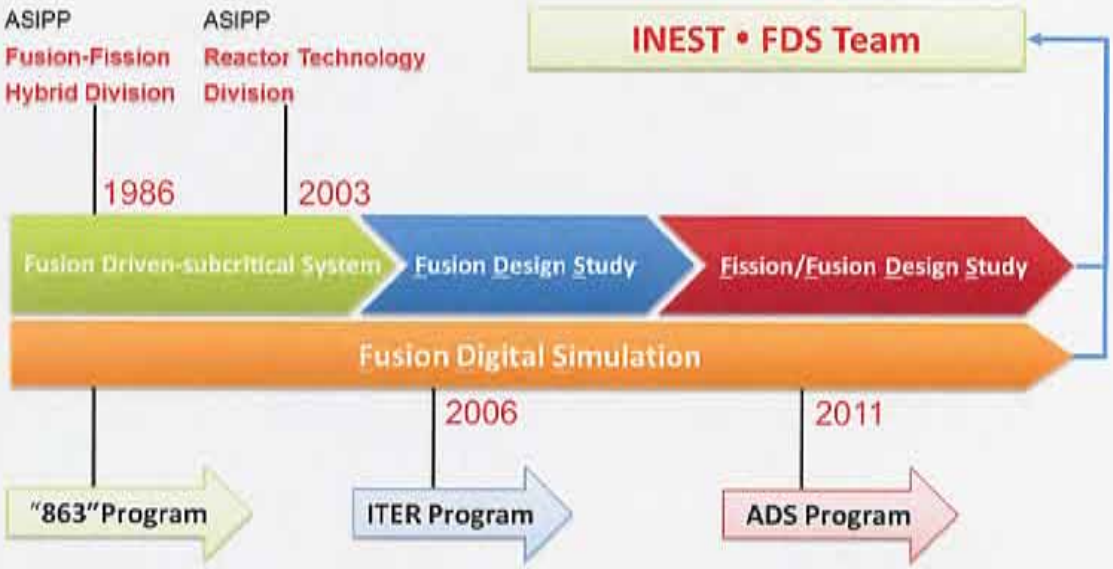
Design and Simulation of Nuclear Energy System

Overview

Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences (abbreviated as INEST) was founded on basis of advanced nuclear energy research team (FDS Team) in September 2011. INEST is the professional institute focusing on basic research of nuclear energy safety. It is also the independent nuclear safety assessment and evaluation center with the aim to promote the sustainable development of nuclear science and technology in China.

Supported by the Strategic Priority Research Program of the Chinese Academy of Sciences "Accelerator Driven Systems–Lead-Bismuth Cooled Reactor" and ITER related international and domestic projects "Fusion Nuclear Technology and Material", the main research areas of INEST / FDS Team cover nuclear reactor physics, nuclear reactor material, nuclear reactor technology, system engineering & safety, numerical simulation & visualization, medical physics & technology, etc.

With distinctive characteristics of culture system and management structure, INEST / FDS Team has more than 300 members, and 80% scientist staffs won Ph.D degrees. It undertakes more than 50 domestic or international important projects, such as national "863" and "973" projects, major research projects of the National Science Foundation, International Thermonuclear Experimental Reactor (ITER) project, International Atomic Energy Agency (IAEA) cooperation projects, etc. It has published more than 1000 papers. 5 of them were collected by "Essential Science Indicators (ESI)" and "highly cited papers".



Research Areas

- **Nuclear Reactor Physics**

  Advanced conceptual design and research; Neutronics analyses and experiments; Coupled neutronics-thermohydraulics; Plasma physics; Nuclear fuel burnup and recycling optimization; Software and nuclear database; etc.

- **Nuclear Reactor Material**

  Low-activation structural material development; Irradiation experiments and simulation; Material database development; Test Blanket Module (TBM) fabrication and experiment; etc.

- **Nuclear Reactor Technology**

  Liquid PbLi / PbBi alloy loop; Water/Helium loop; TBM & tritium technology; Thermohydraulics for reactors; Reactor Special Equipment and Technology; etc.

- **System Engineering and Safety**

  Probabilistic safety assessment; Risk informed decision/risk monitor; Reliability analysis of complex system; Transient safety and severe accident management; Economical analysis on nuclear engineering; Development of related software and database; etc.

- **Numerical Simulation and Visualization**

  Automatic modeling; Scientific visualization; Virtual reality; Integrated simulation; Cloud computing & cooperative work; Software engineering for large complex system; etc.

- **Medical Physics and Technology**

  Digital human modeling; Radiation dose calculation; Inverse planning optimization; Image-guided positioning; Radiation biological effect; Radiation shielding and environmental protection; etc.

Principles

- **Systematic Development**

  Involved with the whole process including system design, analysis and computation and virtual simulation.

- **Modern Innovations**

  Reflecting the recent progress in the good framework and design.

- **Modern Concepts of Software Design, Professional Management of Development Process**

  Software engineering theory ensured high reliability and performance.

- **Friendly Human-Machihe**

  User-friendly, scientific visualization.

- **Good Applicability**

  Appropriate to fusion, fission or hybrid systems.

Representative Achievements

MCAM: Over 200 institutional users in ~40 nations.

TQRM: The first self-developed risk analysis system applied in the safety analysis in Chinese nuclear industry.

ARTS: Accurate / Advanced Radiotherapy System supports Intensity Modulated Radiotherapy (IMRT), Image-Guided Radiotherapy (IGRT) and Dose-Guided Radiotherapy (DGRT).

First Prize of 2011 National Energy Science and Technology Progress Award.

First Prize of 2010 Science and Technology Award of China Nuclear Energy Association.

First Prize of 2009 Province-level Science and Technology Award.

CONTENTS

Physics and Engineering Calculation

Computer Modeling and Simulation

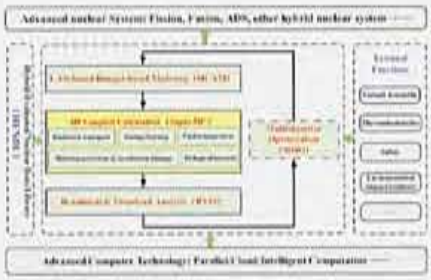
Database Management System

VisualBUS: CAD-Based Multi-Functional 4D Neutronics Simulation System

Introduction

VisualBUS is a CAD-based multi-functional 4D Neutronics simulation system, which is developed by FDS Team based on advanced computer technology. Its main functions including CAD and image based automatic modeling, 4D coupled calculation, dynamical & visualized analysis and multi-objective optimization. VisualBUS is supported by a nuclear data libraries HENDL. Users can perform radiation transport calculation based on Monte Carlo, discrete ordinates, characteristic and coupled methods, burn-up calculation, material activation, shutdown dose rate calculation and fuel management. And virtual assembly, thermo-hydraulics and safety analysis are also supported as extended functions.

VisualBUS has won first prize of National Energy Science and Technology Progress Award, first prize of Science and Technology Award of China Nuclear Energy Association, and first prize of Province-level Science and Technology Award.



System Architecture

Basic Functions

- **CAD / Imaged-Based Modeling (MCAM)**
  - +MC / SN / MC-SN Coupled / MOC ... Geometries
  - +CT / MRI / Sectioned Images
- **4D Coupled Multi-Process Calculation (SuperMC, etc.)**
  - +Radiation Transport / Isotope Burnup / Material Activation / Irradiation Damage / Radiation Dose / Fuel Management
  - +Support Time-Dependent Physical Problems in 3D Space
- **Dynamical & Visualized Analysis (RVIS)**
  - +Static / dynamic physical data fields
  - +Human virtual roaming & dosimetry assessment
- **Multi-Objective Optimization (MOO)**
  - +Artificially Intelligent algorithms
  - +Space optimization of irregular complex solutions
- **Nuclear Data Library (HENDL)**
  - +Multi-function sub-libraries and many kinds of group energy structure
  - +Various kinds of physics effects
  - +Cross section data for neutron with energy up to 150MeV

Extended Functions

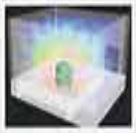
- **Virtual Assembly for Complex System**
- **Neutronics-Thermohydraulics Coupling Transient Safety Analysis**
- **Radiation Dose Calculation**

Features

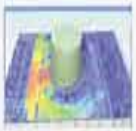
- **Multi-function Seamless Integration**
- **Intelligentized Design, Convenient to Usage**
- **Open Architecture, Easy to Expansion**

Applications

- **International Thermonuclear Experimental Reactor (ITER)**
- **Experimental Advanced Superconducting Tokamak (EAST)**
- **Series of other Advanced Reactors (FDS, ADS)**



Radiation Map Resulting from ITER Activated Divertor



EAST Shutdown Dose Simulation

China LEAd based Reactor ADS CLEAR

Fusion Fission Reactor FDS-I

Fusion Power Reactor FDS-II

Fusion Reactor for Hydrogen Production FDS-III

Spherial Fusion Reactor FDS-ST

FusionReactor

Computational Phantom Modeling and Dose

Dose Calculation

References

[1] Y. Wu, FDS Team. CAD-based Interface Programs for Fusion Neutron Transport Simulation. Fusion Engineering and Design, 2009, 84:1967-1992.

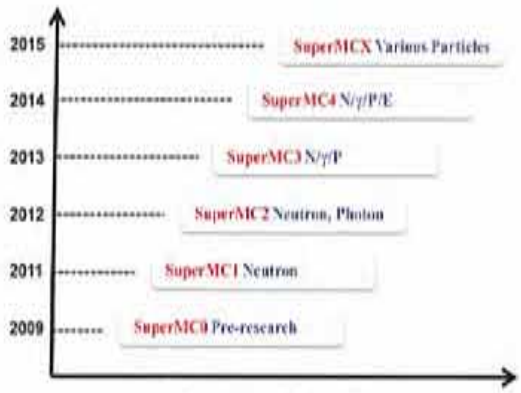
[2] Y. Wu, et al. Conceptual Design Activities of FDS Series Fusion Power Plants in China. Fusion Engineering and Design, 2006, 81: 2713-2718

SuperMC: Super Monte Carlo Calculation Program for Nuclear and Radiation Process

Introduction

Particle transport simulation is the foundation of reactor physics design and radiation shielding analysis. Monte Carlo (MC) method has notable advantages in dealing with complex geometries and multi-dimensional physics problem. It is becoming more and more systematic, multi-functional and intelligent for MC codes in the world over the past years.

The Super Monte Carlo Calculation Program for Nuclear and Radiation Process SuperMC, mainly based on Monte Carlo methods and advanced computing techniques, has been developed by FDS Team. SuperMC which integrates automatic modeling, multi-physics calculation and visualized analysis as a whole system, based on MC, deterministic methods (e.g. SN, MOC) and coupled methods, can perform radiation transport, isotope burn-up, material activation, radiation dose and biology damage simulations.



Route Map of SuperMC

- **Multi-Functional Nuclear Data Library**
  - +Support multi-functional library (transport library, burnup library, activation library, material damage library etc.)
  - +Support evaluation library directly (ENDF / B, JENDL, JEF, BROND etc.)
  - +Support multi-format work library (ACE, MATXS, AMPX, ANISNB, CARD, etc.)
- **Acceleration Method**
  - +Rich variance reduction techniques
  - +MPI and OpenMP hybrid parallel computing technology
  - +Efficient parallel algorithm on particles, space and data field decomposition
  - +Comprehensive service architecture based on cloud computing technology and efficient task schedule method

Features

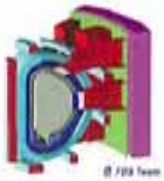
- **Multi-Function and Systematism**
  - +Contain main functions of neutronics computing
  - +Mainly based on Monte Carlo method, coupling with MOC, SN and other methods
- **High Performance and Intelligent**
  - +Adoption of efficient parallel algorithm, advanced computer technology and rich variance reduction techniques
  - +CAD / Image-based automatic modeling and supporting directly import of CAD / image models
  - +Directly dynamic visualized analysis of results
- **Broad Application and Easy Operation**
  - +Versatile and broad application area such as reactor design and analysis, medical physics, nuclear detection, radiation shielding etc.
  - +User oriented interface, easy to use
- **Modularization and Excellent Expansibility**

Functions

- **Multi-Physical Calculation**
  - +Radiation transport, isotopic burnup material activation, radiation damage, radiation dose, biology damage computation
  - +Simulation in 3D space and 1D time
  - +Fixed source computing and critical analysis
  - +MC / SN / MOC and coupled methods
- **Automatic Modeling and Processing of Complex 3D Geometry**
  - +CAD / Image-based automatic modeling
  - +Support arbitrary 3D combination of solids
- **Visualization of Process and Results**
  - +Visualized analysis of results coupled with geometries
  - +Real-time particles tracking visualization
- **Various Particles' Physical Processes Simulation**
  - +Complete physical process simulation of neutron, photon, proton, electron, etc.

Applications

- **Neutronics Calculation and Analysis of ITER**
- **Analysis of China LEAd-based Reactor (CLEAR)**



ITER

CLEAR

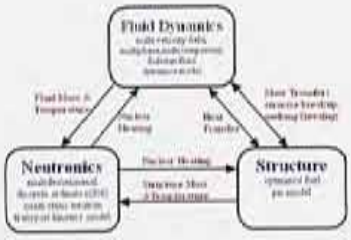
NTC: Neutronics-Thermohydraulics Coupled Simulation Program

Introduction

Reactor transients are complex high complex, nonlinear, interacted physical process. Sufficient consideration of coupling of neutronics and thermal-hydraulics parameters such as reactor power, reactivity, temperature and density is required for accurate transient simulation.

NTC (Neutronics-Thermohydraulics Coupled Simulation Program) is a multi-dimensional, multi-velocity-field, multiphase, multicomponent, Eulerian, fluid-dynamics code coupled with a space- and energy-dependent neutron kinetics model for transient safety analysis of reactor, which is developed by FDS Team.

NTC provides an integrated, consistent, flexible means, coupling the advanced neutronics and thermo-hydraulics methods. It can be applied in the field from the multi-phase flow or nertronics problems to many kinds of reactors.



NTC Overall Code Structure

Functions

- **3-Dimensional Neutronics Transport Calculation**
  - + Multi-group discrete ordinates (SN) quasi-static method neutron transport equation
  - + Flux-shape function neutron flux distribution
  - + Amplitude function kinetics parameters
- **3-Dimentional Thermohydraulics and Structure Calculation**
  - + Independent fluid and structure model
  - + Multi-velocity-field, multiphase, multicomponen, Eulerian, fluid-dynamics model
- **Accident Analysis**
  - + DBA (design basic accident) analysis
  - + Severe accident analysis
  - + Thermal reactor / fast reactor / subcritical reactor transient safety analysis

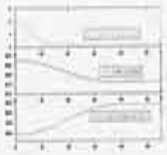
Features

- **High Reliability Based on Advanced Algorithms**
- **High Accuracy Based on the Coupling of Multi-Dimensional Transport Function and Multi-Phase Flow**
- **High Applicability Based on the Design of Neutron Source and Material Thermal Physical Properties**
- **Automatic Modeling and Visualization**

Applications

- **Accident Analysis of Fusion Driven Sub-critical Reactor**

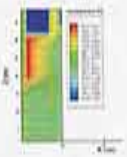
Fusion-Driven Subcritical System



Fuel temperature, fraction and coolant velocity behavior under unprotected loss of flow accident

- **Safety analysis of Accelarator-Driven Subcritical System (ADS)**

Accelerator-Driven Subcritical System (ADS)



Temperature Distribution

References

[1] Y. Ke. Study on Transient Safety Characteristics for the Fusion Driven Sub-critical Reactor. Graduate University of Chinese Academy of Sciences doctoral dissertation, 2006.

MTC: Magnetics Thermohydraulics Coupled Simulation Program

Introduction

Magnetohydrodynamic (MHD) is an important issue in many research fields, such as in the fusion blanket design etc.. The code named Magnetic Thermo-hydraulics Coupling Code (MTC) has been developed by FDS team for years, which is based on the control volume method.

- MTC-F: Based on commercial software Fluent and the B-formulation, it can obtain exact solutions under the condition: Ha<500.
- MTC-H: With the well tested parallel code environment and ability to approach complex geometry, MTC-H can simulate fusion liquid metal blanket MHD flow accurately and efficiently.

MTC has been applied in the analysis of the MHD flow in Chinese liquid LiPb test blanket module in ITER and Chinese liquid metal LiPb experimental loop, DRAGON-IV loop. It has promising prospect in nuclear industry, aircraft technology, metallurgy, chemical industry etc..

Functions

Multi-Physical Coupling Field Simulation Under Complex Conditions

+Flow field, electromagnetic field and temperature field are coupled to give accurate simulation

+MHD flows of different phases under different convection conditions and different magnetic fields distribution can be simulated

+Ability to include multiple solid walls of different conductivities

Reliable Simulation Capabilities

+Mesh structure permits hybrid meshes of hex, prism and tetrahedral elements

+Well tested parallel code environment

+Multiple strategies to account for mesh skewness

Features

Based on Mature CFD Algorithm, High Reliability

+Use simple or projection method to solve the flow field and high reliability is available

+Based on the unstructured mesh, flexible considering complexity of geometry

+The consistent and conservative scheme are employed to calculate the induced current and the Lorentz force exactly

+Exact solution for high Ha~10000

+Completed the code validation on the IEA cooperation framework

Large Capacity of Computation

+Using parallel computing and accelerating the computing process

+Big-sized model with large amount of grids can be computed

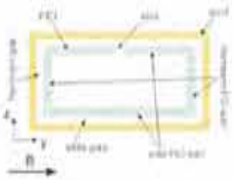
Multi-Physical Coupling Field

+Flow field, electromagnetic field and temperature field are coupled to give accurate simulation

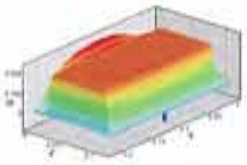
+The MHD flow under the condition of fusion liquid metal blanket can be simulated

Applications

DFLL-TBM with a Flow Channel Insert

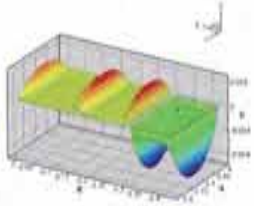


The cross-section view of LL1 poloidal channel with FCI

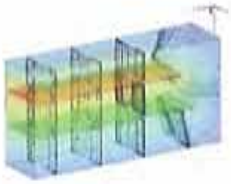


Velocity profiles with one slot at the middle of the side wall

The Results of MHD Flow in ITER-TBM



Velocity profiles in channels in ITER TBM



Current distribution in the channelsinITERTBM

References

[1] T. Zhou, Z. Yang, H. Chen, et al. Code Development and Validation for Analyzing Liquid Metal MHD Flow in Rectangular Ducts. Fusion Engineering and Design, 2010, 85: 1736-1741.

[2] T. Zhou, Z. Meng, H. Chen, et al. Preliminary Numerical Analysis of MHD Flow of DFLL-TBM on the Single Coolant Stage. Fusion Engineering and Design, 2012, 87: 1074-1078.

TAS: Tritium Analysis Program for Fusion System

Introduction

Because of its radioactivity and violent activity, tritium is very easy to permeate out of the container during the fuel circulation, and this will result in the loss of nuclear fuel and the potential radioactive hazard to workers and the public. In addition, tritium control of fusion reactors is one important means to achieve the goal of self-sufficiency and environmental safety.

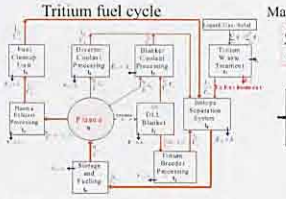
Basing on a series of Li-Pb blanket fusion reactor designed by FDS Team, a tritium analysis program has been carried out to achieve the goal of self-sufficiency analysis, tritium fuel management and safety analysis, using software engineering method and Object-Oriented technology. In addition, TAS 1.0 could also support the design of blanket and fuel circulation system. A series of tests and applications had shown the maturity and effectiveness of the system.

Functions

- **T Self-Sufficiency Analysis**
  - Minimum TBR for self-sufficiency
  - Minimum T supply for self-sufficiency
- **T System Safety Analysis**
  - T release into environment
  - T inventory in reactor
- **T Fuel Management**
  - Required T initial startup inventory
  - Doubling time for T breeding
  - Breeding, burnup, decay
- **Tritium Analysis Related Modules Integrated**
- **Open and Humanized Operation System for Fusion Tritium analysis**

Method

Tritium Fuel Cycle



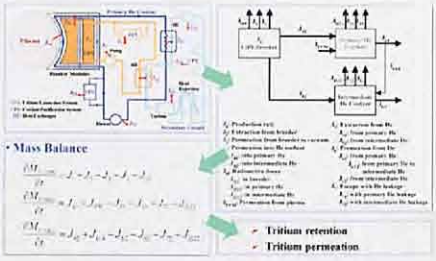
Mass balance:

$$\frac{\partial I_i}{\partial t} = Q_{Inflows} - Q_{Losses} - \frac{I_i}{T_{res}}$$

- Self -sufficiency analysis
- Safety analysis
- Fuel management

- E_i: Nonradioactive loss in subsystem i
- λ: Tritium decay constant
- β: Tritium fractional burnup in the plasma
- N_i: Tritium burn rate in the plasma
- I_i: Tritium inventory in subsystem i
- $Q_{Inflows}$: Tritium flow into subsystem i
- Q_{Losses}: Tritium loss in subsystem i
- T_{res}: Mean residence time of tritium in subsystem i

Tritium in Blanket



Applications

A series of tests have proved TAS1.0 to be an effective and accurate tritium analysis tool

Analysis on fuel cycle

Object	Release 3	
Item	Ref	TAS1.0
M_T	10.5kg	10.2kg
Max M_T	20.2kg	21.4kg

Analysis on breeding system

Object	EUHCLLBlanket	
Item	Ref.	TAS1.0
C_{Li^6LiPb}	0.065g/m³	0.067g/m³
M_{Li^6LiPb}	38.1g	39.2g
M_{Li^6Li}	25.8g	22.5g

✛ITER DFLL-TBM
- Normal Condition: T release into environment as HTO(HT) is ~0.011 (1.62)mg-T/year, much lower than TBM annual release target 1(10)mg-T/year
- Accident Conditions : ~40.4mg

✛FDS-III analysis
- Results of Fuel Cycle Analysis
  - The minimum T inventory reserve in storage is ~9.9kg
  - The double time for T breeding is ~886 days
- Tritium distributing after 1 year

References

[1] M. Ni, Y. Song, Q. Huang, et al. Development of Tritium Analysis System TAS 1.0. Chinese Journal of Nuclear Science and Engineering, 2009, 29(4):355-361.

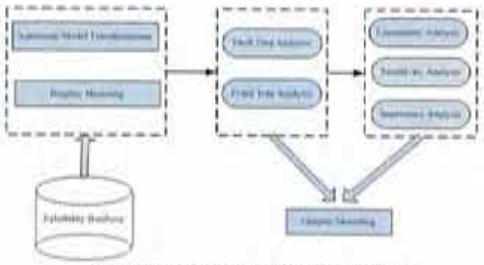
[2] M Ni, Y Song, Q Huang, Y Wu. Tritium Safety Assessment on High Temperature Liquid Blanket for Fusion-Based Hydrogen Production Reactor FDS-III. Fusion Sci. Tech, 2011, 60: 1125-1128.

RiskA: Reliability and Probabilistic Safety Assessment System

Introduction

PSA software is an indispensable tool in the PSA applications, since the models used to reflect the complex system, etc., the nuclear reactor, is complicated. Stimulated by the rapid progress of the nuclear industry, how to develop an applicable and efficient Probabilistic Safety Assessment system has emerged as a hot topic.

FDS Team has developed an integrated probabilistic safety assessment system, named RiskA. RiskA can be used for fault tree analysis, event tree analysis, uncertainty analysis, human reliability analysis, common cause failure analysis, sensitivity and importance analysis.



Main Functions and Structure of PSA Software

Externded Functions

- **Failure Mode and Effects analysis**
- **Reliability Prediction**
- **Reliability Block Diagram**
- **Expert System for Automatic Modeling**

Features

- **Reliable Model, Efficient Algorithms**
  - +Enhanced MCS / ZBDD, improved speed and accuracy
  - +Suitable for real-time risk evaluation
  - +Well-designed data structure, making full use of computation resources
- **Network Architecture for Resource Sharing**
  - +Multi-user environment
  - +Cooperation modeling
- **Graphic Modeling and Visualization of Analysis Result**
  - +Mutual modeling via colored graphs
  - +Automatic model format conversion from other PSA software
  - +Customized output supported
  - +User-friendly, easy to learn
- **Extensive, Intellectual Property Rights Reserved**
  - +Upgrade and extend easily
  - +A platform based on which other advanced applications could being performed (risk monitor etc.)

Functions

- **Management of Reliability Data**
  - +Data acquisition and optimization
  - +Automatic coding rule transformation
- **Fault Tree Analysis**
  - +Qualitative analysis
  - +Quantitative analysis
  - +Model transformation
  - +Accruate analysis based on ZBDD / MCS algorithms
- **Event Tree Analysis**
  - +User-friendly graphic modeling
  - +Qualitative and quantitative analyses of sequences
  - +Qualitative and quantitative analyses of consequences
- **Importance and Sensitivity Analysis**
  - +Various importance analyses supported (FV, RAW, RRW etc.)
  - +Components and parameter level sensitivity analysis supported
- **Uncertainty Analysis**
  - +Quick analysis of confidence interval
  - +Common distributions supported (normal, lognormal, uniform etc.)
  - +Different sampling methods in simulation
- **User-Friendly Environment**
  - +Graphic modeling and automatic error-prone
  - +Scientific visualization
  - +Customization by users easily
  - +Charts and tables created automatically

Applications

- **Accelerator Driven Nuclear Waste Transmuter ADS-CLEAR**
- **International Thermonuclear Experimental Reactor ITER-TBM's Safety Analysis**
- **Experimental Advanced Superconducting Tokamak EAST's Reliability Analysis**
- **Third Qinshan Nuclear Power Plant Risk Monitor (TQRM)**
- **Design of FDS Series Fusion Reactors**
- **Reliability Analysis of Laser Radar System, etc.**

References

[1] Y. Wu, P. Liu, L. Hu, et al. Development of an Integrated Probabilistic Safety Assessment Program. Chinese Journal of Nuclear Science and Engineering, 2007, 27(3): 270~276.

RiskAngel / TQRM: Risk Monitor for Nuclear Power Plant

Introduction

Nuclear safety is the lifeblood of the development of nuclear energy. Probabilistic Safety Analysis (PSA) plays a significant role in the nuclear power plant. Risk monitor is a real-time analysis tool to determine the point-in-time risk based on actual plant configuration, which is an important application of PSA. A risk monitor can monitor the instantaneous risk in order to keep the plant's risk level under control. It can also help to demonstrate risk awareness to the nuclear regulatory authority.

RiskAngel is a risk monitor that was developed by FDS Team independently, which was convenient to customize for the nuclear power plant according to the actual requirement. In collaboration with Third Qinshan Nuclear Power Company (TQNPC), FDS Team made RiskAngel as a risk monitor prototype in the development of the Third Qinshan nuclear power plant Risk monitor(TQRM) successfully. The operation of TQRM demonstrated that it was helpful to Third Qinshan nuclear power plant (TQNPP).

Features

- **Fast and Efficient Instantaneous Risk Calculation**
  - +Advanced instantaneous risk calculation (eg McFarm)
  - +Improved Fault Tree Analysis (eg ZBDD / MCS)
- **Excellent and Reliable Maintenance Schedules' Evaluation**
  - +Component's out of service and back to service analysis
  - +Long-term and short-term maintenance schedules
- **User-Friendly Interface**
  - +Various interface style
  - +Designed for all power plant personnel
- **Extensive, Intellectual Property Rights Reserved**
  - +Upgrade and extend conveniently
  - +Customized accord to the specific requirements easily

Main Functions

- **Instantaneous Risk Calculation**
  - +Various instantaneous risk calculations (eg pre-solved cut sets method, resolving the PSA model and hybrid method to combine the former two together)
  - +Advanced and efficient calculation methods
  - +Advice and suggestions given on technical specification
- **Components' Importance Analysis**
  - +Various importance scale (including FV, RAW, RTS etc.)
  - +Used for the maintenance schedules and selection of SSC
  - +Interface preserved for other importance calculations
- **Mode Transformation**
  - +Long-term and short-term maintenance schedules
  - +Test for component's out of service and back to service
- **Log Management**
  - +Risk operating log
  - +Query according to arbitrary time point
- **Intelligent Output**
  - +Professional standard reports and charts automatically created
  - +Visualization of analysis result

Applications

TQNPP has two 728MW CANDU (CANadian Deuterium Uranium) reactors designed by AECL (Atomic Energy of Canada Limited) which are the only two Pressurized Heavy Water Reactors in the 15 operating reactors in China nowadays. In order to improve the performance of these reactors continuously, TQNPC relegated the development of her risk monitor to FDS Team in 2008.

As Chinese first software in nuclear safety analysis with full intellectual property, TQRM has been developed, which was combined the actual requirement of TQNPP on the basis of RiskAngel.

TQRM has been operating in Third Qinshan nuclear power plant since 2010. The experience of TQRM operating in TQNPP showed that the calculation engine was accurate and efficient and the architecture was stable, and it could be extended and maintained conveniently. It has provided a lot of good advice for the operation of the plant and played an important role in the risk-informed application.

Extened Functions

- **Network Architecture for Resource Sharing**
- **Optimization of Maintenance Schedules**
- **Evaluation on Both Safety and Economics**

References

[1] Y. Li, Development and Application of a Risk Monitor for Nuclear Power Plant. Chinese Academy of Sciences, 2010.

[2] H. Wang, Y. Wu, Y. Li, et al. Software Development for Risk Monitor in Nuclear Power Plants. Nuclear Power Engineering, 2009, 30(1): 26~30.

SYSCODE: System Analysis Program for Parameter Optimization and Economic Assessment of Fusion Reactor

Introduction

Fusion power is still in early stages of development, although the feasibility of fusion energy has been widely verified, its economic efficiency attracts more and more attention in the research community. The research on the methodology on the fusion energy economics and the development of analyses software tools has been placed on the agenda.

Functional modules of SYSCODE

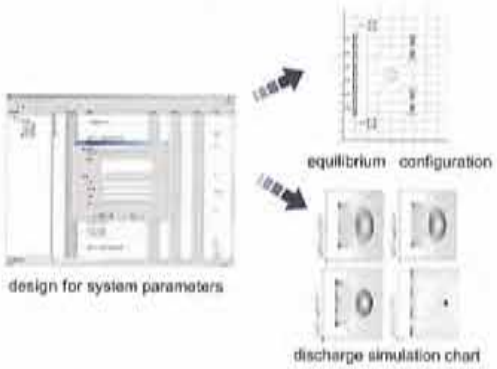
Functions

System Parameter Design

+Physical parameter computation for reactor core

+Equilibrium configuration optimization

+Dynamic simulation of equilibrium evolution during discharging process



design for system parameters

equilibrium configuration

discharge simulation chart

Economic Evaluation

+Economic data source provided

+Graphical modeling, text model supported

+Revisable economic model

+Efficient economic computation system

Sensitivity and Uncertainty Analysis

+Economic analysis for various facts (direct cost, indirect cost, financial cost, etc.)

+The acquisition of influential parameter sequence for economic efficiency

+Monte Carlo sampling technology (stratified sampling, latin hypercube sampling method, etc.)

Design Optimization

+Different optimization methods (neural network algorithm, genetic algorithm, simulated annealing algorithm, etc.)

+Dynamic display of optimization results

Optimization Setting

GeneticAgorithm

Features

Reliable Calculation Methods for Self-Consistent Physical Parameters of Reactors

Economic Analysis System

(Integrated Inner and Outer Cost Calculation Methods)

Accurate and Effective Parameter Optimization for Fusion Reactor

(Advanced Methods)

Versatile Economic Computation Models

(Can be Applied to Fusion, Fission or Hybrid Systems)

Applications

Physical parameter optimization and economic analysis have been carried out for a series of fusion systems including FDS-I (Fusion-driven Subcritical System).

Visualization of FDS-I

References

[1] S. Zhang, D. Huang, L. Hu, et al. Economic Assessment of Fusion and Fusion-driven Subcritical Systems based on Internalization of External Costs and Benefits. Fusion Engineering and Design, 2007, 82: 2879-2884.

[2] S. Zhang, D. Huang, Y. Wu. Preliminary Economic Analysis of the Fusion Power Reactor FDS-II Power Plant with Dual-Cooled Lithium Lead Blanket. Chinese journal of nuclear science and Engineering, 2005, 25(2): 188-192.

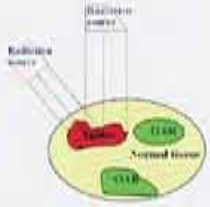
ARTS: Accurate / Advanced Radiotherapy System

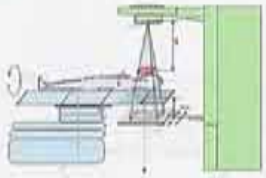
Introduction

Radiotherapy is one of the most important technologies for cance treatment. The key issues related to the improvement of the treatment accuracy have been studied and the Accurate / Advanced Radiotherapy System (ARTS) has been developed by FDS Team. Intensity Modulated Radiotherapy (IMRT), Image-Guided Radiotherapy (IGRT) and Dose-Guided Radiotherapy (DGRT) have been supported by ARTS. Strict phantom and clinical test proved that ARTS was effective.

Features

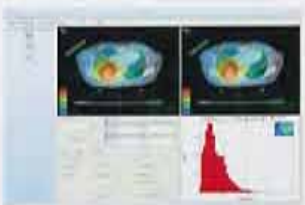
- **Hybrid Dose Calculation**
  - +Fast analytic and accurate Monte Carlo coupling dose calculation methods
  - +Settling the conflict of accuracy and speed in dose calculation and providing practical dose engines for treatment planning design
- **Intelligent Multi-object Optimization in Inverse Planning**
- **Accurate 3D Dose Reconstruction Model**





Functions

- **Treatment Planning System (ARTS-IMRT)**
  - +Image management: image import/output/network transmission
  - +Organ contouring: various of manual and automatic segmentation tools
  - +Image fusion: landmark-based fusion, automatic fusion
  - +Forward planning / Inverse planning
  - +Plan evaluation: plan comparison, dose-volume-histogram (DVH) , isodose line, point dose etc
- **Real-time Positioning and Tracking System (ARTS-IGRT)**
  - +MV / KV X-ray imaging based positioning system
    - Continuous and step motion styles of the couch
    - Real time image acquisition, display , import / export and flexible processing
  - +Infrared positioning and tracking system
    - Real time monitoring of tumor target
    - Provide gating and warning signal for the accelerator Continuous and step motion styles of the couch
- **Dose Reconstruction and Verification System (ARTS-DGRT)**
  - +Plan Import: manage the plan and dose information
  - +Dose Reconstruction: reconstruct 3D dose distribution during the treatment
  - +Dose Evaluation: Fluence evaluation, 2D dose evaluation, 3D dose evaluation



Applications

Experiments were carried out based on anthropomorphic phantom and clinical cancer cases, the results verified the validity of ARTS. Using ARTS-IMRT to make the design of an inverse plan for prostate cancer, it could get the satisfying plan within one minute; the accuracy of 3D/3D image registration and infrared positioning and tracking system of ARTS-IGRT can reach to the sub-millimeter level; ARTS-DGRT can reconstruct 3D dose distribution delivered to patient , the deviation with the measured dose is less than 5%.

References

[1] Y. Wu, S. Gang, R. Cao, et al. Development of Accurate / Advanced Radiotherapy Treatment Planning and Quality Assurance System (ARTS). Chinese Physics C (HEP & NP), 32(Suppl. II), 2008: 177-182.

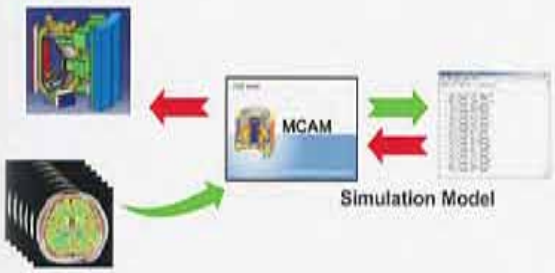
[2] Y. Wu, G. Li, S. Tao, et al. Research and Development of an Accurate / Advanced Radiation Therapy System (ARTS). Chinese Journal of Medical Physics, 2005, 22(6): 83-690.

MCAM: CAD / Image-Based Modeling Program for Nuclear and Radiation System

Introduction

MCAM is a CAD / Image-based automatic modeling program for nuclear and radiation system (MCNP, TRIPOLI, FLUKA, Geant4, Super MC, etc.) developed by FDS team. Researchers could achieve fast "design-calculation-analysis re-design" progresses with MCAM based on CAD models. MCAM is also capable to convert CT / MRI / sectioned color images into accurate human computational phantoms, which would be applied in medical physics and radiation protection.

The development of MCAM has been started since 1999, and it has been used by hundreds of institutes in more than 40 countries all over the world.



Functions

- **Converter**
  - +Converting CAD models into the simulation models. MCNP, TRIPOLI, FLUKA, Geant4, Super MC, etc. were supported
  - +Converting CT / MRI / sectioned images human computational phantoms for MCNP and EGS etc.
- **Inverter**
  - +Converting neutronics models into CAD models for visualization and further update
- **Preprocessor**
  - +Importing and fixing possibly existing errors in the engineering CAD models for simulation
- **Geometry Modeling**
  - +Create and modify primitive solids with creation, boolean operation, array, move, rotate, slice operations etc.
- **Model Analysis**
  - +Interactive analysis of geometry visually
  - +Editing physics attributes visually including material, tally and source definition

Applications

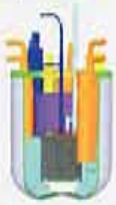
MCAM has been successfully applied to nuclear analysis of fusion, fission and fusion / fission hybrid nuclear system, medical physics, and etc.

- **ITER (International Thermonuclear Experimental Reactor)**

ITER modeling of neutronics model (Alite-4) and its divertor

ITER tokamak building in MCAM

- **CLEAR (China LEAd-based Reactor)**



Engineering Model

Simulation Model

- **Rad-HUMAN (Accurate whole-body Computational Phantom of Chinese Adult Female)**

An accurate whole-body computational phantom of Chinese adult female called Rad-HUMAN was created by using MCAM from color photographic images.

References

[1] Y. Wu, et al, CAD-based Interface Programs for Fusion Neutron Transport Simulation. Fusion Engineering and Design, 2009, 84: 1987-1992.

[2] Y. Li, L. Lu, A. Ding, et al. Benchmarking of MCAM 4.0 with the ITER 3D model. Fusion Engineering and Design, 2007, 82: 2861-2866.

SNAM: SN Modeling Program for Nuclear and Radiation System

Introduction

SN Modeling Program for Nuclear and Radiation System (SNAM), is an automatic modeling system for SN codes, which realizes the automatic bi-directional conversion between CAD models and SN (Discrete Ordinates) code input files. Analysts could shift the time-consuming, error-prone geometry modeling processes into CAD systems by using SNAM. It avoids the simplification of geometric models, which exists in the conventional text-based manually modeling processes. So the modeling efficiency and resolution are obviously enhanced.

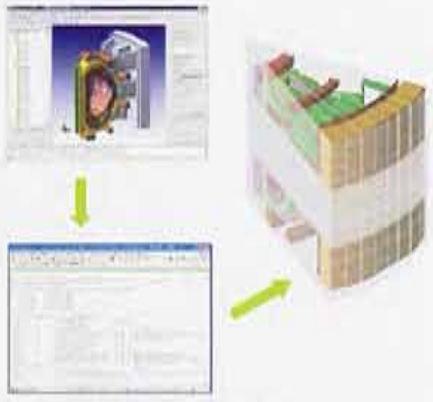
Schematic of SNAM functions

Features

- **With Proprietary Intellectual Property Rights**
- **Compatible with Various Kinds of CAD systems**
- **Characterized by Automatically and Visually Modeling**
- **Supporting Modeling for MC-SN Coupled Simulation**
- **Easy to Extend, Due to the Component-Based Architecture**

Applications

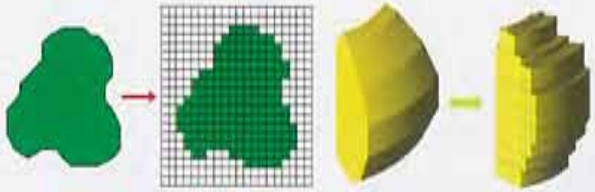
- **Automatic Modeling of ITER Benchmark Model**
  - +Distributed by ITER (International Thermonuclear Experimental Reactor) organization.
  - +Characterized by large volume, large number of solids, and complex shapes.
  - +Calculation models could be automatically generated within half an hour on ordinary personal computers.
  - +Result from auto-generated SN model has a good agreement with the MC calculation.



Work flow chart of SNAM

Functions

- **Geometry Modeling**
  - +Creation of basic models, such as cubes.
  - +Model modification, such as array, Boolean operation.
  - +Import / export at various format.
  - +Check and fix of geometric errors.
- **Physics Modeling**
  - +Supporting many kinds of source.
  - +Creation / Edit of source geometries.
  - +With flexible interfaces.
  - +Setting material of parts.
  - +Management of physics-related parameters
- **Conversion (CAD → SN)**
  - +Discretize arbitrary complex CAD geometries into SN geometry models automatically.
  - +Able to generate full-formed SN input files.
- **Reversion (CAD ← SN)**
  - +Parse various data in SN input files, and reconstruct related geometries.



Discretization of geometries

References

[1] Y. Wu, FDS Team. CAD-based Interface Programs for Fusion Neutron Transport Simulation. Fusion Engineering and Design, 2009, 84: 1987-1992.

[2] P. Long, J. Zou, S. Huang, et al. Development and Application of SN Auto-Modeling Tool SNAM 2.1. Fusion Engineering and Design, 2010, 85: 1113-1116.

RCAM: MC-SN Coupled Modeling Program for Nuclear and Radiation System

Introduction

Coupled Monte Carlo - discrete ordinates MC-SN three-dimension particle transport simulation computational scheme is used to solve the deep penetration problem. The Monte Carlo method is used to simulate the particle generation and transport in the target region with both complex geometry and reaction physics, and the discrete ordinates method is used to treat the deep penetration problem in the bulk shield.

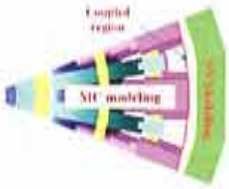
RCAM combined the functions in MCAM and SNAM together, which is able to generate the coupled models for MC and SN codes computation, and could seamlessly cooperate with the simulation codes in the background to carry out the actual coupled calculations.

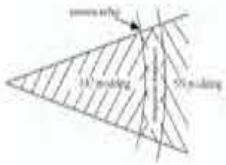
Features

- **Component-based Design, Easily Update and Customized**
- **Support Neutral File Format, such as SAT, IGES, STEP**
- **Intellectual Analysis, Provides Geometry Information**
- **Extend of Attribute of Model, Combines the Geometry Information and Physical Information**

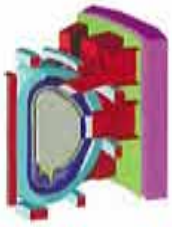
Functions

- **Modeling for MC-SN Coupled Simulation**
  - + Model analysis: provides geometry information (surface equation, type,gemoetry volume), and supports a variety of ways of rendering the model (wire frame, hidden line, triangulated)
  - + Modeling for MC-SN coupled calculation: automatically select common surface, decomposing model for MC region , SN region and coupled region. Converting these models to input files of code of coupling MC / SN method





- **Bi-Directional Transform of MC and SN Model**
  - + With the bridge of CAD data, bi-directional transform between MC model and SN model is performed

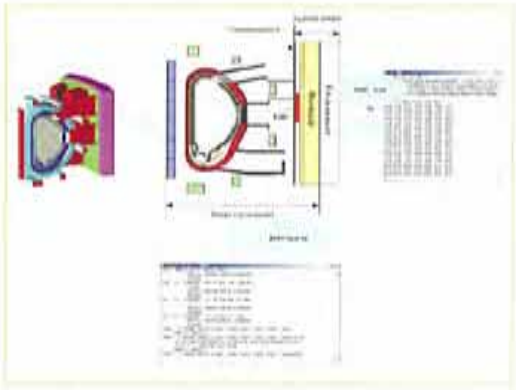


MC model

S_n model

Applications

The ITER benchmark model is issued by ITER IT (International Team) to compare and test the various auto-modeling programs being developed in the ITER PTs (Participant Team). It comprises many complicate models , In order to accurately calculate the neurotics currency in protection region, it must be using coupling MC / SN method to solve this problem. According to requirement of calculating, we decomposing the whole model into 3 parts: MC region ,Coupling region and SN region. With the help of RCAM, and finally produced MCNP input file, tort input file and coupling MC / SN input file.



Workflow of modeling for MC-SN coupled simulation

References

[1] Y. Wu, Q. Zeng, Y. Li, et al. CAD-based Interface Programs for Fusion Neutron Transport Simulation. Fusion Engineering and Design, 2009, 84: 1987-1992.

[2] J. Zhang, L. Hu, Q. Zeng, et al. Development and Application of MC-SN Coupled Auto-Modeling Tool RCAM1.0. Fusion Engineering and Design, 2011, 86: 2783–2786.

RVIS: Virtual Reality-Based Simulation Platform for Nuclear and Radiation Safety

Introduction

Due to the risks involved, work scenario in nuclear and radiation environment is always designed based on experts' and past experience, without considering faults in plant design, human wrong operation by unskillful handing, risks associated with unpredictable situation. So the suggested work scenarios are always not the optimal scenarios according to as low as reasonably achievable (ALARA) principle.

Based on digital reactor and Rad-HUMAN, which is a whole-body voxel phantom of Chinese adult female developed by FDS Team, a Virtual Reality-Based Simulation Platform for Nuclear and Radiation Safety named RVIS has been developed for dose assessment and ALARA evaluation of work scenarios in nuclear and radiation environment.

Functions

- **Visualized Analysis of Dynamical 3D Radiation Field Coupled with Geometry Model**
  - +Multi-style visualized analysis of multi-dimensional data
  - +Directly support the calculation result of MCNP / TORT / VisualBUS
- **CAD-based Modeling and Virtual Assembly Simulation of Complex Components**
  - +Compatible with common CAD systems
  - +CAD-based automatic modeling for neutronics and radiation transport based on MCAM
  - +Real-time simulation and accurate collision detection
- **Virtual Roaming Simulation and Organic Dose Evaluation in Radiation Environment**
  - +Virtual simulation of work process in radiation environment
  - +Real-time sensitive organ dose assessment based on Rad-HUMAN
  - +Accurate evaluation of accumulated dose and individual dose
- **Work Scenarios Design and Optimization**
  - +Interactive design of shielding, maintenance and decommission work scenario in radiation environment
  - +Automatic optimization of scenario based on multi-objective optimization algorithm

Features

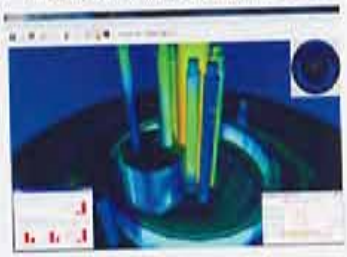
- **Well Support Multi-Users Based on Client/Servers Model**
- **Real-Time Accurate Assessment of Organic Dose Rate**
- **Auto-Optimization of Worker Scenarios Based on Multi-Objective Optimization Algorithms**
- **Large-Scale Virtual Scenes Based on PC**

Applications

- **International Thermonuclear Experimental Reactor (ITER)**
  - +Maintenance scenarios simulation and Organic dose optimization for divertor maintenance of ITER

Application on ITER

- **China LEAd-based Reactor (CLEAR-I)**
  - +The Strategic Priority Research Program of Chinese Academy of Sciences "Accelerator Driven Sub-critical System (ADS)"



Radiation dose assessment for target replacement

- **Experimental Advanced Superconducting Tokamak (EAST)**

Application on EAST

References

[1] Z. Tang, P. Long, S. Huang, et al. Real-Time Dose Assessment and Visualization of Radiation Field for EAST Tokamak. Fusion Engineering and Design, 2010, 85(7-9): 1591-1594.

[2] Y. Luo, P. Long, Y. Xue, et al. Development of Integrated Visualization Platform SVIP for Neutronics Analysis. Chinese Journal of Nuclear Science and Engineering, 2007, 27(4): 374 - 378.

SVIP: Scientific Visualization Program

Introduction

With the development of computer science and scientific calculation method, scientific calculation results become more and more complex and large-scale, and urgently need the support of visualization software. However, conventional visualization software often focus on the general visualization function and failed to take into account the characteristics of various fields, so can not directly provide effective support.

SVIP is a scientific visualization program self-developed by FDS Team for various large-scale complex data. It not only supports a variety of conventional visualization operations, but also provides a variety of advanced visualization functions. SVIP supports the post-processing of various calculation program and provides integrated visual analysis.

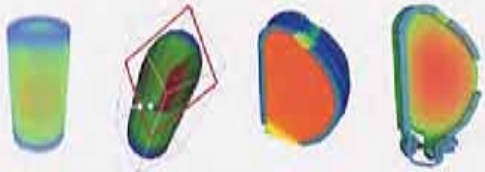
SVIP successfully support VisualBUS, SuperMC, MCNP, TORT, FISPACT and other important scientific calculation programs.

Features

- **With the Proprietary Intellectual Property Rights**
- **Real-Time Volume Rendering Based on 3D Texture Mapping Technology**
- **Mixed Visualization with Data and Geometries**
- **Mapping Volumetric Data onto Arbitrary Geometry Surfaces Based on 3D Texture; Introducing Geometric Models into Visualization Scene to Achieve Flexible Visual Data Analysis.**
- **Integrated Environment for Scientific Visualization**

Functions

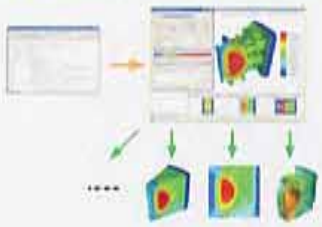
- **Data Import, Management and Processing**
  - + Import and export of multi-format data
  - + Management of multi-data set and multi-visual scene
  - + Supporting the regularization of data and the pretreatment of cutting
- **Visualization of Data Field**
  - + Visualization of 1D/2D/3D/4D
  - + Rapid 3D visualization based on 3D texture mapping technology
  - + Flexibly multi-contour visualization
- **Import, Management and Display of Geometry**
  - + Support various geometry formats, such as: STEP, 3DS, WRL.
  - + Group-based data management and interactive property edition
  - + Support various graphics representation, such as: surface color, translucent display
- **Mapping Volumetric Data onto Geometry Surfaces**
  - + Mapping volumetric data onto arbitrary geometry surfaces based on 3D texture mapping technology
- **Mixed Visualization with Data and Geometry**
  - + Introducing geometric models into visualization scene to realize flexible visual data analysis based on geometric positioning



Applications

Based on SVIP, various styles of visual analyses have been conducted for the neutronics calculations data of ITER benchmark model and CLEAR-IB reactor model.

- **International Thermonuclear Experimental Reactor (ITER)**



- **China LEAd-based Reactor CLEAR-I**
  - + Project supported by the Strategic Priority Research Program of the China Academy of Sciences "Accelerator Driven Sub-critical System(ADS)"

Neutron flux field of CLEAR-IB reactor

References

[1] Y. Luo, P. Long, G. Wu, et al. SVIP-N 1.0: An Integrated Visualization Platform for Neutronics Analysis. Fusion Engineering and Design, 2010, 85(7-9): 1587-1590.

[2] Y. Luo, P. Long, Y. Xue, et al. Development of Integrated Visualization Platform SVIP for Neutronics Analysis. Chinese Journal of Nuclear Science and Engineering, 2007, 27(4): 374 - 378.

FVAS: Fusion Virtual Assembly System

Introduction

Virtual assembly is an efficient way to shorten design cycle and improve quality. But conventional virtual assembly systems emphasize assembly simulation based on virtual hands without effective consideration of assembly simulation requirements of large facilities.

Fusion Virtual Assembly System (FVAS), self-developed by FDS Team in China, is a VR-based (Virtual Reality, VR) application, which aims to make or assist with assembly-related engineering decisions for large facilities by providing assembly planning, evaluation, and training functions.

FVAS has been successfully applied in Experimental Advanced Superconducting Tokamak (EAST) of China, Test Blanket Module for International Thermonuclear Experimental Reactor (ITER) and China Lead-Alloy cooled Reactor (CLEAR) etc.

Functions

- **Automatic Assembly Modeling**
  - +Not only polygon-facet geometry information, but also any assembly information used during assembling, automatically translating from CAD to VR
- **Multi-Way Assembly Planning**
  - +Manually virtual assembly
  - +Assembly path planning
  - +Automatic path planning
- **Multi-Viewpoints Based Flexible Virtual Roaming**
- **Record and Replay of Assembly Processes**
  - +Assembly information is automatically recorded in unit of assembly snippet during assembling. And the snippet based replay is very useful for expression of assembly processes.

Features

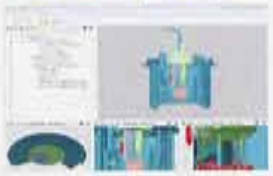
- **Integrating CAD and VR Data**
  - +Automatic data translation between CAD and VR formats.
- **Separation of Display Scene and Collision Detection Scene**
  - +Not only guarantying the assembly precision, but also enhancing the display frame rate
- **User-Friendly Assembly Operation Interfaces**
  - +Save and Load of Assembly progresses
  - +Record and Replay of assembly processes
- **Natural Realistic Virtual Roaming**
  - +Viewpoint-based roaming mechanism, naturally imitate human eyes
  - +Multi-viewpoint based observation, largely convenient.

Applications

- **International Thermonuclear Experimental Reactor (ITER-TBM)**

Virtual Assembly of ITER-TBM

- **China LEAd-based Reactor (CLEAR)**



Validation of Refueling System for CLEAR-I

- **Experimental Advanced Superconducting Tokamak (EAST)**

Virtual Assembly of EAST

References

[1] P. Long, S. Liu, Y. Wu, et al. Design and Testing of the Fusion Virtual Assembly System FVAS 1.0. Fusion Engineering and Design, 2007, 82: 2062-2066.

[2] P. Long, S. Liu, Y. Wu. Preliminary Design of the Fusion Virtual Assembly System Based on Crane. Computer Simulation, 2007, 24(4): 231-234.

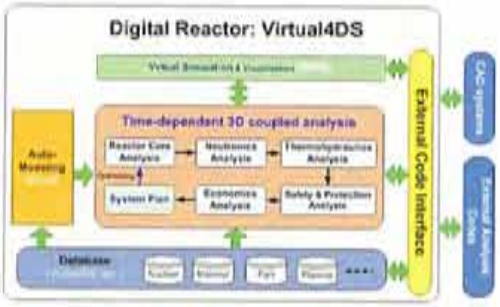
Virtual4DS: Virtual 4-Dimensional System for Integrated Design and Simulation of Advanced Reactors

Introduction

Nuclear energy and nuclear technology research is an important national strategic issue. However, there generally exist two important shortages for existing nuclear related software. On one hand, these software are designed only for one single scenario, can't support the entire design cycle; on the other hand, they can not support the design of advanced nuclear energy systems.

Virtual4DS (Virtual 4-Dimensional System for Integrated Design and Simulation of Advanced Reactors) not only supports the entire design cycle, but also supports the design of advanced nuclear reactors. Virtual4DS can be referred to as "Digital Reactor", and can be extended as "Virtual Plant" for support of operation simulation and decision-making of nuclear power plants.

This system has been applied to the international thermonuclear experimental reactor ITER, the fusion/fission hybrid reactor FDS-I, the fusion power reactor FDS-II, the high-temperature hydrogen generation fusion reactor FDS-III, China IEAd-based Reactor CLEAR and other nuclear energy systems. It is an integrated platform for the design and simulation of nuclear energy systems.



System Architecture

Features

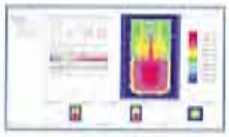
- **Time-Dependent 3D Multi-Physics Coupling Simulation**
- **Automatic Modeling & Visualized Analysis**
- **Integration with Design Capabilities and Operational Simulation**
- **Auto Coupling of Multi-Simulation to Avoid Data Island**
- **Open Architecture, Easy to Expansion**

Applications

- **International Thermonuclear Experimental Reactor (ITER)**

Radiation distribution during ITER activated divertor moving

- **China LEAd-based Reactor (CLEAR)**



Neutron flux distribution of CLEAR

Radiation dose assessment for target replacement

Functions

- **4D Multi-Physics Coupling Simulation**
  - +Neutronics, Thermal-hydraulics, Magneto-hydrodynamics, mechanics, system accident analysis, probabilistic safety assessment, environmental impact assessment, system economy analysis, etc.
- **3D Virtual Integrated Environment**
  - +Virtual assembly, viewing, maintenance, occupational dose assessment, etc.
  - +Naturally interaction based on advanced interactive virtual reality devices
- **CAD-Based Automatic modeling**
  - +Support CAD geometries
  - +Support CT / MRI / Sectioned Images
- **Dynamical and Visualized Analysis**
  - +Multi-dimensional and multi-style representation: volume rendering, dynamic visualization, ...
  - +Intuitive, efficient visualized analysis coupling with geometries
  - +Real-time interactive visualized analysis for varying data field
  - +Human virtual roaming & dosimetry assessment

References

[1] Y. Wu, L. Hu, P. Long, et al. Development of Design and Analysis Software for Advanced Nuclear Systems. Chinese Journal of Nuclear Science and Engineering, 2010, 30(1): 42-50.

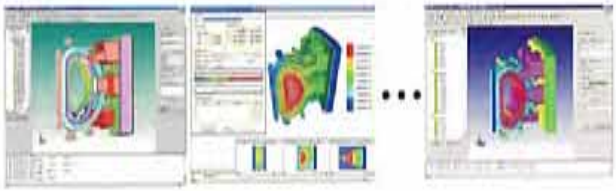
[2] Y. Wu, FDS Team. CAD-based Interface Programs for Fusion Neutron Transport Simulation. Fusion Engineering and Design, 2009, 84: 1987-1992.

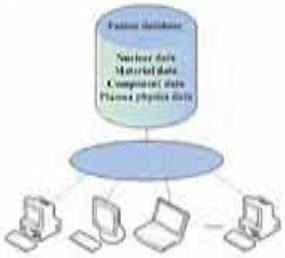
FusionDB: Database Management System for Fusion

Introduction

Fusion energy development is a complex & long-term project, which needs cooperation over the world. Now, Fusion energy development is still in the period of research & design, gathering & sharing fusion data is one of the most important tasks. FusionDB is the first online research center for fusion technology R&D.

Based on EAST (Experimental Advanced Superconducting Tokamak) and ITER (International Thermonuclear Experimental Reactor), FusionDB collects large volume latest & high-quality fusion data; and FusionDB also integrates a set fusion data processing software, which are derived from FDS self-developed nuclear design and simulation software.





Functions

Fusion technology R&D involves fusion reactor design, fusion material research, neutronics analysis, radiation shielding, plasma experiment, etc. Huge data is involved in fusion technology R&D.

+Fusion Nuclear Data: There are evaluation library (ENDF, JENDF, CENDF, etc.) and working library (HENDL, FENDL, etc.).

+Fusion Material Data: For each material, physical property, chemical property, nuclear property, mechanical property and related experiment data are gathered. Now, there are more than 100 kinds of materials including structure materials, nuclear materials and shielding materials.

+Fusion Component Data: There are typical components' CAD model, physics analysis model, etc.

+Plasma Physics Data: Plasma temperature / density, polar field electrical current / voltage / magnetic density, longitudinal field electrical current/voltage / magnetic density, etc.

Services

- **Basic Services**
  - +Data Search / Browse / Download
- **Advanced Services**
  - +Fusion data processing, analysis
  - +MCAM / SNAM / RCAM based component model processing
  - +Visual analysis of plasma physics data
  - +Visual analysis of nuclear data

Features

- **FusionDB is the first comprehensive database management system on-line for fusion technology R&D.**
- **Rich & high-quality data: Data in FusionDB covers main aspects of fusion technology R&D. EAST and ITER ensure data's quality and quantity.**
- **Powerful data processing tools: FusionDB pays emphasis on data processing software development, rich & powerful data processing functions are integrated.**

Applications

FusionDB are providing 7*24 services online (website: http://www.fusion.csdn.cn). FusionDB has played an important role in ITER and EAST related projects. For example, HENDL and MCAM are involved in several ITER projects, including the first finished ITER project in China.

References

[1] Y. Wu, L. Hu, P. Long, et al. Development of Design and Analysis Software for Advanced Nuclear Systems. Chinese Journal of Nuclear Science and Engineering, 2010, 30(1): 55-64.

[2] J. Zou, Z. He, Q. Zeng, et al. Development and Testing of Multi-group Library with Correction of Self-shielding Effects in Fussion-Fission Hybrid Reactor. Fusion Engineering and Design, 2010, 85(7-9): 1587-1590.

HENDL: Hybrid Evaluated Nuclear Data Library

Introduction

To meet the need of numerical simulation for nuclear science and technology, Hybrid Evaluated Nuclear Data Library (HENDL), was developed indigenously by the FDS Team.

The basic components of HENDL include fine-group library HENDL / FG, multi-group library HENDL / MG, ADS library HENDL-ADS / MC/MG, coarse-group library HENDL / CG and point-wise library HENDL / MC.

A series of benchmark calculations and comparative analyses are thoroughly performed based on a number of existing benchmark experiments. The testing results indicate that the HENDL is a reliable and effective nuclear library system.

Functions

- **HENDL / E (Evaluated) Neutron Nuclear Data Source**
  - + From various international evaluated neutron nuclear data libraries, such as FENDL, ENDF / B, JENDL, JEF and BROND
  - + HENDL-Evaluated (for intermediate and high energy (> 20MeV))
- **HENDL Neutron / Photon Transport Library**
  - + ENDL / CG (Coarse-Group) 27n/21g: VITAMIN-E
  - + HENDL / MG (Multiple-Group)175n/42g: VITAMIN-E
  - + HENDL / FG (Fine-Group) 315n/42g: fusion-fission spectrum
  - + HENDL-ADS/MG(366n/42g)366n/42g: ADS spectrum
  - + HENDL / MC (Monte-Carlo)

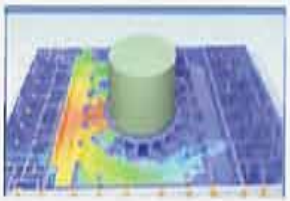
Features

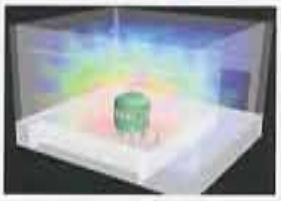
- **Evaluated Data Sources**
  - + Selected from FENDL, ENDF / B-VII, JENDL, EFF, BROND
- **Multi-Function Working Libraries and Different Energy Structures**
  - + Multi-function Working Libraries, Transport.lib, Burnup.lib, Activation.lib, Iriradiation.lib, Dose-factors.lib
  - + Different energy structure: Fine-Group, Multiple-Group, Coarse-Group
- **Physical Effect**
  - + Resonance self-shielding effect
  - + Thermal neutron up-scattering effect
  - + Temperature doppler effect
- **High Neutron Energy Cross Section Library up to 150MeV**
- **Data Formats**
  - + Multi-group : MATXS format
  - + Point-wise : ACE(A Compact ENDF) format

Applications

- **China LEAd-based Reactor**
- **FDS Serials Reactors**

- **ITER / EAST Neutronics Analysis**





References

[1] J. Zou, Z.Z He, Q. Zeng, et al. Development and Testing of Multigroup Library with Correction of Self-shielding Effects in Fusion-Fission Hybrid Reactor. Fusion Engineering and Design, 2010, 85: 1587-1590.

[2] J. Zou, Qin Zeng, Dezheng Xu, Linqin Hu, Pengcheng Long, Design and Producing of Fine-Group Cross Section Library HENDL3.0 / FG for Subcritical System. PHYSOR 2012, 2012: 4583-4591, Knoxville, USA.

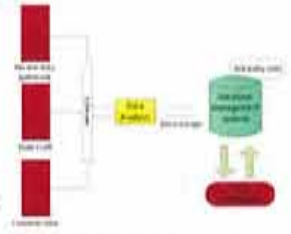
RiskBase: Database Management System for Reliability Analysis

Introduction

Reliability data, could be the numbers, tables, figures, words or even curves, are the foundation of reliability analyses and probabilistic safety assessment. Because of the importance role playing in the preventive maintenance and function test, the reliability data of components are widely used in the nuclear safety field. Therefore database technology has been used to manage the large volume data. Stimulated by the progress of nuclear industry and based on extensive research, FDS Team successfully developed a Database Management System for Reliability Analysis RiskBase. The up-to-date version has the following functions, such as data acquisition, data analysis, data management, data optimization and so on. Users can not only acquire information via advanced data mining, but also deal with them by Bayesian analysis. The validity of RiskBase has been verified by typical examples.

Functions

- **Data Acquisition**
  - +Data selection and pretreatment
  - +Data mining and knowledge discovery
  - +Supplying data craft selection
  - + All kinds of public data source
- **Data Analysis**
  - +Failure times of components
  - +Failure causes of components
  - +Maintenance time
  - +Down time
  - +Unavailable times
  - +Accumulated requirement times
  - +Requirement failure times
  - +Accumulated operation time
- **Data Management**
  - +Management for reliability data
  - +Management for database
  - +Advisable reliability model
  - +User-defined database supplied
  - +User-defined naming rule and code conversion
  - +User Class definition
- **Data optimization**
  - + All kinds of optimiation methods (like Bayesian algorithm)
  - +User-defined optimization types



Flow chart of data processing

Extended Functions

- **The reliability data can be further applied to the repair analysis, recursive data analysis, degradation analysis as well as the optimization analysis of the reliability test, design and the component replacement**
- **Easily connect other databases, such as the material database and nuclear physics database, to make a even larger database platform**
- **Provide the data for the quantitative analysis with the combination of the safety analysis software, reliability analysis software and the economic analysis software for the nuclear power plant**

Features

- **Easy to be Extended and Maintained**
  - +Various technical interfaces of reliability data / parameter computation methods
  - +Following modern software engineering methodology
  - +Well-designed architecture, easy to be maintained and updated
- **More Precise, More Stable Computation Process**
  - +Common Bayesian model, computation precision guaranteed
  - +Advanced quality control system, software stability guaranteed
- **Complete Function System, Wide Range of Use**
  - +Acquisition, analysis, management, optimization of reliability data
  - +Not only providing original characteristic data of devices, but also providing reliability data and parameters
- **Net-Based, Resource Sharing**
  - +Centralized / distributed network
  - +Complete sharing of reliability data
  - +High security data transmission
- **Interactive Software Interface, Easy to Use**
  - +Windows-styled, concise exhibition
  - +Higher speed, easier operation

Applications

- **Providing reliability parameters for Reliability and Probabilistic Safety Assessment Program RiskA**
- **Providing reliability parameters for risk monitor system RiskAngel**

References

[1] Y. Wu, P. Liu, L. Hu, et al. Development of an Integrated Probabilistic Safety Assessment Program. Chinese Journal of Nuclear Science and Engineering, 2007, 27(3): 270-276.

[2] S. Zhang, Y. Wu, P. Liu, et al. Design of net-based PSA Database Management System for Nuclear Power Plants. Chinese Journal of Nuclear Science and Engineering, 2006, 26(4): 368-372.

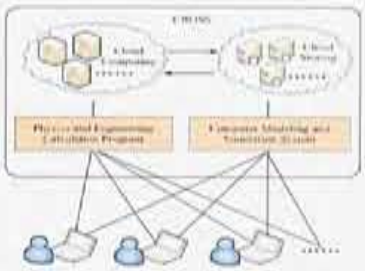
CROSS: Collaborative Research and Science Resource Management Platform

Introduction

Scientific research has entered the time of great science project, which is difficult to complete with non-team work. It is very important to cooperate for the researchers who are in different subjects, areas and culture. It is a big challenge to scientific research and management in the collaborative research.

The construction of collaborative research and science resource management platform can break the question in the applied systems that information is isolated, which can unify all the information in different systems. A good collaborative research and science resource management platform can improve the development of scientific research and the efficiency of managers and researchers, reduce their unnecessary duplication at the same time accelerate the information dissemination speed and help to share the resource.

- **Collaborative Research**
  - + Virtual community's cooperation, exchange and share
  - + Knowledge management and push
  - + High performance computing
  - + Large scale data platform



Main Functions

- **Member Information Management**
  - + Personal information management
  - + Organization structure and member information of team management
  - + Classified information of cooperative member management
  - + Permissions management based on the user' role

- **Statistical Information Management**
  - + Statistic, querying and analysis of management information
  - + Statistic, querying and analysis of research information
  - + Intelligent analysis of information as the basis of decision-making for managers

- **Office Automation**
  - + Notification and anouncement
  - + Work flow, application and approval
  - + Project management and knowledge management
  - + Conference management, video conferencing, instant messaging
  - + Virtual team
  - + Personal assistant
  - + Information portal management

Features

- **Combination of Information Technology and Management**
- **Seamlessly Integrated and Intelligent**
- **Architecture of Cloud Platform and Resource Sharing**
- **Fine-Grained Access Control and Single Sign on**
- **Flexible Design and Expansibility**

Application

CROSS is the key project in the progress of informatization of FDS team, the platform has been applied to research and management activities. It provides an unified platform for collaborative research distributed of the team members in different regions. The use of this platform could assists the implementation of the management system to enhance team execution and improve work efficiency.

廠商資料11

引领核电技术
发展清洁能源

- 服务国家能源与环境战略
- 创新更加安全可靠的核电技术
- 拓展国际核电市场合作
- 积极履行社会责任

国家核电
SNPTC

上海核工程研究设计院
SHANGHAI NUCLEAR ENGINEERING RESEARCH & DESIGN INSTITUTE

上海核工程研究设计院始建于1970年2月，是国内领先的核电研究设计企业之一。1998年10月，获得了质量体系认证机构颁发的质量管理体系认证证书，并于2003年3月获得了GB/T19001-2000 idt ISO9001-2000质量管理体系认证证书。2008年，通过环境管理体系（GB/T24001-2004）、职业健康安全管理体系（GB/T28001-2001）的认证审核。

上海核工院现有员工1300余人，其中专业技术人员1000余人，大多数员工都曾在工程项目前期咨询、环境评价、工程招标、工程设计、工程/设备监理、项目管理的各个岗位上工作过多年，而且与国外公司有过合作工作的经历，有着丰富的工程实践经验、较高的工程技术及项目管理水平。全院共有442项设计科研项目获得国家、国防科工委和部、省（市）级科技进步奖或优秀设计奖。其中，以本院为主设计的秦山30万千瓦核电厂的设计与建造获国家级科技进步特等奖、全国最佳工程设计特等奖。

上海核工院的主管业务范围包括工程设计（甲级），压力容器设计，环境评价，工程监理，工程承包，建筑装饰工程设计（一级），核工程及相关领域的技术服务及新产品的开发、研制、试销等。

目前，上海核工院正在积极开展三代核电技术的引进、消化、吸收和再创新工作，以及大型先进压水堆核电站重大专项工作。

Established in February of 1970, the Shanghai Nuclear Engineering Research and Design Institute (SNERDI), a high-tech civil nuclear power technology enterprise, is one of the key research and design institutes in China. SNERDI has possessed three certificates relating to its management systems of quality, environment, health, and safety (EHS) in conformity with ISO-9001:2000, ISO-14001:2004, and GB/T 28001-2001.

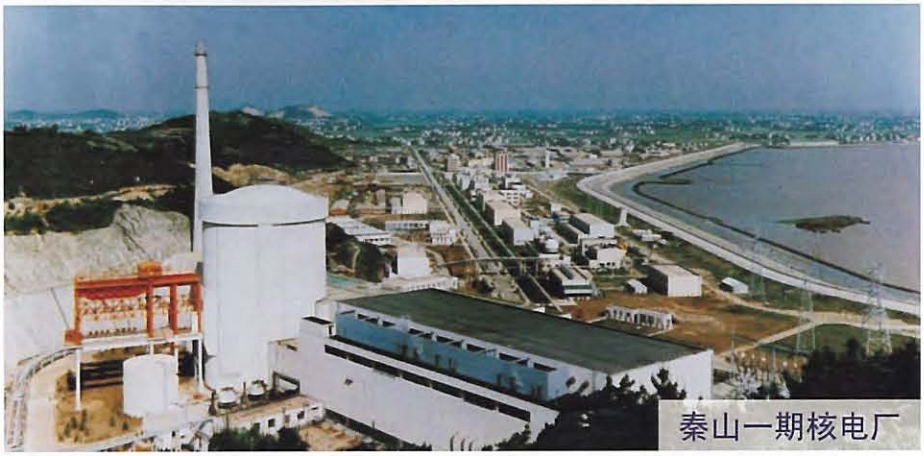
There are over 1300 employees at present, among which more than 1100 are technically skilled professionals with expertise of civil nuclear power. Since the founding of SNERDI, more than 442 research and design projects have been awarded by the State and Ministry not only for the progress made in science and technology but also for excellent design, inter alia, the design of China Qinshan 300MWe Nuclear Power Plant has won the Top Grade Prize of the State Science and Technology Achievement (SSTA) and Special Prize of the Best National Engineering Design.

The business scope of SNERDI is as nuclear power plant including engineering design, pre-project consulting, equipment design and engineering services.

At present, SNERDI is both committed to introduction, digestion, absorption and innovation of Generation III civil nuclear power technology, and responsible for the development of the advanced large size PWR project named as CAP 1400.

业绩任务

自主设计秦山核电站



秦山一期核电厂

国家科学技术进步特等奖

依托项目技术支持

三门一期工程进展

海阳一期工程进展

重大专项技术总负责单位

国核示范工程规划图

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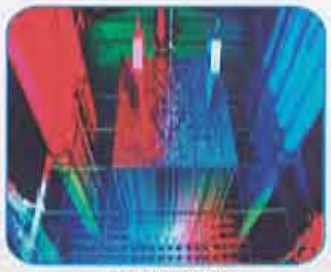
廠商資料12

Nuclear Power Institute of China (NPIC)
中国核动力研究设计院

www.npic.ac.cn

高通量工程试验堆堆芯
The Core of High Flux Engineering Test Reactor

高通量工程试验堆顶盖
Top Head of High Flux Engineering Test Reactor



零功率反应堆
Zero Power Reactor

岷江反应堆堆芯
The Core of Minjiang Reactor

中国核动力研究设计院是我国唯一集核反应堆工程研究、设计、试验、运行和小批量生产为一体的大型综合性科研基地。自1965年建院以来，已经形成包括核动力工程设计、核蒸汽供应系统设备集成采购、反应堆运行和应用研究、反应堆工程实验研究、核燃料和材料研究、同位素生产和核技术应用研究等完整的科研生产体系，是军民结合的国家战略高科技研究设计院。

我院现有在职职工3700余人，各类专业技术人员2300余人，高级工程师及以上技术人员900余人，中国工程院院士3人，博士生导师29人，硕士生导师65人，国家级和省部级突出贡献专家43人，享受政府特殊津贴专家124人。涉及50多个工程专业和学科，下设5个研究所、90多个实验室（其中2个国家级重点实验室，2个国家级研发中心）。迄今为止，全院获得国家、省部级科研成果奖1200多项，其中国家科技进步特等奖1项、一等奖7项、二等奖4项、三等奖9项、国家技术发明奖10项；获得专利技术授权251项，其中发明专利166项、实用新型专利83项、外观设计专利2项。

自建院以来，先后自行设计、建造了我国第一座压水型核动力反应堆、第一座高通量工程试验堆、第一座脉冲反应堆以及岷江堆和两座零功率装置等6座核设施，被誉为中国的“堆谷”。按照江泽民同志批示建立的成都“615”实验基地拥有国内领先、接近世界先进水平的各类试验装置18座，目前新的国家综合性核动力研发基地正在建设中。

我院通过了ISO9001-2000等标准质量体系认证，具备反应堆工程主导工艺甲级设计资格，具备核蒸汽供应系统集成采购和供货能力。由我院承担完成反应堆及反应堆冷却剂系统设计的秦山二期核电站，开创了我国自主设计大型商用核电站的先河。并网发电以来，主要经济技术指标接近或达到世界先进水平。目前承担着国内二代加核电项目核岛主系统或核蒸汽供应系统的工程设计与技术服务，包括秦山二期扩建、岭澳二期、红沿河、福清、方家山、宁德、阳江、昌江、徐大堡等核电工程。

我院积极致力于核电研发，成功开发了国产化核电机组CP1000和CPR1000，承担着新一代压水堆核电站研究开发、核能海水淡化、核能低温供热、超临界水冷堆技术预先研究等科研项目。

我院积极为所有在役和在建核电站提供专业化的技术服务，开展了核电站换料设计、工程改造、老化管理、安全审查、核岛大修、核级设备鉴定、三废处理等方面的工作，同时为核电站提供电气贯穿件、松动部件与振动监测系统、棚架度监测系统等核级产品，初步形成了民用同位素生产及其配套的多种医用治疗机、工业用探伤机、“云克”抗类风湿系列药品和新材料等支柱性产品。

四十多年来，我院为国防现代化建设和国民经济建设做出了巨大贡献，被吴邦国委员长誉为“中国核动力工程”的摇篮。面向新世纪，按照科学发展观的要求，秉承“自主创新，勇攀高峰”的核动力精神，将努力打造中国核动力工程的研发中心，朝着“创国际一流研究设计院”的发展目标不断奋进，为国防建设和国民经济建设再立新功，再创辉煌。

Nuclear Power Institute of China (NPIC)

Nuclear Power Institute of China (NPIC) is the only large-scale nuclear reactor engineering R&D base in China incorporating nuclear reactor engineering research, design, test, operation and small batch production. Founded in 1965, NPIC has established a complete R&D system, including nuclear power engineering design, nuclear steam supply system assembly, reactor operation and application research, reactor engineering research, nuclear fuel and material research, isotope production and research on nuclear technology application, etc... It is now a high-tech research and design institute of strategic importance integrating civilian and military R&D in China.

NPIC is currently staffed by more than 3,700 employees, including 2,300 professionals and 900 senior engineers and technicians, 3 academicians of Chinese Academy of Engineering, 29 PhD supervisors, 65 master supervisors, 43 experts with outstanding contribution at national or provincial and ministerial level and 124 special governmental allowance winners. NPIC consists of five sub-institutes and more than 90 laboratories (including 2 national key laboratories and 2 national R&D centers) relating to more than 50 specialties and subjects. So far, NPIC has won more than 1,200 national and provincial (ministerial) awards, including 1 national special-class award, 7 the first-class awards, 4 the second-class awards, 9 the third-class awards for scientific and technological progress and 10 national technology invention awards, as well as 251 patents, including 166 invention patents, 83 utility model patents and 2 design patents.

NPIC designed on self-reliance and constructed 6 nuclear facilities, including the 1st nuclear power reactor of pressurized water type, the 1st high flux engineering test reactor, the 1st pulsed reactor, Minjiang reactor and 2 zero power installations and was praised as "Reactor Valley of China". The experiment base "615 engineering" constructed according to the former Chinese President Jiang Zemin's instruction includes 18 different kinds of leading test installations in domestic and/or worldwide. And now, a new national comprehensive nuclear power R&D base is under construction by NPIC.

NPIC passed the accreditation of quality control system according to the Standard ISO9001-2000 and is qualified as a class A designer of the dominant technologies for reactor engineering as well as an integral NSSS supplier. It completed the reactor and reactor coolant system design of Qinshan phase-II nuclear plants, creating the precedent for self-developed large-scale commercial nuclear power plant in China. Since its connection to grid, the main economic and technical parameters of Qinshan phase-II nuclear plants has been approaching and reached the world advanced level. At present, NPIC undertakes the engineering design and technical service of main system of nuclear island or NSSS system of Generation II plus nuclear power projects in China, which include Qinshan phase-II extension, LingAo phase-II, Hongyanhe, Fuqing, Fangjiashan, Ningde, Yangjiang, Changjiang and Xudapu nuclear power plants.

NPIC is actively engaged in the research and development of nuclear power plants and developed the localized nuclear power plants, such as CP1000 and CPR1000 nuclear power plants. It undertakes the research and development of next generation nuclear reactors, nuclear seawater desalination, low temperature heat supply by nuclear power and super critical water reactor and so on.

NPIC provides professional technical service for all the operating nuclear plants and that under construction, including refueling design, engineering modification, ageing management, safety review, overhaul, nuclear equipment qualification and radioactive waste treatment and so on. It can provide a series of nuclear products, such as electrical penetration assembly, loose parts and vibration monitoring system and boron concentration monitoring system and so on. It also has capacity of the batch production of isotopes for civil use and various kinds of therapy units, industrial flaw detectors, a series of drug-Technetium Methelenediphosphonat (TM) for anti-Rheumatoid Arthritis and new materials.

In the past 40 years, NPIC has made great contribution to national defense modernization and national economy, and it is praised as the cradle of nuclear power engineering of China by Wu Bangguo, Chairman of Standing Committee of National People's Congress. Facing the new century and according to the scientific development concept, it strives to build a nuclear power engineering centre in China with the spirit of "independent innovation, bravely scale the heights". It also has put forward a striving target of building an international top-class research and design institute and to make new contribution to national defense and national economic development to create resplendence again.

创新研发
Innovative R&D

医用同位素生产堆

医用同位素生产堆以$UO_2(NO_3)_2$溶液为核燃料，反应堆具有负温度系数大，自调节能力强，固有安全性好等突出的优点。利用医用同位素生产堆生产^{99}Mo、^{131}I、^{89}Sr 等医用放射性核素，^{235}U耗量少、放射性核素产量高、生产工艺简单、生产成本特别低、废物量少。

在国家支持下，中国核动力研究设计院开展了医用同位素生产堆（MIPR）的相关研发工作，完成了一系列的关键技术攻关和试验验证，目前已具备工程应用条件。

MIPR反应堆系统图
MIPR Reactor System Diagram

Medical Isotope Production Reactor

MIPR (Medical isotope production reactor), with $UO_2(NO_3)_2$ solution as the fuel, has the outstanding advantages of high NTC (negative temperature coefficient), strong self-regulating ability and good inherent safety. It can produce more medical radioactive nuclides such as ^{99}Mo, ^{131}I, ^{89}Sr etc...with less ^{235}U, simple production technology, extremely low costs, and with less wastes.

With support from the Government, Nuclear Power Institute of China carried out relevant R&D of MIPR and has completed serious of verification and validation and tackled many key problems. Currently, the MIPR has been ready for an engineering application.

新型燃料、材料研发
R&D of New Fuels and Materials

耐辐照防火密封系列产品
Series of Radiation-resistant, Fire-resistant Sealing Products

中国核动力研究设计院正在研发具有我国自主知识产权的先进的核电燃料组件和研究堆燃料组件。研发的N36锆合金材料适合于核电站轻水堆工况条件，可用作核电反应堆高燃耗燃料元件包壳及堆芯。研究结果表明实验室规模的锆合金的堆外综合性能优于锆-4合金。开发的核级耐辐照防火密封系列产品包括耐辐照膨胀型防火密封胶、耐辐照弹性防火密封胶和耐辐照防火涂料，全面通过了相关标准检验，具有耐辐照、可去污性等优点，可广泛应用于核电站、民用建筑等设施。研发的铀钼合金具有铀密度高、辐照性能优良和后处理简单等优点，是研究试验堆用高铀密度低富集度燃料的首选材料，可制造成燃料元件，应用于研究堆、零功率堆、微型研究堆、高通量工程试验堆等。

NPIC is developing advanced fuels assembly for nuclear power plants and research reactors of its own intellectual property. The developed products include: N36 zirconium,alloy which is applicable for the light water nuclear power plant. It can be used as cladding of high burn-up fuel element and reactor core. Research indicates that the out-core combination property of lab-scale N36 is superior to that of Zr-4 alloy; Series of radiation-resistant and fire-resistant sealing products such as the expandable fire and radiation-resistant sealant, the elastic radiation-resistant sealant and radiation-resistant, fire-resistant coating, have all passed relevant tests and inspection. With an advantage of radiation-resistance and decontamination, the products can be widely used in nuclear power plants and civil architecture, etc...; and the Uranium-molybdenum alloy, with advantages of high uranium density, superior radiation-resistance and simple reprocessing, is the first choice of high uranium density and low concentration nuclear fuel for research reactor and test reactor. It can be fabricated into fuel elements for research reactor, zero power reactor, mini research reactor, and high-flux engineering test reactor, etc.

铀钼合金
Uranium-molybdenum Alloy

创新研发
Innovative R&D

浮动式核电站

浮动式核电站是指利用海上浮动平台建造的可移动的核电站，浮动式核电站可用于发电、淡化海水、提供工艺蒸汽与采暖，能满足区域供电、区域供热、海上石油开采、化工、极地或偏远地区、孤岛等的特殊需要。浮动式核电站可满足海岛开发项目、深海油气田开发项目对能源的较大规模需求。

浮动式核电站的最大特点是它的可移动性以及在大多数海岸地区包括永冻区都可以建设的可实施性，不需要过多的基础设施和运行人员，可根据能源需求分批建设。浮动式核电站在海上建设不占用陆地面积，通过其固有安全特性和非能动安全设计可满足取消厂外应急要求。

目前，中国核动力研究设计院正积极开展浮动式核电站总体技术方案、关键技术等的论证研究工作，并与国内外相关方就浮动式核电站开展了多轮合作交流。

Floating Nuclear Power Plant

The Floating Nuclear Power Plant (FNPP) is a movable nuclear power plant constructed on the offshore floating platform. FNPP could be utilized for power supply, desalination of seawater, production of steam for process heat and heating, satisfying the specific requirement of local power & heat supply for offshore drilling, chemical industry on polar region, remote areas and isolated islands. And it is also capable of meeting the large scale requirement of power on island and deep sea oil-gas field.

The advantage of FNPP is its mobility and applicability for most coast area including the permafrost region with no extra requirement on infrastructure and operating personnel, and the construction could be scheduled according to the requirement. The offshore construction eliminates not only the need of building land, but also the off-site emergency response accommodated with inherent safe and passive design of FNPP.

The emerging research and argumentation on general technical program, critical technologies and etc. have been carried out by Nuclear Power Institute of China (NPIC). At the same time, the communication about the collaboration on this filed between NPIC and units related both in home and the world is ongoing.

核能海水淡化
Seawater Desalination by Nuclear Energy

目前可被人类使用的淡水资源仅占世界水总量的1/2000，淡水供应成为21世纪全球面临的主要问题之一。中国是世界上13个最贫水的国家之一，缺水已经成为地区经济发展的瓶颈。海水是取之不尽，用之不竭的资源，海水淡化是一条重要出路。20世纪60年代，国际原子能机构（IAEA）就已开展了核能海水淡化的可行性研究。中国核动力研究设计院从2002年开始进行核能海水淡化研究，形成了海水淡化专用的池壳式反应堆技术方案，并开展了工程验证性试验，所编制的池壳式反应堆设计准则已得到国家核安全局批准。

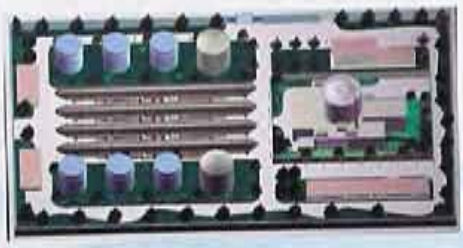
反应堆模块

- 大型核电站燃料组件
- 步进式磁力提升驱动机构
- 螺旋盘管直流蒸汽发生器
- 内置氮气加压稳压器
- 屏蔽电机轴流泵
- 反应堆模块由上下两个子模块组成，中间通过法兰连接

Nowadays, the freshwater can be used in the world only takes up 1/2000 percent of the overall water resource; therefore, supply of freshwater becomes one of the major problems challenging the world in the 21st Century. China is one of the thirteen waterpoorest countries where water shortage has become a "bottleneck" restricting the economic development. Even so, the desalination of seawater, an inexhaustible resource, finds a way out. Since the 1960's, the International Atomic Energy Agency(IAEA) has started research on the feasibility of desalinating seawater by nuclear energy. The history of research on seawater desalination by nuclear energy in Nuclear Power Institute of China(NPIC) can be traced back to 2002. NPIC has designed the special pool-shell type reactor technical program for seawater desalination and accomplished engineering verification tests. The Design Criteria for pool-shell reactor worked out by NPIC has been approved by China National Nuclear Safety Administration.

Reactor modules

- fuel assembly of commercial NPPs
- step-type magnetic control rod drive mechanism
- helical coil once-through steam generator (OTSG)
- internal pressurizer pressurized with nitrogen
- shielded motor drive flow pump
- reactor modules including the top and bottom sub-modules connected by flange



海水淡化堆全厂布置图
The Layout of Seawater Desalination Plant

模块式小型堆

中国核动力研究设计院自主研发的模块式小型堆具有高安全性和良好的经济性，采用了国际领先的非能动安全技术和模块化技术，具有革新性安全技术特征，综合性能指标要求达到国际第三代+核能系统技术水平，部分性能指标达到国际第四代核能系统技术水平。

模块式小型堆可应用于核能发电、热电联供、水电联供、城市区域供热、海水淡化、工业工艺供热、自备电厂等多种用途。该种堆型堆芯衰变热少，放射性源项低，环境热污染极低，通过设计实现固有安全特性和非能动安全。可根据装机容量需求灵活地选择模块数量，滚动建设、分批投入、融资压力小。厂址选址有灵活性，可建在软地基、多震地区和人口密集区附近。

表1 模块式小型堆主要性能指标
Table 1 The major performance parameters of ACP100

参数名称Parameter	参数值Value
全厂模块组合数量/Number of modules	2~6
单模块反应堆热功率/Reactor thermal power (Single module)	310MWt
单模块最大发电能力/Maximum generation capacity (Single module)	100 MWe

模块式小型堆
Small Modular Reactor

Small Modular Reactor

SMOR (ACP100) developed by NPIC has high security and good economics. It has the character of innovative safety technique by adopting the international leading passive safety technique and modular technique. The comprehensive performance parameters are required to reach the nuclear energy system technical level of the international "Gen Ⅲ+", and some of which can even reach that of "Gen Ⅳ".

ACP100 is multipurpose which can be used for electricity generation, co-production of heat and power , co-production of water and power, urban regional heat supply, seawater desalination, industrial process heating, self-provided power plant etc... This kind of reactor has low core decay heat, low radio-nuclide source term, as well as extremely low environment pollution, and the inherent safety and passive safety can be accomplished. The number of module can be flexibly chosen according to the requirements of network capacity. ACP100 has the characteristics of being constructed in succession, investing in bathes and low financing pressure. Besides, ACP100 has flexible site selection, and can be built on soft ground, seismically active areas and densely populated areas.

ACP1000三代核电技术

ACP1000 是由中国核工业集团公司（CNNC）下属的中国核动力研究设计院（NPIC）和中国核电工程有限公司（CNPE）共同自主研发的百万千瓦级三代核电技术。ACP1000为三环路的压水型反应堆，堆芯采用177盒先进燃料组件方案，换料周期为18个月，具有60年设计寿命。ACP1000采用单堆布置，减少机组间干扰，提高核电厂址方案选择的灵活性；采用双层安全壳设计，安全相关厂房抗大型商用飞机撞击。ACP1000采用LBB技术，简化系统设计；采用0.3g进行抗震设计，提高电厂抗震能力；增大稳压器容积，提高电厂运行稳定性。ACP1000采用全数字化仪控系统和先进的主控制室设计，具有友好的人机界面；采用先进的堆芯测量系统，中子探测器布置在压力容器顶部，提高压力容器结构安全性，实现LPD和DNBR在线监测。ACP1000具有更长的操作员不干预时间（宽限时间为30分钟），采用完善的应急运行规程、严重事故管理导则和应急计划。

为提高核电厂抵御和承受事故的能力，ACP1000采用能动与非能动相结合的设计理念，实现72小时的非能动导热能力；ACP1000具有比较完善的严重事故预防和缓解措施：

设置堆腔注水冷却系统，实现严重事故后压力容器内堆芯熔融物的滞留；
设置非能动的氢气复合系统，防止发生氢气爆炸；
设置一回路快速卸压系统，防止发生高压熔堆；
设置反应堆压力容器高位排气系统，排除事故后积聚在压力容器上封头处的不可凝气体；
设置二次侧非能动余热排出系统，为发生全厂断电事故时堆芯及一回路的热量导出提供手段；
设置非能动安全壳热量导出系统，用于在超设计基准事故工况下安全壳的长期排热。

考虑了应急补水的技术方案，可以在地震叠加全厂断电事故时，利用全厂可用淡水水源通过临时手段向一回路和堆芯补水，从而防止堆芯裸露而造成堆芯熔化。

表2 ACP1000主要性能指标
Table2 The major performance parameters of ACP1000

参数名称Parameter	参数值Value
设计寿命/Design Life	60年/ Year
换料周期/Refueling Cycle Length	18月/ Month
NSSS额定热功率/Nominal NSSS Thermal Power	3060 Mwt

反应堆及反应堆冷却剂系统布置图
Reactor and RCS configuration

ACP1000: The GEN III Technology of Nuclear Power

ACP1000 is one of the GEN III technologies of 1000 MWe class nuclear power plant, developed by Nuclear Power Institute of China (NPIC) and China Nuclear Power Engineering (CNPE) Corp., which are two subsidiaries of China National Nuclear Corporation (CNNC). ACP1000 is a 3-loop pressurized water reactor with advanced core design of 177 fuel assemblies. The design life of ACP1000 is 60 years and the refueling cycle is 18 months. Its single-reactor unit layout lessens the interference between multiple units and improves its flexibility for NPP siting. The double containment ensures the integrity of safety related structure even crashed by large commercial airplanes. The implemented Leak-Before-Break (LBB) technology simplifies the system design and enlarged pressurizer enhances the stability of NPP operation. Especially the seismic design based on 0.3g acceleration significantly ameliorates its capability against earthquake. ACP1000 adopts digital I&C system and advanced main control room design with a friendly human-machine interface. The advanced reactor core monitoring system with online LPD and DNBR measurement uses a specific configuration for neutron detectors on the top of the reactor vessel to improve structure safety. It has a even longer toleration time (30 minutes) as no operator intervention with sophisticated Emergency Operation Procedure (EOP), Severe Accident Management Guidelines (SAMG) and Emergency Plan (EP).

The unique design of active and passive safety systems integration greatly enhances the capability of ACP1000 for prevention and mitigation of accidents to passively remove the decay heat for 72 hours with comprehensive severe accident prevention and mitigation measures as following :

Cavity Injection and Cooling System (CIS) for corium in-vessel retention under severe accidents;
Passive Containment Hydrogen Combination System (CHC) to prevent hydrogen explosion;
Dedicated Depressurization System of Reactor Coolant System (RCS) against high pressure melt ejection;
Reactor Vessel High Point Venting System to remove non-condensible gas accumulated in the upper-head of reactor vessel under accident conditions;
Passive Residual Heat Removal System (PRS) at secondary side for decay heat removal during Station Black-Out accidents;
Passive Containment Heat Removal System for long-term heat removal under Beyond Design Basis Accidents;
Emergency Core Makeup Project to temporarily provide cooling water for RCS and prevent core uncover and consequent core damage under severe conditions similar to Fukushima accident.

廠商資料13

中国核工业集团公司核工业西南物理研究院

介　绍

核工业西南物理研究院(以下简称核西物院)建院于1965年，隶属中国核工业集团公司，地处四川省成都市西南航空港经济开发区，是我国成立最早、规模最大的从事受控核聚变能源开发研究的专业研究单位，是我国国际热核聚变实验堆(ITER)计划专家委员会主要成员单位。1991年4月21日，江泽民总书记曾视察我院，参观了我院中国环流器一号(HL-1)托卡马克聚变实验装置，并为我院题词：“开发核聚变能源，造福子孙后代”。

本院资产总额约10亿元，在职职工1700余人，科技人员约1100人，其中中国科学院院士1人。核西物院依托核工业体系，经过近50年的努力，为核聚变能源开发，先后成功研制了“中国环流器一号装置(HL-1)”、“中国环流器新一号装置(HL-1M)”、“中国环流器二号A装置(HL-2A)”等22个托卡马克及其他类型的核聚变实验装置，目前在国家国防科工局支持下正在研制“中国环流器二号M装置(HL-2M)”。

核西物院在聚变能源开发、中国环流器装置物理实验等方面取得丰硕科技成果。全院已取得了5000多项科研成果，获国家科技进步奖18项，其中国家科技进步一等奖1项，二等奖4项；获部省级成果奖400余项。近期获得的科技奖有：《中国环流器二号A（HL-2A）装置工程研制》获2005年国家科学技术进步奖二等奖；《中国环流器二号A（HL-2A）装置高温等离子体诊断系统研制》获2010年国家科学技术进步奖二等奖、2009年国防科技进步奖一等奖；《托卡马克等离子体若干重大物理问题的实验研究》获2011年国防科学技术进步奖一等奖、中核集团科学技术奖特等奖；荣获中核集团2012年第二届“钱三强科技奖”一项。在现役的“中国环流器二号A装置”的聚变研究方面，取得了许多具有创新性和里程碑意义的成果。

核西物院是我国参加国际热核聚变实验堆(ITER)计划的两个主要承担单位之一，作为国家ITER计划的主要技术支撑单位，自2003年开始，率先在ITER中国固态增殖剂试验包层（TBM）方面开展了研究。之后，在国家科技部ITER国内项目的支持下，承担并完成了973计划ITER专项、2008年ITER预研项目、2009年和2010年ITER国内配套项目；正在承担2011年、2012年和2013年ITER计划专项项目。通过ITER国内项目的研究，本院掌握了ITER相关设计与关键工艺技术，取得大量创新性成果，为承担ITER采购包任务打下了基础。

目前，中国核聚变能源计划执行中心已与核西物院签订了ITER项目的磁体支撑结构、氚送气系统、中子诊断的采购包协议，核西物院还拟将承担ITER项目的屏蔽包层模块、放电清洗系统、朗谬尔探针系统和ITER中国固态增殖剂试验包层等采购包任务。

核西物院在从事核聚变能源开发的同时，还致力于核聚变中间技术与等离子体应用技术的成果转化。研制了具有自主知识产权的复合渗注镀技术集成试验平台，成功开发出多种等离子体复合表面处理工艺，创造了良好的经济效益和社会效益。

2000年本院与成都理工大学合作在乐山基地创办了“成都理工大学乐山学院”，2003年发展为“成都理工大学工程技术学院”。该学院主要从事本、专科学历教育，现有在校生约2万人。

本院的发展受到了党和国家领导人的关注，得到了国家有关部委、地方各级政府以及业内专家的大力支持，也获得了国际机构、外国政府和组织以及国际友人的帮助。我们一定不辜负他们的希望，不懈努力，与时俱进，在本世纪内升起中国的“人造太阳”，造福子孙后代！

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