附錄5-蔡員簡報

Institute of Nuclear Energy Research

Performance Tests after High Pressure Turbine Retrofit for Maanshan Nuclear Power Plant Unit 1

Yea-Kuang Chan, Yu-Ching, Tsai, Chin-Jang Chang, Chun-Chang Lu, Ping-Ling Hsieh

Presented at ICONE-21
by
Yu Ching Tsai

July 31 ~ August 02, 2013

Institute of Nuclear Energy Research

Outline

- Introduction
- System flow diagram
- Key parameters for performance test
- Test procedures
- Requirements of test conditions
- Test results evaluation
- Conclusions

2

Institute of Nuclear Energy Research

Introduction (1/6)

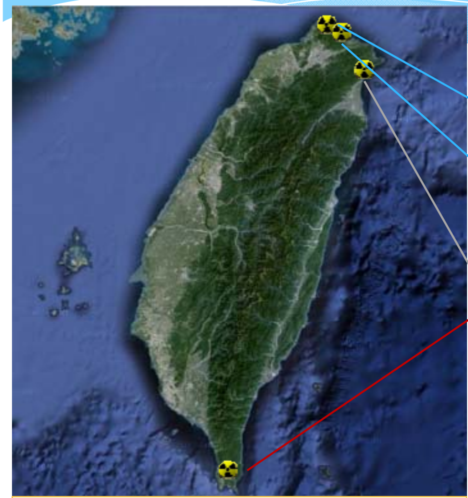


Fig. 1 Locations of Taiwan's Nuclear Power plants.

Ref: Google map & Taiwan Power Company website

- The Nuclear Power Plant in Taiwan:
  - CHINSHAN
    - BWR : 636 MWe x 2
  - KOUSHENG
    - BWR : 985 MWe x 2
  - MAANSHAN
    - PWR : 951 MWe x 2
  - LUNGMEN
    - Under construction
    - ABWR : 1350 MWe x 2

3

Institute of Nuclear Energy Research

Introduction (2/6)

- The Nuclear power shared 18.4% electricity demand in Taiwan.

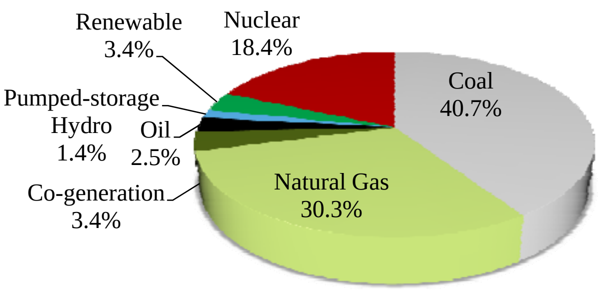


Fig. 2 2012 electricity consumption in Taiwan.

Ref: Taiwan Power Company website

4

Institute of Nuclear Energy Research

Introduction (3/6)

- Thought the nuclear power has already been a low carbon technology, the nuclear power plants (NPP) can also make their contributions on CO_2 reduction of the power sector by improving their operating efficiency.
- In order to increase the operating efficiency or power output for old NPP in Taiwan, several actions including power uprates, turbine retrofits and cycle isolation improvements are taken in recent decades,.
- In this paper, the High pressure turbine retrofits case in Maanshan NPP in Taiwan was presented.

5

Institute of Nuclear Energy Research

Introduction (4/6)

- The Maanshan NPP is a two-unit PWR plant owned by TPC. Each unit has original licensed thermal power (OLTP) of 2775 MWt, and began commercial operation in July 1984 and May 1985, respectively. After implementing MUR PU in 2009, the reactor thermal power has been uprated to 2822 MWt (101.69% OLTP).

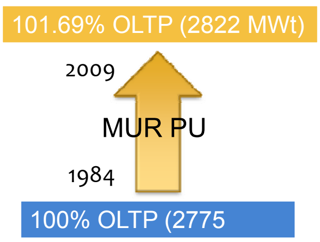


Fig. 3 Maanshan Nuclear Power Plant.

Ref: http://wapp4.taipower.com.tw/nsis/optiono-3.asp

6

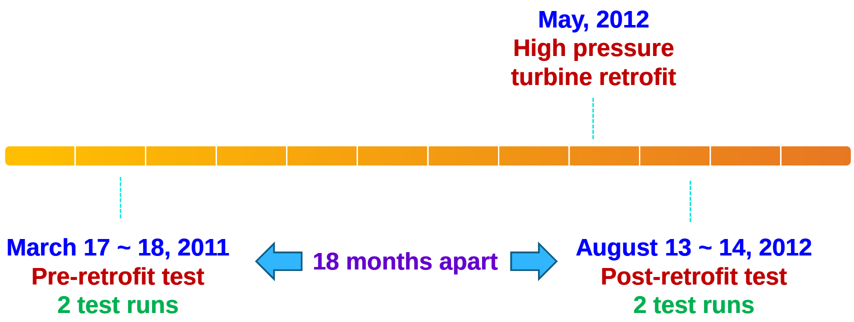
Introduction (5/6)

- The original double flow high pressure turbines (provided by GE) of both units of Maanshan NPP have been operated more than 27 years. The low pressure turbines were replaced by ABB in 1992 and 1991 for Units 1 and 2, respectively.
- In order to improve the efficiency and reliability of operation, Maanshan NPP decided to replace the high pressure turbines provided by ALSTOM for both units.
- For performance improvement evaluation, two tests: the pre-retrofit test (baseline performance test) and post-retrofit test (verification test) were conducted in accordance with the ASME PTC 6-2004 "Steam Turbines" Performance Test Code, and two test runs were conducted for each test.

Institute of Nuclear Energy Research

Introduction (6/6)

- Schedule of the performance test



Institute of Nuclear Energy Research

System flow diagram

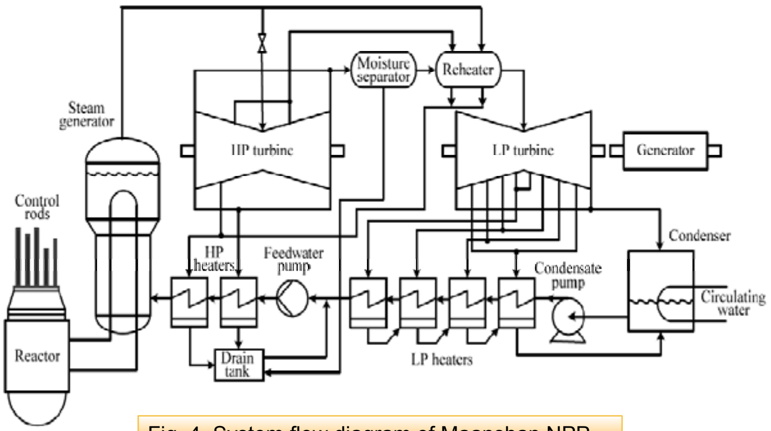


Fig. 4 System flow diagram of Maanshan NPP.

Ref: Y. K. Chan, C. J. Chang, C. C. Lu, Y. C. Tsai, "Baseline Performance Test for Unit 1 of Maanshan Nuclear Power Plant ", NUTHOS-9, Kaohsiung, Taiwan, September 9-13, 2012.

9

Institute of Nuclear Energy Research

Key parameters for performance test

- The calibrated special test instruments were temporarily installed by the vendor of the high pressure turbine to measure important parameters that directly affect the corrected output. Calibrated, permanently installed station instruments provided other data.
- Key measurements are as follows:
  - Steam generator outlet pressure
  - Steam pressure at high pressure turbine stop valve inlet
  - Condenser backpressure
  - Atmospheric pressure
  - Feedwater flow and temperature to steam generators
  - Steam flow to feedwater pump turbines
  - Generator output
  - Temperatures

10

Institute of Nuclear Energy Research

Test procedures (1/2)

- Before testing:
  - Cycle isolation is equally important for both the full-scale and alternative procedures and the accuracy of the test results depends on the isolation of the system. Extraneous flows should be isolated, if possible, to eliminate errors.
  - The plant was operating as close as possible to the design cycle and isolated the valves listed in the test procedure.
  - A preliminary test should be conducted first to make sure the isolation and test conditions fulfilled the requirement.
- Between two tests:
  - Between each test, there must be a break in isolation (to maintain hotwell levels) and a change in high pressure governor valve positions to reduce the load by 15% (approximately 150MWe) as required by ASME PTC 6.

11

Institute of Nuclear Energy Research

Test procedures(2/2)

Table 1 Test schedule for post-retrofit test.

Run number	Test 1	Test 2
Close normally open valves	14:05-15:05	11:30-12:30
Cycle isolation completed (start of 1-hour plant stabilization period)	15:05-16:05	12:30-13:30
Test at rated conditions (required stable conditions have been achieved)	16:05	13:30
Period of test time	16:05-18:05	13:30-15:30
Date	Aug. 13, 2012	Aug. 14, 2012

12

Institute of Nuclear Energy Research

Requirements of test conditions (1/3)

Table 2 Test conditions required by ASME PTC-6.

Target permissible deviation of the average of the test conditions from specified				Permissible fluctuations during any test run
	Specified	Minimum	Maximum	
Core thermal power Pre-test (MWt) Post-test (MWt)	100% 2822 2822	99.0% 2794 2794	100% 2822 2822	+/-0.25%
Steam generator outlet pressure Pre-test (psia) Post-test (psia)	 980 980	-3% 950.6 950.6	+3% 1009.4 1009.4	5 psi
Steam generator outlet steam moisture Pre-test (%) Post-test (%)	0.25% 0.25 0.25	0% 0.00 0.00	0.75% 0.75 0.75	N/A
Condenser backpressure Baseline test (inHg)	Test condition Value			0.04 inHg
Condenser backpressure Verification test (inHg)	Test condition Value	-0.1 inHg of baseline test value	+0.1 inHg of baseline test value	0.04 inHg

Ref: ALSTOM, Maashan unit 1 HP retrofit performance test uplift final report, HTCZ584662, 2012.

Institute of Nuclear Energy Research

Requirements of test conditions (2/3)

- Since the pre-retrofit test and post-retrofit test are nominally 18 months apart, the variation in low pressure turbine exhaust pressure (condenser backpressure) is expected to be outside the limits specified in the test requirements.
- The low pressure turbine output would be largely effected, and the clarification of output contribution between high and low pressure turbine was necessary. Thus, the correction curve for condenser backpressure provided by low pressure turbine vendor (ABB) needed to be checked.

Institute of Nuclear Energy Research

Requirements of test conditions(3/3)

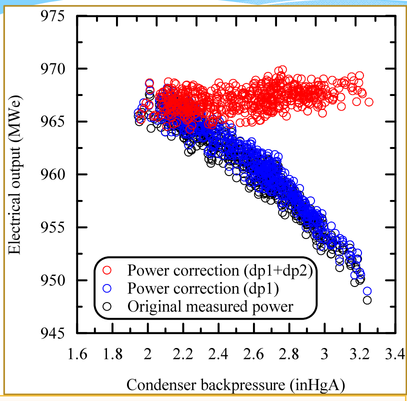


Fig. 5 Correction of the output dataset to rated thermal power (dp1) and condenser backpressure (dp2) for historical data.

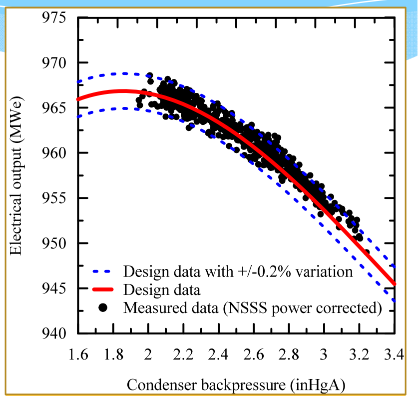


Fig. 6 Comparison of the output dataset with the ABB backpressure correction curve.

- dP1 shows the correlation between NSSS Power and change in electrical output
- dP2 shows the correlation between condenser backpressure and change in electrical output

15

Institute of Nuclear Energy Research

Test results evaluation (1/)

- The NSSS (nuclear steam supply system) thermal power was calculated as follows:

$$P_t = W_{fw}(h_s - h_{fw})/1000$$

P_t : NSSS thermal power (MWt)
W_{fw} : Steam generator outlet flow rate(kg/s)
h_s : Steam generator outlet enthalpy (kJ/kg)
h_{fw} : Final feedwater enthalpy (kJ/kg).

- The corrected post-retrofit performance is determined using the following equations:

$$MW_V = \frac{P_{VG}}{1+(\sum dP_{iV}/100)} + dP_7$$

$$HR_V = \frac{P_{VTH}}{P_{VG}} \times 3600 \times \left[1+\left(\sum dP_{iV}/100\right)\right]$$

MW_V : Corrected electrical power
P_{VG} : Measured electrical power
HR_V : Corrected heat rate
P_{VTH} : Measured NSSS thermal power

$$\sum dP_{iV} = dP_1 + dP_2 + dP_3 + dP_4 + dP_5 + dP_6 + dP_8 + dP_{9V}$$

16

Institute of Nuclear Energy Research

Test results evaluation (2/)

Table 3 Correlation parameter.

Parameters	Correction Parameters
NSSS Thermal Power (MWt)	dP_1
Steam Generator Outlet Pressure (Psia)	dP_2
Condenser Backpressure ("HgA) (for 1.8~3.6 "Hg)	dP_3
Heater 1 TTD (°F)	dP_4
Steam Generator Feedwater Pump Turbine Flow (Δ%)	dP_5
Condenser Subcooling (°F)	dP_6
Power factor	dP_7
Blowdown Flow (% of SG Outlet Flow)	dP_8
Baseline Test Ageing Correction	dP_{9B}
Verification Test Ageing Correction	dP_{9V}

Heater 1 TTD : Difference between Heater 1 shell side saturated temperature and tube side outlet flow temperature.

17

Institute of Nuclear Energy Research

Test results evaluation (3/)

- The performance test results were corrected for reactor thermal power, steam generator outlet pressure, and condenser backpressure, etc..
- Correction factors are as stated by ASME PTC 6 code. Heat rate and electrical output must be corrected to the specific operating conditions by using the correction curves normally provided in the unit's thermal kit.

18

Institute of Nuclear Energy Research

Test 1 | Test 2

steam generator outlet pressure

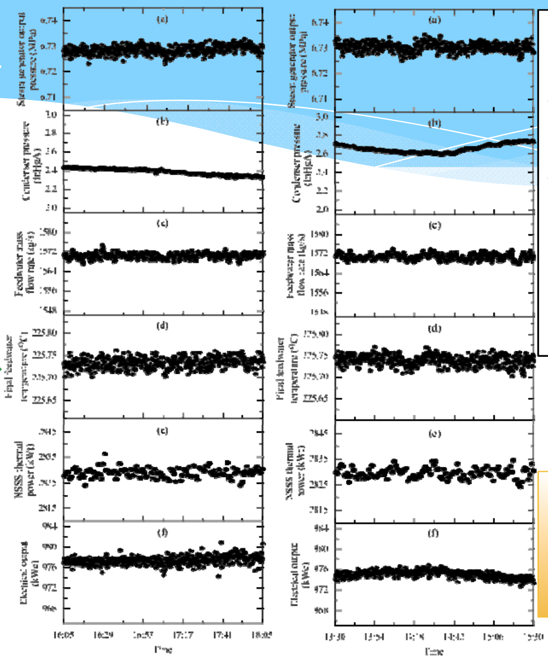
condenser pressure

feedwater mass flow rate

final feedwater temperature

NSSS thermal power

electrical output



The operating conditions between two tests were quite stable except condenser pressure which was unable to be controlled. And the correction curve mentioned previously was used for it correction.

Fig. 6 Trending data of post-retrofit test for Test 1 (left side) and Test 2 (right side).

19

Institute of Nuclear Energy Research

Test results evaluation (6/)

Pre-retrofit test results

- The average corrected output for pre-retrofit test was 965.6 MWe, and the heat rate was 10558 kJ/kWh.

Table 4 Test results of pre-retrofit test.

Parameter description	Test 1 value	Test 2 value
NSSS thermal power (MWt)	2833.41	2830.50
Steam generator outlet pressure (psia)	988.8	988.0
LP turbine exhaust pressure (inHgA)	2.33	2.34
Power factor	0.9984	0.9995
Measured generator output (MWe)	962.72	962.01
Overall output correction factor	0.9972	0.9961
Corrected electrical output (MWe)	965.38	965.82
Corrected heat rate (kJ/kWh)	10566	10550

20

Institute of Nuclear Energy Research

Test results evaluation (8/)

Post-retrofit test results

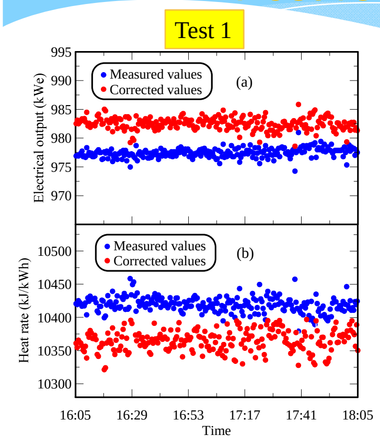


Fig. 7 Comparison of the measured and corrected data during the period of Test 1: (a) electrical output, (b) heat rate.

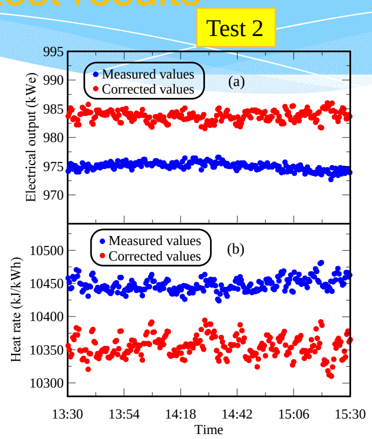


Fig. 8 Comparison of the measured and corrected data during the period of Test 2: (a) electrical output, (b) heat rate.

21

Institute of Nuclear Energy Research

Test results evaluation (7/)

Post-retrofit test results

Table 5 **Corrected electrical output and heat rate for Test 1 of post-retrofit test.**

Parameter description	Specified value	Test 1 value	Output correction factor
NSSS thermal power (MWt)	2834.0	2828.9	-0.1903
Steam generator outlet pressure (psia)	980.0	976.6	-0.0021
LP turbine exhaust pressure (inHgA)	2.00	2.39	-0.3228
Heater 1 TTD (°F)	8.92	8.91	0.0004
Steam flow to SGPFT (lb/hr)	133275	134529	-0.0104
Condensate subcooling (°F)	2.47	1.97	0.0056
Power factor	0.9990	1.0	-0.0107
Overall output correction factor	0.9948		
Corrected electrical output (MWe)	982.54		
Corrected heat rate (kJ/kWh)	10365		

22

Institute of Nuclear Energy Research

Test results evaluation (8/)

Post-retrofit test results

Table 6 Corrected electrical output and heat rate for Test 2 of post-retrofit test.

Parameter description	Specified value	Test 2 value	Output correction factor
NSSS thermal power (MWt)	2834.0	2829.5	-0.1682
Steam generator outlet pressure (psia)	980.0	976.8	-0.0020
LP turbine exhaust pressure (inHgA)	2.00	2.66	-0.7106
Heater 1 TTD (℉)	8.92	8.90	0.0004
Steam flow to SGPFT (lb/hr)	133275	136602	-0.0277
Condensate subcooling (℉)	2.47	1.75	0.0080
Power factor	0.9990	0.9999	-0.0107
Overall output correction factor	0.9910		
Corrected electrical output (MWe)	983.87		
Corrected heat rate (kJ/kWh)	10353		

23

Institute of Nuclear Energy Research

Test results evaluation (8/)

Post-retrofit test results

- The average value of measured electrical outputs was 976.2 MWe. After correcting the electrical power to the specified conditions, the average gross electric output was 983.2 MWe, which was 7.0 MWe higher than the measured electrical power.
- The corrected heat rate for the two performance tests were 10365 and 10353 kJ/kW, respectively. The deviation between two corrected heat rates was 0.11% thereby satisfying the ASME PTC 6 test code of 0.25% for the permitted test deviation.

24

Institute of Nuclear Energy Research

Conclusions

- Comparing pre- and post-retrofit results, the electrical output was increased from 965.6 MWe to 983.2 MWe (↑1.82%), and the heat rate was improved from 10558 kJ/kWh to 10359 kJ/kWh.
- The improvement in gross electrical output was 17.6 MWe comparing with the pre-retrofit test, which exceeded the 10.0 MWe basic performance guarantee by turbine vendor.
- The result indicates that the increase of electrical output due to high pressure retrofit is not only improving plant operating performance but also decreasing the fuel cost per MW output.
- Moreover, the major parameters of the turbine cycle measured during performance tests have established a reference base for monitoring the plant operating performance.

25

~Thanks for your attention~

Institute of Nuclear Energy Research

26

原子能院堆工所反应堆物理及临界安全方面的情况

1、引言

是我国最早反应堆物理研究基地，在我所下设反应堆物理研究室，一直从事堆物理理论及实验研究、程序开发、研究堆核设计，先后有10 多位院士在该研究室工作。核工业集团公司的临界安全中心设在我所。

2、具有的条件

（1）计算分析软件

拥有多套核电站堆芯燃料管理软件：其中 CASMO+SIMULATE（用于方形燃料组件），ANC-H+PHOENIX-H（用于六角形燃料组件）；

拥有多套核临界安全分析软件及数据库：MONK、MCNP 及 KENO 等；

同时拥有多套研究堆核设计软件：WIMS、CITATION 等。

（2）实验装置

被誉为零功率反应堆的摇篮，重水、轻水、石墨、氢化锆，超热中子、快中子，铀溶液等各种零功率装置，为反应堆物理启动、物理测量、仪表考验提供强大的实验平台。

3、 主要工作业绩

（1）研究堆核设计

先后完成了中国先进研究堆（CARR）、中国实验快堆（CEFR）、重水研究堆（HWRR-II）、游泳池式轻水堆（49-2）、高通量工程试验堆（49-3）、阿尔及利亚和平堆、微型中子源反应堆（MNSR，9 座）、

医院中子照射器反应堆(IHNI)、加速器驱动次临界装置(启明星1)、约旦次临界反应堆等核设计；

（2）程序开发

先进燃料管理程序（先进节块法）开发

MC程序开发

数据库开发（中国核数据中心在我院）

临界安全数据库收集评价

（3）反应堆物理实验及测量

基于拥有的零功率装置，建立了完备的实验测量手段，重点在反应性测量、中子通量测量、动态参数测量。

（4）燃耗信任制技术

一直从事燃耗信任制技术研究，已开发完成一定技术手段，可用于乏燃料密集储存。

4、 合作展望

在核电站堆芯燃料管理、乏燃料水池设计分析、核燃料临界安全及相关的软件开发等领域均可以合作。

联系方式：kgt2000@163.com，010-69357318

安全培训教材之二

核临界安全技术培训

（上册）

中核集团公司

二〇一二年十月

中国先进研究堆

CHINA ADVANCED RESEARCH REACTOR

中国原子能科学研究院
CHINA INSTITUTE OF ATOMIC ENERGY

中国原子能科学研究院
反应堆工程研究设计所

CHINA INSTITUTE OF ATOMIC ENERGY
DEPARTMENT OF REACTOR ENGINEERING
RESEARCH AND DESIGN

DRERD

附錄7-廠商學術機構資料

廠商資料1

Solutions for Nuclear & Renewable Power Generation

AREVA Supplies Solutions for Power Generation with Less Carbon

Its expertise and unwavering insistence on safety, security, transparency and ethics are setting the standard, and its responsible development is anchored in a process of continuous improvement.

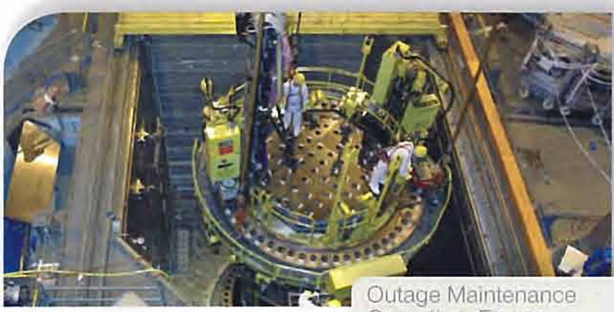
Ranked first in the global nuclear power industry, AREVA's unique integrated offering to utilities covers every stage of the fuel cycle, nuclear reactor design and construction, and related services. The Group is also expanding its operations to renewable energies – wind, solar, bioenergies, energy storage – to be one of the leaders in this sector worldwide.

AREVA Across the Globe

AREVA
forward-looking energy

A Global Offer for Safe, Reliable and Competitive Power Generation

Serving the Nuclear Operating Fleet



Outage Maintenance Operation, France

Plant Upgrade

- Solutions-based approach to plant upgrades, license renewal and Long-Term Operation
- Reference I&C system for all reactor designs
- Safety Alliance program to support safety upgrades

Operations Performance

- Equipment and services for 250+ reactors of all designs
- World's leading supplier of outage services, supporting 100+ outages per year

Fuel Assembly Skeleton Inspection, France

Security of Fuel Supply

- One of the world's leading uranium producers operating mines on three continents
- 30 years experience in Enrichment & Conversion
- 35% of worldwide LWR fuel fabrication

Sustainable Solutions for Used Fuel Management

- #1 worldwide in used fuel recycling
- #1 for dry storage in the U.S.
- #1 worldwide in cask design, fabrication and logistics

Helping Build Next-Generation Capacities

Olkiluoto 3 EPR™ construction site, Finland

Nuclear Power

- Unrivalled track record: 98 nuclear reactors built worldwide
- Support for plant completion: engineering, procurement and safety upgrades
- 4 EPR™ reactors currently under construction in China, Finland and France
- World's largest inhouse EPC team

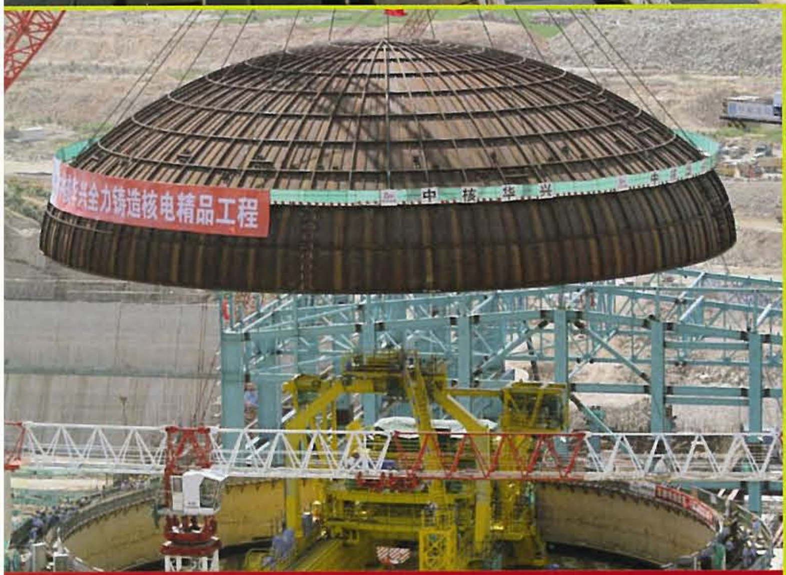
Alpha Ventus Windfarm, North Sea, Germany

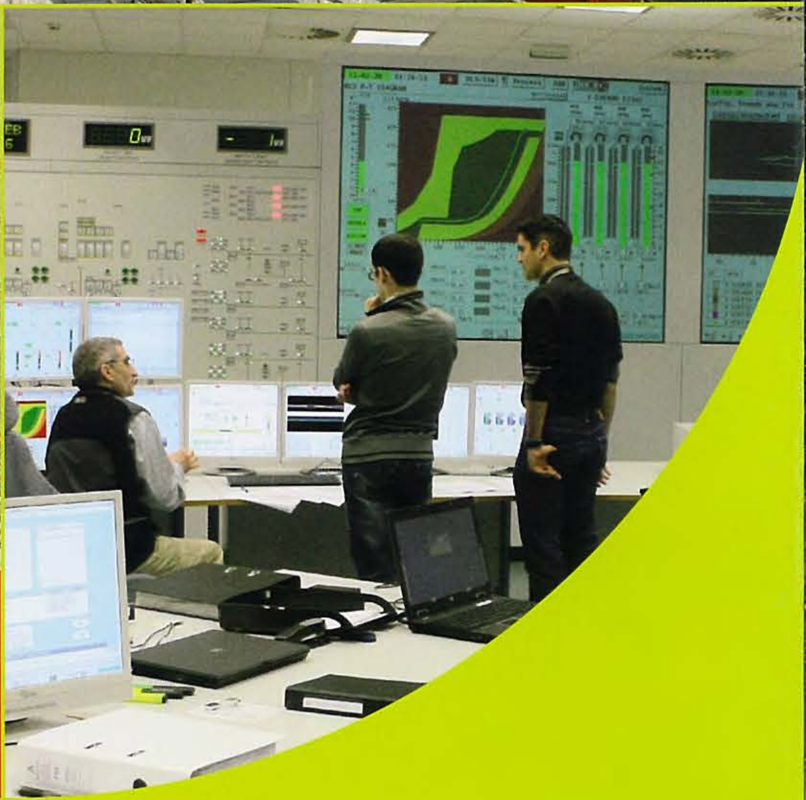
Renewable Energies

- Sea-proven 5MW wind turbine with multiple-year track record
- Advanced Compact Linear Fresnel technology for Concentrated Solar Power plants or as a booster to fossil-fired plants
- World leader with nearly 100 biomass plants in operation worldwide

AREVA
33, rue La Fayette — 75009 Paris — France — Tel.: +33 1 34 96 00 00 — Fax: +33 1 34 96 00 01

廠商資料2





EPR™ 反应堆

新建核电项目的标杆

EPR™ by AREVA

AREVA

经验的价值

阿海珐有4座EPR™ 反应堆正在不同国家建造，因此在许可证申请和施工方面拥有无以伦比的经验，能够向世界各地的核电厂交付高性能的新一代核反应堆项目。

持续的项目经验让我们获得了最佳实践机会

拥有向不同监管机构申请许可证的经验

是世界上唯一有**五个单独许可证申请流程**正在进行的反应堆。

- 在芬兰、法国和中国已被授予建造许可证
- 在英国被授予"完全设计验收确认"
- 在美国的许可证审核正在进行中

唯一一个提交进行欧洲"福岛核事故后"压力测试的第三代反应堆设计

项目管理优势

- 拥有最大的内部核电设计－采购－施工 (EPC) 团队:
  - 超过1000名熟练的项目管理人员
  - 超过6000人的经验丰富的工程设计与项目团队
- 台山项目负责人大多数曾在Olkiluoto 3或Flamanville 3项目工作过

全公司反馈流程

- 从众多核设施建设中吸取了教训：EPR™ 反应堆和燃料循环工厂
- 强化持续的积累过程：已经有超过1600条教训被吸取、捕捉并加以分析

位于芬兰的 Olkiluoto 3项目
世界上最先进的新一代核电项目

位于法国的 Flamanville 3项目
法国电力公司 (EDF) 的新建 EPR™ 反应堆堆群中第一座反应堆

位于中国的 台山1期和2期项目
EPR™ 反应堆项目按计划将如期交付

实践证明有能力取得经验和提高项目交付业绩

制造

综合能力

-2 年

与Olkiluoto 3项目相比，台山项目蒸汽发生器交付时间缩短两年

采购

世界核级设备和完全运作的供应链

600+

合格供应商在按时高质量交付方面取得已被证实的改进，

在国产化策略方面
具有跟踪记录

中国，南非，芬兰，韩国……

施工

业绩改进
台山项目从第一罐混凝土浇注到穹顶吊装，工期为

24 个月

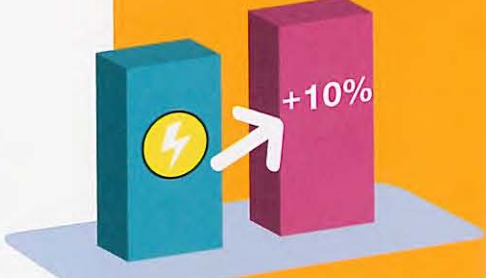
(比Olkiluoto 3工期缩短23个月)

对环境的影响 最小化

由于设计优化和总体效率很高，EPR™ 反应堆减少了对环境的影响。正常运行期间，能够确保对环境和工作人员造成的影响明显减少。
EPR™ 反应堆设计成具有卓越的安全性，而且还提高了安全壳防御能力，即使在发生严重事故时对环境的影响也不会长时间持续，因此强化了核电的可持续性。

能实现对环境影响最小化的设计

- 提高了输出功率 (1650MW净功率)，优化了土地使用
- 与热效率只有37%的二代反应堆设计相比，效率提高了
- 降低了水消耗



提高了效率：在释放相同热量的情况下，能生产更多电力

废物管理得到优化

- 对放射性废气进行过滤、控制和监测，以确认排出物在任何情况下都不会造成显著影响
- 堆芯尺寸更大，控制棒数量更多，从而实现了放射性废液减容
- EPR™ 反应堆运行性能更高，直接影响对铀的消耗 (铀消耗量减少15%)，从而也直接影响高放废物的数量 (高放废物减少10%)

EPR™ 反应堆更高的运行性能减少了高放废物数量

通用型废物密封容器

优化了废物管理
减小了最终废物容量

改善了对运行和维护人员的保护

- 缩短了换料大修和检修的工期
- 改进了潜在放射性系统和部件的布置
- 根据检修作业优化了辐射屏蔽的厚度
- 所以，作为EPR™ 反应堆设计的优先目标之一，其集体剂量目标值与经合组织国家相比较降低一半

按其设计，即使在发生严重事故的情况下也能够避免对环境产生长期影响

60年设计寿命

土地和资产的长期使用

安全第一，安全至上

EPR™ 反应堆设计是采用从全世界以前建成的80多座压水堆获得的经验反馈进行的渐进型设计，它吸收了近期在运的并且成熟的法国N4反应堆和德国KONVOI反应堆设计的经验，包括了关键创新解决方案，数十年先进研发项目的成果。

主要安全原则……

- **多样性**原则，防止共模故障
- **冗余性**原则，克服单一故障
- **互补性**原则，在能动系统和非能动系统之间实现互补性

……实现基本的安全当务之急

- **抵御极端危险**
- **强化冷却能力**
- **防止造成环境损害**

抵御极端危险

按其设计，EPR™ 反应堆能够对极端危险（比如地震、洪水、极端温度、飞机坠毁、爆炸或这些危险的叠加）具有独特的抵御能力。


防飞机撞击外壳（蓝色结构）


密封安全壳设计有过滤环廊，降低了燃料循环成本

对地震具有高度的结构性抵御能力

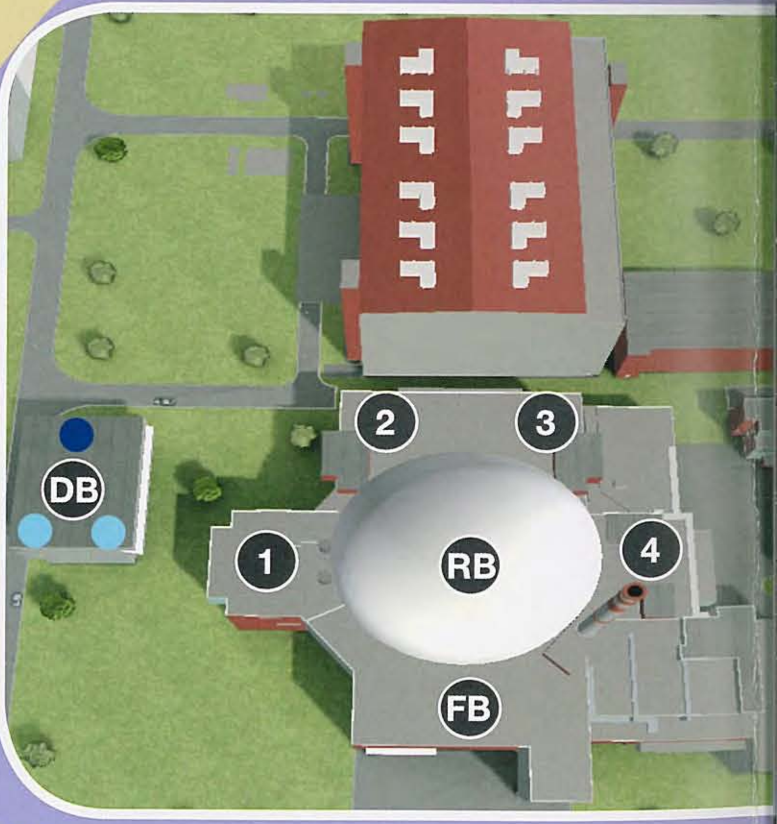
- 核岛厂房采用整体混凝土筏基和预应力混凝土内壳，因此保证了其牢固
- 重要设备均设计成对地震具有很高的抵御能力并且经过相应的试验

对洪水的抵御能力

除了各厂房的初始标高（干厂址概念）以外，反应堆厂房、安全厂房、燃料厂房和柴油机厂房均防水。

实物保护与地理分隔

- 反应堆厂房、燃料厂房和两栋安全厂房采用防飞机撞击外壳（APC壳）进行防护：EPR™ 反应堆能抵御大型商用飞机的冲击
- 安全厂房和柴油机厂房的地理分隔：只有其中一栋厂房可能受到影响，而不会对其他厂房造成任何安全影响



核岛
RB - 反应堆厂房
FB - 燃料厂房 - 燃料池
1,2,3,4 - 安全厂房内的安全系统
DB - 柴油机厂房

应急柴油发电机
全厂断电柴油发电机

EPR™ 反应堆从一开始就考虑提高安全性，它将纵深防御概念与防止大多数有记录的问题结合起来。
EPR™ 反应堆的设计包括冗余技术，多样性技术以及能动系统和非能动系统正确平衡，以便达到全面的安全防护。
与以前几代反应堆比较，EPR™ 反应堆堆芯损坏的概率降低了10倍以上。无论严重事故的概率有多低，EPR™ 反应堆各系统都将确保反应堆的坚固性和安全壳的密封性，防止对环境造成长期影响。

强化冷却能力：供水自给时间超过7天

无论在什么情况下，尤其是当失去厂外电源或者失去主冷却水源时，EPR™ 反应堆的设计都能提供多重厂内解决方案，确保堆芯冷却，保护电厂完整性。

冗余安全系统

受到防护的并且地理上隔开的4个安全系统中的任何一个系统都能自行对反应堆实施冷却。

多重多样化的并且受保护的后备措施，给安全系统供电


堆芯熔融物捕集器

- 有4台冗余应急柴油发电机 (EDG)……
- ……由2台多样化的全厂断电 (SBO) 柴油发电机提供后备
  一台柴油发电机即可给安全系统供电

厂内水池，冷却堆芯

- 一共有4个受防护的应急给水系统水箱，每个安全厂房各一个
- 有额外的受防护的厂内水源，比如消防水箱
- 安全壳内的换料水箱 (IRWST) 储存有大容量的含硼水，位于反应堆厂房内

受防护的燃料池

燃料池位于一栋单独的受防护的建筑内，备有两台冗余冷却水池，另有第三台多样性水池作为后备。

→ **EPR™ 反应堆厂内水池和燃料池可为安全系统完全自给供水超过7天。**

防范环境损害

EPR™ 反应堆安全方案能显著限制燃料损坏的后果，以防范对环境造成任何长期影响。

压力控制

专用严重事故阀门确保了快速卸压，以防止高压堆芯熔化。

防止氢爆

与安全壳的特定设计有关的非能动氢气复合器能防止氢爆。

采用堆芯熔融物捕集器密封可能的堆芯熔融物

堆芯熔融物捕集器专门设计用于收集、密封和非能动地冷却堆芯熔融物。

不对环境造成长期影响

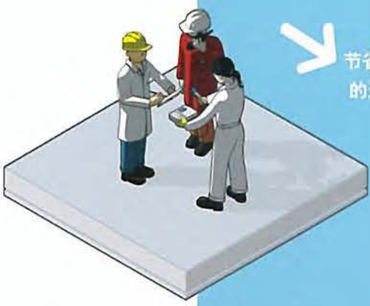
有一密封双层安全壳，在其内层壳体和外层壳体之间设计有一环廊，能够明显限制场外辐射后果。

具有竞争性
的业务

考虑到主要欧洲用户的要求，得益于阿海珐在反应堆设计和施工方面的丰富经验，EPR™ 反应堆安全设施和渐进型设计有助于实现高水平的竞争力和可预测的业绩。

成本高效利用的功率输出

- 每兆瓦时运行维护成本下降20%
- 输出功率更高，实现了规模效益
- 60年的设计寿命
- 厂址使用优化
- 灵活的负荷跟踪



高使用率（设计目标：92%）

按照《欧洲用户要求》规定的方法进行计算

- 由于安全系统的冗余性，能够进行在线预防性维护，有助于减少维护时间
- 由于为缩短大修时间增设了额外的卸压阀，因此提高了反应堆的冷却速度

厚钢材反射层设计有助于减少燃料循环成本

燃料管理得到优化

- 节省了铀消耗量：与其他反应堆相比，每生产一兆瓦时电力节省15%天然铀：
  - 蒸汽发生器中的轴向节能装置产生更高压力，使热效率高达37%
  - 厚钢材中子反射层提高了堆芯效率
- 灵活的燃料管理
  - 运行周期12至24个月
  - 能够装载全MOX堆芯

灵活的运行循环长度：12、18或24个月

→ EPR™ 反应堆具有大功率、高使用率，因而与其他新一代堆型相比，能节省20%的运行维护成本和15%的燃料成本






新建核电项目
的标杆

安全性的标杆

EPR™ 反应堆设计具有最高安全水平：
- 已经在法国、芬兰和中国获颁许可证
- 对极端危险有很强的抵御能力—这一点已被欧洲安全检查所确认
- 稳固的冷却能力：供水自给时间超过7天

渐进型设计

EPR™ 反应堆的设计基于：
- 成熟的法国N4反应堆和德国Konvoi反应堆技术
- 从数十年研发项目获得创新型特性
- 超过80座压水堆的运营跟踪记录

具有竞争力的设计

高功率输出和创新特性有助于：
- 节省20%运行维护成本
- 节省15%燃料成本
- 厂址和土地使用得到优化

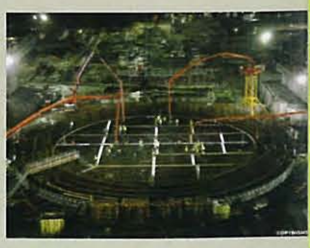
项目交付有信心

阿海珐目前有四座EPR™ 反应堆分别在芬兰、法国和中国建造，正在获得全球独一无二的项目交付最前沿经验。

阿海珐的综合支持能力

- 自行制造能力，全球范围运作的供应链
- 全球最大的内部核电EPC团队
- 完整的核燃料循环专业技术
- 为世界上超过250座的反应堆提供服务

我们正在共同建设EPR™ 核反应堆堆群



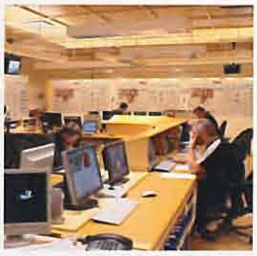
廠商資料3

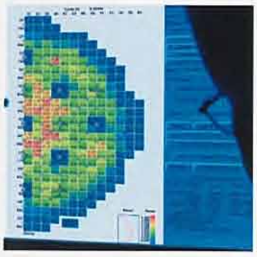
Studsvik

Nuclear Fuel Analysis Software

Nuclear Reactor Analysis Software and Services

Studsvik is the global leader in the development and support of fuel vendor-independent reactor analysis software. We offer a full suite of licensing-grade software and engineering services to support operating utilities, fuel vendors, safety authorities, and research organizations. Our products are used throughout the world for light water reactor core design, analysis, and operational support.





Our Product Line

For over 30 years, Studsvik has provided the commercial nuclear power industry with cutting-edge solutions to address emerging issues and industry initiatives.

Unparalleled in the industry, the Studsvik product line offers a full lifecycle solution, meeting all your core analysis requirements:

- Fuel and Loading Pattern Design & Optimization
- Reactivity Management & Core Tracking
- Transient Core Analysis
- Fuel Performance Analysis
- Operational Support
- On-line Core Monitoring
- Cycle-Specific Training Simulator Models
- Fuel Pool Criticality
- Back-End (Storage and Cask) Analysis

Studsvik offers advanced reactivity management and operational support solutions with state-of-the-art physics models and automated engineering functions. Our products allow organizations to maximize engineering resources without sacrificing accuracy.

The Global Leader

Our licensing-grade software allows our customer to perform their own confirmatory fuel cycle analyses, independent of the fuel vendor. Currently over 70 organizations are uisng our products.

Together, we have performed analyses of every commercially available light water reactor fuel design over thousands of combined reactor operating cycles.

Our fuel vendor independence allows our customers the freedom to change fuel vendors or to benefit from potential cost advantages of mixed-vendor solutions, without having to retrain their engineers.

Relying on robust, first-principle physics modeling, advanced numerical techniques, and first-of-a-kind engineering features, Studsvik has created the most popular reactor analysis software in the world.

Cloud computing

We now offer many of our software products as "hosted solutions."

Studsvik provides secure connections to our centrally hosted fuel analysis software, removing the IT burden of maintaining, supporting, and managing the software.

In-Core Fuel Management

Studsvik sets the industry standard for in-core fuel management software with unparalleled accuracy, production-level run times, and easy-to-use input.

CASMO5
State-of-the-Art Lattice Physics

SIMULATE
3D, Steady-State Nodal Simulator

SIMULATE3-K
3D Transient and Safety Analysis

ENIGMA
Thermomechanical Fuel Performance Analysis

XIMAGE
Automated Loading Pattern Design

"Studsviks has created the most popular reactor analysis software in the world."

Engineering Services

With hundreds of years of combined experience in reactor analysis, Studsvik's engineers can help organizations with a wide range of core analysis services, including:

- Core Reload Design and Verification
- Independent Fuel Bid Evaluation
- Refueling Shuffle Optimization
- Safety Analysis
- Design Certification

Training Simulator Core Models

Modern training simulators require high fidelity to the plant and real-time response. Studsvik simulator solutions help organizations meet these requirements by providing cycle-specific core models that can be added to most existing plant simulator installations.

S3R
Cycle-Specific Simulator Core Model

Spent Fuel Analysis

Managing spent nuclear fuel demands an increasing amount of engineering resources. We offer advanced, integrated solutions to analyze fuel pools / racks and optimize the loading of fuel storage casks.

SNF
3D Spent Nuclear Fuel Analysis

CASKLOAD
Cask Loading Optimization

Operations Support

Studsvik's integrated product line allows a single cycle-specific core model to simplify many aspects of plant operations, from on-line core monitoring to refueling optimization.

GARDEL
Advanced On-line Core Monitoring and Automated Reactivity Management

MARLA
BWR Refueling Optimization

Studsvik

Studsvik Scandpower, Inc.
309 Waverley Oaks Road, Suite 406
Waltham, MA 02452-8443
USA
Phone: +1 617 965 7450

Studsvik Scandpower AB
Stensborgsgatan 4
SE-721 32 Västerås
Sweden
Phone: +46 21 41 5770

Studsvik Scandpower GmbH
Rathausallee 28
DE-22846 Norderstedt
Germany
Phone: +49 40 3098 08810

Studsvik Japan Limited
Nakamura Bldg. 3F
2-7-114 Shibuya, Shibuya-ku
Tokyo 150-002
Japan
Phone: +81 0 3 5464 3771

廠商資料4

AFCR

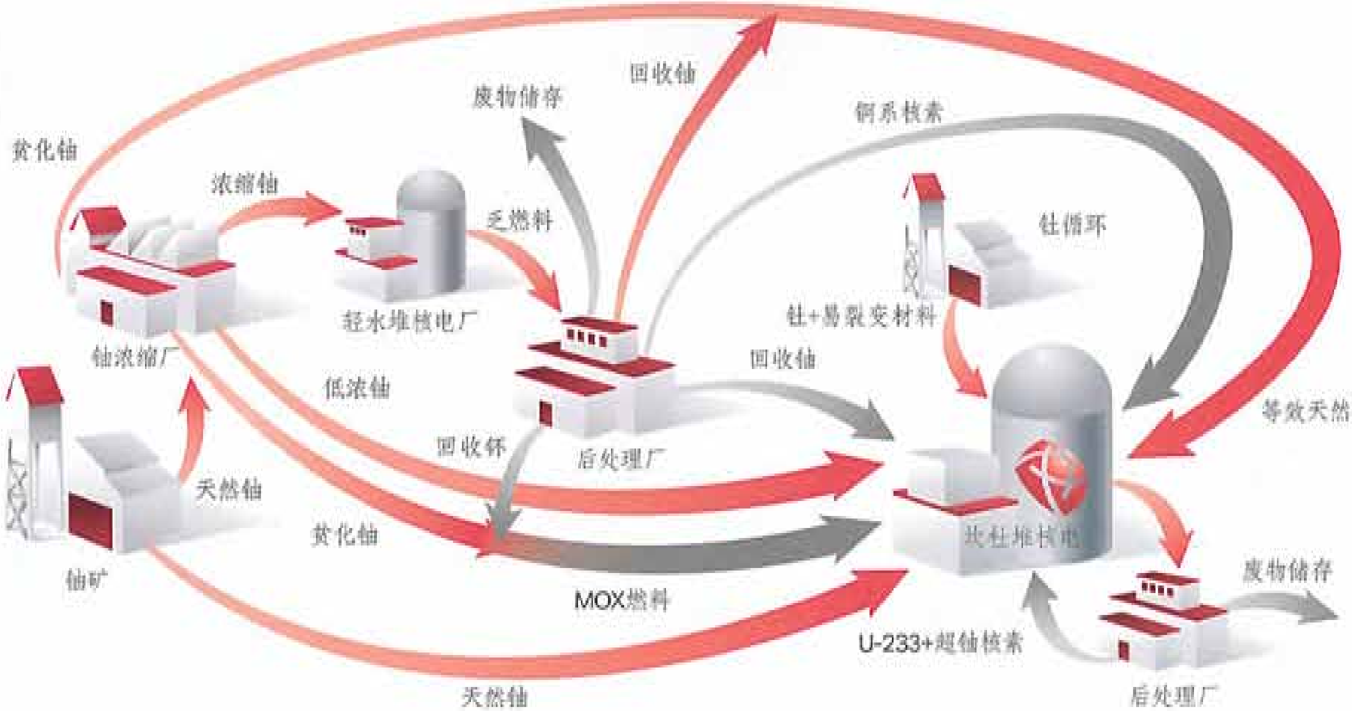
先进燃料坎杜重水堆

Advanced Fuel CANDU Reactor

战略互补

为业主创造更大价值

Candu™



先进燃料坎杜重水堆AFCR（Advanced Fuel CANDU® Reactor）是坎杜能源公司第三代70万千瓦级的核电机组设计。AFCR传承成熟坎杜重水堆技术特点，汲取最新技术进步，采用渐进创新的发展策略，可以高效利用回收铀和钍等先进燃料。

AFCR是坎杜能源公司对三代增强型坎杜6型设计（EC6®）的进一步优化以便应用替代燃料，坎杜6型机组已拥有三十多年优异的运行业绩和成功经验。AFCR和EC6设计全面汲取了核电运行经验反馈并系统地考虑后福岛发展趋势和要求，同时提高运行性能和经济竞争力，最大程度地满足业主的需求。

AFCR第三代设计强化包括以下方面：

- 60年的机组寿命
- 运行和安全裕量提高
- 先进燃料设计
- 强化全面应对内外部事件的能力
- 防御事故的固有安全性特点
- 增强应对长时间全厂断电事故的安全性能
- 强化避免堆芯损坏和对严重事故的响应能力
- 更先进的防火系统

燃料灵活性

AFCR设计实现燃料灵活性，与全球其他反应堆设计相比，这是其独特优势。在传统成熟的坎杜堆芯设计基础上，采用CANFLEX®先进燃料组件专利设计，通过少量的设计变更和优化，使AFCR具备利用回收铀和钍基燃料的能力，而且反应堆性能得到强化，运行安全裕量进一步提高。

坎杜能源公司和中方单位合作，一同致力于开发应用更先进、更高效、轻重水堆互补的解决方案，为客户带来更高的资源利用率。中国秦山第三核电厂成功示范应用等效天然铀，证明了坎杜反应堆技术具备工程应用替代核燃料的能力与现实可行性。

使用等效天然铀、回收铀和钍基燃料，能够有效缓解大规模发展核电和严重依存天然铀燃料之间的矛盾，同时开辟利用新型燃料资源的途径。在没压水堆产生的大量乏燃料经后处理加工得到的回收铀，无须再浓缩，即可直接用于坎杜反应堆；每三个压水堆的乏燃料回收铀可以为一个AFCR反应堆提供足够的核燃料。

回收铀示范应用

坎杜能源与中国单位合作，在秦山坎杜反应堆顺利完成了等效天然铀燃料入堆辐照示范项目，成功验证了回收铀可与贫铀混合制成等效天然铀，直接作为核燃料在坎杜反应堆中再利用。秦山第三核电厂全堆应用等效天然铀的项目设计工作也已完成，待通过核安全局审评许可后，计划在2014年实施全堆应用等效天然铀燃料。

坎杜能源的AFCR设计是近期最可行和经济的方案，能满足中长期燃料的可持续供应，而没有太的投资和技术风险。

不断创新的传统

AFCR是基于三代增强型设计EC6，在许多设计改进的基础上又针对使用替代燃料进行了设计优化。2013年6月底，EC6已经顺利完成并通过了加拿大核安全委员会的项目前期设计评审工作，具备为具体厂址申请建造许可证的有利条件。

AFCR是EC6的继续发展和优化，既保留了参考设计的成熟特点，又吸收了燃料相关的创新优势。

AFCR保留成熟坎杜设计的许多基本特点，包括：

- 水平燃料通道设计
- 不停堆换料
- 燃料设计简单，易于操作和生产制造
- 低压和独立的重水慢化剂
- 充水堆腔
- 能动和非能动堆芯冷却能力
- 两套完全独立的快速停堆系统
- 固有和非能动应急冷却能力
- 反应堆厂房可进入以便于在线维护

与现有机组协同发展

AFCR可以高效利用从轻水堆乏燃料经后处理得到的大量回收铀资源。这有助于核电的大规模、可持续发展，同时避免了再浓缩回收铀相关的复杂性和高成本。坎杜堆利用回收铀既提高了铀资源的利用率，又为业主节约燃料成本而带来经济效益。

先进的安全特性

全球在役坎杜重水堆核电厂已拥有数十年的安全高效运行业绩，AFCR保留并发挥成熟坎杜重水堆堆型的固有安全特性。由于应用先进燃料，AFCR堆芯设计具备比传统天然铀重水堆更有优势的安全裕量。

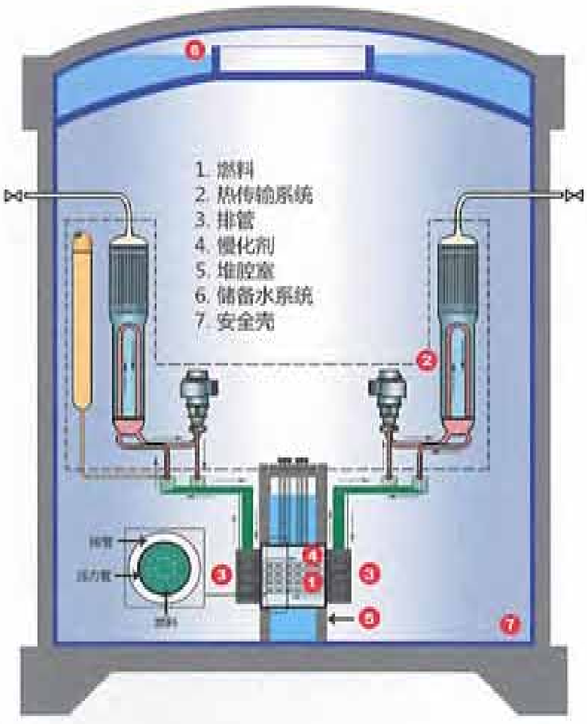
基于纵深防御理念，AFCR提供了一个由多层次固有特性和专设防御措施（物理特性、高质量设备、有效流程）构成的体系来避免事故的发生并提供足够的防护。AFCR确保一系列实体屏障，使得放射性材料停留或包容在确定位置。

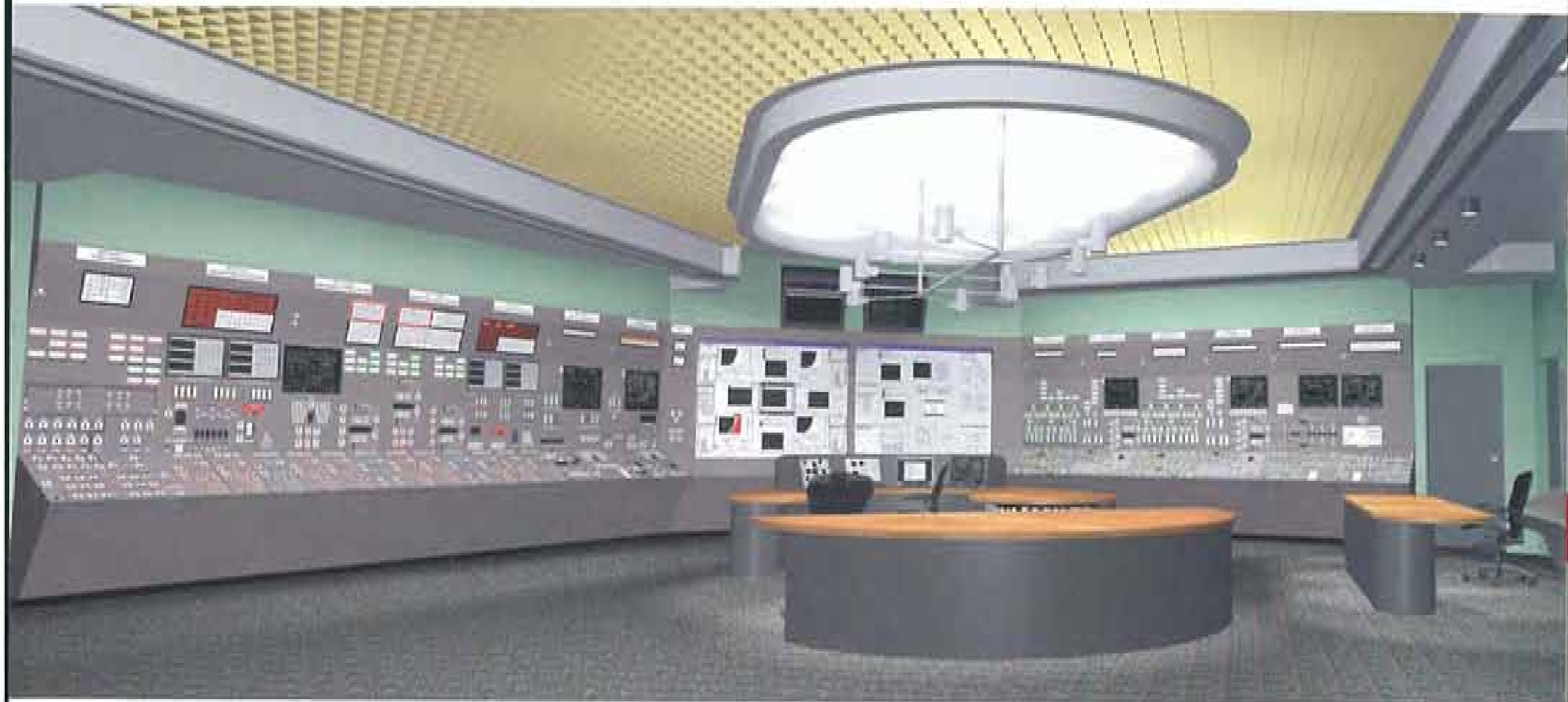
坎杜能源公司的AFCR是现有中国压水堆完美的战略补充，可以高效利用压水堆乏燃料的回收铀。

遵循坎杜反应堆传统设计理念和实践，AFCR采用两套在物理实体与功能原理相互独立、非能动固有安全的快速停堆系统。AFCR的安全系统设计，始终确保在发生事件或事故时能实现安全快速停堆，有效排出衰变热，防止放射性释放。在设计过程中严格采用隔离、冗余、高可靠性能等原则来保证实现快速停堆、应急堆芯冷却、安全壳等系统的安全功能。传统的应急供水系统经设计优化升级为一个增强型应急排热系统（Emergency Heat Removal System，简称EHRS），一旦发生常规热阱失效，EHRS可作为替代热阱来排出衰变热。安全系统之间的高度冗余性，确保安全功能的完全实现。

CANDU设计拥有防御严重事故的固有安全性特点。低压低温慢化剂是坎杜重水堆固有的非能动热阱，在超基准设计事故工况下可以排出堆内的衰变热。包围反应堆排管容器外侧的堆腔内有大量的屏蔽水，是堆芯的第二道固有非能动性应急热阱，能缓解和控制住堆芯严重损坏的进程。AFCR还专门设有严重事故恢复和排热系统，使严重事故潜在风险最小化。该系统包括由重力作用、非能动性的补水管线和由泵驱动的恢复回路，确保排管容器的完整性，控制和避免堆芯发生严重损坏，即便发生超基准设计事故也能确保安全壳的完整性。

对于潜在的由于火灾、飞机撞击和设计基准威胁引发的事件，AFCR有足够的安保设施和实体防护措施，可以迅速响应，对其进行有效控制。





面向客户的设计理念

AFCR设计还充分汲取了中国核工业集团公司秦山坎杜重水堆核电厂业主的经验反馈和优化建议。

坎杜反应堆采用独特的设计技术，实现不停堆换料和具有在线维护能力。遍布加拿大、亚洲、欧洲、南美洲的在役坎杜堆业主，凭借坎杜反应堆技术的优势，实现了比其他堆型更高的全寿期容量因子。

AFCR机组全寿期六十年能力因子达90%

清洁能源

每座AFCR双机组核电厂可满足大约200万人口的日常用电需求，同时保证氮氧化物、硫氧化物、有毒重金属、粉尘、臭氧和其他污染物的零排放。

每座AFCR双机组核电厂：

- 如替代传统燃煤发电厂，每年可减少近1300万吨二氧化碳的排放量
- 如替代燃烧天然气的发电厂，每年可减少近600万吨二氧化碳的排放量

国际核电项目业绩

最近建成的七座坎杜重水堆核电厂——全部按预算、按时或提前投产——在全球核电供应商中创造了最佳的新建项目记录。获得这些国际项目的成功，坎杜能源公司得益于实力雄厚的加拿大及国际供应链体系伙伴的大力支持和合作。

廠商資料5

EDF

THE BRANCH ASIA - PACIFIC

CHINA SOUTH EAST ASIA SOUTH ASIA JAPAN KOREA

S BUGET
Gas Engineering
EDF: 20%

S EBECC
China Division
EDF: 100%
Net Participation: 1740 MW

R SEA (Thaïlande)
South Asia Division
EDF: 100%
Net Participation: 830 MW

R Representation
Offices for SAD in
New Delhi and Hanoi

R Japan-Korea Delegation

S DSPC – Project SANME XIA II
2x600 Supercritical coal
EDF: 35%
Commissioning: 2008

S SZPC
6x300 MW Coal
2X600 MW Coal
2.16 Billions USD
EDF: 19.6%
Last commissioning: 2005

S TNPJVC
Project TAISHAN 1 & 2
EPR 2x1700 MW Nuclear
JV EDF 30%, CGNPC 70%
Under construction

S FIGLEC (EDF 100%) & SYNERGIE (EDF 85%)
Project LAIBIN B
2x360 MW coal
616 Millions USD
EDF: 100%
Commissioning: 2000

S MECO
Project PHY MY 2.2
715 MW CC GAS – 407 Millions USD
EDF: 58.25%
EPC Commissioning: 2005

S NTPC - NAM THEUN 2
1070 MW Hydro
1.25 Billions USD
EDF: 40%
Building: from May 2005 to the end of 2009
Commissioning: April 2010

P DAYA BAY
2xPWR 985 MW nuclear
Overall design, owner's engineer, construction

P LING AO 1 et 2
4XPWR 1000 MW Nuclear
Assistance Owner's engineer

P Reprentation   S Filiale   P Projet

EDF Trading
Chine: EB Bureau à Pékin / Shanghai
Bureaux :
Thaïlande / Singapour / Australie / Chubu Energy Trading JV (CET) / Japon)

THE BRANCH ASIA-PACIFIC

EDF IN ASIA

ISSUES AT STAKE IN THE ASIA PACIFIC

Growth in world energy demand, like economic growth, is being driven by the Asia Pacific region. Energy demand will grow by 40% come 2035, of which China alone will account for 36%, and India 18%.

In order to satisfy such energy demands, the region is equipped with a variety of means of production, including nuclear power. Japan and South Korea already have highly developed industries in this domain. China and India are positioning themselves as the giants of tomorrow: China already has 15 reactors (accounting for 13 GW), is constructing 28 others and plans on reaching 60 to 80 GW by 2020, while India has 7 under construction in order to increase its current installed nuclear capacity of 15 GW. Finally, there are a number of other countries in the region that are also planning to make use of the atom in generating the electricity they need: Vietnam and perhaps in time Malaysia and Thailand.

Fossil-fired power remains the most accessible and cheapest means of generating electricity, where many projects continue to be executed. Given concerns related to climate change, gas, supercritical coal, and ultra-supercritical coal technologies are generally favoured. China is already the world leader in the latter of these. Indeed, energy efficiency and renewable energies are at the heart of energy policies in all of the region's countries.

The large amount of sunshine that tropical countries enjoy and the significant run-off in the region, especially in South and South-East Asia, make them very suitable in this regard and there is growing interest in applying better environmental and social practices in such projects.

In working with countries in the Asia Pacific region to construct the means of production that their growth requires, the EDF Group brings with it expertise and know-how that aid the region's sustainable growth.

THE BRANCH ASIA-PACIFIC
CHINA

ASSETS

FIGLEC	100% EDF subsidiary, owner of the 2x360 MW Laibin B plant in the Guangxi Province (south west China). It is the first 100% foreign electric concession, and the first BOT contract in China. The plant has the triple certificate (environment, quality and security).
Synergie	Sino-French Joint Venture (85% EDF) created to operate the Laibin B plant.
SZPC	Joint Venture created in 1998 by the Shandong electrical company SEPCO (36.6%), CLP Hong Kong (29.4%), EDF (19.6%) and a regional investment company SITIC (14.4%). It insured the construction of three thermal power plants which are now all operating, with a total capacity of 3000MW.
DSPC	Joint Venture between China Datang Corporation (60%), EDF (35%) and the Sanmenxia municipality (5%), for the operation of a coal thermal plant of 600MW commissioned in 2007.
BUGET	Gas engineering company in which EDF holds 20% of the shares.

THE TAISHAN PROJECT

Through its subsidiary TNPJVC (Taishan Nuclear Power Joint Venture Company Limited), a joint venture with its Chinese Partner CGNPC, EDF, which holds 30% of the company for 50 years, takes part in the development of the first EPR in China and will be involved in its operation.

The construction site of the two Taishan EPR 23 octobre 2011 © Groupe EDF

THE BRANCH ASIA-PACIFIC CHINA

PROSPECTS AND ISSUES

In 2010, China became the world's second largest economy, while keeping growth potential of 8 to 10% per year for the next decade.

With 70 to 80 GW installed each year for the past 5 years, and a **production growth expectation of nearly 50% until 2020,** China is the world's largest electricity and energy market. Today, the world's centre for electrical industry is moving toward China. The ability of EDF, the world's first electrician, to remain an industrial leader, depends on the Group's presence in the country.

Facing a major pollution problem, **China has set up an ambitious policy to reduce CO_2 by GDP point of 40 to 45% between 2005 and 2020.** In order to achieve this goal, China develops technological solutions such as supercritical and ultra supercritical coal plants, nuclear plants, hydro-power plants and new energies. This development is supported by large efforts in innovation and development and a strong political will.

In China, the Group develops nuclear, thermal, hydraulic, as well as energy efficiency projects and considers the area of renewable energies. In the country, ERDF positions itself on the optimization of the distribution grid. The Group's reputation and the success of its past projects set EDF as a recognized actor towards institutions and players on the Chinese Market.

The Group carries a partnership policy with local actors for the development of common projects. To closely follow the fast cycles of research and development in the country, and support the Group activities, **a R&D center opened in Beijing in 2011.**

THE BRANCH ASIA-PACIFIC

SOUTH ASIA

ASSETS

MECO	**EDF holds 56,25% of the Franco-Japanese consortium, created to design, build and operate the Gas Combined Cycle plant Phu My 2.2 in Vietnam. The 715MW plant was commissioned in 2005.**
NTPC	**Nam Theun 2 Power Company, Joint Venture created in 2002, in which EDF holds 40% of the shares, together with Electricité du Laos (25%), and EGAT (35%). The company operates the 1070MW hydro-power plant of Nam Theun 2.**

Nam Theun 2, a genuine industrial success, was designed to integrate a comprehensive set of economic, environmental and social programs, in order to improve the living conditions on the entire project area and to mitigate the effects of the project on the local populations and the surrounding ecosystems. These programs were designed in consultation with the local population and the international financial institutions involved in the project.

The achievements of the project are internationally recognized and NT2 is promoted worldwide by the World Bank as a model of responsible and sustainable project. Nearly 30 private or public actors, inc lud in g th e World Bank, the ADB, the COFACE, the French Development Agency (AFD), Thai and international banks, are involved in the project.

NAM THEUN 2

La centrale de Nam Theun 2

THE BRANCH ASIA-PACIFIC
SOUTH ASIA

OUTLOOKS AND CHALLENGES

South Asia include countries of various demographic and economic weights, from the rich city-state of Singapore to Cambodia and Laos, ranked among the world's least developed countries. However, the area is experiencing a 5% annual growth on average. The sustained increase in urban population led to a sharp increase in its energy needs. **Today, the installed capacity is 290 GW and it is forecast to reach 540GW in 2020 and 1150 GW by 2030.**

There are many opportunities and EDF can rely on the good image and experience brought by the projects already undertaken in the field of hydro and gas combined cycle. Nam Theun 2 is an example of responsible hydropower development, and Phu My 2.2 is a showcase of the Group's know-how in Vietnam, with the prospect of getting involved in new gas or coal projects in this country, and throughout the area. In India, the Group watches closely the context and the actors.

The Group is present throughout the area to support countries in developing national nuclear programs, regardless of the selected technologies.

Promising opportunities exist in the fields of renewable energies, energy efficiency, sustainable and smart cities, of which Singapore sets the example in the region.

* Thaïland, Vietnam, Laos, Indian Subcontinent, Cambodge, Myanmar, Indonesia, Malaisia, Philippines, Singapore, Australasia

LA DIRECTION ASIE-PACIFIQUE
JAPAN SOUTH KOREA

The Group is present in Japan and Korea, where it aims at following up the context and the actors, as well as to strengthen the existing partnerships.

OUR PARTNERS

In terms of nuclear manufacturing abilities, the Japanese industry has, with a few key companies, an important place in the panel of EDF' s suppliers. It also acts as a supplier in the development of nuclear power in China.

In the field of EDF projects development, Sumitomo Corp. and TEPCO have joined forces to answer to the first international call for tender launched in Vietnam for the development of the 715 MW Gas Combined Cycle of Phu My 2-2. Thanks to the intensely active JBIC (Japan Bank for International Cooperation), Japanese companies can benefit from favorable financing conditions and are key players in the region, especially in Southeast Asia.

EDF Trading has created the joint venture Chubu Energy Trading (CET) with Chubu Epco, the third Japanese electric utility, for the coal supply to its plants. After nearly three years of operation, the experiment is a tremendous success, and the cooperation with Chubu Epco has been strengthened.

Arc photovoltaïque de Gifu

R&D, INNOVATION AND ADVANCED TECHNOLOGIES

Japan as well as Korea made major efforts in R & D, including in the areas of energy efficiency and renewable energies. Both countries excel in research applied to areas such as heat pumps, photovoltaic, electric batteries and vehicles or smart grids. The main actors in R & D are industrial conglomerates.

EDF WORKFORCE IN ASIA

975	employees in seven countries
426	Chinese
362	Lao
76	Vietnamese
60	French
11	Thais
3	Indian
1	Japanese

EDF has been present in China and in Asia for the past 30 years. EDF's goal is to answer the needs of the Asia Pacific region's countries in the sector of production and electrical services.

HISTORICAL OVERVIEW OF PROJECTS DEVELOPED BY EDF IN ASIA

The Asia Pacific Branch, based in Beijing, was created in 2002 in order to manage and develop the Group's projects in the Region

1983	Signing of the first contract entrusting EDF with the preliminary studies on a nuclear plant, which will be Daya Bay, China's first nuclear power plant
1985-1999	25 engineering and consultancy contracts
1986	Beginning of Daya Bay construction
1990	Opening of a liaison office in Beijing
1994	Commissioning of Daya Bay
1996	Opening of the New Delhi office
1999	Opening of the Hanoi office.
	EDF wins the contract for the inspection, and the follow up, of the fabrication of electromechanical materials for the Three Gorges Dam
2000	Commissioning of Laibin B, first BOT in China
1997/2003/2004	Commissioning of the Shandong province power plants
2002	Establishment of the Asia Pacific Branch. Commissioning of Ling Ao, Daya Bay's sister plant. Opening of the Bangkok office.
2005	Commissioning of Phu My 2.2. Opening of the Tokyo office.
2010	Commissioning of the Nam Theun 2
Depuis 2007	Construction of the two Taishan EPR

廠商資料6

西屋承诺提供最先进的商用核电技术




西屋专注于开发全系列的商用核电技术。我们承诺为全球提供其所需的核电技术，以满足增长的电力需求。

全球近百分之五十的核电站是基于西屋的技术。西屋旗下的覆盖各个环节的核服务业务，核电自动化产品及服务业务，和核燃料业务一直处在业内的领先地位。西屋是唯一可以为包括沸水堆和压水堆的各种轻水堆型提供整套燃料的供应商。

西屋的**AP1000**技术是唯一通过美国核管会认证的三代加核电技术。全球首批采用此技术的核电站现在正在中国和美国进行建设。

与依靠能动设备如柴油发电机和泵不同的是，**AP1000**依靠的是自然重力，自然循环和压缩气体以防止由极端事故所造成的反应堆过热。即使在没有操作员干预和电站丧失厂内和厂外交流电源的情况下，**AP1000**反应堆仍然可以安全停堆并保持冷却。

正是由于非能动设计，**AP1000**核电站比一般的核电站占地更少，所需设备也大大减少，这也减少了其建设和维护费用。

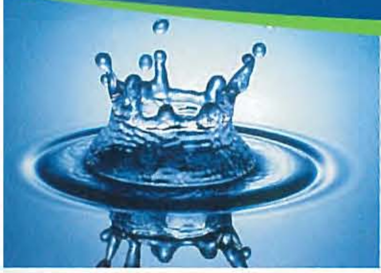
在过去的二十年中，西屋投资了超过6亿美元和成千上万的人年开发先进非能动技术。今天西屋的**AP1000**技术已经成为全球大多数规划中的三代加核电站的设计基础。

西屋承诺为未来提供安全，清洁和可靠的电力。

Westinghouse

www.westinghousenuclear.com

WESTINGHOUSE IS COMMITTED TO PROVIDING THE MOST ADVANCED COMMERCIAL NUCLEAR TECHNOLOGY




Westinghouse is solely focused on a full range of commercial nuclear technology, and we are committed to bringing the world the nuclear capacity it needs to meet the growing demand for electricity.

Nearly 50 percent of the world's nuclear plants are based on Westinghouse technology, and we are leading the way with a full range of nuclear services, nuclear automation products and services, and nuclear fuel. In fact, Westinghouse is the only supplier to provide a complete range of fuel for all types of light water reactors—both BWRs and PWRs.

Westinghouse is also the only supplier with a Generation III+ plant design certified by the U.S. Nuclear Regulatory Commission, the **AP1000®** nuclear power plant. The first of these plants are currently under construction in China and the United States.

Rather than relying on active components such as diesel generators and pumps, the **AP1000** relies on the natural forces of gravity, natural circulation and compressed gases to prevent overheating in the highly unlikely event of an accident. Even with no operator action and a complete loss of all on-site and off-site AC power, the **AP1000** will safely shut down and remain cool.

Because of its passive design, the **AP1000** has a smaller footprint and significantly less components than typical nuclear power plants, which also helps to reduce construction and maintenance costs.

In the past 20 years, Westinghouse has invested more than $600 million and thousands of man years in advanced/passive technology. Today, the Westinghouse **AP1000** is identified as the design basis for the majority of the Generation III+ plants planned around the world.

Westinghouse is committed to providing future generations with safe, clean and reliable electricity.

Westinghouse

www.westinghouse**nuclear**.com

廠商資料7

®ACP1000

能动+非能动的先进压水堆 →

- 安全、可靠、经济
- 基于丰富经验和充分实验分析验证的设计改进
- 满足国际及国内安全法规和标准
- 满足三代核电站的用户要求
- 吸取福岛事故经验反馈

CNNC

ACP1000 总体描述

ACP1000是中核集团立足于中国核电30年的技术基础，自主研发的安全、可靠、经济的先进压水堆核电站。ACP1000技术方案采用能动与非能动相结合的设计理念，满足三代核电的安全要求。

安全

- 能动+非能动安全设计
- 完善的严重事故预防和缓解措施
- 提高外部灾害防护
- 改进应急响应措施
- 经验证的设计和设备物项

可靠

- 基于成熟技术和丰富的工程经验
- 长期运行验证的核蒸汽供应系统
- 成熟的制造和施工技术

经济

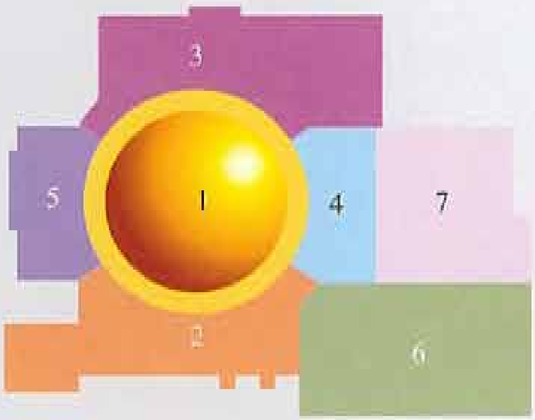
- 延长换料周期
- 延长电厂设计寿命
- 提高电厂可利用率
- 缩短建造周期

主要参数

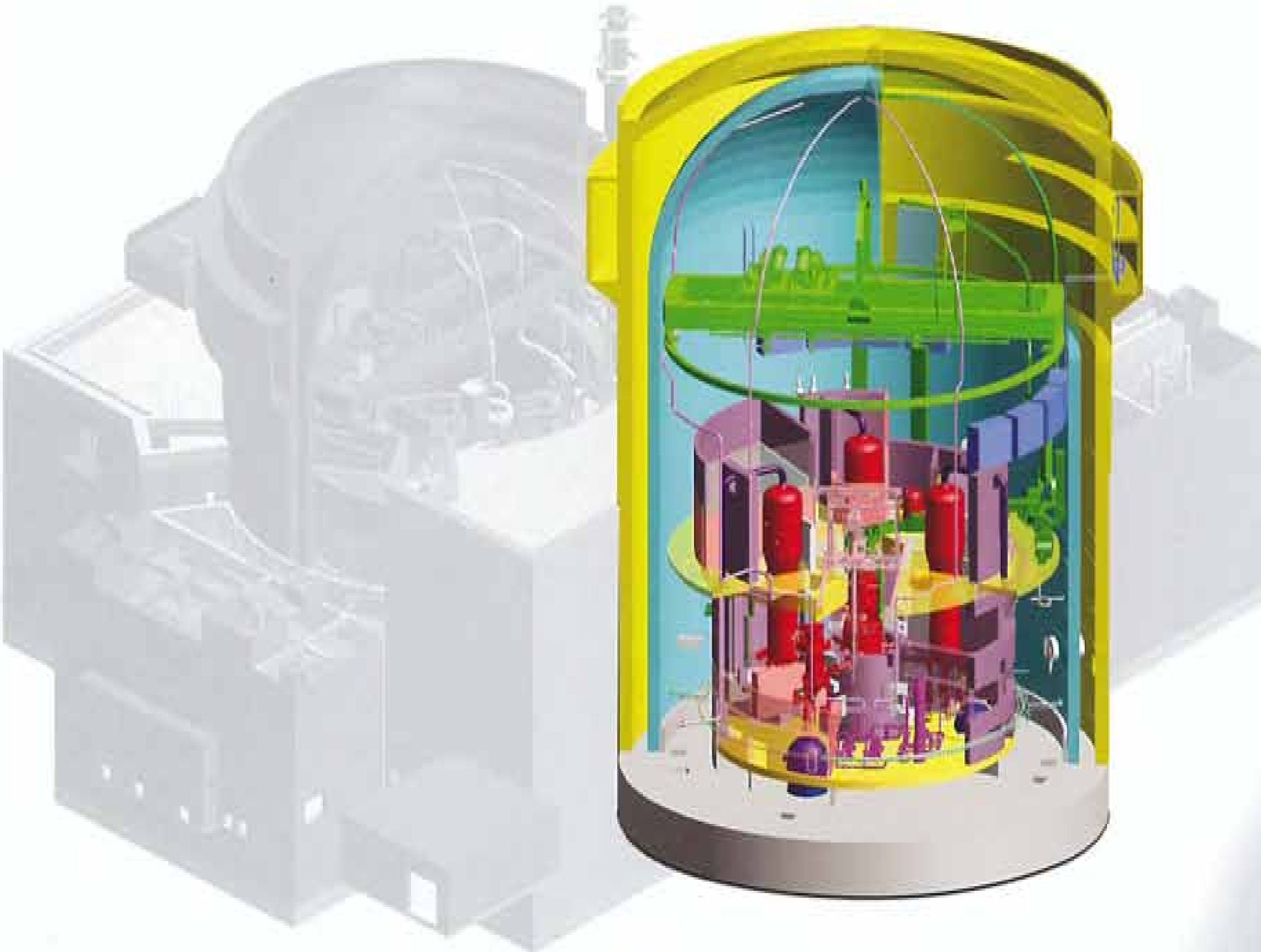
序号	项目	单位	参数
1	额定电功率	MWe	≥1100
2	设计寿命	年	60
3	换料周期	月	18
4	电厂可利用率		≥90%
5	非计划紧急停堆	1/年	<1
6	日负荷跟踪能力		是
7	地面峰值加速度	g	0.3
8	堆芯损坏概率	1/堆·年	$\leq 10^{-6}$
9	大量放射性释放概率	1/堆·年	$\leq 10^{-7}$
10	职业照射剂量	人·希伏/堆·年	<1

ACP1000 总平面布置

单堆布置

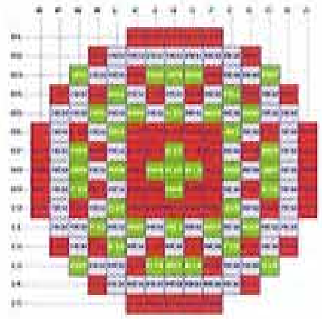


1 反应堆厂房
2 燃料厂房
3 电气厂房
4 安全厂房（A）
5 安全厂房（B）
6 核辅助厂房
7 放射性废物厂房



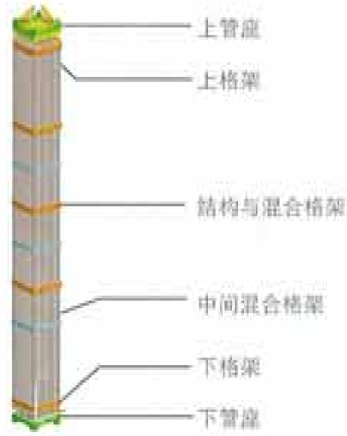
主系统

反应堆堆芯设计



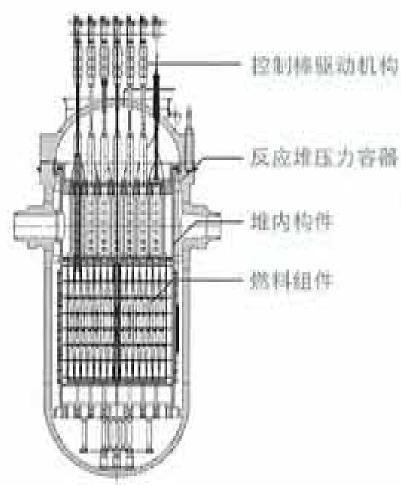
- 177盒先进燃料组件
- 低线功率密度，提高热工裕量
- 18个月换料
- 低泄漏燃料装载方案

先进燃料组件CF3



- 17×17排列
- 优秀的热工水力性能
- 先进的N36锆合金包壳
- 优秀的抗弯曲能力
- 可更换的管座以便于维修和检查
- 优秀的防异物能力

反应堆压力容器



- 60年设计寿命
- 取消了压力容器下封头贯穿件，提高了下封头可靠性
- 从顶部贯穿实现在线监测LPD和DNBR的先进堆芯测量系统

反应堆冷却剂系统

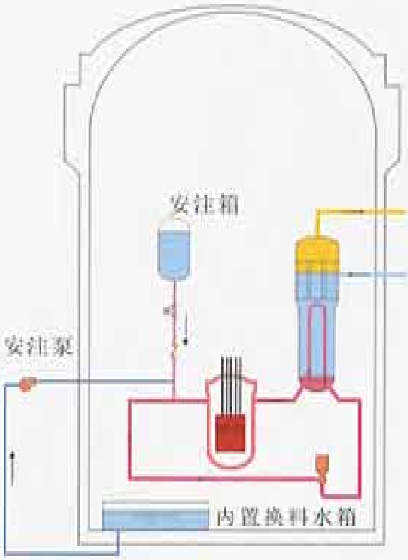
- 反应堆压力容器
- 稳压器
- 反应堆冷却剂泵
- 主管道
- 蒸汽发生器

设计描述	参数
堆芯额定热功率	3050MWt
核蒸汽供应系统名义热功率	3060MWt
热工设计流量	$3\times22840m^3/h$
反应堆入口温度	291.5℃
反应堆出口温度	328.5℃
运行压力	15.5MPa
设计压力	17.23MPa
设计温度	343℃

能动+非能动设计特征

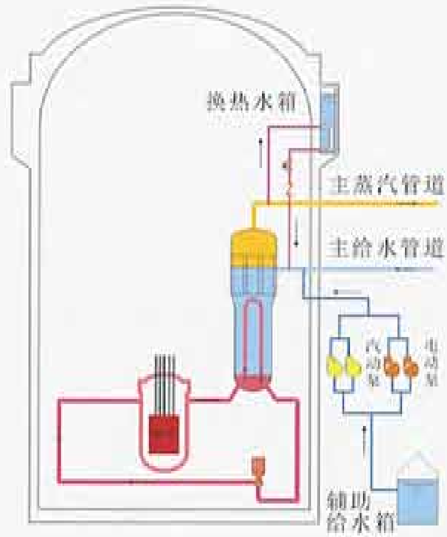
应急堆芯冷却

- 失水事故时向堆芯提供应急冷却
- 能动的中、低压安注系统
- 非能动安注箱注入系统



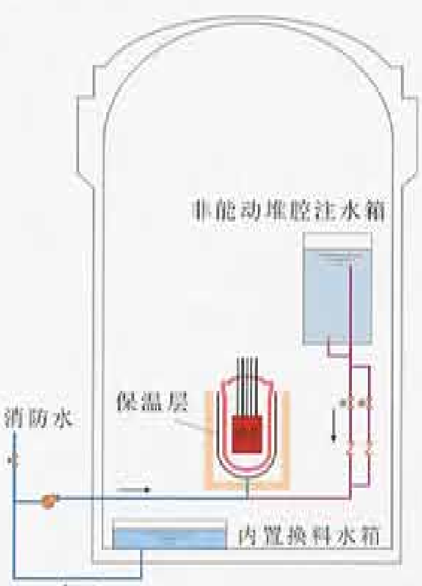
二次侧热量导出

- 从蒸汽发生器的二次侧导出堆芯余热
- 能动的辅助给水系统
- 非能动二次侧余热排出系统



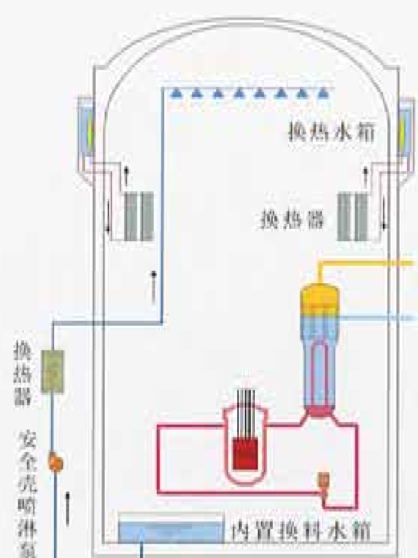
堆腔淹没和冷却

- 冷却压力容器下封头，保持其完整性，实现堆芯熔融物滞留
- 能动堆腔注水冷却系统
- 非能动堆腔注水冷却系统



安全壳热量导出

- 事故情况下排出安全壳内热量，降低安全壳内的温度和压力
- 能动的安全壳喷淋系统
- 非能动安全壳热量导出系统



ACP1000 安全特征

严重事故应对措施

	事故现象	应对措施
应对安全壳失效	氢爆	非能动氢复合器
	高压熔堆、安全壳直接加热	一回路快速卸压系统
	安全壳长期超压	非能动安全壳热量导出系统/安全壳过滤排放系统
	安全壳底板熔穿	堆腔注水冷却系统
	全厂断电	二次侧非能动余热排出系统，增加后备电源
	其他严重事故应对措施	压力容器高位排气系统，提高主控室可居留性，等

极端外部事故应对措施

- 双层安全壳
- 抗震设计基于地面水平峰值加速度0.3g
- 抗商用大飞机撞击

福岛核事故经验反馈/ACP1000设计优化

- 应急供水
- 更保守的地震裕量
- 乏燃料水池冷却与监测
- 提高应急设施的可居留性与可用性
- 延长操作员不干预时间
- 移动电源与电源多样性

CNNC
中国核工业集团公司
地址：北京市西城区三里河南三巷1号 邮编：100822
电话：86-10-68512211 传真：86-10-68533989
Http://www.cnnc.com.cn