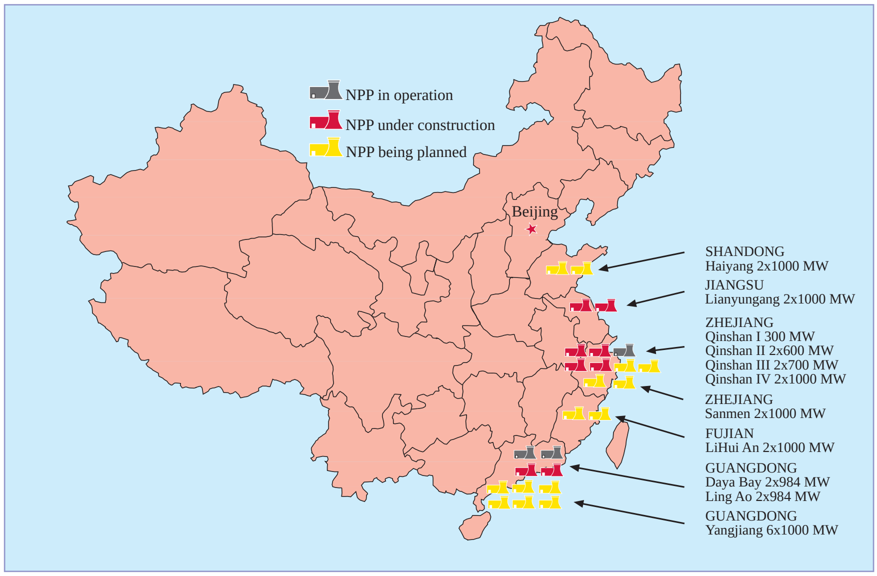
Project CPWR 1000
A WORLD-CLASS DESING FOR THE CHINESE NUCLEAR PROGRAM

A.RUIZ - E. VALERO

The Spanish Industry participates with Westinghouse and Mitsubishi in the offer of a PWR adapted to the Chinese needs



China`s Nuclear Power Plants map

INTRODUCTION

Under the name Grupo Nuclear SEPI, the companies BWE, ENDESA, ENSA, ENRESA, ENUSA and INITEC, in a partnership based on their present or past membership in SEPI and with extensive experience in the nuclear sector, have in the last few years been coordinating technical and commercial actions targeted primarily at the Chinese nuclear market.

These actions have been carried out under Westinghouse's leadership, for the purpose of providing a 1000 MWe nuclear power plant design tailored to the local requirements defined by experts and authorities of the People's Republic of China (project CPWR 1000).

As members of an international consortium that includes Westinghouse and Mitsubishi Heavy Industries, the goal of the Spanish firms is to take part in the upcoming International Tenders that the Chinese authorities of the People's Republic of China (PRC) plan on convening for building the nuclear power plants to be included in the Tenth Five-Year Plan (2001-2005).

At the industrial level, the Spanish participation in CPWR 1000 is articulated through a Spanish Consortium formed by INITEC, BWE and ENSA. ENUSA's membership would depend on the scope assigned to it for the supply of nuclear fuel.

- INITEC will act as the supplier of plant engineering and a significant volume of electrical equipment.
- ENSA will supply the steam generators and other components of the primary system and solid radioactive waste system.
- BWE will be responsible for supplying the condensers, cranes and a significant volume of mechanical equipment.

The other two member firms of Grupo Nuclear SEPI, ENDESA and ENRESA, provide important institutional support to the Spanish Consortium, and it is expected that the latter will participate extensively as a consultant and collaborator in managing nuclear waste in China.

THE CHINESE ENERGY MARKET AND THE ROLE OF NUCLEAR POWER

China needs enormous amounts of energy; installed electrical capacity is only 0.19 kW per capita, and more than 80 million people live in homes without electricity.

China has a fourth of the world's coal reserves and is the largest producer in the world. Dependence on this fuel for generating electricity amounts to 80%, and the rest is primarily covered by hydraulic energy (18%). Natural gas is virtually unexploited, and nuclear power accounts for only 1.5% of installed power.

To address increasing demand at rates of up to 10%, the PRC has installed 10,000 MWe of new capacity per year in the last ten years, and it plans to maintain this pace of investments until it duplicates current installed capacity (250 GWe) by the year 2010 (510 GWe).

Nuclear power, gas and renewable energy development is perceived in China as a way to reduce the environmental impact caused by coal combustion, which has a high sulfur content and is carried out in facilities not equipped with emission reduction technology. The success of this gamble will have major worldwide repercussions because of China's high CO_2 emission potential and its impact on Climatic Change.

The first Chinese nuclear power plant began commercial operation in late 1991: the Chinese-designed Qinshan I NPP (300-MWe PWR) with partially imported supplies. In February and May of 1994, the two units of Daya Bay NPP (2 x 900 MWe PWR) of French design and supply went into commercial operation.

Today, China has several nuclear power plants under construction: Qinshan II (2 x 600-MWe PWR), designed by the Chinese Institutes of nuclear engineering and with BWE and ENSA supplies; Ling Ao (2 x 985-MWe PWR), of French design similar to Daya Bay; Qinshan III (2 x 700-MWe CANDU), Canadian heavy water reactors; and Lianyungang (2 x 1000-MWe PWR), Russian VVER-type reactors.

In the future, China plans to build an additional 10,000 nuclear MW for commissioning before 2010.

PROJECT CPWR-1000

Project CPWR 1000, based on the proving and succesfully operating Vandellós II nuclear power plant with some upgrades and adaptations to local characteristics, has been developed with the collaboration of Westinghouse, INITEC and two Chines institutes of energy technology: the East China Electric Power Design Institute (ECEPDI) and Shanghai Nuclear Engineering Research Design Institute (SNERDI).

CPWR 1000 has been very enthusiastically accepted by Chinese nuclear officials and is supported by the Shanghai authorities and industry. A preliminary proposal was submitted in the summer of 1997 to the CHINA NATIONAL NUCLEAR CORPORATION (the senior body in charge of nuclear power) for the supply of two 1000-MWe units. If the order is obtained, CPWR 1000 would become the standard model for the next phase of development of the Chinese nuclear plan.

The purpose of project CPWR 1000 is to develop a safe, proven, advanced, competitive design of a PWR nuclear power plant with a power of around 1000 MW, based on Vandellós II NPP, named CPWR 1000 (China Standard Nuclear Power Plant), and to be built on different sites in the People's Republic of China.

REQUIREMENTS OF THE CPWR 1000 DESIGN

The Design Bases imposed on CPWR 1000 as the foundation on which the entire design effort will be supported are as follows:

- Electric Power: 1000 MW
- Grid Frequency: 50 Hz
- Safety Margins:
  - 15% margin in DNBR
  - 15% margin in overpower
- Core Fusion Probability: 1.10-5/year
- Plant Lifetime: 60 years
- Availability: 90%
- Fuel Cycle Economy:
  - 18-24 month cycle
  - Burn-up > 45,000 MWd/t
- Use of Advanced, Proven Designs
  - Advanced fluid systems
  - Advanced Instrumentation & Control Technology
  - Advanced Control Room
- Seismic Design Criterion: 0.2 g
- Local Design/Manufacturing Component: 40% for the first two units, up to 90% for the 5th and 6th units

COMPETITIVE ADVANTAGES OF CPWR 1000

Project CPWR 1000 is on the cutting edge of current PWR plant designs, as it offers the following competitive advantages:

1. It increases safety margins as compared to current 3-loop PWR reactor designs, as on one hand the core power density is lower since it is formed by 193 fuel assemblies versus the 157 assemblies of a standard core, and on the other hand it significantly increases the inventory of primary circuit coolant since the loop, pressurizer, steam generator and accumulator volumes are larger than in a standard plant.
In addition, as a result of the application of advanced fluids, the safety injection functions are separated from the load functions, since the Chemical and Volume Control system only works during normal plant operation to maintain the inventory and chemistry of the reactor coolant and is not assigned the safety injection function, which results in higher safety margins. The new Emergency Feedwater System also helps to increase these margins; this system performs the safety functions previously assigned to the Auxiliary Feedwater System, and the Main Feedwater System is used for startups and shutdowns through a new startup motor pump with 20% capacity.

2. It increases available electric power, such that the 2912 MWt, which can be uprated to 3150 MWt, produce 1061 MWe gross or 1001 MWe net.

3. High availability factor, since with 18 to 24 month fuel cycles, 35-day refuelings and an availability of more than 85% in the Reference Plant (Vandellós II NPP), it is to be expected that CPWR 1000 will surpass this ratio.

4. Low fuel cycle cost, by maintaining a low power density in the core, low-enrichment fuel, reduced neutronic releases and high burn-up.

5. Simplified operation and failure reduction, as it uses advanced I&C technology based on digital systems, with the resulting cost reductions and system flexibility.

6. Based on a proven design and extensive experience in operating plants. Westinghouse is the technology provider of 166 nuclear units, which account for 40% of all plants in operation around the world.
The main components of proven design include the following:
   - Steam generators model Δ75
   - Reactor coolant pumps model 100D
   - 17x17 PERFORMANCE+ fuel
   - Control rod drive mechanism as per standard series 312 and 412
   - Reactor vessel internals as per standard series 312 and 412
   - Reactor vessel as per standard series 412.

7. Total load rejection capacity, allowing for 100% rejections without reactor scram and return to power in a short period of time, thus achieving more time for energy production.

8. Load following capacity by using gray rods, with the resulting elimination of the Thermal Boron Regeneration system.

9. The purpose of this design is to achieve a plant life of 60 years. In general, the lifetime of most components can easily reach 60 years. The critical component for achieving this goal is the reactor pressure vessel, as it is subjected to high neutronic fluence. Since the CPWR 1000 vessel is larger, the core power density is lower and the fuel used has a low neutronic flux rate, damage to the vessel from neutronic flux is substantially decreased, thus achieving a longer design life for the CPWR 1000 vessel than in a traditional PWR.

OTHER NOTABLE FEATURES

CPWR 1000 includes the improvements that have been made in the reference plant, Vandellós II NPP, since its commissioning. In addition, the design provides for systems upgrades such as the ones described below:

a) Emergency Core Cooling System:

- Designed so that core is not uncovered for ruptures equal to or less than 5".

- The safety injection function is separate from the load function.

- An inadvertent safety injection to the reactor coolant system is impossible, thus avoiding pressurizer safety valve actuation and thermal shock owing to cold water injection, since the discharge pressure with high-pressure safety injection pump valves closed is less than the reactor coolant system operating pressure.

- The residual heat removal system rating is increased from 600# to 900# and, as a result, when it acts as a low-pressure safety injection, the probability of LOCA in the RHR / RCS interface is reduced, and when it acts as a residual heat removal system as such, it can start operating during the plant cooling phase at an earlier time.

- Mid-loop operation, thus preventing air from entering the RHR pumps and therefore pump cavitation.

- The increased discharge pressure of the low-pressure safety injection pumps (LHIP) and increased volume of water in the accumulators result in a considerable overlap between injection flows, which assures an adequate safety injection flow for any type of break.

b) Emergency Feedwater System

- It only performs safety functions under post-accident conditions.

- It is composed of two independent, redundant subsystems, each of which is equipped with a motor pump and a main steam-driven turbopump.

- It is provided with safety-class water storage devoted exclusively to this service.

- It uses cavitation venturis in each steam generator feed line to prevent excessive emergency water flow in the event of a main steam line break.

c) Containment Spray System

- The NaOH addition subsystem is replaced by metallic mesh baskets containing trisodium phosphate located in the containment recirculation sumps. This prevents the adverse effect that an inadvertent actuation of the containment spray system would have on the equipment.

d) Gas Fuel Control System

- In addition to the traditional hydrogen recombiners, there is a subsystem of hydrogen igniters distributed throughout the containment.

e) Main Steam, Condensate and Feedwater Systems

- Turbine bypass designed to permit 100% load rejection without reactor scram.

- Condenser sized to admit 85% main steam flow bypass during load rejection.

- Startup motor pump with a 20% capacity in parallel with the two main feedwater turbopumps, which performs the functions of feeding the steam generators at low load (startup and shutdown) and maintaining 100% feedwater flow when one of the turbopumps trips.

- The turbine cycle includes a degasifier, feedwater tank and a new high-pressure heater.

f) Steam Generator Blowdown and Condensate Demineralization Systems

- Steam generator blowdown is reduced, sized for 1% of maximum steam production rate, with the resulting economy of equipment and energy.

- A demineralization system is added with the capacity to process 100% of the condensate flow.

CONSTRUCTION PROGRAM

The construction program spans a period of 54 months, from the first structural concrete to fuel loading, and includes the following milestones:

• The time from Contract signature to the first concrete structural pouring will be 18 months, which can be reduced to 10 months if preparation of the PSAR is authorized 8 months before Contract signature.

• The time between the first structural concrete pouring and the first fuel loading is scheduled to last 54 months.

• Commercial Operation will begin 6 months after the first fuel loading.

Total Program duration will be between 70 and 78 months. There will be an 18 month phase difference for construction of two units.

It is expected that the goals of this ambitious program will be achieved, since:

• It is based on the program established for the Reference Plant, Vandellós II NPP.

• All materials and amounts are sufficiently defined.

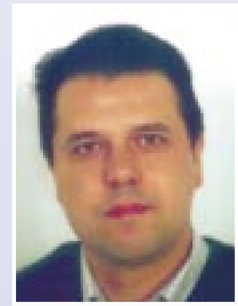
• The evaluation of work volumes is clearly defined, as evidenced by similar plants.

• The construction methods and procedures are based on those of plants currently under construction.

• Use of compact equipment modules.

CONCLUSION

Project CPWR 1000 is the result of the Spanish industry's efforts, in collaboration with Westinghouse, to offer a World-Class Design for developing the nuclear program of the People's Republic of China.



Ángel RUIZ SANTOS is Senior Telecommunication Engineer, High Technical School for Telecommunication Engineers, Polytechnic University of Madrid and Master in "Programme of General Management", IESE, Barcelona,1975. He starts his professional career at AUXIESA in 1975; he joins the Ascó I and II Nuclear Plant Project, and performs various functions within the project; being in charge of the Technical Project Coordination and being subsequently appointed Head of the Instrumentation and Control (I&C) Group and Technical Coordinator in the Plant during its Commissioning and Start Up phases.
In 1985, he joins the Vandellós II Nuclear Plant Project in Madrid, as Head of the I&C Group, and is subsequently appointed Engineering Representative on the Plant, participating in the phases of construction, commissioning, start-up and connection to the network.
After completion of the Work on the Vandellós II Nuclear Plant, he is appointed Manager of the Joint Venture formed by INITEC, INYPSA and E.A. to provide the engineering support for the nuclear plants of Ascó I and II, and Vandellós II.
In 1994, he is promoted to Manager of INITEC Nuclear Division.

Enrique VALERO ABAD is "Ingeniero de Caminos, Canales y Puertos" and Master MBA (IESE).
He has been Nuclear Director and Planning & Generation Marketing Director of Compañía Sevillana de Electricidad (ENDESA Group), Vice-Chairman of Almaraz NPP, Project Manager of the Spanish Advanced Lihgt Water Reactors Programme, Managing Director of Valdecaballeros NPP, Project Manager of Cofrentes NPP and Construction Manager of Almaraz NPP.
Enrique Valero is General Director of SEPI Nuclear Group.