



XA0056470

# KOREAN EXPERIENCE IN SELF-RELIANCE FOR NUCLEAR POWER TECHNOLOGY (A CASE STUDY IN THE REPUBLIC OF KOREA)

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## Abstract

This paper describes the Korean experience in achieving self-reliance in nuclear power technology. The chronology of the nuclear program is presented introducing key factors and strategies for technological self-reliance. Experience in successful technology transfer of Nuclear Steam Supply System (NSSS) design, manufacture of NSSS and Turbine/Generator (T/G) equipment, nuclear fuel design and manufacture, and Architect/Engineering (A/E) is described. The nuclear plant standardization program is also described along with design and development approaches. Finally, experience in nuclear technology export is elaborated.

## 1. OVERVIEW

Domestic energy resources are scarce in the Republic of Korea, so stable energy supplies have been a principal consideration in formulating energy policy. As energy security is also of concern and nuclear power is considered semi-domestic because uranium is imported while other major sources of energy are domestic with self-reliance in design, manufacturing and construction, it was chosen as one of the main sources of electricity. Korea has put in place a highly successful nuclear self-reliance program employing technology transfer and standardization of nuclear power plants.

### 1.1. Chronology of the Korean Nuclear Power Program

The nuclear power program in Korea started with a feasibility study of plant introduction in the late 1960's. At the end of 1997, twelve units of nuclear power, 10 Pressurized Water Reactors (PWR) and 2 Pressurized Heavy Water Reactors (PHWR) are operating with an additional eight units under construction [1]. Nuclear power in Korea can be categorized in the following generations from the point of view of technology self-reliance:

#### 1.1.1. *The first generation: Total dependence and the imitation period*

During the first generation, from the late 1960s to the early 1970s, three units, Kori - 1&2 and Wolsong - 1, were constructed through a turnkey contract, with the foreign vendor as prime contractor. This can be characterized as a period of total dependence and imitation of technologies. Due to lack of domestic experience in nuclear industries, Korea Electric Power Corporation (KEPCO) totally relied on foreign suppliers, granting them overall responsibility for project management from design and construction to start-up. Domestic industries were limited to civil and architectural work in service facilities, as subcontractors. Major goals for

self-reliance in this period were to find items available to be localized and to imitate the technology (exactly as instructed) of the foreign suppliers.

#### *1.1.2. The second generation: Self-reliance preparation period*

During the second generation, from late 1970s to early 1980s six units, Kori - 3&4, YGN (Yonggwang) - 1&2 and UCN (Ulchin) - 1&2, were constructed through a component base contract with foreign prime contractors. In that time, KEPCO managed project construction assisted by a foreign Architect/Engineering (A/E) company. KEPCO procured the balance of plant equipment and Korean contractors managed site construction, while domestic industries expanded their engineering and equipment supply roles. During this period, domestic participation increased and various vehicles of technology self-reliance were opened as well.

#### *1.1.3. The third generation: Self-reliance promotion period*

In the third generation, from late 1980s to late 1990s, KEPCO led component base projects as before, but construction project management was internal. KEPCO assumed overall responsibility by awarding the prime contracts to Korean entities, while foreign suppliers served as subcontractors. In this period, YGN - 3&4, the first project of its kind, was started along with a technology transfer contract to increase self-reliance in parallel with plant construction. For the UCN - 3&4 project, Korean entities took responsibility for the entire project while foreign suppliers were mainly consultants.

### **1.2. Key factors for technology self-reliance**

Korea has attained self-reliance in nuclear technology through a national policy for long-term self-reliance in fuel and plant design, manufacturing, construction and operation. To execute the policy, technology transfer and power plant standardization were chosen as major vehicles for self-reliance. The scope and responsibilities were defined and divided among the participating Korean entities as shown in Table I, and in conjunction with that, plant standardization was conducted. For effective transfer, joint design<sup>1</sup> with foreign partners was chosen as the mechanism for implementation [2].

### **1.3. Strategy [3]**

The strategy to acquire self-reliance in nuclear power technology was supported by four major means; actual project execution, technology transfer, power plant standardization and gradual improvement through research and development(R&D).

YGN - 3&4 project was selected as the base for self-reliance. Since the nuclear market was a buyer's market when YGN-3&4 project was planned, the government included technology transfer as a condition of the contract. As a result, KEPCO engaged domestic main contractors while foreign subcontractors warranted the project. Well planned training and joint design were adopted as mechanism of implementation. The scope of technology transfer included the transfer of technical information, patents license, classroom training (CRT) and on-the-job training (OJT) and R&D participation and consultation.

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<sup>1</sup> All design activities are jointly carried out by engineers of the technology recipient and the technology supplier. The technology supplier takes all responsibilities and the warranties on the results of the joint design.

TABLE I. DIVISION OF RESPONSIBILITIES

ENTITY	RESPONSIBILITIES
KINS <sup>a</sup>	Licensing Support for the Government
KEPCO	Project Management, Operation
KOPEC <sup>b</sup>	Plant Design (A/E), Development of A/E Design Technology
KAERI <sup>c f</sup>	NSSS Design, Fuel Design, R&D
HANJUNG <sup>d</sup>	Component Design & Manufacturing, Development of Manufacturing Technology
KNFC <sup>e</sup>	Fuel Manufacturing, Development of Fuel Manufacturing Technology
Universities	Research & Tests of Key Technologies, Development of Key Technology

<sup>a</sup> Korea Institute of Nuclear Safety.

<sup>b</sup> Korea Power Engineering Co., Inc.

<sup>c</sup> Korea Atomic Energy Research Institute

<sup>d</sup> Korea Heavy Industries & Construction Co., Ltd.

<sup>e</sup> Korea Nuclear Fuel Co., Ltd.

<sup>f</sup> The division of responsibilities above was effective up to the end of December 1996. Currently, KOPEC is responsible for NSSS design and KNFC for fuel design.

Power plant standardization began with YGN - 3&4 as the reference plant. Korean-Standard Utility Requirements Document (K-SRED) and Korean-Standard Safety Analysis Report (K-SSAR) were the main outputs. The objectives of standardization were to develop the concept, identify items for design improvement, and improve the design over the reference.

Standardization means constructing plants to the same specifications in series for economic gains from repetitive works. But, new technology must be adapted to enhance safety and performance. In Korea, UCN - 3&4 is the first standardized plant and YGN - 5&6 and UCN - 5&6 replicate it, although gradual improvement through R&D was applied. Currently, Korea is developing the next generation reactor with a higher capacity, based on technology attained through self-reliance in 1000 MWe standard plant implementation.

## 2. TECHNOLOGY TRANSFER

### 2.1. YGN - 3&4 contract structure [4]

YGN - 3&4 was the first nuclear power project implemented on a component basis by local prime contractors. This was a turning point in Korean nuclear history because domestic involvement was markedly increased by technology transfer. KEPCO, the owner, designated KOPEC as the prime contractor for Architect/Engineering, HANJUNG for supply of the nuclear steam supply system and turbine/generator, KNFC for nuclear fuel manufacturing, and HECC for the construction. Procuring the balance of the plant was the responsibility of KEPCO as the owner. KAERI was designated as subcontractor to HANJUNG and KNFC for the design of NSSS and initial core, respectively. These entities subcontracted with foreign companies such as Sargent & Lundy (S&L), General Electric (GE) and Asea Brown Boveri-Combustion Engineering (ABB-CE) for engineering and equipment and related technology. The contract structure for the YGN - 3&4 project is shown in Figure 1.

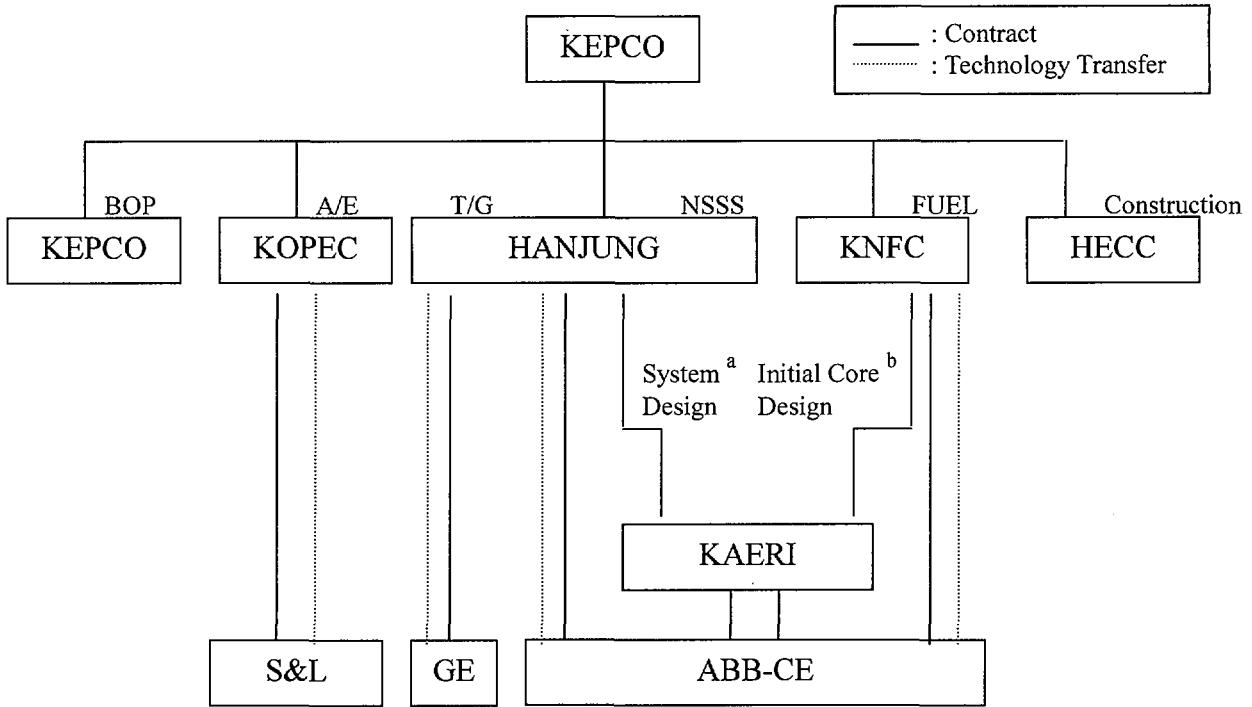


FIG. 1. YGN-3&4 contract structure.

## 2.2. Implementation method

Although there are various methods for transfer of technology, technical document, computer codes and patents licenses transfer are primary, in parallel with training and consultation. Korean entities added two more : joint design and research and development participation/joint research and development, to secure self-reliance.

Documents that were transferred were generic documents, including licensing related, quality assurance (QA) documents and procedures, and reference documents, including design documents, calculation notes, manuals, drawings, specifications, and procedures. Installation, verification and validation were major tasks in the transfer of computer codes, including source programs, manuals and QA verification documents. During the transfer, consultation was available when detail or additional works were needed.

The ten year technology transfer agreement made in 1987 was renewed and extended for another ten years in a technology cooperation agreement as of May 15, 1997.

## 2.3. NSSS design [4]

Technology transfer for NSSS design was implemented through four phases.

The first was the period of self-reliance for nuclear fuel technology. During this period, KAERI independently developed technology for PHWR fuel, and imported technology for PWR fuel from Siemens-KWU through technology transfer and joint design.

<sup>a</sup>Currently, NSSS design by KOPEC.

<sup>b</sup>Currently, Fuel design by KNFC.

In the second phase, YGN - 3&4 was executed through technology transfer and joint design with ABB-CE. In this period, system design was supported through technical review, design repeat, mock-up design and joint R&D with ABB-CE.

In the third phase, KAERI performed its own NSSS design works with some technical consultation from ABB-CE. UCN - 3&4 was the first project of the period and became the reference plant for follow-on Korean Standard Nuclear Power Plants (KSNP). The standardization project was launched then and K-SRED and K-SSAR were the main outputs. R&D continued and improved design features were applied to the follow-on plants.

YGN - 5&6 and UCN - 5&6 projects are being executed independently by Korean entities with much less consultation from ABB-CE. Next generation reactor development has begun as well.

## **2.4. NSSS and T/G manufacturing [5]**

Technology transfer for manufacturing NSSS and T/G equipment and components was accomplished in four phases: import, expansion, improvement and standardization and enhancement.

In phase I, partial domestic manufacturing was conducted under foreign supervision for the YGN - 1&2 and UCN - 1&2 projects, and this technology was expanded during phase II when components of YGN - 3&4 were manufactured under foreign supervision. A technology transfer agreement was made with the YGN-3&4 project contracts, and technical documents and computer programs were transferred from ABB-CE and GE. In keeping with the agreement, on-the-job training and on-the-job participation, consulting, mock-up tests for critical operation and facility improvement were performed.

Phase III was the period of technology improvement, UCN - 3&4 components were manufactured by Korean entities and technology previously transferred was utilized and improved.

In Phase IV, the period of standardization and technology enhancement, the YGN - 5&6 project was implemented and component manufacture expanded. Standardization and the development of advanced technology are the main targets in this period.

## **2.5. Nuclear fuel design & manufacturing [6]**

To achieve self-reliance in nuclear fuel design and manufacturing, reload core was the first to be localized. KAERI imported design technology for reload core from Siemens-KWU and reload design was done jointly for eight Westinghouse type reactors.

For the initial core design, technology was transferred from ABB-CE along with the YGN - 3&4 project execution. According to the technology transfer agreement, technical data and computer codes were transferred and classroom training was delivered. During the execution of the YGN - 3&4 project, joint design with ABB-CE was fulfilled as a vehicle for technology transfer. Although preliminary design was done jointly with ABB-CE, final design was independently performed by KAERI and approved by ABB-CE. For the follow-on projects (UCN - 3&4 and YGN - 5&6) initial core designs were done by Korean engineers.

For fuel manufacturing, technology has been transferred from both Siemens-KWU and ABB-CE. Technical supervision has been provided for construction and operation of the factory.

## **2.6. Architect/engineering [7]**

The technology self-reliance program for A/E was in three phases: import, localization and self-reliance consolidation.

During the first phase, related technology was imported from companies with previous experience in nuclear power projects. Bechtel provided engineering services for Kori - 3&4 and YGN - 1&2. French companies such as EDF, Framatome and Alsthom provided services for UCN - 1&2, and Canadian companies such as AECL and CANATOM provided services for Wolsong - 2,3&4. KOPEC participated as a subcontractor with foreign prime A/E contractors.

The YGN - 3&4 project was also the vehicle for self-reliance for KOPEC. KOPEC signed a technology transfer contract with S/L and technical information, including documents and computer programs were transferred. For the architect engineering of YGN - 3&4, S/L was responsible for initial design while KOPEC was responsible for final design. To add to technical abilities, KOPEC utilized consultation for technology transfer.

During Phase III, KOPEC attempted to consolidate self-reliance through utilization and improvement of the transferred technology. Projects for the Korean Standard Nuclear Power Plants such as UCN - 3&4, YGN - 5&6 and UCN - 5&6 were executed with gradual design improvement.

## **3. NPP STANDARDIZATION**

### **3.1. Plan**

The standardization of nuclear power plants in Korea was implemented in four phases beginning April 1983. The preliminary concept was formulated during the first phase from April 1983 to July 1985.

During phase II, from September 1985 to August 1987, standardization was developed by review of construction and operating experience, technology development, and identification of items for design improvement.

Since the YGN - 3&4 project was executed with technology transfer, it was used as the reference plant of the Korean Standard Nuclear Power Plant (KSNP). In this third phase, from February 1989 to April 1991, KSNP was developed referencing YGN - 3&4 and incorporating selected advanced design features.

Phase IV has been the period of constructing Korean Standard Nuclear Power Plants with UCN - 3&4 the leading plant. More units including YGN - 5&6 and UCN - 5&6 are under construction and will be completed by 2005. During Phase IV, gradual design improvements have been pursued.

### **3.2. Design approach [8]**

To design the Korean Standard Nuclear Power Plant, four major factors are considered: enhanced safety, improved performance, use of proven technology, and severe accidents. Nuclear safety is a major concern and to secure it, advanced design features have been incorporated in the standard design. Improved performance is achieved through modularization of components and equipment and through standardized, gradually improved design and construction processes. Proven technology is required for licensing the standard plant, and for that, proven design and analysis methods, systems, components and structures are used.

Severe accidents are examined as a separate category for an additional safety margin beyond design basis accidents. To do so, post-Three Mile Island (TMI) action items, unresolved safety issues (USI) and generic safety issues (GSI) are selectively resolved and design features related to severe accident prevention and mitigation are incorporated.

### **3.3. Development approach [4]**

Gradual improvement is key to the design of the Korean Standard Nuclear Power Plant. YGN - 3&4 (that is, a scaled down version of the System 80 plant of ABB-CE) was selected as the reference plant for the KSNP and improved with selected advanced design features. Electric Power Research Institute (EPRI) utility design requirements for Advanced Light Water Reactor (ALWR) and previous experience in construction and operation were considered in the development of the KSNP.

The first units of the Korean Standard Nuclear Power Plant are UCN - 3&4 and follow-on units such as YGN - 5&6 and UCN - 5&6 are under construction as a series of KSNP 1000 MWe class. Though the KSNP will be constructed repetitively, design will be gradually improved through R&D.

## **4. TECHNOLOGY EXPORT EXPERIENCE**

### **4.1. Technical assistance and consultation**

In 1993, KEPCO signed a three year technical assistance contract with Guangdong Nuclear Power Plant (PWR, 900MWe x 2units) in China. To implement this contract, engineers from KEPCO, KOPEC and the Korea Power Plant Service Co., Ltd. (KEPOS) were dispatched to Daya Bay Nuclear Power Plant to share experiences from operation and maintenance of the plants in Korea. In addition, Chinese staff were stationed at Ulchin Power Plant in Korea and trained in operation and maintenance [9].

In 1995, KAERI was awarded a consulting services contract from the Turkish Electricity Generation and Transmission Corporation (TEAS) to support the introduction of the first nuclear power plant to Turkey. KAERI's scope of work was as follows:

- Comparison of commercial reactor types and designs accepted internationally for applicability in Turkey, and recommendations for nuclear energy planning,
- Preparation of new Bid Specifications through revision and update, and
- Review of Bids, and support of TEAS in Bid evaluations and contract negotiations.

In 1996, KEPCO provided the Qinshan Nuclear Power Corporation with consulting services for the Qinshan Phase III project. KEPCO's was to review the draft contract for the

supply of CANDU plant, to support the Qinshan Nuclear Power Company Ltd. in bid evaluation and contract negotiation, and to provide technical consultation based on experience from construction and operation of Wolsong - 1 Nuclear Power Plant.

#### **4.2. Export of nuclear equipment**

Experience from the Wolsong CANDU project allowed Korea's first export of nuclear equipment through a contract between AECL and HANJUNG in early 1997 for the supply of steam generators, pressurizers and heat exchangers for Qinshan Phase III project (PHWR, 700 MWe x 2 units) in China.[10] For the Qinshan Phase III project, HANJUNG is to supply 19 items of NSSS equipment, while 55 items are supplied by HANJUNG for Wolsong 3&4 project. [11]

### **5. CONCLUSIONS**

Self-reliance in nuclear power technology in the Republic of Korea was achieved through well-developed policy and proper implementation. Considering the Korean experience, it may be concluded that the key factors are:

- Establishment of a long-term national plan to achieve self-reliance in nuclear power technology,
- Award of nuclear plant construction contracts with separate agreements stipulating specific avenues for technology transfer, and
- Establishment of a nuclear power plant standardization plan.

It is recommended that developing countries conduct joint work after, or in parallel with, training and transfer of technical information and computer codes through a separate technology transfer agreement.

As the technical capabilities of domestic industries grow through technology transfer and joint work, self-study (design repetition and mock-up design) and R&D should follow to implant and improve the transferred technology. Where a number of nuclear power plants are constructed in series within the framework of a long-term national power development plan, nuclear power plant standardization can definitely facilitate self-reliance in the technology.

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