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Byong Whi LEE and Kyu Nam CHAE*
Department of Nuclear Engineering, Korea Advanced Institute of Science and Technology, Taejon 305-701, Republic of Korea, bwlee@kaist.ac.kr, Fax. +82-2-544-0479 and *Nuclear Power Industry Division, Ministry of Commerce, Industry, and Energy, Republic of Korea

Nuclear Energy Technology Innovation and Restructuring Electric Power Industry for Sustainable Development in Korea in 21st Century - Issues and Strategies

ABSTRACT

After TMI and Chernobyl accidents, concerns on nuclear safety and radiation health risk from radioactive wastes become the target issues for anti-nuclear. Nevertheless, nuclear power is a substantial contributor to the world electricity production, supplying more than 16% of global electricity.

The objectives of Korean nuclear energy technology innovation are to improve safety, economic competitiveness, energy security and the effectiveness of radioactive waste management in harmony with environment. Meeting such objectives, public concerns on safety and health risks would be cleared. Innovative nuclear energy system will certainly enhance socio-political acceptance and enable wider application of nuclear energy for sustainable development in Korea in the 21st Century.

In parallel to such technology innovations, the effective first phase restructuring of electric power industry is in progress to enhance management efficiency and customer services. The power generation division of the former state-run utility, Korea Electric Power Corporation (KEPCO) was separated and divided into six companies - five thermal power and one hydro and nuclear power generation companies - in last April. After the reorganization of KEPCO and the break-up of monopoly, the new electric power industry will be driven by market force.

1. Introduction

Nuclear Power is a substantial contributor to world electricity production, supplying 2,500 TWh in 1999, more than 16% of total world electricity production. In view of large increase in energy requirements and the limitation of oil and gas supply for the 21st Century, the issue is how to maintain the stable supply of increasing energy electricity demand in harmony with the environment for sustainable development.

Kyoto Protocol implies that the future energy mix would likely to depend upon non-carbon energy such as nuclear, hydro, and hydrogen energy. Except for such energy base, no other at the present is likely to meet the expected large electric power and transportation demand, and satisfy the greenhouse gas concerns and economic viability at the same time. With the growing international consensus on the harmful health and environmental impact of fossil energy use, there is recognition on the potential role of nuclear energy in delivering large amount of energy without emitting environmental pollutants and greenhouse gases. With its remarkably low fuel requirement, nuclear energy can contribute to meeting the national and global goals for sustainable development.

As a result of the rapid economic growth and industrialization since 1970 in Korea, the annual electricity consumption per capita reached about 5,000 kWh level. But, this amount is only about 2/3 times that of Japan and 2/5 times that of U.S.A. Thus, the electricity demand is likely to grow continuously in this century. Korea's economic growth has to be supported by the imported energy. About 98% of energy was imported in 2000 while only 48% in 1970. Therefore, current high oil price will bring a large negative impact on Korean economy. Fossil fuels contributed 88% of energy consumption and induced to 140 million ton-C of CO2 emission, which account for 1.8% of world greenhouse gas emission in 1997.

Korean nuclear power program has been vigorously sought to overcome the weakness of not having enough indigenous energy sources. Currently Korea has 16 nuclear power units of 13.7 GW in operation, 4 Korea Standard Nuclear Power Plants (KSNP) under construction, and six units in planning stage.

Status	Nuclear Power Plants	Capacity	Reactor Type
In Operation	Gori 1,2,3,4	587, 650, 950 x 2	WH PWR
(16 units, 13,716 MW)	Wolsung 1,2,3,4	679, 700 x 3	AECL PHWR (CANDU)
	Younggwang 1,2,3,4	950 x 2, 1,000 x 2	WH PWR(1,2), CE PWR(3,4)
	Uljin 1,2,3,4	950 x 2, 1,000 x 2	Framatome PWR(1,2), KSNP(3,4)
Under Construction	Younggwang 5,6	1,000 x 2	KSNP
(4 units, 4,000 MW)	Uljin 5,6	1,000 x 2	KSNP
Plan Fixed	Shin-Gori 1,2,3,4	1,000 x 2, 1,400 x 2	KSNP(1,2), APR-1400(3,4)
(6 units, 6,800 MW)	Shin-Wolsung 1,2	1,000 x 2	KSNP
Planned	New PWRs	1,400 x 2	APR-1400
(2 units, 2,800 MW)			

Table 1. The Status of Korean Nuclear Power Program
* WH : Westinghouse, AECL : Atomic Energy of Canada, Limited, CE : Combustion Engineering

In the R&D side, Advanced Power Reactor 1400 (APR-1400) and System-integrated Modular Advanced Reactor (SMART) are under development as near-term reactor options. Also, 'Direct Use of PWR fuel In CANDU (DUPIC)' fuel is under development as a fuel cycle option. The Extended High Burn-UP Fuel is continuously commercialized to improve availability and economics of operating nuclear power plant. Korea Advanced Liquid Metal Reactor (KALIMER) for power generation and Hybrid Power Extraction Reactor (HYPER) are under development as mid and long term reactor options to cope with the limitation of nuclear fuel resource.

In parallel to Nuclear Energy Technology Innovations, Korea is heading for the deregulation of its electricity market. The power generation division of KEPCO, the nation's sole utility company, has been separated into six subsidiary companies. These subsidiary companies except nuclear power are to be privatized. All these efforts will bear fruits in the competitiveness and socio-political acceptance of the nuclear energy and its industry.

2. Nuclear Energy Technology Innovation

2.1 Reactor Technology Innovation

APR-1400 is the evolutionary next generation reactor with some advanced passive safety design features based on System 80+ of Combustion Engineering and the development experience of Korean Standard Nuclear Power Plants (KSNP). The target date for commercial operation of the first APR-1400 is set around 2010. This is the 1,400 MW advanced PWR unit with 60 year of design life, 25% improvement in economics and 10 times improvement in safety compared with KSNPs. APR-1400 will have severe accident mitigation features and an improved control room design with digital I&C and human factor engineering suitable to Korean operator.

APR-1400 project is in its final stage of development with the aim to get a standard design certification from the Korean regulatory body by early next year. The basic design is in accordance with Korea Utility Requirement Document which is equivalent to EPRI URD Rev.7 and European Utility Requirement. Thus, the performance of APR 1400 will be equal to EPR and System 80+. In order to reduce capital investment and improve availability, it is based on twin unit design with many common facilities and fueled with 24 month cycle extended high burn-up fuel for central base load mode of operation.

Another reactor under development is SMART. This is for co-generation, desalination, district heating or industrial process heat supply. The conceptual development program of SMART was launched in 1996. The reactor aims to produce 40,000 m3/day of potable water and generate 90 MW of electricity by 330MW rated thermal power. The conceptual design was completed in March 1999. It is designed for 60 year life, a single or modified one and half batch 36 month fuel cycle, plant availability of better than 90%, and less than one automatic scram per year

Its preliminary safety analysis shows that the SMART would be properly responding to design accidents by meeting the safety criteria. The design combines firmly established commercial reactor design technology with new advanced technology. The new and advanced features provide significant enhancement in safety through innovative design, inherent safety characteristics, and passive engineered safety systems. Features such as system simplification, bulk quantity reduction, component modularization, shop fabrication, reduction of construction time, and provision of an integrated construction plan and procedure enhance the economy as well as reliability and may overcome the economy of scale by the adoption of component mass production system. For the SMART integrated nuclear desalination plant, a preliminary economic evaluation was carried out using the IAEA Desalination Economic Evaluation Program. The results was that the cost of seawater desalination with SMART is either comparable to or more economical than that with fossil fuel plants.

2.2 Fuel Technology Innovation

The next generation fuel, DUPIC has been developed from the last decade. As the spent PWR fuel of 35,000 MWD/MTU discharge burn-up has about 1% of U-235 and 0.5% of Pu-239 fissile content, it can be directly reused in heavy water reactors which are designed for natural uranium fuel. The concept of the DUPIC fuel cycle is to directly re-fabricate

spent PWR fuel materials for heavy water reactor fuels by thermo-mechanical process. Therefore, there are no separation process of uranium and plutonium from spent PWR fuel during entire DUPIC fuel cycle. The DUPIC fuel cycle has advantages of the proliferation resistance and the reduction of high-level radioactive compared with other fuel cycles. At the present, Korea research team has successfully fabricated DUPIC fuel to evaluate the performance of the fuel through irradiation. Initial assessments show that DUPIC cycle will be simpler and cheaper than the conventional reprocessing fuel cycle.

There are a large and growing stockpile of spent LWR fuel around the world. About double the thermal energy can be extracted from spent fuel by recycling in CANDU, compared to recycling in a LWR. The many recycle options in CANDU enable a country to optimize its fuel cycle according to its own conditions, constraints and priorities. Because of high neutron economy, it is not necessary to even remove the fission products, although removing the rare earth, neutron absorbing fission products will increase the burn-up, and improve the economics of recycling.

If all the spent PWR fuels accumulated in Korea were used as DUPIC fuels, this would provide about 50 reactor-years of fuel for one CANDU-6 reactor. This would enhance energy security by utilizing and indigenous energy resource (spent PWR fuels) that otherwise be considered a waste. An additional benefit of the DUPIC fuel cycle is a significant reduction in disposal costs by eliminating decay heat sources such as cesium. The decay heat of the DUPIC spent fuel is about the same as the decay heat of the CANDU fuel. The DUPIC fuel cycle exploit the synergism between PWR and CANDU reactors. After successful irradiation tests for the performance evaluation of DUPIC fuels, the commercial viability depend on many socio-political variants.

3. Electric Power Industry Restructuring in Korea

For the past 40 years, the electric power industry of Korea has been monopolized by the state-run company, Korea Electric Power Corporation (KEPCO). This system had the merits of economy of scale and in the financial aspect and it has satisfied electricity supply and demand requirements effectively. However, with recent advancements in power plant operation and information-communication technology, small-scale high-efficiency power generation facilities have been developed to make an electricity market deal system possible. This has led to the worldwide trend of electric power industry privatization and introduction of competition. Reflecting this environmental change, Korean government decided to introduce the concept of competition to the electricity sector to increase efficiency and transparency, attracting private sector's interest. After many stages of review and consultation, the basic plan for the restructuring of Korea's electricity supply industry was finalized in January 1999.

As a follow-up to the Special Law on Expedition of Electricity Industry Restructuring, an action was taken to revise the Electricity Business Law, which was passed by the National Assembly in December 2000. This law calls for a full-scale reorganization of the electricity industry and lays the foundation for the establishment of an electricity exchange agency which will operate the market, and an electricity committee which will function as a market watchdog and consumer protection agency. In accordance with the enactment of related laws, the action plan for the first stage reorganization of the electric power industry was finalized in February 2001. Under this plan, the power generation division of KEPCO was divided into six separate companies - five thermal power companies and one nuclear power company - in April 2001. At the same time, the electricity exchange agency and the electricity committee were established to ensure true competition. Privatization of the generating companies, excluding the nuclear power company, will be translated gradually into action from 2002.

Along with the privatization in the power generation sector, an wholesale competition system will begin operating in 2003 when the distribution sector of KEPCO will be separated and divided into several regional distribution companies. The privatization of the distribution companies will be completed and retail competition will be introduced by 2009, when the restructuring of Korea's electricity power sector is to be completed. After the complete market reorganization and the break-up of the KEPCO monopoly, electricity prices will be decided by market.

Phase	Title	Period	Actions
I	Preparation	1999 - 2000	Announcement of the basic plan for restructuring the electricity industry Amendment of related laws and regulations
II	Power Generation Competition	2001 - 2002	Establishment of power generation subsidiaries Establishment of an independent regulatory body Dividing the distribution sector from KEPCO
III	Wholesale Competition	2003 - 2008	Commencement of wholesale competition Selling off power generation subsidiaries
IV	Retail Competition	2009 -	Commencement of retail competition Elimination of regional monopolies in the distribution sector

Table 2. Korean Electricity Sector Restructuring Plan

Through the restructuring, it is estimated that the electricity rates will be decreased by introducing competition in management planning, budgeting, operation of manpower and marketing. According to the estimation of an analysis, an 11% reduction in electricity rates is expected by 2009. It is also anticipated that the level of service to the customers will generally be improved by diversification of customer choice. The restructuring will foster a power industry with efficient

resource allocation based on the market mechanism, rationalization of management and promotion of customer benefits. The financial structure of overall electric power sector will be strengthened by the introduction of private capital and efficiency enhancement.

4. Concluding Remarks

The 20th century was an era of mass production, mass consumption, and mass waste disposal based on fossil fuel energy. As a consequence, the drastic environmental degradation and rapid exhaustion of the precious fossil fuel resource are in progress globally. In order to remedy the situation and meet the multitude of challenges ahead of us, the 21st century will be the age of energy technology innovation, energy conservation, higher efficiency, and recycling - no harmful waste discharge to the clean environment. To meet such challenges and requirements, the most promising option at this moment is the nuclear energy technology innovation. Given the current energy situation in Korea, nuclear energy is a vital and viable alternative to fossil thermal power generation. In the long-term, nuclear powered hydrogen production would also improve Korean energy security and CO2 emission reduction requirement for sustainable development.

For the utility, the economics competitiveness of energy system would be the vital factor for best energy mix choice. For the country, the energy security improvement would be the foremost factor for national sustainable development. APR-1400 and SMART as well as currently operating PWRs and CANDUs, in combination with DUPIC fuel cycle would be able to meet the vital requirements for the sustainable development. The concerted efforts should be made for continued improvement of nuclear safety and economic competitiveness of nuclear energy technology through active incorporation of cutting-edge technologies.

The rapid changes in management innovation, such as the introduction of competition into the electric power industry and growing commitments to the global environment protection, offer new challenges and opportunities to nuclear energy. Clear environmental benefits and national energy security improvement by nuclear energy utilization will help realize a renaissance of nuclear industry in the 21st century. Since the capability and resources of any single country are very much limited, in order to meet the multitude of challenges ahead of us on nuclear energy for sustainable development in the 21st century, an essential ingredient for the 'Nuclear Renaissance' is the viable international cooperation to regain the public confidence on nuclear energy.

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