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The Effects of Standardization for the Nuclear Power Plants in Korea

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ABSTRACT

This paper highlights the economic effects of nuclear power plants standardization in Korea. The major effects of nuclear power plants standardization appear in the reduction of time-related costs. By using this major economic effects of standardization, an optimal plant mix of electric power until the year 2005 is suggested by means of WASP computer model. And the effects between the standardized case and the non-standardized case is compared.

1. Introduction

Since Korea performed a series of successful five-year Economic Development Plans beginning in the early of 1960s', dramatic economic growth and the following improvement of well-being have been accompanied by an increase of demand for electricity.

In Korea, nuclear power has been considered as a vital energy source to meet the increasing electricity demand. Ever since Korea's first nuclear power plant(NPP), the Kori 1, went into its commercial operation in 1978, nine units have been in operations and two other PWR units

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under construction now. Moreover, the nuclear energy as well as the fossil fuel energy is expected to be a main energy source for next generation.

However, the ralative advantage of nuclear power plants is diminishing recently, because of their long construction periods and increase of financial costs accrued to those periods. The reinforcement of safety regulations and the problem of public acceptance make it difficult for the nuclear power plants to remain as a major energy source. On account of the scarcity of natural resources in Korea, the success of efficient management of nuclear power plants appears critical to the nation's economy.

Therefore, in Korea as well as in any other countries, to maintain the relative advantage and to enhance the safety of nuclear power plants, standardization of nuclear power plants seems essential to the success of adequate supply of electric power.

But the lack of experiences in standardization and insufficient data on the effects of standardization make it difficult to estimate the exact effects of standardization. Considering these difficulties, we try to estimate the standardization effects in Korea by adopting the foreign experiences of standardization procedures.

The two stages of analysis are performed in this parper. The first stage in this paper shows the amount of reduction in total construction costs due to adopting standardization. This analysis is purposed to see the standardization effects of forthcoming nuclear power plant and the results are used as an input to the second stage of analysis. In the second stage, an optimal plant mix for Korea is suggested as a guideline until the year 2005 through WASP. Computer model this guideline is hoped to be useful to desicion-making of the long-term electric system expansion planning.

2. The Standardization of NPP in Korea

2.1 Status of Standardization

In Korea, the first three nuclear power plants, Kori 1, Kori 2, and Wolsung 1 were constructed under a form of turnkey contract, mainly due to the lack of the nuclear power technology. With some experiences cumulated in the course of the first phase of nuclear power projects, the Younggwang 1, 2 were constructed under the framework of non-turnkey contract for the purpose of self-reliance of nuclear technology. As a result, our technology went as far as to level of self-construction of nuclear power plant except a few core parts. By virtue of their successful experience in indigenous developments, Younggwang 3, 4 units are under construction which is performed by domestic main contractors, while foreign suppliers are participating as subcontractors.

The self-reliance of nuclear power technology policies initiated by the government in 1978 claimed that new nuclear power plant to be constructed in the future should be carried out only with the domestic contractors. Accordingly, the government set the plan of nuclear power technology self-reliance program for the construction of nuclear power plant and have managed it efficiently through the division of responsibilities in nuclear power development as shown in table 1.

Table I. Division of Responsibilities in Nuclear Power Development in Korea

Role \ Organization	KEPCO	KAERI	KHIC	KOPEC	KEPOS	KNFC
Project Management	0					
NSSS −System Design −Component Design & Manufacturing		0	0			
T/G			0			
BOP −System Design −Component Design			 0	0		
Repair & Maintenance					0	
PWR Fuel −Design −Fabrication		0				 0
CANDU Fuel		0				

(Note) KEPCO : Korea Electric Power Corporation
KAERI : Korea Advanced Energy Research Institute
KHIC : Korea Heavy Industries & Construction Co., Ltd.
KOPEC : Korea Power Engineering Co.
KEPOS : Korea Electric Power Operations & Services Co.
KNFC : Korea Nuclear Fuel Co.

In standardization of nuclear power plants, Younggwang 3, 4 units is the reference plant and Uljin 3, 4 units is the first standardized plant. The nuclear power plant standardization program requires a lot of manpower and funds over a long period. Therefore, it is neccessary to establish an elaborated schedule reflecting foreign experiences and country's economic and technological situation. The stages of standardization program can be classified as shown in table 2.

Table 2. Standardization Schedule

Stages	Periods	Main Contents
First Stage(Establishment of Basic Concepts)	'83. 4–'84. 3.	○ Front–End Tasks Studies ○ Research on Concept of Design
	'84. 7–'85. 7.	○ Survey of Basic Design ○ Establishment of Evaluation Method for Safety and Reliability
Second Stage(Research on Improvement in Design)	'85. 9–'87. 8.	○ Examination of Domestic and Foreign Nuclear Power Plant Design ○ Comparison and Study of Foreign Standardized Plants ○ Study of Items for Improving Design ○ Research on Optimal Size and Layout
Third Stage(Documentation of KSRED and KSSAR)	'89. 1–'90. 11.	○ Documentation of Korea Standard Requirement Document (KSRED) ○ Documentation of Korea Standard Safety Analysis Report (KSSAR)
Fourth Stage(Basic and Detailed Design)	'90. 1–'92. 12	○ Standardization of Uljin 3, 4 units will be completed through capabilities obtained in design.

2.2 Standardization Effects Analysis

A major undertaking in this section was to compute the effects of standardization on the "overnight" and "time-related" components of total cost.

– Construction Period :

In Japan and France, there is a clear evidence that construction period was drastically decreased by introducing the standardized NPPs. Because Korea has not had enough experiences in the NPPs standardization, we referred to the cases of France and Japan which have been successfully carried out. Thus, the reduction of construction period was estimated by using these country's data in this study.

In France, its government and a single electric utility have taken the initiatives to accomplish PWR standardization programs. This situation is similar to that of Korea. With respect to the case of Japan, reduction rate is estimated by using the experiences of Fukusima II series. These two reduction rates of France and Japan were calculated to 9.7% and 29.5% respectively.

These two rates were respectively applied to estimate the time-related cost savings due to the shortening of construction period in Korea.

−Overnight Costs :

The reduction rates of overnight costs used in this analysis were based on the rates that were given in AIF(American Atomic Industry Forum) Report. The report shows that when NPPs are standardized, there are two possible limits, upper and low, of the reduction rates of overnight costs. The detailed reduction rates are as follows.

	Cost Items	Reduction Rates	
		Low	Upper
Estimated Reduction Rates	Design and Management Services	66%	72%
	Permanent Equipment and Material	5%	10%
	Construction Overhead	12%	20%
	Owner's Costs	3%	5%

2.2.1 Input Data

The real discount rate is assumed to be 8% per year. At present, the Korean government recommends that this value be used for the economic evaluation of projects. Because Korea has no escalation indices in nucler power plants, we assumed that the real escalation is zero. In addition to that, overnight costs and time-related costs have been converted into constant price of Dec. 1988. All costs are expressed in terms of national currency "won".

In this study the economic effects of standardization were estimated by using the costs of Younggwang 3,4 units.

Overnight costs could be broken down into four cost items as shown in table 2 and this paper analyzed the cost savings by each cost item. Table 3 shows the original cost data of Younggwang 3,4 units exclusive of standardization effects.

The reduction rates of construction costs and periods have been already presented in section 2.2.1. The overnight cost of standardized plant were calculated from the original data using above reduction rates (See table 4).

Table 3. Original cost data of Younggwang 3,4 units

(unit : million won/kw)

Cost Item	Input Values
Design and Management Services	317,975 (15%)
Permanent Equipment and Material	1,142,283 (52%)
Construction and Construction Overhea	339,190 (16%)
Owner's Costs	362,478 (17%)
Total Overnight Costs	2,161,926 (100%)

Table 4. Overnight Costs of Standardized Plant

(units : million won/kw)

Construction Costs	Upper Limit	Low Limit
Design and Management Services	89,033 (5%)	108,112 (6%)
Permanent Equipment and Material	1,028,055 (59%)	1,085,169 (59%)
Construction Overhead	271,352 (16%)	298,487 (16%)
Owner's Costs	344,354 (20%)	351,604 (19%)
Total Overnight Costs	1,732,794 (100%)	1,843,371 (100%)

Construction periods (*)	
–Referring to the experiences in France (decrease by 9.73%)	: 68 months
–Referring to the construction periods of Fukusima II series in Japan (decrease by 29.51%)	: 53 months

Notes (*) : 68 months = 75 months x (1 − 0.0973)
53 months = 75 months x (1 − 0.2951)
Where 75 months is the construction period of Y.G 3,4 units.

2.2.2 Results

This analysis employs two case studies and examines the standardization effects in Korea by using the reduction rates obtained in section 2.2.1.

2.2.2.1 Case A

In the following analysis, the lead time data obtained in the experiences of Japan's NPPs construction are applied. Therefore, we assumed that construction period of a typical standardized NPP is 53 months in Case A. This construction period is used to calculate the reduction of time-related costs and table 4 shows the payment schedule applied to the calculation.

Table 4 Payment Schedule (Case A)

(unit : percent)

Year	Design and Mgt. Service	Equipment and Material	Construction Overhead	Owner's Costs
1	21.4	8.9	3.5	3.5
2	22.5	19.0	8.2	8.2
3	28.9	30.2	32.8	32.8
4	17.2	26.9	37.5	37.5
5	10.0	15.0	18.0	18.0

Table 5 summarizes the final impacts of standardization on the total capital costs of a standardized nuclear plant. The impacts of cost savings are calculated separately for both upper and low limit.

Table 5. Cost savings due to standardization

(unit : 1,000won/kWe)

Components of Costs	Original Costs of YG 3,4 Units	Standardization cost savings		Standardized Plant Costs	
		Upper	Low	Upper	Low
Design and Mgt. Service	169	122	111	47	58
Equipment and Material	608	61	31	547	577
Construction Overhead	180	36	21	144	159
Owner's Costs	193	9	6	184	187
Total Overnight Costs	1,150	228	169	922	981
Time-Related Costs(IDC)	366	234	226	132	140
Total Capital Costs	1,516	462	395	1,054	1,121

The impact of standardization on time-related costs (IDC) is even more dramatic. The most significant factor of the reduction of costs is the shortening of construction period. Time-related costs decreased by 63.9% and 61.7%, respectively, in upper and low. When these savings are combined with those savings of overnight costs, and the total capital costs are diminished by 30.5% and 26.1%, respectively. Figure 1 shows table 5 by a graph. It shows the percentage reduction of overnight cost in each case of upper and low limit, that is, when the original overnight cost of Y.G 3,4 is 100%, the cost is reduced to 80% and 85%, respectively, after standardization. It also shows the proportion of IDC before and after standardization.

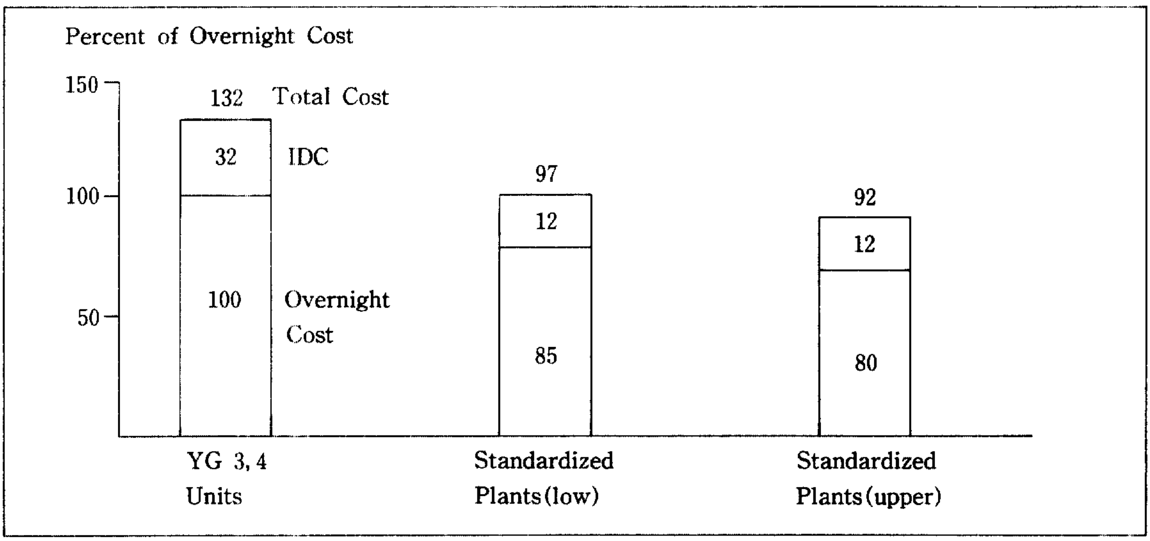

Figure 1. Proportion of Overnight cost and IDC

2.2.2.2 Case B

In the following analysis, the lead time data obtained in the experience of French NPPs construction are applied. In this case, the construction period of a typical NPP in Korea is assumed to be 68 months in Case B. All other procedures are the same as Case A. Table 6 shows the payment schedule applied to Case B.

Table 6. Payment Schedule(Case B)

(unit : percent)

Year	Design and Mgt. Service	Equipment and Material	Construction Overhead	Owner's Costs
1	20.0	8.0	3.0	3.0
2	21.0	17.0	7.0	7.0
3	27.0	27.0	28.0	28.0
4	16.0	24.9	32.0	32.0
5	10.0	15.0	18.0	18.0
6	6.0	9.0	12.0	12.0

Table 7 shows the impacts of standardization on the total capital costs of a standardized nuclear plants.

Table 7. Cost savings due to standardization

(unit : 1,000won/kWe)

Nuclear Plant Components of Costs	Original Costs of YG 3,4 Units	Satandardization cost savings		Standardized Plant Costs	
		Upper	Low	Upper	Low
Design and Mgt. Service	169	122	111	47	58
Equipment and Material	608	61	31	547	577
Construction Overhead	180	36	21	144	159
Owner's Costs	193	10	6	183	187
Total Over-night Costs	1,150	228	169	922	981
Time-Related Costs(IDC)	366	174	161	192	205
Total Capital Costs	1,516	402	330	1,114	1,186

Results are very similiar to those of Case A. Most of the cost savings can be obtained in the time-related costs.

The impact on time-related costs (IDC) is even more dramatic. The most significant factor is also the shortening of construction period like Case A. Time-related costs decreased by 47.5% and 43.9%, respectively, in upper and low. When these savings are combined with the savings of overnight costs, and the total capital costs are diminished by 26.5% and 21.7%, respectively.

Figure 2 also shows table 7 by a graph. The interpretation is exactly the same as figure 1. Overall, in Case B, overnight cost is the same as in Case A. The only difference is the cost reduction of time related cost. Because the shortening effect of construction period in Case A is larger than in Case B, the time related cost in Case A is reduced more than in Case B.

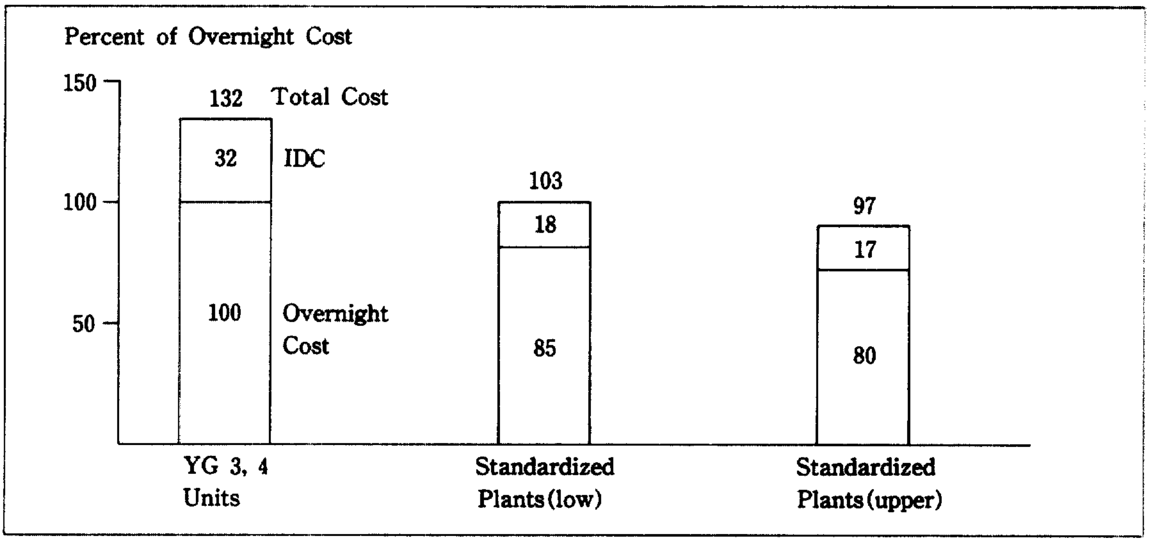

Figure 2. Proportion of Overnight cost and IDC

3. Electric System Expansion Planning by WASP Program

3.1 Overview

In Korea, the results of WASP have played an important role in establishing the long term electric system expansion planning (ESEP). The optimal solution of WASP program has been closely related to the decision of the long-term ESEP and it is greatly influenced by such input data as construction cost, fuel cost, and technical characteristics. Therefore, it seems meaningful to examine if there is any change in an optimal plant mix in the future when the cost savings of NPPs construction through standardization are taken into account.

However, because this paper did not fully include all the effects of NPPs standardization such as *O&M* costs and self-reliance of technology, it is true that this analysis is confined to measuring the degree of influences of reduced construction cost on WASP performance.

In this paper, emphasis is given to an generation plant mix mainly among NPPs and coal power plants(CPPs) which are, will be the major generating sources in Korea.

3.2 Basic assumption

Excluding the data on construction cost, most of the input data for WASP are ones recommended by the Korean government in 1989. Also, the NPPs configurations of WASP until the late of 1990s' are the fixed ones as confirmed by government last year. It was assumed that standardized NPPs would be able to commercially operate after the end of 1990s'.

3.2.1 Discount rate

Discount rate is used in the case of converting the future cost into the present cost or vice versa and is one of the most important factor in determining an optimal plant mix by WASP. In this paper, the annual rate of 8% in real term which is recently being used officially establishing the long term ESEP in Korea, is applied.

3.2.2 Construction costs

As shown in Section 2, the calculation of NPPs construction costs are based on the data of Y.G 3,4 units being under construction currently.

Table 8 shows the construction costs per kWe both in Case A and Case B. In table 8, construction costs per kWe is converted into US $ by applying the exchange rate as of Dec. 1988(684.1 won/US $).

Table 8. Data on the Construction Cost

<Case A> (Unit : constant dollar of Dec. 1988)

Type/Capacity	Unit	Scenario		
		Reference	Low limit	Upper limit
Coal/500MWe	US $/kWe	1,481	1,481	1,481
Nuclear/1,000MWe	US $/kWe	2,216	1,639	1,541

<Case B> (Unit : constant dollar of Dec. 1988)

Type/Capacity	Unit	Scenario		
		Reference	Low limit	Upper limit
Coal/500MWe	US $/kWe	1,481	1,481	1,481
Nuclear/1,000MWe	US $/kWe	2,216	1,734	1,628

3.3 WASP Results

3.3.1 CASE A

Table 9 summarizes the result of WASP in Case A. A lot of coal power plants is supposed to be added until the year 2005 unless the standardized NPPs are considered.

However, some of NPPs was substituted for coal power plants owing to the effects of NPP standardization. Consequently, in each case of low and upper limit, the total of thirteen and sixteen units of NPPs, including Y.G 3,4 and Uljin 3,4 units, are supposed to be introduced until the year 2005. On the other hand, the 500MW class coal power plants are expected to be decreased by seven and eleven units relative to reference case.

Table 9. WASP Result in Case A

(Unit : numbers of units)

Year	Reference	Low limit	Upper limit
	C500/C900/N1000	C500/C900/N1000	C500/C900/N1000(*)
1996	16 / 0 / 2	16 / 0 / 2	16 / 0 / 2
1997	3 / 0 / 0	3 / 0 / 0	3 / 0 / 0
1998	1 / 0 / 1	1 / 0 / 1	1 / 0 / 1
1999	3 / 0 / 1	3 / 0 / 1	3 / 0 / 1
2000	1 / 2 / 0	0 / 0 / 3	0 / 0 / 3
2001	1 / 2 / 0	0 / 0 / 2	0 / 0 / 2
2002	2 / 1 / 0	1 / 0 / 1	1 / 0 / 1
2003	0 / 3 / 0	0 / 3 / 0	0 / 3 / 0
2004	3 / 3 / 0	3 / 2 / 1	0 / 3 / 2
2005	5 / 2 / 0	1 / 2 / 2	0 / 0 / 4
Total	35 / 13 / 4	28 / 7 / 13	24 / 6 / 16

Note(*) : C500 and C900, and N1000 represent coal 500MWe and coal 900MWe, and Nuclear 1,000MWe types, respectively.

3.3.2 CASE B

Even if the effects of standardization of Case B are not as much as those of case A, it still remains great. According to the results, it is expected that, in both case of low and upper limit, the total of units of NPPa are supposed to be introduced into the electric system until the year 2005. On the other hand, 500MW class coal power plants are expected to be decreased by seven units relative to the reference case for both low and upper limit. The detailed results of Case B are as shown in table 10.

Table 10. WASP Result in Case B

(Unit : numbers of units)

Year	Reference	Low limit	Upper limit
	C500/C900/N1000	C500/C900/N1000	C500/C900/N1000(*)
1996	16 / 0 / 2	16 / 0 / 2	16 / 0 / 2
1997	3 / 0 / 0	3 / 0 / 0	3 / 0 / 0
1998	1 / 0 / 1	1 / 0 / 1	1 / 0 / 1
1999	3 / 0 / 1	3 / 0 / 1	3 / 0 / 1
2000	1 / 2 / 0	1 / 0 / 2	0 / 0 / 2
2001	1 / 2 / 0	1 / 0 / 2	0 / 0 / 3
2002	2 / 1 / 0	1 / 0 / 1	1 / 0 / 1
2003	0 / 3 / 0	0 / 3 / 0	0 / 3 / 0
2004	3 / 3 / 0	1 / 2 / 2	3 / 2 / 1
2005	5 / 2 / 0	1 / 2 / 2	1 / 2 / 2
Total	35 / 13 / 4	28 / 7 / 13	28 / 7 / 13

Note(*) : C500 and C900, and N1000 represent coal 500MWe and coal 900MWe, and Nuclear 1,000MWe types, respectively.

4. Conclusion

This paper estimated the effect of construction cost savings of NPPs resulting from the implementation of NPPs standardization. By using these estimates, the ESEP was performed to capture the NPP standardization effects on an optimal plant mix with a special emphasis on two major power sources, nuclear and coal, in Korea. Since Korea has little experience in NPPs standardization, it is hard to have enough data to rely on yet. This prevented us from finding out the precise effects of NPPs standardization on cost savings. In spite of this difficulty, this paper clearly demonstrates the significance of the economic effects caused by NPPs standardization on the electric system expansion plannings.

Finally, since the nuclear power occupies a great portion, about 50%, in power generation in Korea, any reduction of nuclear power generation costs has a direct effect to the cost of electric system. Therefore, standardization of NPPs is expected to greatly contribute to the improvement of the efficiency of whole electric system.