Perspectives on the North-east Asia System Interconnection
- From South Korea –

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I. INTRODUCTION

The South Korean power system is like an island after having been isolated from the North Korean network in 1945 and, thereafter, there has never been any effort to connect it to power systems of neighboring countries. Instead of that, all the efforts have been focused on developing generating resources and enhancing network in order to supply the power demand and to support the booming economy of the Republic of Korea during the last three decades. However, the Korean power industry has been confronted with many difficulties and will continue to be so in the future.

Among the many reasons why the industry has faced such difficulties, the most important are as follows. Firstly, South Korea is very poor in natural resources and must import 97.4% of the total primary energy domestically consumed. Secondly, South Korea is very much small mountainous country and 70% of its territory is covered with mountains. Furthermore, due to military and political tension between South and North Korea until recently, there were many limitations to developing generating resources and expanding network for supplying the heavy load in the northern part near Seoul.

In such a situation, the peak demand and the installed generating capacity in 2000 are 40.9 and 48.0 GW, respectively[1]. According to the recently revised long-term plan for power supply[2], the peak demand is expected to increase annually by 4.3% and reach 67.5 GW in the target year 2015.

The long-term plan has a 17-year time horizon from 1999 to 2015. By the target year at the end of this period, 34 generating units, 9.5 GW in total, are likely to be retired and thus 106 generating units, 45.2 GW in total, must be constructed in order to supply the forecast peak

[1] The peak demand appears at summer season and additional generating unit(s) can be committed from the summer season to the end of December. For example, the generating capacity at the end of year 2000 is 49.1[GW], larger than 48.0[GW] at the summer season.

[2] Ministry of Commerce, Industry and Energy, "The fifth long term plan for power supply", Jan. 2000

demand and replace the retired units. In the target year 2015, nuclear and thermal generating capacity will be 26.1 GW and 46.1 GW, respectively. These values are 33.0% and 58.2% of the projected total installed generating capacity of 79.1 GW[3]. Furthermore, many substations and transmission lines also must be constructed to adequately reinforce the network.

In order to implement this plan, about 55.5 billion US$ at the 1999 fixed price must be invested from 1999 to 2015. Such a huge amount might be another great burden in addition to many difficulties caused by shortage of natural resources, small and mountainous territory, political and military tension between South and North Korea, and so on.

One of best ways to overcome such difficulties in supplying the power demand seems to be cross-border system interconnection. System interconnection and, as a result, trade of electricity must be beneficial to all the participating countries, as has been proven in many regions. Interconnections between national systems have been carried out in North and South America, Europe, Africa and South-east Asia; that is, in most regions of the world except for North-east Asia. However, there have never been any official talks on the system interconnection in the North-east Asia including Russia, China, Japan, Mongolia, North and South Korea.

The reasons for this lack of official consideration of grid interconnection in North-east Asia are not clear but there might be many barriers. In this context, national perspectives from South Korea are described in this paper based on the present and future power supply situation in South Korea. In addition, what the barriers are and how to overcome them are discussed.

II. STATISTICS ON THE KOREAN POWER INDUSTRY

1. Power demand and generating capacity

The government must make a long term plan for power supply every two years[4]. According to this plan, decided published in January, 2000, the peak demand in 2000 was 40.9 GW. Peak demand is forecast to increase annually by 4.1% and reach 67.5 GW in the target year 2015, as shown in Table 1. In order to supply this peak demand, 106 generating plants, about 45.2 GW in total, must be constructed and 34 generating units, 9.5 GW in total, will be decommissioned. As a result, the installed generating capacity in the target year will be 78.5GW including a reserve capacity of 11GW. Here, 78.5 GW is the installed capacity in the summer-time when the peak demand occurs and different slightly from the capacity 79.1 GW

[3] The generating capacity at the beginning of year 1999 was 43.4 GW, so 43.4+45.2-9.5=79.1 GW.

[4] Ministry of Commerce, Industry and Energy, "The fifth long term plan for power supply", Jan. 2000

at the end of the target year.

Table 1. Peak demand and generating capacity (GW)
(Generating capacity in summer-time when the peak demand appears)

	'00	**'05**	**'10**	**'15**
Peak Demand	40.9	51.7	60.7	67.5
Generating Capacity	48.0	60.4	71.4	78.5
Reserve Capacity(%)	7.1 (17.4)	8.7 (16.8)	10.7 (17.6)	11.0 (16.2)

Considering that South Korea must import almost all the primary energy domestically consumed, the generation mix must be diversified so that the country will be better able to withstand an energy crisis such as an oil shock. The policy of diversification can be clearly shown in Table 2. In 2000, nuclear, thermal and hydraulic generating capacities accounted for 28.0%, 65.6% and 6.4% of the total generating capacity in South Korea, respectively. Because of the lack of hydraulic resources, Korea must be highly reliant on nuclear and thermal power. However, it should be noticed that the year 2000 thermal generating capacity, which is 65.6% of total capacity, is diversified into coal-fired (28.6% of total capacity), LNG-fired (27.1%) and oil-fired (9.9%) units. Furthermore, such a policy for generation mix, that is to diversify fuels for generation on generation mix seems to be adopted during next 15 years except that reliance on nuclear power will be increased from 28.0% in 2000 to 33.0% in 2015.

Table 2. Generation mix
(at the end of the target year)

	'00		**'05**		**'10**		**'15**	
	Capacity	***%***	**Capacity**	***%***	**Capacity**	***%***	**Capacity**	***%***
Nuclear	13.7	*28.0*	17.7	*28.8*	22.5	*30.2*	26.1	*33.0*
Coal-fired	14.0	*28.6*	18.1	*29.5*	20.6	*27.6*	21.2	*26.8*
LNG-fired	13.3	*27.1*	16.5	*26.7*	18.4	*24.6*	18.9	*23.8*
Oil-fired	4.9	*9.9*	4.9	*7.9*	6.8	*9.1*	6.0	*7.6*
Hydro	3.1	*6.4*	4.4	*7.1*	6.3	*8.5*	6.9	*8.8*
TOTAL	**49.0**	***100.0***	**61.6**	***100.0***	**74.6**	***100.0***	**79.1**	***100.0***

2. Consumption and production of electricity

As shown in Table 3, 224.2 billion kWh in total was consumed in 2000 in South Korea, which is equivalent to 4,740 kWh/person. The consumption of electrical energy between 2000 and 2015 is expected to increase at nearly the same rate as the peak demand, that is, at an average annual rate of 4.1%. The government forecasted that the electricity consumption per person in 2015 would be about 7,400 kWh. This is slightly higher than the 1997 Japanese consumption of 6,200 kWh per capita, but still considerably lower than the 12,434 kWh/capita consumed in

the U.S.A. in 1997[5].

Table 3. Electrical energy consumption (kWh)

		'00	'05	'10	'15
Korea	**Total (*10^9)**	224.2	294.7	343.2	381.8
	Per person	4,740	6,000	6,780	7,390
Japan		*6,273 kWh/person in 1997*			
U.S.A		*12,434 kWh/person in 1997*			

Table 4 shows that 250.6 TWh was generated in 2000: 40.4% from nuclear plants, 35.9% from coal-fired plants, 11.5% from LNG-fired plants and 10.4% from oil-fired generation facilities. As mentioned above in the context of the South Korean generation mix, production of electricity is also highly reliant on nuclear and thermal power plants. Table 4 shows that 98.3% of the gross total electricity produced in 2000 was generated by nuclear and thermal power plants.

Furthermore, the current high reliance on nuclear power plants is not likely to change during the next 15 years for two reasons: (1) a shortage of domestic hydraulic resources, and (2) a lack of intention to promote, market, and/or develop renewable energy. As of 2000, all the hydraulic resources available in South Korea have been nearly fully developed, and the total generating capacity is about 3.2 GW. During the next 15 years, only several small-sized hydraulic and pump-storage plants are planned for development. In such a situation, the government is planning to implement renewable energy with the total capacity of 40 MW, only 0.05% of the installed capacity in 2015, by the target year. As a result, the reliance on nuclear and thermal power plants must become higher rather than lower.

Table 4. Production of electricity (TWh)

	'00		'05		'10		'15	
	Prod.	***%***	**Prod.**	***%***	**Prod.**	***%***	**Prod.**	***%***
Nuclear	101.2	*40.4*	126.4	*38.4*	153.2	*39.9*	190.1	*44.5*
Coal-fired	90.0	*35.9*	124.4	*37.8*	144.1	*37.5*	149.0	*34.9*
LNG-fired	28.8	*11.5*	44.3	*13.5*	43.3	*11.3*	46.3	*10.8*
Oil-fired	26.2	*10.4*	28.3	*8.5*	31.7	*8.3*	30.7	*7.2*
Others[*1]	4.4	*1.7*	6.0	*1.8*	11.9	*3.1*	10.7	*2.5*
TOTAL	**250.6**	***100.0***	**329.5**	***100.0***	**384.2**	***100.0***	**426.8**	***100.0***

*1 : Hydro, Pumped storage, Wind power, Photovoltaic and so on

[5] Ministry of commerce, industry and energy, "Statistics on Power Industry", 2000.

3. Air pollution

According to an institute in South Korea[6], generating power plants emit 16.5% of the SO_x, 12.5% of the NO_x and 22.6% of the CO_2 produced in our country, as shown in Table 5. Considering that the Kyoto Protocol, signed by South Korea and most other nations, provides that the total emissions of greenhouse gases expected in 2010 or 2020 should be reduced by 20-40%, the reduction of emissions from generating units should be a key goal.

Table 5. Air pollution (tons)

	SO_x	**NO_x**	**Dust**	**CO_2**
Total "T"	1,320	1,230	430	103,820
Generation "G"	217	153	11	23,460
G/T * 100[%]	16.5	12.5	2.6	22.6

As shown in Tables 2 and 4, the proportion of the generation mix and of electricity production provided by thermal power plants will gradually become lower and lower. However, due to the shortage of hydraulic resources, there cannot be a great change in the reliance on the thermal power plants without constructing much more nuclear power plants. However, in addition to safety and environmental effects of nuclear power plants, there is a technical limit to increasing the total capacity of the nuclear power plants. In other words, nuclear power plants are used for supplying the base load and, therefore, their total capacity should be less than the base load.

The government planed to lower the reliance on thermal power plants, in the viewpoint of generation mix and production of electricity. Furthermore, the government has a plan to implement clean coal technology, 900 MW in total, by 2015[7]. In spite of this effort, more than 32% of the primary energy supplies in the ROK by 2015 are expected to be consumed in generating electricity, a slight increase from 2000 (31%), as shown in Table 6. In addition, emissions of CO_2 gas are not likely to be very much improved, with the emission rate falling only from 0.1185 kg-C/total kWh generated in 2000 to 0.1038 kg-C/kWh in 2015 for all kWh generated.

[6] Ministry of Commerce, Industry and Energy, "The fifth long term plan for power supply", Jan. 2000

[7] Ibid.

Table 6. Primary energy consumption

	'99	**'05**	**'10**	**'15**
Total "T"	181.3	235.7	275.0	307.1
Generation "E"	56.2	78.6	92.9	100.5
T/E * 100[%]	**31.0**	**33.3**	**33.8**	**32.7(?)**

4. Costs and siting

As previously mentioned, 70% of South Korea's territory is covered with mountains and, furthermore, the residents are reacting extremely negatively to the construction of power facilities near their owned houses and lands, the so-called "NIMBY" ("Not in my back yard") effect. Considering these points, there might be many difficulties in siting new generation units and transmission lines.

KEPCO needs to site 67 generating units, including 43 units now under construction, by 2010. Fortunately, 9 sites for 18 units have been already decided. However, they still have to find out 2 more sites for 6 units. Of course, there are likely to be additional difficulties in starting and finishing construction of generating plants even where the sites were already decided. In addition, it will become more and more difficult to site and construct new generating plants. However, there are very limited possibilities for alleviation of the difficulties in siting, and how to overcome these difficulties will be "homework" given to the privatized generating companies that will be spun off from KEPCO.

In addition to generating plants, the network company, called TRANCO or post-KEPCO, must construct many transmission lines and substations, including about 10,000 Circuit-km of transmission lines and 200 substations. Considering gradually increasing concerns about electrical environment and complaints about the destruction of natural scenery, the per-unit construction costs will of these facilities in South Korea are bound to increase.

The government estimated the construction costs needed for the next 15 years, based on the fixed price at 1999 and the discount rate of 8%. According to the 5th long term plan, the costs are about 38.2 billion US$ for generating plants including IPP's, plus investments totaling 17.3 billion US$ for transmission lines and substations [8]. The total electricity sector investment required is thus about 55.5 billion US$. It is not clear whether this total amount, 55.5 billion US$, will be a great financial burden to South Korea or not. However, in my view, many alternatives should be investigated before committing to a project that costs such a huge amount.

[8] Ibid.

III. ECONOMIC ADVANTAGES

1. Size of trade in electricity

Basically, South Korea seems a country likely to receive electricity from neighboring countries rather than a country to supply. In this viewpoint, it might be sufficient to analyze how much electricity can be imported, considering the characteristics of domestic power system.

Figure 1 shows the daily load variation in 2000, with the red colored line showing the daily peak load and blue colored one showing the daily minimum load. Looking at the minimum load curve, there are two points showing extremely small load, about 18 GW at the beginning of February and 17.8 GW at the middle of September. Both days are holidays: New Year's Day and Thanksgiving Day on the lunar calendar. Except for these two days, the annual minimum load is about 22 GW and the daily minimum load on the average is 25 GW. In addition, it should be noted that the majority of the minimum load, that is, the base load, was supplied by nuclear power plants, which had a total capacity of 13.7 GW in 2000.

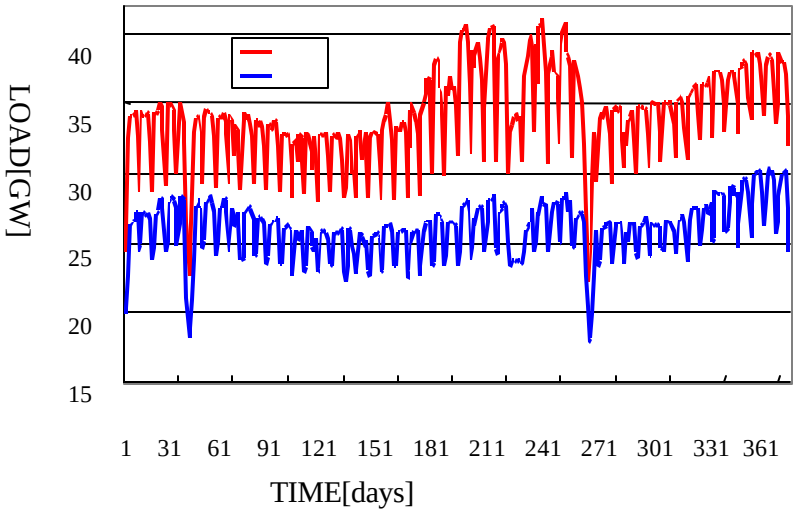

Figure 1. Daily load variation curve in 2000

(Red line- daily peak, Blue line – daily minimum)

The size of any potential trade in electricity involving South Korea is certainly dependent on the reliability of power generation on the supplying side including interconnection lines, the characteristics of the power system in the receiving side and other factors. Therefore, various system analyses must be carried out in order to determine how much and how electricity is traded. However, considering such load characteristics, stability and reliability, fixed electric power inflows to South Korea through cross-border interconnection lines are likely to have to range from 2 to 3 GW in 2000 and 3 to 4 GW in 2015, or about 10% of the daily minimum load in South Korea.

In addition to the steady power inflow, extra power could be exchanged for supporting the neighboring countries suffering from temporary shortage of electricity, i.e. in emergency state. . In other words, how much and how electricity is traded is dependent on contract between the connected power systems and, therefore, cannot be discussed in detail at this stage.

2. Impact on national energy security

The electric power that can be imported to South Korea from neighboring countries might be 2 to 3GW in 2000 and 3 to 4 GW in 2015. This size is only about 5% of the installed generating capacity and does not seem to have a significant impact on national energy security.

However, if the overall reliability would be enhanced or power systems would be tightly interconnected through many transmission lines, more power inflow could be accepted. As a

result, the impact on the national energy security of the cross-border interconnection becomes larger and larger.

3. Electricity tariffs

The following is a discussion of electricity tariffs of neighboring countries and the U.S.A. By electricity tariff, I mean how much money should be paid for consumption of electricity (kWh). Table 7 shows the lowest, highest and average rates in each country, converted to Korean monetary unit, WON.

Table 7. Electricity tariff

	S. Korea	Russia	China	Japan	U.S.A.
Min.	A 44.04			S 118.92	I 52.23
Max	C 102.45			R 253.31	S 126.80
Average	71.59		69.55	211.69	78.57
Exchange Rate			1RMB =163.67	1¥ =11.2184	1 US$ =1145.4

Note: A stands for agriculture, C for commerce, S for street lighting, R for residential and I for industry.

The tariff is dependent on areas and uses, for example agriculture, residential and so on, in the same country. Furthermore, its system is too complex and the rates are dependent on the exchange rate. Considering these points, it is not easy to directly compare the tariff of neighboring countries.

Roughly speaking, the Korean tariff on the average is close to the average tariffs of China and the United States, but is extremely low compared to Japanese rates—about one-third of the Japanese tariffs. Unfortunately, data on Russian tariffs, which are possibly the most meaningful in the context of regional electricity trades, are not available. However, tariffs there may be around 4 cents, about 70% of Korean rates, considering the Russian economy and the generation mix of the Irkstuk area, which has a strong position to supply electricity to the member countries of the region.

In the viewpoint of electricity tariff, Russia can be a major supplier and Japan can get a great economic advantage by importing electricity from any neighboring country. Considering that South Korea seems a sink rather than a source for electricity, South Korea is likely to be able to expect a meaningful economic advantage by importing electricity from Russia because of the tariff difference of about 2 cents. However, it is likely that the electricity tariff in South

Korea will gradually rise until competition and market-based tariffs are set up and settled as a result of restructuring. If this occurs, the difference of tariff rates between China and South Korea will become larger and can make it also feasible to interconnect both power systems. Although a similar restructuring process may also take place in China, China is rich in natural resources such as coal and hydraulic. However, South Korea must import 97% of the primary energy that is domestically consumed.

4. Economic advantages

There might be many factors that should be taken into account in evaluating economic advantages of regional grid interconnection. For example, the construction costs of interconnection lines and converter stations, the reduction of construction costs of new generating plants, the reduction of operating reserve, the environmental impact including emission of air pollutants and other factors, must be considered. Hence, detailed quantitative evaluation is left to the future study and the economic advantages of interconnection, from South Korea's viewpoint, is roughly guessed at here based on three assumptions as follows:

- The imported electricity is about 17,000 GWh/year, equivalent to import of 2 GW for 1 year at a capacity factor of nearly 100 percent.
- The expected margin (savings to South Korea) on electricity imports is 12 WON/kWh, i.e. 1 cent. This is about a half of the tariff difference between South Korea and Russia.
- Only the effects of tariff difference and reduction of CO_2 emission are considered.

Then the total margin for one year is 175 billion WON, about 1% of the total sales of electricity in 2000. In this viewpoint, this project could be compensated for by 1% or more reduction of electricity tariff.

Furthermore, in 2000, the CO_2 emission rate in the Korean power industry was 0.1185 kg-C/kWh, and the total production of electricity was about 251TWh. This means that the total emission of CO_2 in 2000 from the South Korea power sector was about 30 million ton-C. If 17 TWh/year is imported and the value of avoided CO_2 emissions is 25 US$/ton, the impact on the reduction of CO_2 is equivalent to about 50 million US$, i.e. 60 billion WON and about 0.34% of the value of total sales of electricity in 2000. However, considering that the import of electricity means the reduction of electricity produced from thermal power plants, the real effect seems larger than 0.34% and nearly equal to 1%. This is likely to be one of the significant economic advantages that should be taken into account in making decisions on cross-border system interconnection.

In addition, there might be other advantages. For example, the enhancement of reliability, the

development of generating resources including green energy in the neighboring countries, and so on. Considering these effects, cross-border system interconnection must be beneficial to South Korea. Furthermore, it should be noted that the interconnection of power system in the Western Europe is being compensated for by more than 3 % reduction of operation costs.

IV. FACTORS INFLUENCING GRID INTERCONNECTION

1. Barriers and countermeasures

The Northeast Asian system interconnection seems beneficial to South Korea, and this option should be taken into account in planning long-term power supplies. However, it is true that there are still various problems on the way toward the Northeast Asian interconnection. Among them, the most difficult one is that this project is extremely sensitive to the political relationship between North and South Korea, which is of great uncertainty. Another one is weak trust in each others countries in the region as a whole, which is mainly due to the historical background and the economic and political instability in this region.

In addition, there are some other difficulties caused by a situation of "little motivation and much would-be criticisms". This means that there are too many risks and too little motivation for the government officials to take action on an interconnection initiative. Also, there is another factor that makes it difficult for the government officials to decide on their policy of the regional system interconnection. This is the deregulation of power industry, which is giving birth in South Korea and other countries to many power companies replacing a single, integrated company. Each company will pursue their own interests, and will have different views on the regional interconnection.

How each company will react to the regional interconnection cannot be clearly determined at this stage. However, there seems to be overwhelming advantages to compensate for disadvantages. For instance,

- First, interconnection gives generating companies more opportunity to develop generating resources in the neighboring countries and to export their own electricity.
- Secondly, it gives the network company a chance to enlarge its business.
- And finally, it gives consumers more choices so that they can use cheaper electricity.

In conclusion, all the most difficult problems are the military and political tension between North and South Korea, political and economic instability in this Northeast Asia and weak trust in each others country. Regarding these problems, there might be a question "which is first, to clear all the problems or to commence this project ?." In my view, to commence this project is first. The reason is that this project will be helpful for alleviating the tension, enhancing political and economic stability and, also, building trust in each other.

However, in order to commence this project, it seems required to reduce the risks and burdens to the decision makers and help them to have self-confidence. For instance, to set up regular meetings of decision makers and/or to start a feasibility study might be helpful for doing so. Information on expected problems and countermeasures, quantitative costs and benefits, and so on, are likely outcomes of a feasibility study and are needed to discuss this project. Also, through the regular meetings, they can enhance trust in each other and find out countermeasures to overcome the barriers.

For the feasibility or pre-feasibility study, there seem to be two questions as follows: (1) who should fund it and (2) how to organize the project team. Concerned with the first question, the member countries should fund it. If there is any difficulty, one alternative is a loan from international organizations such as ADB or WB, which might require the guarantee of the governments. This loan could be paid back by construction companies or owners of the interconnection lines. Regarding the second question, the study seems to have to be managed by an international steering committee consisting of a few delegates from each member country and carried out by an international consortium consisting of a few organizations drawn from each member country.

V. CONCLUSION

Basically, in South Korea, only the government can make decisions on the North-east Asia system interconnection because this project is extremely sensitive to the political relationship between North and South Korea. In more details, the Ministry of Commerce, Industry and Energy, called MOCIE, should make a plan and, thereafter, seems to have to get the sanction of State Council chaired by the President. The Electricity Council and network company will take a certain degree of the role by advising MOCIE.

However, the most important point is to make MOCIE move toward the regional interconnection. The most effective way is to set up regular meetings so that the government officials of the member countries can discuss the expected problems and find out solutions.

Finally, our institute, KERI, and Energy Systems Institute (ESI) in Russia are planning to start an international joint pre-feasibility study on the system interconnection between Russia and the Korean peninsula, including North Korea. If funding is successfully obtained, this project will start this year and North Korean delegates are expected to join our project team.