Northeast Asia Interconnection, and Power Flow Analysis Considering Seasonal Load Patterns

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Abstract - This paper presents the effects of an increase or a decrease of a power reserve by load flow calculations under the seasonal load patterns of each country for the future power shortages faced by the metropolitan areas or by the southeastern area of South Korea in North-East Asia. In this paper, the various cases of the power system interconnections in Far-East Asia are presented, and the resulting interconnected power systems are simulated by means of a power flow analysis performed with the PSS/E 28 version tool. Data for simulation were obtained from the 2-th long term plan of electricity supply and demand in KEPCO. The power flow map is drawn from simulated data and the comparative study is done. In the future, a power flow analysis will be considered to reflect the effects of seasonal power exchanges. And the plan of assumed scenarios will be considered with maximum or minimum power exchanges during summer or winter in North-East Asian countries.

Keywords: Northeast Asia Power System Interconnection, Power Flow Map, PSS/E, Reserve, Seasonal Power Pattern, South Korea Power System

1. Introduction

Economical and technical considerations are usually the underlying factors for interconnecting electric power systems. Among some of the benefits that may be realized are plant capacity savings, interchange due to diversity, emergency power interchange, and spinning reserve savings. Development of such ties in the future can result in more effective utilization of power station's installed capacities, and fuel economy, to the improvement of the ecological situation in a region.

However, the planning of interconnection is a demanding task and needs to be met with a wide range of technical aspects. The interconnection of the power systems among North-East Asian countries (Russia, China, Mongolia, Japan, and Korea) has been proposed on numerous occasions, but little progress has been made due to the complicated political issues and economical problems involved. Interstate electrical ties of power systems of the Northeast Asian countries are currently practically not developed.

Now, the necessity for this power system interconnection is increasingly being felt due to the benefit of each country. Because of these reasons, the Korean peninsula takes the role of connecting a bridge between different areas of Northeast Asia, such as Russia, Mongolia, China, and Japan [1-5].

The problem of utilizing 2,000MW of power output in the future has been studied, and a 345kV or 765 kV HVAC interconnection between South Korea and North Korea has been discussed with several papers [6-12].

In South Korea, the potential increase in power demand is higher than that of any other country. The metropolitan area situated in the central parts consumed nearly 43% of the total electricity generated, and the southeast area consumed about 33%.

However, most of the large-scale power plants have been constructed in the southern part of South Korea. Consequently, the existing power grid includes multiple routes designed to supply the metropolitan area so that, by and large, the direction of power flow is toward the north.

The future substitutes are toward relieving the problems of power imbalance and the shortage of power in the Seoul metropolitan areas in South Korea and the Pyongyang metropolitan areas in North Korea.

In this paper, we present various scenarios and the accompanying power flow analyses considering seasonal load patterns, in order to provide interconnection of the electric power grids.

A distribution map of the projected power flow will be drawn by the results of simulations performed using the PSS/E tool.

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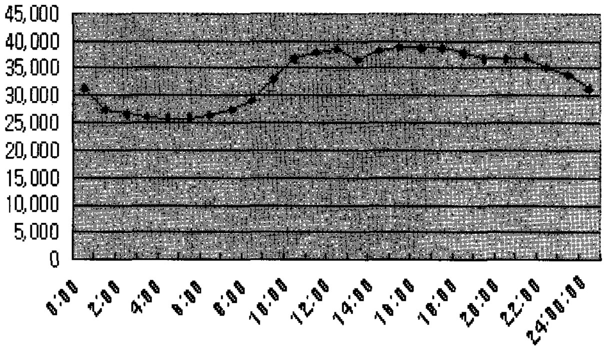
2. Power System Status and Seasonal Load Patterns in Northeast Asia

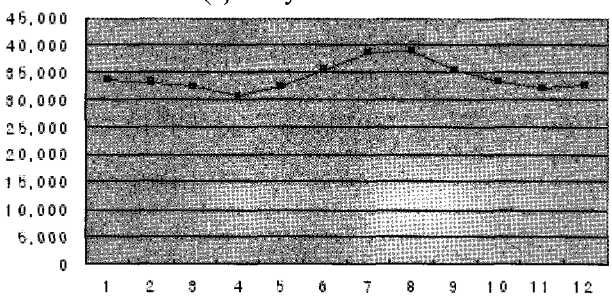
In this section, we will explain the general characteristics and the seasonal load patterns of the existing power systems used in South Korea, North Korea, Russia, China, and Japan [13-20].

2.1 Power system and seasonal load patterns in South Korea

The South Korean electricity generation system can be divided into 7 geographical areas that take geographical boundaries into account. The transmission voltages used are 345kV for the major networks, and 154kV or 66kV for the local systems. Most 66kV lines are now either being removed or replaced by higher voltage lines. The power system on Jeju Island is now connected to the mainland via a 100km-long submarine transmission system, comprised of HVDC (High Voltage Direct Current) cables. Because the power demand is increasing rapidly in the metropolitan area, 765kV facilities are in the process of being constructed and now come into operation in order to provide a stable large-scale power transmission between the large power generation plants and the areas where the consumers are located. Figs. 1(a) and 1(b) represent the daily load curve and the monthly load curve in South Korea.



(a) Daily load curve



(b) Monthly load curve

Fig. 1. South Korea load curves for day and for month.

Table 1 shows the current status of KEPCO's transmission grid facilities at the end of 2001. Table 2 represents a mid-to-long term forecast in demand and supply. Table 3 shows a power capacity of 6 generating companies in South Korea, 2002. (The below data was obtained from KEPCO in Korea) Fig. 2 represents a load demand and a generating facility capacity for districts. Figs. 3(a) and 3(b) represent the daily load curve and the monthly load curve with the assumed material in North Korea. As shown below in Figs. 3(a) and 3(b), the pattern of a curve has a flat and small variation.

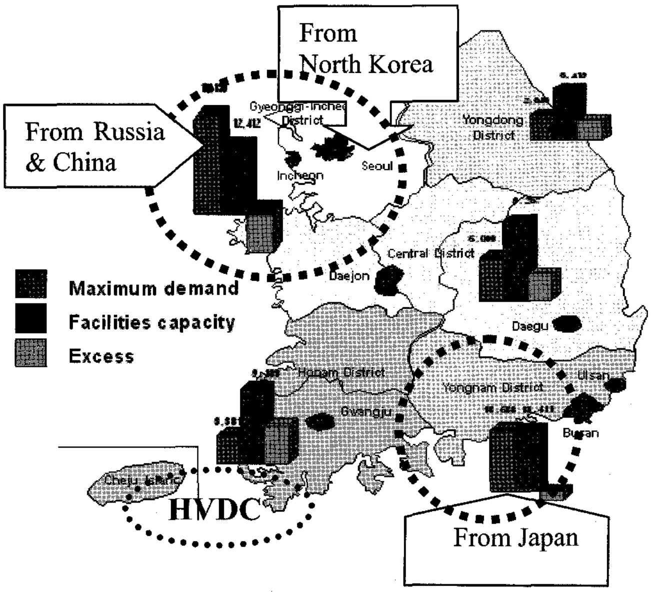
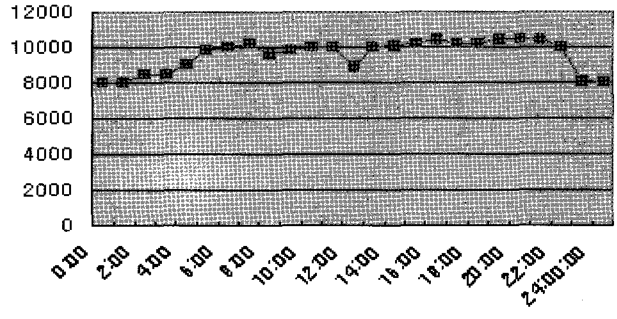


Fig. 2. Demand and facility capacity by regions.

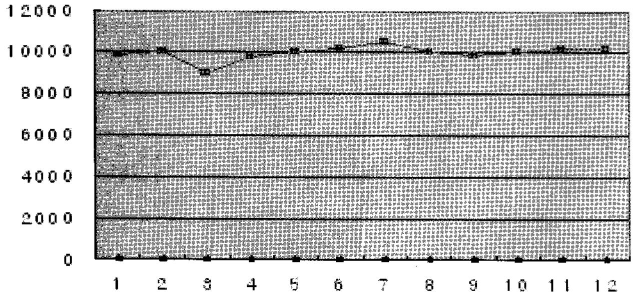
* The information in this figure was obtained from KEPCO.

2.2 Power system and seasonal load patterns in North Korea

At present, the data concerning the transmission system of North Korea are insufficient and aren't arranged well. Only slight data is available from Russia, UN, CIA, the Korean Board of Unification, etc.



(a) Daily load curve



(b) Monthly load curve

Fig. 3. North Korea load curves for day and for month. (assumed material)

Accordingly, the previous researches of interconnection in the Korean Peninsula have just focused on the analyses of the present data and scenarios. This study assumes that the power system in North Korea is divided into 5 areas. The power system in North Korea is smaller than that in South Korea. Most of the hydroelectric power plants are located in the hilly region of the northern areas in North Korea and most of the thermoelectric power plants are located in the metropolitan area. Moreover, power capacity in North Korea has been estimated to be approximately 7,000MW. Currently, it is known that transmission line voltage is composed of 110kV and 220kV.

Table 1. Current Status of KEPCO's Transmission Grid Facilities (At the end of 2001)

	Transmission facilities				**Substation facilities**	
	Circuit length (C-km)			Support (ea)	Number of substation (ea)	Transformer capacity (MVA)
	Overhead	Underground	Total			
765 kV	662	-	662	666	1	1,110
345 kV	7,234	111	7,345	9,914	65	63,577
180 kV(HVDC)	30	202	232	553	-	-
154 kV	16,111	1,465	17,576	24,581	449	78,119
66 kV	1,531	9	1,540	7,112	25	1,225
22 kV	-	-	-	-	9	248
Total	24,037	1,778	25,815	42,826	540	144,279

Table 2. Mid-to-Long Term Forecast in Demand and Supply

Year	**Peak Demand [MW]**	**Installed Capacity [MW, as of year end] (%)**						**Capacity Margin [%]**
		Nuclear	**Coal**	**LNG**	**Oil**	**Hydro**	**Total**	
2001 (Record)	43,130	13,720 (27.0)	15,530 (30.5)	12,870 (25.3)	4,870 (9.6)	3,880 (7.6)	50,860 (100)	15.1
2005	51,860	17,720 (28.6)	18,170 (29.3)	16,810 (27.2)	4,670 (7.6)	4,490 (7.3)	61,850 (100)	16.8
2010	60,620	23,120 (29.2)	24,270 (30.7)	20,440 (25.9)	4,820 (6.1)	6,390 (8.1)	79,020 (100)	25.1

Table 3. Power Capacity for Generation Companies in South Korea, 2002

Company	**Base(MW)**	**Middle(MW)**	**Peak (MW)**	**Total(MW)**
KOSEPCO	3,565	500	1,500	5,565
KOMIPO	3,400	0	3,337	6,737
KOWEPO	3,066	1,400	2,880	7,346
KOSPO	3,000	400	2,200	5,600
KEWESPO	2,900	1,800	2,800	7,500
KHNP	15,715	0	528	16,243
OTHERS	0	58	4,186	4,244
TOTAL	**31,646**	**4,158**	**17,431**	**53,235**
%	**59.5**	**7.8**	**32.7**	**100**

2.3 Power system and seasonal load patterns in Far East Russia

The above data had been obtained from SEI in Russia. Table IV represents the present seasonal data of power in Russia (2001). Table V is the present seasonal data of power in Eastern Siberia (2001). Table VI shows the present seasonal data of power in Far East Russia (2001).

The United Power System (UPS) of Eastern Russian provides electric power to the most inhabited and industrially developed regions. UPS consists of seven large regional electric power systems: Amur, Far East, Kamchatka, Magadan, Sakhalin, Khabarovsk and Yakut. Now the Amur, Khabarovsk and Far East electric power systems are unified on parallel operation, and in parallel with them the southern part of the Yakut electric power system is also working.

The maximum electric loading in UPS falls at winter and makes about 5.8 GW (basin on the data for 2001). The minimum electric loading makes approximately half from a maximum and falls at the summer period. The maximum of UPS was in 1990 and made approximately 30 billion kWh.

In 2000, the value of electrical energy consumption was approximately 24 billion kWh, in 2001 this value was about 25.5 billion kWh. It is planned, that by 2005, consumption will be about 28.7 billion kWh by 2010 - 32 billion kWh, and by 2025 - about 50 billion kWh. The current consumption is distributed non-uniformly. More than 40% of the electric power is consumed in the Far East electric power system. The remaining 60% is distributed between the Khabarovsk, Amur and Yakut electric power systems.

Table 4. Present seasonal data of power in Russia (2001)

Type		Unit	Present seasonal data				Year
			Spring	**Summer**	**Autumn**	**Winter**	
Hydro	Hydro	TWh	45.3	48.0	41.7	40.9	175.9
	Pumped-storage power						
Nuclear		TWh	33.3	27.7	36.8	39.1	136.9
Thermal		TWh	140.9	105.2	146.5	185.9	578.5
Including	Conventional steam turbine		56.9	46.2	64.4	80.7	248.3
	Co-generation		83.4	58.6	81.6	104.5	328.0
Renewable energy		TWh	-	-	-	-	-
Total		**TWh**	**219.5**	**180.9**	**225.0**	**265.9**	**891.3**

Table 5. Present seasonal data of power in Eastern Siberia (2001)

Type		Unit	Present seasonal data				Year
			Spring	**Summer**	**Autumn**	**Winter**	
Hydro	Hydro	TWh	22.0	26.4	24.2	22.3	94.9
	Pumped-storage power						
Nuclear		TWh	-	-	-	-	-
Thermal		TWh	9.9	3.9	8.7	14.3	36.8
Including	Conventional steam turbine		5.1	1.0	4.1	8.4	18.6
	Co-generation		4.8	2.9	4.6	5.9	18.2
Renewable energy		TWh	-	-	-	-	-
Total		TWh	**31.9**	**30.3**	**32.9**	**36.6**	**131.7**

Table 6. Present seasonal data of power in Far East Russia (2001)

Type		Unit	Present seasonal data				Year
			Spring	**Summer**	**Autumn**	**Winter**	
Hydro	Hydro	TWh	1.13	0.98	0.97	1.77	4.85
	Pumped-storage power						
Nuclear		TWh	-	-	-	-	-
Thermal		TWh	5.29	3.57	5.04	6.75	20.65
including	Conventional steam turbine		1.54	1.27	1.52	1.72	6.05
	Co-generation		3.75	2.30	3.52	5.03	14.60
Renewable energy		TWh	-	-	-	-	-
Total		TWh	**6.42**	**4.55**	**6.01**	**8.52**	**25.50**

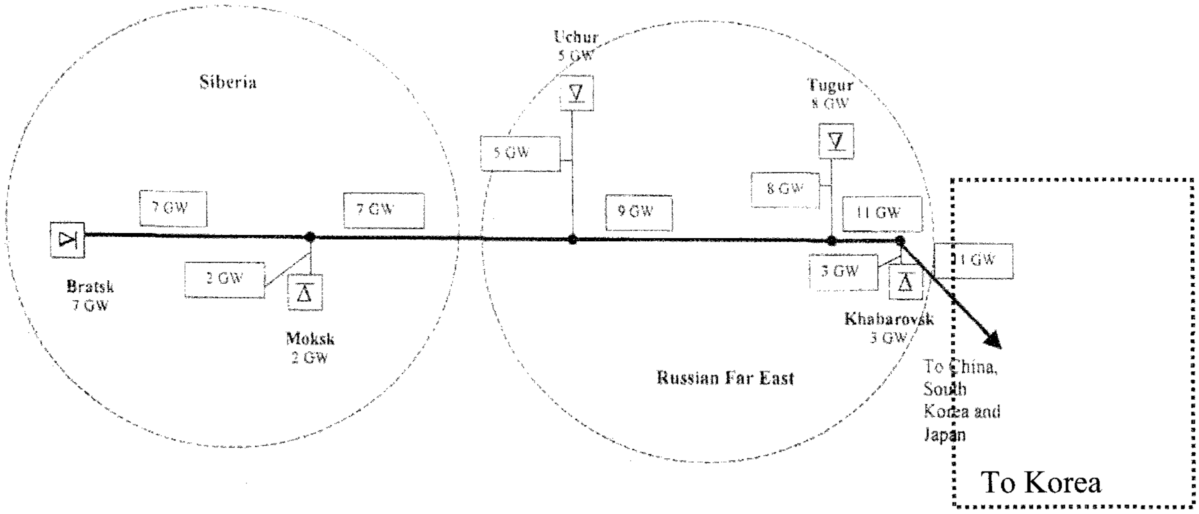


Fig. 4. HVDC interconnection lines in Siberia and Far East Russia.
*This figure was obtained from paper of L. S. Belyaev et al [4].

The backbone electrical network of the UPS consists of 220 and 500 kV transmission lines. The general extent of 500 kV lines is approximately 2000 km. The total installed capacity of power stations (nuclear, thermal and hydro) is about 11 GW [13]. Fig. 4 represents the HVDC interconnection lines in Siberia and Far East Russia.

2.4 Power system status in North East China

Fig. 5 represents the seven regions and power consumption map in China. This map presents an overview of the different regional grid systems within China, showing year 2002 generating capacities and outputs in each region, as well as indicating interconnections between regional grids. In China, Liaoning's power network covering the 147,500 square kilometers of land is a modern power network with a long and vigorous history.

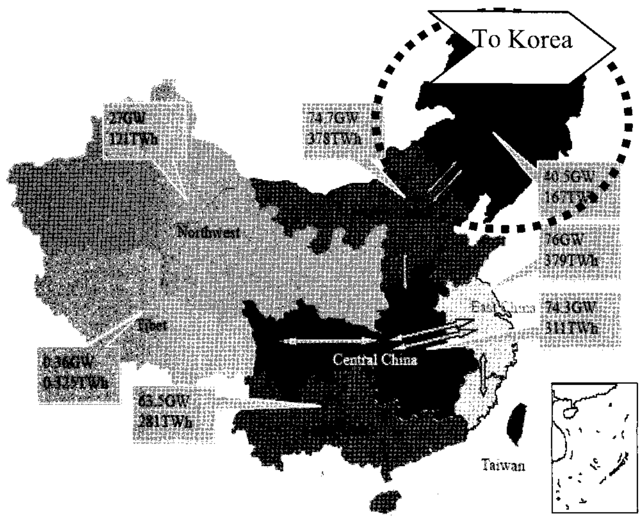


Fig. 5. Regional power consumption map in China.
* This figure was obtained from EPRI in China.

Liaoning Province is the power load center in Northeast China. It has one 500kV line and six 220kV lines to connect with the power network in Jilin province. It also has two 500kV lines and one 220kV line to connect with the eastern part of Inner Mongolia. By the end of 2000, the total installed capacity in Liaoning Province was 15,185MW (hydro power: 1,156MW; thermal power: 12,559MW).

The total installed capacity of the wholly-owned and holding power generation plants of Liaoning Electric Power Co., Ltd. is 2,854MW (hydro power: 456MW; thermal power: 2,398MW), which takes up 18.8% of the total installed capacity of the entire province. The independent power generation company has a total installed capacity of 10,861MW (hydro power: 488MW; thermal power: 10,373MW) and it takes up 71.5%. The local self-supply power plants have a total installed capacity of 3,006MW, taking up 19.8%. The installed capacity of the plant at Sino-Korean boundary river is 545MW, taking up 3.6%.

2.5 Power system status and seasonal load patterns of Kyushu in Japan

Japan's power system is divided into 9 regional companies serving the areas of Hokkaido, Tohoku, Tokyo, Chubu, Hokuriku, Kansai, Shikoku, Chugoku, and Kyushu, and transmission consists of 500kV, 220kV, 110kV, and DC250kV lines. Fig. 6 shows a cascade power flow map in Japan. The frequency used is 60Hz in the western part and 50Hz in the eastern part of the country. According to statistics published in 2001, the total generating capacity of the nine power companies is 33,765MW due to hydropower, 118,112MW due to thermal power, and

42,300MW due to nuclear power. The total capacity is therefore 194,177MW.

Kyushu's infrastructure is composed of nuclear, thermal, hydro, and geothermal power generating plants. In the Kyushu region of Japan, 2001, summer peak was 16,743[MW], and winter peak was 12,961[MW]. The nuclear power plants are located both in the southwest coastal region and at the furthermost tip of Kyushu's northwest coast. The thermal power plants are located mainly on Kyushu's northeast and the northwest coasts. The hydro power plants are randomly distributed within the north and south central regions.

The geothermal power plants are located in the north and south central regions. Among these regions, Kyushu has a total land area of 42,163 km^2 and is located in the southernmost part of Japan. The generating capacity of Kyushu's Electric Power Company is approximately 30,200MW. The backbone of its transmission system consists of 500kV, 220kV, and some 110kV lines.

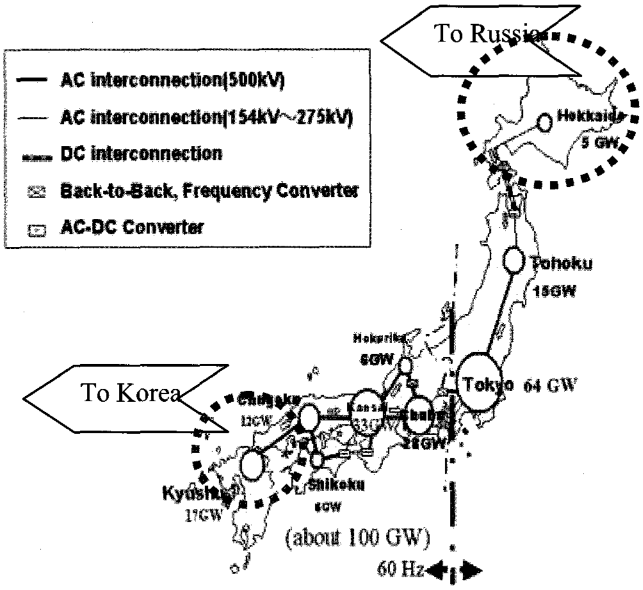


Fig. 6. Cascade power flow map in Japan.
* The information in this figure was obtained from Symposium [18].

3. Assumed Seasonal Power exchange Quantity for Power Flow Calculation

Table 7 represents the assumed peak load data for summer and winter in South Korea, 2005. To simulate the PSS/E package, the load was decreased with 2,000MW in summer season and decreased with 1,000MW in the winter season. Table 8 has the assumed peak data for summer and winter in North Korea, 2005. All the load and supply patterns were assumed with constant quantity. Table 9 indicates the assumed peak data for summer and winter at Kyushu in Japan, 2001. Table 10 has the assumed export power for summer and winter in Far East Russia. Table 11 represents the assumed export power for summer and winter in North East China.

Table 7. Assumed peak data for summer and winter in South Korea, 2005

Seasons	Generation [MW]	Load [MW]	Receive Power[MW]
Summer peak	51857.8	51,090.4	2,000+1,000
Winter peak	41,857.8	41,090.4	1,000+500

Table 8. Assumed peak data for summer and winter in North Korea, 2005

Seasons	Generation[MW]	Load [MW]	Transmission P[MW]
Summer peak	9,000	9,000	-
Winter peak	9,000	9,000	-

Table 9. Assumed peak data for summer and winter at Kyushu in Japan, 2001

Seasons	Generation [MW]	Load [MW]	Transmission Power(Japan → Korea)
Summer peak	17,743	16,743	1,000
Winter peak	13,461	12,961	500

Table 10. Assumed export power for summer and winter in Far East Russia

Seasons	Generation [MW]	Load [MW]	Transmission Power(Russia → Korea)
Summer peak	2,000	0	2,000
Winter peak	1,000	0	1,000

Table 11. Assumed export power for summer and winter in North East China

Seasons	Generation [MW]	Load [MW]	Transmission Power(China → Korea)
Summer peak	2,000	0	2,000
Winter peak	1,000	0	1,000

4. Power Flow and Map by Assumed Scenario

4.1 No interconnection among other countries

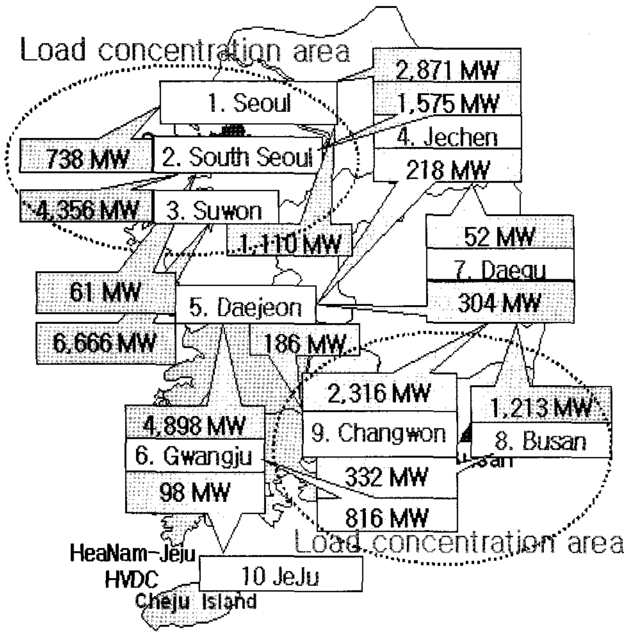


Fig. 8. Load flow map without interconnection in South Korea.

Fig. 8 shows South Korea's load flow map in the case of isolated operation (2005 data provided by KEPCO).

4.2 Interconnection among other countries

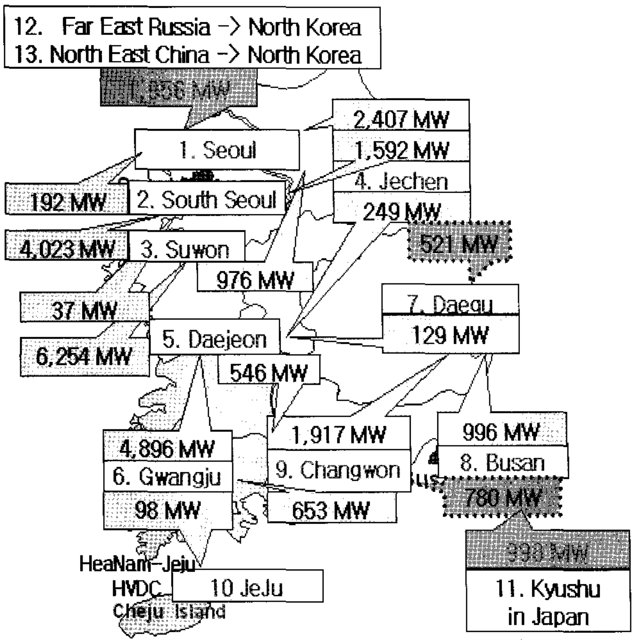


Fig. 9. Load flow map for summer season in Far East Russia or North East China-North Korea-South Korea-Japan.

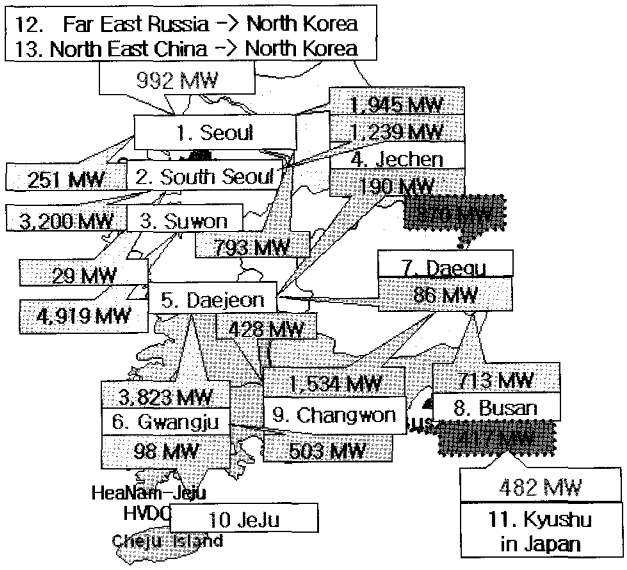


Fig. 10. Load flow map for winter season in Far East Russia or North East China-North Korea-South Korea-Japan

Fig. 9 depicts that the load flow for summer is calculated to provide a load increase of 2,000MW in S.K. In these cases, the load flow is primarily in the southward direction. The two regions have a change of load flow direction as shown on the right side in Fig. 9. Fig. 10 illustrates that the load flow for winter is calculated to provide a load decrease of 10,000MW in comparison with summer peak in S.K. In these cases, also, the load flow is primarily in the southward direction. The two regions have a change of load flow direction as seen in the right side in Fig. 10.

5. Conclusion

The purpose of this paper was to execute a power flow analysis considering seasonal load patterns for the increase or for the decrease of a reserve power for the future power shortages faced by the metropolitan areas or by the southeastern area of South Korea in North-East Asia. Several cases were considered as follows:

- Securing South Korea's power reserve by a power interchange considering seasonal effects in North East Asian countries.
- Drawing possible scenarios and power flow maps for relieving the power shortages faced by the metropolitan areas and the southeastern area in the Korean Peninsula.
- Considering seasonal load patterns and studying power flow for the interconnection with 2,000MW in Far-East Russia or in Northeast China, and 1,000MW in Japan to utilize remote power sources.

The preliminary considerations above consist only of a scenario-based power flow analysis included with seasonal load patterns; however, the results of this research may be referred to the government for use in the establishment of a future construction plan for the power system in South Korea. Moreover, these may be expecting to improve political and economical relationships in North East Asian countries.

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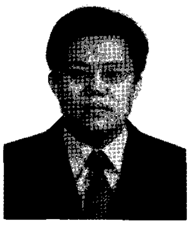

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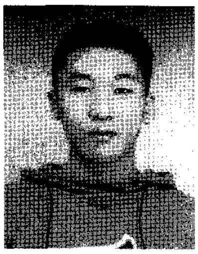

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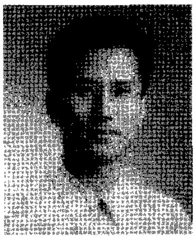

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