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동북아 연계선로 구성 및 계절별 영향을 고려한 우리나라 계통의 조류계산

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Northeast Asia Interconnection and Load Flow considering Seasonal Effects in South Korea

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Abstract - 본 논문에서는 향후 남한의 예비력 증대방안으로 동북아 지역 (러시아, 중국, 몽고, 북한, 한국, 일본)의 지역의 전력계통연계선로의 구성 및 동북아 지역의 계절별 패턴을 고려한 조류계산을 수행하여 전력수급의 분포도를 파악하고자 한다. 특히 한반도 전체의 전력수급을 고려하여 볼 때 남-북한의 수도권 및 영남 지역의 두 지역은 향후 계속적인 전력 수요의 증가로 인한 발전력의 부족상태가 계속되리라 여겨지며, 이러한 문제의 해결방안으로 북한의 신포지역에 2,000MW KEDO 경수로를 건설하여 공급하는 방안이 있겠으나 현재 여러가지 정치적 상황으로는 건설을 중단하게 되었다. 이러한 정치적 상황의 변화로 다른 대안이 필요하게 되었다. 이들 중의 하나가 극동러시아나 시베리아 및 중국 그리고 일본과의 연계에 의한 예비력을 확보하는 방안이 될 것이다. 본 논문에서는 동북아 지역과 연계를 할 수 있는 가능한 지역을 고려하여 연계선로를 구성하고 계절별 효과를 고려한 조류계산을 실시하여 연계 시 융통전력의 분포도를 연구하고자 한다.

Index Terms--Northeast Asia, Interconnection, Seasonal Power Pattern, Power Flow Map, Power Reserve, HVDC, HVAC 765kV, PSS/E.

1. Introduction

Economic 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, spinning reserve savings. However, the planning of interconnection is a demanding task and needs to meet 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. Now, the necessity for this power system interconnection is increasingly being felt due to the benefit of each country. Because of these reasons, Korea peninsula takes the role connect a bridge between different areas of Northeast Asia, such as Russia, Mongolia, China, and Japan [1-5].

The problem of utilizing 2,000MW power output after the successful construction for the Sinpo nuclear power plant in future has studied, and a 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%.

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

2. Power system status and seasonal load

2.1 Power system and seasonal load patterns in South Korea

Figures 1 and 2 represent the load curve for day and the load curve for month in South Korea and in North Korea. The pattern of a curve in North Korea has a flat and small variation.

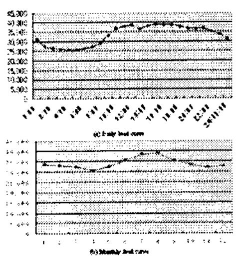

Fig. 1. S. K. load curves.

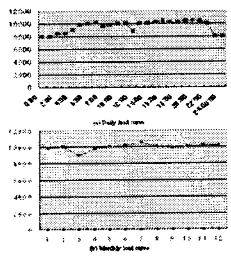

Fig. 2. N. K. load curves.

2.2 Power system status 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. 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.

Figure 3 is the installed capacity and the annual peak demand with rapid increase pattern of power demand from 1961 to 2001 in South Korea.

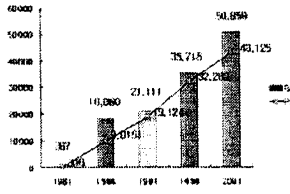

Fig. 3. Installed capacity and annual peak demand.
* This figure was obtained from KEPCO.

2.3 Power system status in North Korea

At present, the data about transmission system of North Korea are insufficient and aren"t arranged well. There are only a little data from Russia, UN, CIA, the Korean Board of Unification, etc. 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. Figures 4(a) and 4(b) represent the load curve for day and the load curve for month with the assumed material in North Korea.

2.4 Power system status in Far East Russia

Figure 4 represents the HVDC interconnection lines in Siberia and Far East Russia.

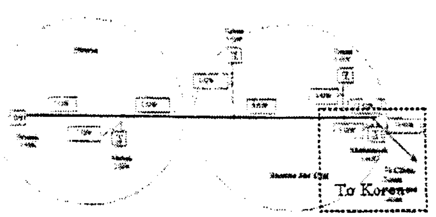

Fig. 4. HVDC interconnection lines in Siberia and Far East Russia.
* This figure was obtained from paper of L. S. Belyaev et. al [4].

2.5 Power system status in North East China

Figure 5 represents the seven regions and power consumption map in China. This map shows 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.

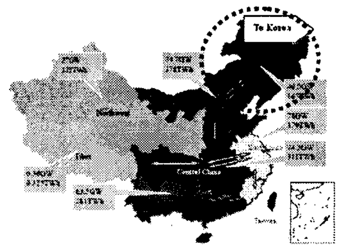

Fig. 5. Regional power consumption map in China.
* This figure was obtained from EPRI in China.

In China, Liaoning"s power network covering the 147,500 square kilometers of land is a modern power network with long history and full of vigor. 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 eastern part of an 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) and takes up 18.8% of the total installed capacity of the whole province. The independent power generation company has a total installed capacity of 10,861MW (hydro power: 488MW; thermal power: 10,373MW) and 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%.

2.6 Power system status of Kyushu in Japan

Figure 6 shows a cascade power flow map in Japan.

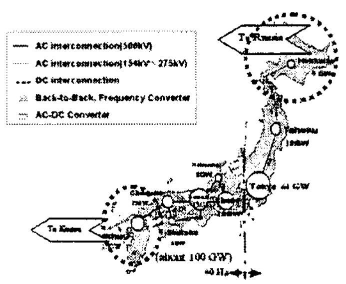

Fig. 6. Cascade power flow map in Japan.
* The information in this figure was obtained from Symposium [18].

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. 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 Kyushu region of Japan, 2001, summer peak has 16,743[MW], and winter peak has 12,961[MW]. 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.

3. Power flow considering seasonal load pattern

3.1 No interconnection among other countries

Figure 7 shows a South Korea s load flow map in the case of isolated operation (2005 data provided by KEPCO).

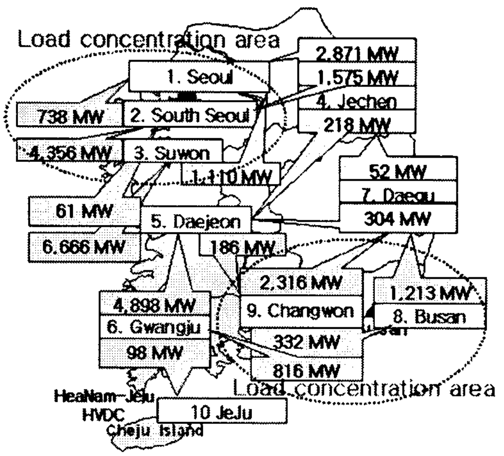

Fig. 7. Load flow map in South Korea.

3.2 Interconnections for Far East Russia (or North East China)-North Korea-South Korea-Japan considering seasonal load patterns

Figure 8 shows 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 right side in figure 8.

Figure 9 shows 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 right side in figure 9.

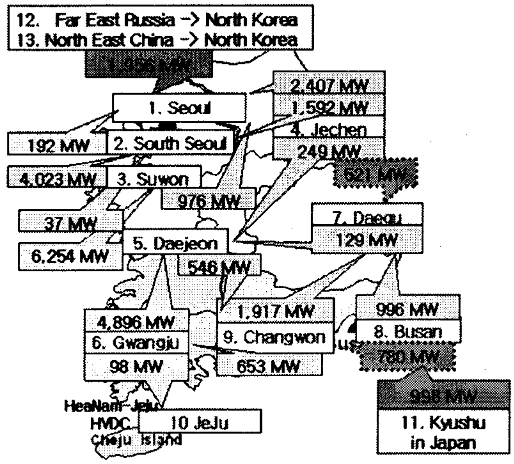

Fig. 8. Load flow map for summer in Far East Russia (or North East China)-North Korea-South Korea-Japan.

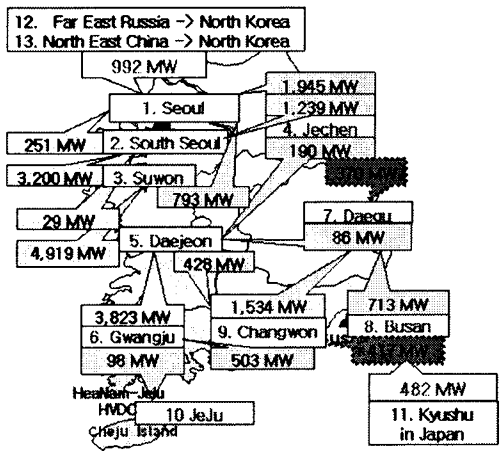

Fig. 9. Load flow map for winter in Far East Russia (or North East China)-North Korea-South Korea-Japan.

3.3 Assumed seasonal power exchange quantities for power flow calculation

Table I represents the assumed peak load data for summer and winter in South Korea, 2005. To simulation the PSS/E package, the load was decreased with 2,000MW in summer season and decreased with 1,000MW in winter season.

Table II 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 III is the assumed peak data for summer and winter at Kyushu in Japan, 2001.

Table VI has the assumed export power for summer and winter in Far East Russia.

Table V represents the assumed export power for summer and winter in North East China.

Table I

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 II

Assumed peak data for summer and winter in Nouth Korea, 2005.

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

Table III

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 IV

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 V

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. Conclusions

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

(i) Securing South Koreas power reserve by a power interchange considering seasonal effects in North East Asia countries.

(ii) Exchanging and Leveling power among North East Asia countries.

(iii) Drawing possible scenarios and power flow maps for relieving the power shortages faced by the metropolitan areas and southeastern area in Korean Peninsula.

(iv) 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 utilizing 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 Asia countries.

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