An Analysis on Price Limits of Imported Power via Northeast Asian Power System Ties

Koo-Hyung Chung† and Balho H. Kim*

Abstract – This paper presents an engineering approach to derive the optimum price levels of transacted power. In this paper, with the assumption that power import is possible through the system connection in Northeast Asia regions, the upper price limit of imported power deserving economic efficiency was derived with respect to the time and amount of power import. The proposed approach was demonstrated based on the data from the National Power Development Planning in 2004 with the WASP model.

Keywords: Demand-supply planning, Northeast Asia, Power system ties, Price limit of imported power, WASP.

1. Introduction

Power system ties among neighboring countries have been an important measure for energy cooperation resulting from the economic blocks of each territory before the restructuring of the power industry and it shows a rapidly increasing tendency since the 1990's. Especially, the Northeast Asian territory has high mutual complementarities in terms of resource distribution, load shape, and fuel mix and is expected to have the highest economic efficiency when system connection is implemented compared to any other territories around the world [1].

As the Korean power system has difficulty in importing power abroad owing to geographical and political specificities, it has grown as an independent system in that all the demand is fulfilled by itself. In addition, some expensive generators are operated for less than 10 hours a year to meet the national reliability standard. In such a situation, if power import or export is possible through system ties in the Northeast Asian territory, the system demand would be provided more economically with enhanced availability of excessive facilities resulting mainly due to the demand diversity and the consequent potential advantage of corresponding prices among systems [2].

In this paper, with the assumption that power import is possible through the system connection in Northeast Asia, the upper price limit of imported power having economic efficiency was derived depending upon the time and amount of power transacted. As the analysis of economic efficiency of power systems usually requires the consideration of the sizes and technological properties of existing generators, future power demand levels and consumption patterns, sizes and properties of new generators, fuel prices, and operation standard of power systems (based on dispatch), the analysis is usually performed with a computer-simulation package. In this paper, the WASP (Wien Automatic System Planning Model) [4] model is employed as it has been used in National Power Development Planning since the 1970s in Korea.

† Corresponding Author: Dept, of Electrical Engineering, Hongik University, Seoul, Korea (ga3310401@wow1.hongik.ac.kr)
* Dept. of Electrical Engineering, Hongik University, Seoul, Korea (bhklim@wow.hongik.ac.kr)
Received 13 November, 2006 ; Accepted 12 February, 2007

2. Assumption in the Analysis

In this paper, the economic effects of various power import scenarios are analyzed based on the National Power Demand-Supply Program established in 2004 [3]. Since the economic effects of power exchange should be analyzed for the long term, this paper sets the year from 2010 to 2020 as a study period. As a national Power Demand-Supply Program has been established to cover until 2017, cost minimization scenarios by WASP model were separately investigated for the period after the year 2017 and, based on such result, the economic efficiencies of various power import scenarios were evaluated [4]. Also, to assure 100% of utilization of imported power, analysis was performed by economic dispatch; in addition, analysis was performed for 90% and 80% utilization of imported power so as to identify the influences depending upon the terms and conditions of the agreement on power import.

2.1 Key Input Data

To analyze the economic effects of power import through the system ties in Northeast Asia, the forecasted load and generation expansion plan in the 2nd Power Demand-Supply Program was adopted for the period from 2010 to 2017, while the load forecast from 2018 to 2020 was performed with average annual growth rate. The generation expansion planning for that period was obtained with the WASP model, and the data on operation costs were based on the year 2004.

2.2 Analysis Scenarios

To analyze the economic feasibility of power transactions through the inter system ties, four transaction scenarios were analyzed: importing no power (Scenario S0); importing 2GW (Scenario S1); import of 3GW (Scenario S2); and import of 4GW (Scenario S3).

The objective of the analysis is to compare the economic efficiency of the 4 scenarios. For this, the amount (MW) and the price (KRW/kWh) of imported power should be determined. However, as there is no available information on the prices of imported power, the upper limit of import price was calculated backwards in consideration that the total costs of optimum solution obtained in the import scenarios are the same as the total costs of optimum measures obtained in scenario S0. Therefore, if the real import price of power is documented in the future, the difference of the upper limit of import price calculated in this paper and the real import price will act as an economic profit.

Table 1. Transaction Scenarios

Scenario	Amount of Imported Power	Remark
S0	N/A	Base case
S1	2GW	Alternative 1
S2	3GW	Alternative 2
S3	4GW	Alternative 3

3. Analysis of Price Limit of Imported Power through Power System Ties

After performing economic dispatch so that the utilization factor of imported power becomes 100%, the solutions for cost minimization to each scenario were obtained with WASP and the results are presented in Table 2. As the objective function of WASP is to minimize the total cost cumulated to the final year, the import price of power was calculated based on 2020 and the total costs for interim years (2010, 2015, and 2017) are provided for reference.

As shown in Table 2, the total cost for the final year (2020) is 154,326,064 million won in the base scenario S0, where the present value was obtained with a 7% discount rate.

Table 2. Estimated import prices of power by scenario

Scenario	Total Cost (Million ₩)				Estimated Price (₩/kWh)
	2010	2015	2017	2020	
S0	16,220,636	75,667,920	94,434,816	**154,326,064**	N/A
S1	16,149,057	75,487,472	94,254,624	**154,312,432**	**56**
	16,165,994	75,573,824	94,362,000	154,483,472	57
	16,182,932	75,560,176	94,470,968	154,654,512	58
	16,199,869	75,746,528	94,579,136	154,825,584	59
	16,216,806	75,832,888	94,687,320	154,996,640	60
	16,233,743	75,919,240	94,795,488	155,167,680	61
S2	16,109,544	75,377,384	94,123,600	**154,166,624**	**56**
	16,134,950	75,506,896	94,285,840	154,423,200	57
	16,160,356	75,635,416	94,448,080	154,679,760	58
	16,185,761	75,765,928	94,610,320	154,936,320	59
	16,211,167	75,895,448	94,772,560	155,192,880	60
	16,236,573	76,024,968	94,934,800	155,449,424	61
S3	16,075,707	75,352,352	94,096,176	**154,132,032**	**56**
	16,109,582	75,525,016	94,312,464	154,474,112	57
	16,143,456	75,697,688	94,528,760	154,816,224	58
	16,177,331	75,870,360	94,745,048	155,158,288	59
	16,211,205	76,043,024	94,961,328	155,000,384	60
	16,245,080	76,215,696	95,177,616	155,842,464	61

When importing power (i.e. with scenarios S1, S2, and S3), it was found that power import at 56 KRW/kWh or lower price bears better economic efficiency compared to scenario S0. That is, as shown in Table 2, when 2GW, 3GW, and 4GW of power is imported into domestic power systems, all of their competitive price limits are bound at the 56KRW/kWh level.

Meanwhile, when reviewing the obtained result in detail, it can be identified that the competitive upper limit of power import prices differ by study period and import amount. As shown in Table 2, power import at the 60 KRW/kWh price level is competitive in all of the scenarios, i.e. S1, S2, and S3, based on 2010; however, when based on 2015, S1 and S2 are found to be competitive at the 58 KRW/kWh level and S3 at the 57 KRW/kWh level. When based on 2017, it is found that all the S1s, S2s, and S3s are competitive at the 57 KRW/kWh level.

With these results, it may be concluded that power import at high prices may be competitive when the study period is short; however, when the study period is long, power import at relatively lower prices may be competitive. It seems that setting a long term study period results in new facilities generation to be added that compete with import power. As new generation facilities largely consist of nuclear 1,400MW or coal 800MW and the generation cost with such facilities is at the 30-40 KRW level, the competitive level of import price should be below 40 KRW per kWh. Meanwhile, it was found that not only the study period but also the importing amount gives some difference to price competition levels for each price level. The ranks of total costs at all the price ranges in each scenario were found to be as follows when the upper limits of import prices are ignored.

- When import price is 56 KRW/kWh: S3 - S2 - S1 -S0
- When import price is 57 KRW/kWh: S0 - S2 - S3 -S1
- When import price is 58 KRW/kWh: S0 - S1 - S2 -S3
- When import price is 59 KRW/kWh: S0 - S1 - S2 -S3
- When import price is 60 KRW/kWh: S0 - S1 - S2 -S3
- When import price is 59 KRW/kWh: S0 - S1 - S2 -S3

As shown in the above ranks, Scenario S3 importing 4GW of power is the best in case of 56 KRW/kWh or lower import price; when Scenario SO is excluded, Scenario S2 importing 3GW of power is the best in case the import price is 57 KRW/kWh; when import price is 58 KRW/kWh or higher, Scenario S1 importing 2GW is the best. As a result, if the import price is set at 56 KRW/kWh or lower, it is best to import the largest available amount (4GW) and, if import price exceeds 56 KRW/kWh, it is economical not to import power.

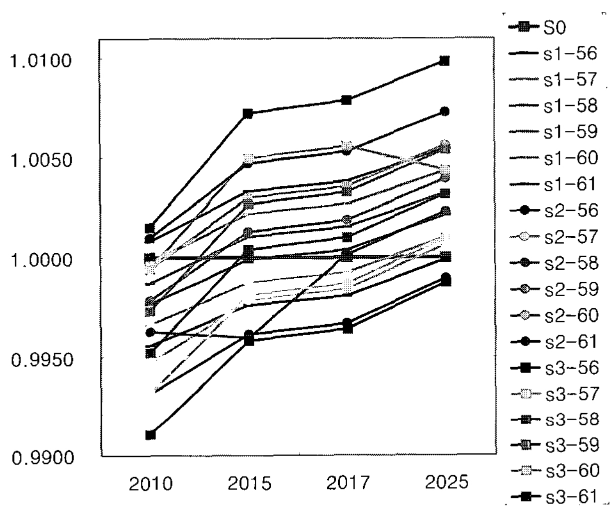

Fig. 1. Relative orders of total cost by scenario (S0 = 1.0)

4. Comparison of Upper Limit of Import Prices by Utilization Factor

This section analyzes the four scenarios with different utilization factors of imported power. For the analysis, an economic dispatch algorithm was performed for the two alternative utilization factors of 80% and 90%. The results are shown in Table 3.

One finding from the analysis is that the price limit of economic power import becomes higher as utilization of imported power becomes lower. The results on the economic feasibility versus the utilization factors are summarized in Table 4.

It is found from the results that it would be beneficial to import power selectively for the time periods where high system demands occur rather than utilizing 100% of the imported power. However, since this finding is based on the simulation using the Load Duration Curve (LDC) rather than the real-time Chronological Load Curve (CLC), a different result may occur with the real economic dispatch when the employed utilization factor of the imported power is different to 100%. Accordingly, it would be reasonable to set the ceiling price at 100% utilization factor with a more feasible transaction condition so as to utilize the imported power for the peak periods [5, 6].

Table 3. Estimated import prices of power by utilization factor

Scenario		Total Costs (Million ₩)	Estimated price (₩/kWh)
S0		**154,326,064**	N/A
S1 (2GW)	Utilization factor 90%	153,870,608	56
		154,026,160	57
		154,181,680	**58**
		154,337,248	59
		154,492,784	60
	Utilization factor 80%	153,900,688	60
		154,041,312	61
		154,181,936	62
		154,322,560	**63**
		154,463,184	64
S2 (3GW)	Utilization factor 90%	153,580,416	56
		153,810,848	57
		154,041,264	58
		154,271,196	**59**
		154,502,112	60
	Utilization factor 80%	153,841,968	60
		154,057,264	61
		154,272,560	**62**
		154,487,856	63
S3 (4GW)	Utilization factor 90%	153,316,752	56
		153,623,616	57
		153,928,000	58
		154,232,320	**59**
		154,536,656	60
	Utilization factor 80%	153,692,000	60
		153,973,184	61
		154,254,352	**62**
		154,535,552	63

Table 4. Ceiling price vs. utilization factors

Scenario	Ceiling price (₩/kWh)		
	100%	90%	80%
S1	56	58	63
S2	56	59	62
S3	56	59	62

5. Conclusion

This paper proposes a practical methodology deriving the level of ceiling price and the amount of the power imported through the hypothetical system ties among the Northeast Asian countries. The analyses include the decision of optimal time and amount of the imported power which bears economic efficiencies. For the analyses, an optimization package amenable to dealing with technological properties of existing generators, demand forecast and consumption patterns, technical characteristics of new generators, future fuel prices, and operation standard of power systems (based on economic dispatch), and WASP, is employed.

The analyses show that an economic benefit can be achieved if the power is imported at or below 56 KRW/kWh. It is expected that the imported power will substitute the peaking units, and since their variable costs (system marginal cost) in the current cost-based Korean power market range between the 58 and 63 KRW/kWh level, the derived level of import price of 56 KRW/kWh deserves good estimation.

Since the WASP model was performed with very accurate technology and economic data adopted in the 2nd National Power Development Planning stage, the information provided by the simulation deserves relatively high reliability. However, though the imported power could not be evaluated hour by hour due to the intrinsic algorithmic property of the WASP model, one needs a macroscopic approach to the Northeast Asian power system project at the present, and the analyses performed with annual base by WASP would bear no significant methodological problem. Nevertheless, since the power industry bears a highly uncertain future and, especially, the Northeast Asia power system interconnection project would confront various political and economic difficulties, future studies need to consider such factors to perform more practical analyses.

Acknowledgements

This work was funded by Ministry of Education and Human Resources Development for BK21 (2nd phase) Project (Research on New Energy Resource & Power System Interface).

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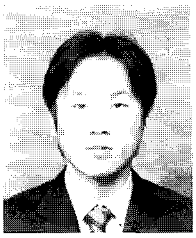
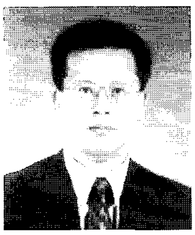


Koo-Hyung Chung
He received his B.S., M.S., and Ph.D degrees from Hongik University, Seoul, Korea, in 2001, 2003, and 2007, respectively. He is currently working as a BK21 post-doctoral researcher at Hongik University. His research interests are market analysis, public pricing, and power system operation & planning.



Balho H. Kim
He received his B.S. degree from Seoul National University, Korea, in 1984, and his M.S. and Ph.D. degrees from the University of Texas at Austin in 1992 and 1996, respectively. He was with KEPCO (the Korea Electric Power Corporation) from 1984 to 1990 and joined Hongik University in 1997 where he is presently Associate Professor of Electrical Engineering. His research fields include distributed optimal power flow, public pricing, B/C analysis, and power system planning and operation.