Transactions of the Korean Nuclear Society Autumn Meeting
Pyeongchang, Korea, October 30-31, 2014

Preparatory Work for a Scenario-Based Electricity Expansion Plan for North Korea after Hypothetical Reunification using WASP-IV

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1. Introduction

The research is to answer the question of how we could meet power demand after reunification of two Koreas. After reunification, various infrastructures such as roads, rails, communication, and ports would be necessary, and projects to construct these infrastructures would compete to get funding out of limited resources available at that moment. However, it is noteworthy that North Korean government itself has demanded other parties' cooperation in the field of power sector as the top priority to deal with North Korean own economic issues [1]. In this light, the researcher consider that how to build power capacity in North Korean area after reunification needs to be stuided with priority. A scenario-based approach is being adopted, and three (3) scenarios are proposed: Scenario 1) increasing capacity at 2.4% annual rate, 2) Imitating South Korean electricity expansion history, and 3) reaching 80% of South Korean Annual Peak Load in 35 years. In order to carry out the research, WASP-IV (Wien Automation System Planning-IV) code developed by IAEA is, with reasonable assumptions, being executed. Annual Peak Load prediction for each scenario, load duration curve, and existing power generating facilities in North Korea are presented herein. This research is being conducted as a preparatory work for the further study.

2. Methods and Results

In this section, the tool used to propose electricity expansion plan for North Korea after reunification, WASP-IV, is described. WASP-IV includes LOADSY, FIXSYS, VARSYS, CONGEN, MERSIM, and DYNPRO.

2.1 Description WASP-IV

WASP was developed by R. Taber Jenkins of Tennessee Valley Authority and D.S. Joy of Oak Ridge National Laboratory in 1974 to model power generating facility expansion plan. IAEA modified WASP and launched WASP-II and now WASP-IV is being used by its Member States. WASP model is composed of mutually related six (6) modules, and the user can immediately know the result of execution of the module.

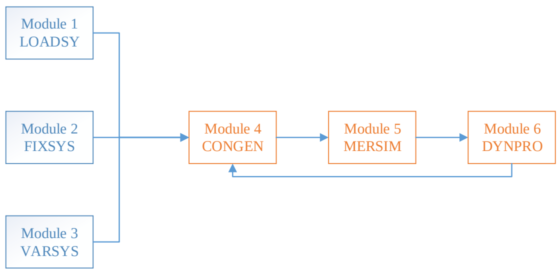

Fig. 1. Modular Structure of WASP-IV

The number designation of first three (3) modules is arbitrary; in other words, each module can be executed without order. However, modules 4, 5, and 6 have to be run in series after the first three (3) modules. Module 7 is to sum up the results of the previous six (6) modules [2]. Modular structure of WASP-IV module 1 to 6 is shown in Fig. 1.

2.2 Annual Peak Load Scenarios

LOADSY requires Annual Peak Load as an input. In this research, three (3) scenarios are proposed for North Korea electricity expansion after reunification.

Scenario 1 is to project North Korea's future Annual Peak Loads at 2.4% annual increase rate, starting from 7,220 MW for 15 years. 7,220 MW is North Korea's installed capacity as of 2012 [3]. Applied 2.4% annual increase rate corresponds with South Korea's latest 6^{th} Long Term Power Development Plan in which South Korea's Annual Peak Load growth is predicted at 2.4% annual increase rate [4].

Scenario 2 is based on South Korea's development history. The research reviews installed capacity and population of North Korea and compares with South Korean counterparts to locate the present status of North Korean power sector on South Korea's power development history. It is identified that North Korea's 0.296 kW/person is between South Korea's year 1985 (0.399 kW/person) and 1980 (0.251 kW/person) [2]. With interpolation, Scenario 2 reaches 0.758 kW/person in 15 years after reunification and the value 0.758 kW/person is multiplied by the projected North Korean population in 15 years.

Scenario 3 is based on assumption made by S.Y. Kim as referred by Y.S. Park [5]. Kim estimated that should

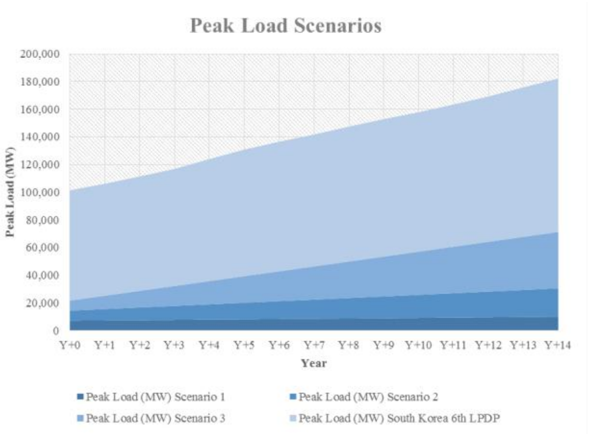

Fig. 2. Annual Peak Load Scenarios

South Korean government and private sector provide capital and technology to North Korea, rapid growth by North Korea would be possible for first ten to twenty years and approximately fifteen years would be taken for North Koreans' income to reach 80% of the South Koreans. Thus, scenario 3 is established to bring North Korea's Annual Peak Load to 80% of the South Korea in 35 years (the study is cut at year 15 to maintain timeframe with other two (2) scenarios, though).

Fig. 2 visualizes above-described three (3) scenarios against South Korea's anticipated Annual Peak Load. Peak-Load Ratios is a ratio of the peak load in each period. As the researcher set one (1) period per year, Peak-Load Ratio is set to 1.0 as required by the manual.

2.3 Load Duration Curve

A load duration curve provides the pattern of electricity demands of the concerned users and serves as the base information for adding new facilities. However, when researchers are studying North Korea, one of the common difficulties they face is lack of information [1]. As North Korea's load duration curve is not available to the researcher, a load duration curve is modified from South Korea's load duration curve. Fig. 3 is South Korea's normalized inverted load duration curve. The curve is based on demand forecast for year 2013 availa-

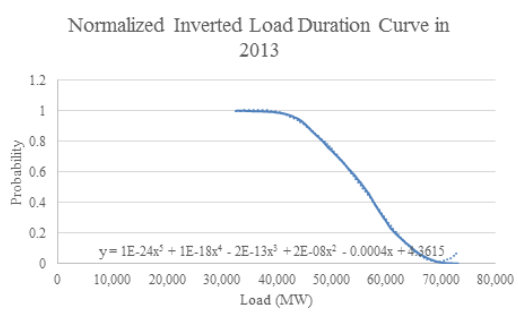

Fig. 3. South Korea's Normalized Inverted Load Duration Curve in 2013

-ble at Electric Power Statistics Information System of Korea Power Exchange [6].

Fig. 3 is then to be modified to reflect differences between South Korea and North Korea load characteristics. Differences being low utilization of industries of North Korea [7]. This low utilization of industries may lead low load factor, lowering the slope of the curve. For our analysis, Fig. 4 is utilized.

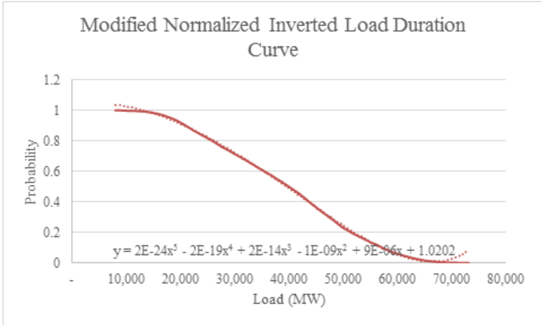

Fig. 4. Modified Normalized Inverted Load Duration Curve for North Korean Case

LOADSY requires coefficients of the load duration curve. In the regard, although the researcher calculated 5th order coefficient suing a commercial spreadsheet as shown on the Fig. 3 and Fig. 4, LOADSY failed to accommodate the order of calculated coefficient. Thus, representing 25 points out of the above mentioned demand forecast were selected and entered.

2.4 Existing Power Generation Facilities in North Korea

FIXSYS requires data about existing plants. Previous works are reviewed as tabulated below [8] [9]. Although it is known that North Korea has numerous small hydropower plants throughout the country, such is disregarded in the research as those are small in size and not connected to the national grid. The researcher identifies discrepancies between S. Kim [8] and Han [9]; the smaller values are taken.

3. Conclusions

IAEA's WASP-IV is adopted for a scenario-based electricity expansion plan for North Korea after hypothetical reunification between Koreas. Input data including Annual Peak Load, load duration curve, and existing facilities are built and presented. Additional future research includes inputting candidate plants' data, cost data such as construction period, operation & maintenance costs, and fuel costs, as well as decommissioning of aged power plants in North Korea to complete WASP-IV execution.

Assuming reunification, electricity expansion plan would need to integrate North and South Koreas' dema-

Table I: Major Power Plants in North Korea

Power Plant	MW	Type	Completion Year	Location
Bookchang Thermal	1,600	Coal (Anthracite)	71 (300MW) '71 (300MW) '73 ~ '75 (500MW) '77 ~ '84 (400MW)	Bookchang, PyungNam Province
PyungYang Thermal	500	Coal (Anthracite)	'65 '66 ~ '68 '70 (10MW)	PyungYang
SeonBong (Woongki) Thermal	200	Heavy Oil	'74 (100MW) '77(100MW)	Woongki, Hambuk Province
CheongCheon River Thermal	200	Coal (Bituminous)	'76 ~ '77	GaeJeon, PyungNam Province
CheongJin Thermal	150	Coal (Bituminous)	'85 (100MW) '96 (50MW)	JeongJin, Hambuk Province
SoonCheon Termal	210	Coal (Anthracite)	'87 '88	SoonCheon, PyungNam Province
DongPyungYang Thermal	50	Coal (Anthracite)	'94	PyungYang
December Thermal	50	Coal (Anthracite)	'96	DeaDong, PyungNam Province
SooPong	700	Hydro	'43	SakJu, PyungBuk Province
TeaPyungMan	190	Hydro	'87	SakJu, PyungBuk Province
WoonBong	400	Hydro	'74	JaSeong, JaGang Province
WeWon	390	Hydro	'90	WeWon, JaGang Province
SeoDooSoo	510	Hydro	'72(200MW) '76 (250MW) '82 (60MW)	CheongJin, HamBuk Province
HeoCheon River	390	Hydro	'40 ~ '45	HeoCheon, HamBuk Province
KangKye CheongNyun	246	Hydro	'64	KangKey, JaGang Province
DocRo River	90	Hydro	'59	ManPo, JaGang Province
TeaCheon	470	Hydro	'87 (150MW) '88 ~ '02 (320MW)	TaeCheon, PyunkBuk Province
JangJin River	381	Hydro	'37 ~ '38 (371MW) '63 (10MW)	HamJu, HamNam Province
BuJeon River	262	Hydro	'30 ~ '35 (259MW) '61 (3MW)	ShinHeung, HamNam Province
DeaDong River	200	Hydro	'83	DeokCheon, PyungBuk Province
AnByeon CheongNyun	200	Hydro	'00	AnByeon, KangWong Province
BuRyung	40	Hydro	'38 ~ '40 (36MW) '60 (4MW)	BuRyung, CheongJin
GaeSung	90	Hydro	'43	GaeSung
NamGang	50	Hydro	'43	DeaDong River, PyungYang
Mirim	30	Hydro	'82	Sadong, PyungYang
BongHwa	20	Hydro	'83	GangDong, PyungYang
TongCheon	13	Hydro	During Japanese Occupation	TongCheon, KangWon Province
CheonMa	12	Hydro	-	CheonMa, PyungBuk Province
EoJiDon	15	Hydro	-	BongSan, HwanBuk Province
NaeJungRi	12	Hydro	-	YangGang

-nds and facilities. However, this research narrows down its scope to North Korean demand and facilities only. Such integrated simulation could be the topic for the later research.

This work was supported by the 2014 Research Fund of the KINGS.

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