July 15, 2004

IEEE POWER ENGINEERING SOCIETY

ENERGY DEVELOPMENT AND POWER GENERATING COMMITTEE

PANEL SESSION: POWER GENERATION AND TRANSMISSION EXPANSION PLANNING PROCEDURES IN ASIA: MARKET ENVIRONMENT AND INVESTMENT PROBLEMS

EXTENDED PANEL SESSION SUMMARIES

IEEE 2004 General Meeting, Denver, 6-12 June 2004
Tuesday, June 8, 2004, Room Gov Square 17, 2:00 p.m.

PANEL SESSION INTRODUCTION

Sponsored by: International Practices for Energy Development and Power Generation Subcommittee

Chairs: Tom Hammons, Chair, International Practices for Energy Development and Power Generation, University of Glasgow, Scotland, UK; E-mail: T.Hammons@ieee.org
Nikolai I.Voropai, Energy Systems Institute, Irkutsk, Russia.
E-mail:voropai@isem.sei.irk.ru

Track 1: Active Load Participation and Its Impact on Markets

The panel reviewed the present status and prospective ideas of power generation and transmission planning procedures in a market environment. This problem is very important for different countries in Asia, as well as for other countries that have taken part in the liberalization of the electric power industry. Japan, Korea, China, India, Russia and others are now on the way of transition of their electric power industries to a new market structure and new economical conditions.

One of the main aims of electric power industry liberalization is the attraction of investment for new more effective generation and transmission development. The objective estimation of needed investment can be made on the basis of new advanced procedures of generation and transmission expansion planning in a market environment. This will be examined. There are many issues in the discussed problem. These include technology of power generation and transmission expansion planning procedures; methods of making decision on generation and transmission network in a market environment; specific features of solving the discussed problem in different countries of the region; use of the correlation state regulation and market mechanisms for attraction of investment; and improvement of surplus generation for effective electricity market operation; etc.

The Session stimulated discussion and exchange of ideas on this very important and timely topic.

Presenters and Titles of their Presentations were:

1. *N.I. Voropai, E.Yu. Ivanova* (Energy Systems Institute, Irkutsk, Russia). Problems of Electric Power System Expansion Planning in a Market Environment and Procedures of Their Solution (Paper GM 0741).
2. *K. -S. Kook, Y. -H. Moon, D. -W. Park* (Korea Electro technology Research Institute, Eaiwang, Korea). Proposed Performance Criteria for Transmission System Planning based on Regulating Framework of TWBP in Korea.
3. *Subrata Mukhopadhyay* (Central Electricity Authority, New Delhi, India) Power Generation and Transmission Planning in India – Methodology, Problems and Investments.
4. *F.F. Wu, Fushuan Wen, Gang Duan* (The University of Hong Kong, Hong Kong, China). Generation Planning and Investment under Deregulated Environment: Comparison of USA and China.
5. *L.S.Belyaev, N.I.Voropai, S.V. Podkovalnikov, V.V. Trufanov, G.I. Sheveleva* (Energy Systems Institute, Irkutsk, Russia), *A.R. Yankilevsky* (The Ministry of Energy, Moscow, Russia). Investment and Development Problems of Russia's Power Industry. (Paper 04GM 0732).
6. *Sang-Seung Lee, Jong-Keun Park, Seung-Il Moon, Jong-Fil Moon, Jae-Chul Kim, Seul-Ki Kim, Ho-Yong Kim* (Korea). Northeast Asia Interconnection Scenario Map and Power Reserve Strategy in South Korea (Paper 04GM0885).
7. *Jong-Keun Park* (Seoul National. University, Korea}. Generation and Transmission Sector in Korean Power Systems (Paper 04GM1277).
8. *Xiaomin Bai, Shuti Fu* (Electric Power Research Institute, Beijing, China). Power System and Power Market Development in China---Problems and Proposed Alleviation Measures. (Paper 04GM1295).

Each Presenter spoke for approximately 20 minutes. Each presentation was discussed immediately following the respective presentation. There was a further opportunity for discussion of the presentations following the final presentation.

The Panel Session was organized by Nikolai Voropai (Energy Systems Institute, Irkutsk, Russia) and Tom Hammons, (University of Glasgow, UK).

Tom Hammons and Nikolai Voropai moderated the Panel Session.

1). The first presentation was on problems of electric power system expansion planning in a market environment and the procedures of their solution. Nikolai I.Voropai Energy Systems Institute, Irkutsk, Russia presented it .The presentation discussed different variants of power industry structure in a market environment and the character of electric power system expansion planning problems. Many mathematical methods to solve the problems of electric power system expansion planning were discussed.

Nikolai I. Voropai is Director of ESI. He was born in Belarus in 1943. He graduated from Leningrad Polytechnic Institute in 1966. N.I. Voropai received degree of Candidate of Technical Sciences in 1974 and Doctor of Technical Sciences in 1990. His research interests include: modeling power systems; operation and dynamic performance of large interconnections; reliability, security and restoration of power systems; development of national, international and intercontinental interconnections. N.I. Voropai is a Member of CIGRE, a Senior Member of IEEE and a Member of PES.

2). The second presentation was entitled: Proposed Performance Criteria for Transmission System Planning based on Regulating Framework of TWBP in Korea. Kyung Soo Kook, Young-Hwan Moon, Dong-Wook Park, Korea Electro-technology Research Institute, Korea prepared it. The presentation was made by Dong-Wook Park.

This presentation discusses a regulating framework of Two Way Bidding Pool focusing on the transmission network planning, and examining the proposed performance criteria for transmission system planning in Korea. Performance criteria of transmission systems are expected to be a guideline for investment in transmission networks. Though the Korean government has decided to maintain government-leading resource planning even after restructuring of the electricity industry, objective and transparent criteria for transmission system planning are required in electricity markets where various market participants trade electric energy. The presentation discussed this critically.

Dong-Wook Park is Vice-President, Korea Electro=technology Research Institute, Changwon, Korea.

3). The third presentation discussed Power Generation and Transmission Planning in India – Methodology, Problems and Investments. It was prepared and given by *Subrata Mukhopadhyay*, Central Electricity Authority, New Delhi, India.

India, starting from an overall installed capacity of little above 1,300 MW at the time of its independence in late forties, through its successive five-year planning periods could achieve a level of about 110,000 MW with energy generation of the order of 600 billion units in five and half decades. Though initial generation was concentrated to meet load in urban areas, at present vast countryside areas too have been covered under the massive electrification program. This presentation examined methodology, problems and investments that are being considered and looked into in power generation and transmission planning in India at this time

Subrata Mukhopadhyay was born in Asansol, India in 1947. He graduated in Electrical Engineering from Jadavpur University, Calcutta in 1968 and gained his Master's and Doctorate Degrees from Indian Institute of Technology, Kharagpur and Roorkee in 1970 and 1979 respectively. His employment experience of 33 years includes teaching and research in Roorkee and power system planning, design and operation with the Central Electricity Authority of Government of India. He has authored two books and twenty-five papers, and was awarded the IEEE Third Millennium Medal in 2000, the PES Delhi Chapter Outstanding Engineer Award & PES Asia-Pacific Regional Outstanding Engineer Award for 2001, and the 2002 RAB Leadership Award. He is a Fellow of the Institution of Engineers (India).

4).; The next presentation was entitled Generation Planning and Investment under Deregulated Environment: Comparison of USA and China. It was prepared by *Felix.F. Wu, Fushuan Wen,* and *Gang Duan,* Center for Electrical Energy Systems The University of Hong Kong, Hong Kong, China. Felix Wu present it.

The electric power industry has gone through fundamental restructuring in recent years from regulated or state-owned monopolies to competitive markets. In many developed countries, such as USA, where power companies are mostly investor-owned private enterprises, changes are brought about in large part because independent power producers use newer technologies so that they can compete favorably with generation from traditional power companies.

In this presentation, first the process for generation planning and investment in the deregulated environment in the West was discussed, in particular, in USA, as well as in China, and then the impact of such different approaches was discussed in terms of the goals of deregulation, i.e., efficiency incentive, economic signaling and risk distribution.

Felix F. Wu (Fellow, IEEE) received his PhD from University of California at Berkeley (UCB). He is now Professor of Electrical Engineering in the University of Hong Kong, and an Emeritus Professor in the Department of Electrical Engineering and Computer Science, UCB. His research interests are in power industry restructuring, power system investment planning, design of modern control centers, distribution automation, distributed processing etc.

Fushuan Wen received his B. Eng. and M. Eng. degrees from Tianjin University, and PhD degree from Zhejiang University, China, in 1985, 1988 and 1991 respectively, all in electrical engineering. He joined the faculty of Zhejiang University, China, in 1991, and had been a professor there from 1997 to 2003. He is currently with the University of Hong Kong. His research interests are in power industry restructuring and fault diagnosis in power systems.

Gang Duan received his B. Eng., M. Eng. and Ph. D. degrees in power system and its automation from Tianjin University, China, in 1994, 1997 and 1999 respectively. Then he worked as a postdoctoral research fellow at Tsinghua University, China from 2000 to 2002. Currently he is a visiting scholar at The University of Hong Kong. His research interests are in electricity market, energy management system, operator training simulator, and power system planning.

5). The fifth presentation was concerned with Investment and Development Problems of Russia's Power Industry. It was prepared by *L.S.Belyaev, N.I.Voropai, S.V. Podkovalnikov, V.V. Trufanov, and G.I. Sheveleva* (Energy Systems Institute, Irkutsk, Russia), and *A.R. Yankilevsky* (Ministry of Energy, Moscow, Russia). Nikolai Voropai will present this paper.

Lev S. Belyaev is a Chief Researcher at Energy Systems Institute (ISEM). In 1975-1976 he was with the Energy Program at the International Institute for Applied Systems Analysis – IIASA (Luxemburg, Austria). His main research interests are: development, simulation and optimization of energy systems including global ones, energy technology assessment, interstate electric ties, and methodology of decision-making under uncertainty. He is the author and co-author of more than 200 scientific papers and books.

Nikolai I. Voropai is Director of ESI. His research interests include: modeling power systems; operation and dynamic performance of large interconnections; reliability, security and restoration of power systems; development of national, international and intercontinental interconnections. He is a Member of CIGRE, a Senior Member of IEEE and a Member of PES.

Sergey V. Podkovalnikov received an electrical engineer's degree from Irkutsk Polytechnic Institute in 1980. In 1989 he received the Ph.D. degree in electrical engineering. Currently he is a Principal Researcher at Energy Systems Institute (ISEM). His research interests are: interstate electric ties and interconnected power systems, expansion planning of electric power industry in market environment, electric power industry liberalization, methodology for decision-making under uncertainty and multiple criteria. He is the author and co-author of more than 70 scientific papers and books.

Galina I. Sheveleva was born in 1956. She received an economic mathematician's degree from Novosibirsk State University in 1978. Currently she is a Senior Researcher at Energy Systems Institute (ISEM). Her main research interests are: development, simulation and optimization of electric power systems, methodology for investment process management in electric power industry. She is the author and so-author of more than 30 scientific papers and books.

Victor V. Trufanov received an economic engineer's degree from Irkutsk State Polytechnic Institute in 1970. Currently he is a Principal Researcher at Energy Systems Institute (ISEM). His main research interests are: development, simulation and optimization of electric power systems, methodology for decision-making under uncertainty and multiple criteria. He is the author and so-author of more than 100 scientific papers and books.

Andrey R. Yankilevsky is an advisor to the Deputy Minister of Energy of RF. The area of his interests covers the problems of attracting investments in the electric power industry development in a market environment and the problems of determining the rational participation of the state in regulation of the electric power industry development.

6). The sixth presentation was entitled: North-East Asia Interconnection Scenario Map and Power Reserve Strategy in South Korea. It was authored by *Sang-Seung Lee, Jong-Keun Park, Seung-Il Moon, Jong-Fil Moon, Jae-Chul Kim, Seul-Ki Kim,* and *Ho-Yong Kim* (Korea). Sang-Seung Lee presented it.

It presented five scenarios that have been proposed according to the assumed scenario for substitutes for relieving 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.

The first case of the scenario involved 765 kV HVAC interconnection between the Yangju bus of South Korea and the Pyongsan bus of North Korea.

The second case of the scenario concerned 765 kV HVAC interconnection between the Yangju bus of South Korea and the Pyongsan bus of North Korea to supply the Sinpo nuclear power plant which is to be constructed with 2,000MW capacity in future.

The third case of the scenario included HVDC interconnection between the Busan area in South Korea and the Kyushu area in Japan to solve the power shortage in the Gyeongnam area of South Korea.

The fourth case of the scenario consisted of an HVDC interconnection between the Sredne-Uchurskaya HPP in Far-East Russia and rhe Wongi bus in North Korea without supplying the Sinpo nuclear power plant in the future,

In the fifth case of a scenario, the assumed scenario for an HVDC interconnection between Liaoning's power network in North-East China and Supung bus in North Korea was proposed without supplying Sinpo nuclear power plant in the future.

Sang-Seung Lee was born in Goseong, Gyeongnam, Korea on April 2, 1960. He received Ph.D. degree in the School of Electrical Engineering at the Seoul National University, Seoul, Korea in 1998. Currently, he is the research leader of Power System Research Division (PSRD) of the Electrical Engineering and Science Research Institute (EESRI), 130-Dong, Seoul National University, Seoul, Korea. His interest areas are power system interconnection, control, power system economics and power distribution system plan.

Jong-Keun Park was born in YuSeong, Chungcheongnam-do, Republic of Korea, on October 21, 1952. He received his B.S. degree in electrical engineering from Seoul National University, Seoul, Korea in 1973 and his M.S. and Ph.D. degrees in electrical engineering from The University of Tokyo, Japan in 1979 and 1982, respectively. In 1982, Dr. Park worked as a researcher at the Toshiba Heavy Apparatus Laboratory. He is currently a professor of School of Electrical Engineering, Seoul National University. In 1992, he attended as a visiting professor at Technology and Policy Program and Laboratory for Electromagnetic and Electronic Systems, Massachusetts Institute of Technology. He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and Japan Institute of Electrical Engineers (JIEE). Also, he is presently acting as a fellow of the Institution of Electrical Engineers (IEE) and the Korean representative of the study committee SC 5 “Electricity Markets and Regulation” in CIGRE.

Seung-Il Moon was born in Jeonnam, Korea on Feb. 1, 1961. He received B.S.E.E. degree in Electrical Engineering from Seoul National University, Seoul, Korea in 1985, and the M.S.E.E. and Ph.D. degrees in Electrical Engineering from Ohio State University in 1989 and 1993, respectively. Currently, he is an associate professor of School of Electrical and Computer Engineering and he has been with the School of Electrical and Computer Engineering of 301-Dong, Seoul National University, Seoul, Korea as a professor. His present research interests are power system modeling, analysis and control.

7). The penultimate presentation concerned the Generation and Transmission Sector in the Korean Power Systems and was prepared by *Jong-Keun Park* (Seoul National. University, Korea}. Sang-Seung Lee presented it.

Throughout the world, restructuring and competition are being introduced into the electric power industry. In Korea, the act on restructuring the electric power industry was approved to allow division of generation businesses on December 23, 2000. Amongst the radical changes since restructuring, they are fleshing out their experiences associated with investment and expansion planning in the generation and transmission sectors. They need to work out a long-term generation investment plan, taking into account scheduled and reasonably foreseen unscheduled outages as well as transmission installations. This was discussed.

Jong-Keun Park was born in YuSeong, Chungcheongnam-do, Republic of Korea. He received his B.S. degree in electrical engineering from Seoul National University, Seoul, Korea in 1973 and his M.S. and Ph.D. degrees in electrical engineering from The University of Tokyo, Japan in 1979 and 1982, respectively. In 1982, Dr. Park worked as a researcher at the Toshiba Heavy Apparatus Laboratory. He is currently a professor with the School of Electrical Engineering, Seoul National University. He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and the Japan Institute of Electrical Engineers (JIEE). Also, he is a fellow of the Institution of Electrical Engineers (IEE) and Korean representative of the study committee SC 5 “Electricity Markets and Regulation” in CIGRE.

8). The final presentation discussed Power System and Power Market Development in China---Problems and Proposed Alleviation Measures. Xiaomin Bai, and Shuti Fu, Electric Power Research Institute, Beijing, China prepared it. Shuti Fu presented it.

The economy of China has developed at a quite fast rate with an average annual increase of GDP of 9.5% from 1978 to 2000. Most of the time, the power industry has been under the pressure of capacity shortage. Only in recent years have most of the power systems experienced capacity abundance, particularly for the years between 1997-1999. The presentation highlighted what is being done in respect of the power market and system development in China under the changed status of generation system capability that exists and will exist with system development in forthcoming years, generation planning and transmission expansion planning in China, and energy shortage problems and proposed alleviation measures.

Xioamin Bai received BS degree from the Electrical Engineering Department of Tsinghua University, China in 1977, and his M.S and Ph.D. degree from the Graduate School, EPRI, China (1982, and 1988 respectively). He is a Deputy Chief Engineer of China EPRI, Senior Member of CSEE, Member of IFAC and observer of CIGRE C5. His main research interest includes power system analysis and control, power market, EMS and DMS.

Shuti Fu received BS degree from the Electrical Engineering Department of Tsinghua University, Beijing, China in 1948. He has been Deputy Chief Engineer for China Electric Power Institute, and is now a consultant. His main research interest includes power market and EMS. He is a LM of IEEE.

The final EXTENDED PANEL SESSION SUMMARIES follow

SUMMARIES:

Rec'd 2 Feb, 2004

1. PROBLEMS OF ELECTRIC POWER SYSTEM EXPANSION PLANNING IN A MARKET ENVIRONMENT AND PROCEDURES OF THEIR SOLUTION

N. I.Voropai, E.Yu.Ivanova, Energy Systems Institute, Irkutsk, Russia. E-mail: voropai@isem.sei.irk.ru

Abtract: The paper analyzes different variants of the power industry structure in a market environment and the character of electric power system expansion planning problems. Many mathematical methods to solve the problems of electric power system expansion planning are discussed.
Keywords: Electrical Power System, Market Structure, Expansion Planning Problems, Mathematical Methods

Summary

In a liberalized environment different variants of the electric power industry structure are possible. These variants predetermine specific features of the problems of electric power system (EPS) expansion planning. In general this problem is solved by the rational combination of market mechanisms and state regulation, provided there are many subjects of relations (power supply companies, consumers, authorities, etc.) with a great number of commonly non-coincident criteria. And the uncertainty of future conditions for EPS expansion is responsible for a multi-variant character of possible decisions to be made and compared.

Complexity and multi-dimensionality of current extended EPSs, plurality of variants and criteria, availability of different preferences in decision choice all make it impossible to solve the EPS expansion problem as a general synthesis problem. In the centrally planned power industry this problem was solved by applying the hierarchical approach that was based primarily on the expert, but a posteriori technology of problem solution. In the liberalized power industry the problem is drastically complicated and the technology of its solution can be represented by different variants depending on specific features of the industry structure.

We will analyze different variants in the structure of power industry [1] that generate distinctions in the composition and character of EPS expansion planning problems. These variants comprise a regulated monopoly at all levels; interaction of vertically integrated EPS at an open access to the ain grid; a single buyer-seller of electricity (an electric network company) with competition of generating companies; competition of generating companies and a free choice of electricity supplier by selling companies or/and consumers, when the main grid renders only transportation services; in addition to conditions of two previous cases competition of selling companies in electricity supply to concrete consumers; intermediate and mixed variants based on the considered ones.

The general problem of EPS expansion planning can be divided into three groups of problems [2]:

- the state strategies and programs for development of the power industry and EPS (the federal, interregional and regional levels);
- strategic plans for development of power supply companies (vertically integrated, generating, network);
- investment projects of electric power installations (power plants, substations, transmission lines).

In making decisions on EPS expansion different groups of subjects of relations have own, largely non-coincident, interests that are expressed by the corresponding criteria. In particular:

1) Electricity producers or/and sellers (vertically integrated, generating or selling companies, an electric network company as the single buyer-seller of electricity) and also subjects of electric power industry rendering electric power services in the wholesale electricity market (maintenance of active and reactive power reserves, provision of system reliability, etc.) are interested in profit maximization as a result of their business.

2) Electricity consumers (selling companies of different levels, concrete onsumers) are interested in minimization of the tariffs for electricity bought (in the wholesale or/and retail markets), provision of its quality and power supply reliability.

3) Interests of the authorities (federal and regional) are directed to maximization of payments into budgets of the corresponding levels, minimization of the environmental impact of electric power facilities, provision of the energy security of the country and regions, etc.

4) External investors (banks, juridical and natural persons) are interested in minimization of the period for return of investments in electric power installations, maximization of dividends, etc.

We will discuss the composition and specific features of EPS expansion planning problems from two points of view: technology and structure.

As to the technology an EPS is viewed as a technically single system consisting of power plants operating in parallel and connected with each other and consumers by an electric network. EPS can be modeled in different ways subject to the problem character and the level of consideration. For example, the structure and allocation of generating capacities of the Unified electric power system (UPS) of Russia are chosen as a rule on the base of aggregated representation of large subsystems (e.g. interconnected EPSs – IPSs) and transfer capabilities of tie lines among them. If the same problem is solved for IPSs, their structure is described similarly in the form of aggregated subsystems and transfer capabilities of tie lines among them. To plan the network expansion it is necessary to represent it in detail with generation capacities and their allocation that are determined at the previous stages. The UPS level usually deals with the UHV backbone network. At the IPS level the electric network is represented in greater detail considering transmission lines, substations of lower voltage classes. This set of problems on EPS expansion planning is a hierarchical sequence of problems, where decisions on system expansion are adjusted (or new decisions are made) at each stage by means of its more detailed examination in the technological and territorial aspects.

As to the structure the technically single EPS in decision making on its expansion is a set of structural units, i.e. companies, interacting with each other. If the expansion problems are solved depending on the structure, an EPS should be represented by vertically integrated, generating and network companies which will expand based on their technological interaction within the system. When choosing decisions on generation and transmission network expansion the vertically integrated company, for example, has to take into consideration potential decisions of neighboring companies on their expansion. The generating company has to allow for prospects in expansion of competing similar companies and the network company as well. The network company, in turn, should have an idea on expansion of generating companies when analyzing trends in its expansion.

Each generating company in this case should consider both prospects for expansion of other companies and the state energy policy (at the federal, interregional and regional levels) and mechanisms of its implementation in the form of tax, credit, tariff and other policies. On working out the strategies and programs of power industry development the state, in turn, should implement its energy policy by taking into account incentives, possible behavior and interaction of generating companies in their expansion.

In general the problems of EPS expansion planning as applied to many subjects of relations that are guided by many non-coincident criteria are of a multi-criteria game character. Let us examine specific features of such statements for the mentioned three groups of problems.

The state strategy and programs of power industry development at the federal and regional levels are elaborated commonly on the base of the hierarchical game multi-criteria statements of problems [3]. Such problems appear, when the state is at the upper level and the power supply companies are at the lower level. These problems are solved by the formal methods for creating the incentives for subjects' behavior at the lower level by the appropriate mechanisms foreseen at the upper level.

Here the hierarchical game multi-criteria problems may be cooperative or non-cooperative depending on conditions.

These problems can take place at interaction of the federal and regional levels, when the state strategies and programs are elaborated for the power industry development. Such problems are aimed to coordinate interests of the country and its regions. The state priorities in the industry development are formed at the federal level and then they are transformed into concrete trends in expansion of generation capacities and electric networks in the considered region. In general when the principles of authority sharing are adjusted and non-contradictory, the hierarchical multi-criteria game problems of a cooperative nature can be involved. The mechanisms of inducement or persuasion are applicable here, however, with somewhat different conceptual interpretation as against the previous case.

The indicated two problems can be studied jointly as one problem that reflects interactions among three groups of subjects: federal and regional levels of the country and power supply companies. Such problems are considered, in particular, as active systems with the distributed control and also reduce to hierarchical game models.

In individual cases the simpler statements of the hierarchical two-level problem as a two-stage sequence of multi-criteria problems of mathematical programming can be used. The strategy of the national power industry development is considered at the first stage, the appropriate recommendations are adjusted at the level of strategies of regional power industry development.

An analogous two-stage sequence of problems can be analyzed in intersectoral terms, when the basic proportions in power industry development are determined at the first stage by the territorial-production model of the fuel and energy complex. Then these proportions are adjusted on more detailed models for decision making on power industry development.

Main attention in the considered problems is paid to mechanisms of interaction between the federal and regional or the energy and sectoral levels of elaborating the state strategies and programs of power industry development. Therefore, consideration of incentives for the behavior of power supply companies by one or another technique for representing uncertain factors becomes necessary. The key task for power supply companies in this case is to work out effective economic, legal and institutional mechanisms. They are to stimulate the companies to take into account priorities of the state policy in electric power industry when elaborating strategic plans of their expansion and making decisions on investment projects. The optimal proportions of such mechanisms can be improved by solving the hierarchical game problems for the subjects "state – power supply companies" mentioned above.

Now we will analyze the next group of problems dealing with elaboration of strategic plans of power supply company expansion. At least three classes of such problems can be discussed here.

For the regulated monopoly without competition it may turn out necessary to solve multi-criteria problems of mathematical programming in terms of uncertainty and different preferences [4]. A rather simple way for considering uncertain factors is a scenario representation of combinations of their values. The game problems in the class of "games with the nature" may be analyzed on the base of ordinary and fuzzy payoff matrices in the other cases.

Elaboration of the strategic plan of the network company expansion, when there are vertically integrated or purely generating companies, refers to the second class of problems. Considering, in a certain sense, a subordinate role of the network company that reduces in the most general case to provision of competition for power producers and a free choice for power consumers, the problems of the network company expansion can be studied in terms of "games with the nature". In this case the uncertainty in behavior of both power producers and consumers in the wholesale market is essential and taken into account by the appropriate payoff matrix of the game. For the network company as the single buyer-seller of electricity the conceptual meaning of uncertain factors is determined, as before, by the competition and at the power consumption level it depends only on demand uncertainty and elasticity. However, here the problem can also be examined in terms of “games with the nature”.

The coordination between generating companies especially under state regulation is possible. Than we gave the problem of cooperative game [5].

And finally, the third class of problems is related to elaboration of the strategic expansion plans of competing vertically integrated or purely generating companies. Without the state regulation the problem reduces to a multi-criteria non-cooperative game. With the state regulation the problem takes the form of a multi-criteria cooperative game, probably of a multi-stage character, i.e. it reduces to a positional game [6,7].

The problems of the third group dealing with decision making on investment projects of electric power installations (power plants, substations, transmission lines) work out a business plan for construction of the corresponding installation. Mathematically the problem statement depends on the investor position. If the power supply company (e.g. the network company) invests in the installation, the investment project may call for the multi-criteria assessment. For an independent investor one should allow for an incentive for behavior of the other concerned subjects and the problem can be associated with the game statement. It can be either cooperative or non-cooperative depending on conditions.

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Nikolai I. Voropai is Director of ESI. He is also the Head of the Electric Power System Department of the Institute and Professor at Irkutsk Technical University. He was born in Belarus in 1943. He graduated from Leningrad Polytechnic Institute in 1966. N.I. Voropai received degree of Candidate of Technical Sciences in 1974 and Doctor of Technical Sciences in 1990. His research interests include: modeling power systems; operation and dynamic performance of large interconnections; reliability, security and restoration of power systems; development of national, international and intercontinental interconnections. N.I. Voropai is a Member of CIGRE, a Senior Member of IEEE and a Member of PES.

Rec'd 2 Feb, 04

2. PROPOSED PERFORMANCE CRITERIA FOR TRANSMISSION SYSTEM PLANNING BASED ON REGULATING FRAMEWORK OF TWBP IN KOREA

Kyung Soo Kook, Young-Hwan Moon, Dong-Wook Park, Korea Electrotechnology Research Institute, Korea

Abstract--This paper describes a regulating framework of Two Way Bidding Pool focusing on the transmission network planning, and examines the proposed performance criteria for transmission system planning in Korea. Performance criteria of transmission system are expected to be a guideline for investment into transmission network. Though Korean government decided to maintain government-leading resource planning even after the restructuring of electricity industry, objective and transparent criteria for transmission system planning are required in electricity market where various market participants trade electric energy.

Index Terms—Transmission system planning, performance criteria, planning standards, electricity market

2.1 Introduction

After Korean Government unveiled "The Basic Plan for Restructuring of Power Industry" in 1999, Korean Electric Power Industry has been under restructuring. Now, Cost Based Pool has been operated by KPX (Korea Power Exchange) from 2001, and market design of Two Way Bidding Pool is coming to the finish. As these circumstances change, power system planning is one of the most influenced parts by restructuring in electric power industry in Korea. When power system was operated by a vertically integrated utility; KEPCO (Korean Electric Power Company), planning was actually done by KEPCO on behalf of government, and the "long-term power development plan" has been made in accordance with national electricity law. But, as Korean electric power industry has been restructured, various market participants already appeared and will appear in electricity market, so new regulating framework is established to guarantee the transparency of the electricity market, even though Korean government decided to maintain government-leading resource planning even after the restructuring of electricity industry under the name of "electricity resource baseline plan"taking demand/supply situation into consideration. Especially in the case of transmission system planning, it has been discussed that objective and transparent criteria are required to be developed because a transmission company remains as a type of monopoly after restructuring in Korea, and transmission network is strongly co-related to all market participants. This paper briefly reviews the progress of restructuring in Korean electric power industry, and examines the proposed regulating framework focusing on transmission network planning. In addition, this paper describes the proposed performance criteria for transmission system planning in Korea.

2.2 The Progress of Reconstructing in Korea

In "The Basic Plan for Restructuring of Power Industry" unveiled by Korean government in 1999, the restructuring is scheduled as following steps.

Phase 1 (~ 2002) : Generation Competition
o The generation sector of KEPCO was spilt up into six generation subsidiaries, five of which are to be privatized step by step. o Gencos trade electricity by bidding through the Korea Power Exchange.

⇩

Phase 2 (2003~ 2008) : Wholesale Competition
o The Distribution/retail sector is to be separated from KEPCO into separate companies, followed by the privatization of these companies as well. o The transmission network will remain open to all market participants to ensure nondiscriminatory use of the national transmission network o Introduction of consumer choice for large consumers; small, residential consumers will supplied by local distribution companies

⇩

Phase 3 (2009~) : Retail Competition
o Every customer will be able to choose his or her own supplier of electricity

Figure 1. The plan for restructuring of Power Industry

Now, market design of Two Way Bidding Pool for introducing wholesale competition and retail competition into electricity market is coming to the finish in Korea though some issues like the separation of Distribution/retail sector from KEPCO are still under discussion. Following tables are summaries of what have been achieved until now.

TABLE I

THE PROGRESS OF RESTRUCTURING IN KOREA

Title	Contents
Grouping of Power plants for Gencos. (1999, 9)	o Thermal plants were grouped into five GenCos in consideration of balanced generating capacity ·revenue· asset value. o Nuclear and Hydro plants were combined into one group in the interest of ensuring safety and maintaining control of water resources
Market Simulation (2000. 4 ~ 2001. 3)	o One year of simulation prior to setting up the electricity trade market and establishing the Korea Power Exchange
Necessary Legislation Enacted.	o "ACT ON PROMOTION OF RESTRUCTURING OF THE ELECTRIC POWER INDUSTRY" enacted on December 23, 2000 enables the separation of generation sector into several companies. o "THE ELECTRICITY BUSINESS ACT" amended on Feb 24, 2002, mandates the establishment of an electricity trade market (Power Exchange) and a regulatory agency (Korea Electricity Commission)
Establishment of Korean Power Exchange (2001. 4)	o Korean Power Exchange was established as a non-profit independent organization, to facilitate transparent and fair management of the electricity trade market
Establishment of Korean Electricity Commission (2001.4)	o Korea Electricity Commission manages the privatization process and oversees market operation. It also takes necessary measures to protect consumers from unfair and deceptive business practices and to ensure fair competition among all participants
Establishment of Six Generation Companies (2001.4)	o The six independent generation subsidiaries of KEPCO are -Korea South-East Power Co. Ltd (KOSEPCO) -Korea Midland Power Co. Ltd (KOMIPO) -Korea Western Power Co. Ltd (KOWEPO) -Korea Southern Power Co. Ltd (KOSPO) -Korea East-West Power Co. Ltd (KEWESPO) -Korea Hydro & Nuclear Power Co. Ltd (KNHP)
Preparation for the Privatization of GenCos.	o Five thermal power generation companies will be up for privatization. Hydro and nuclear generation company is excluded from the plan. o Plan consists of two stages of privatization (1) Stage 1 : Beginning in 2002, two generation companies will be consecutively privatized. (2) Stage 2 : After completion of stage 1, the remaining three will be privatized(Process will begin no later than 2005)

2.3 Regulating Framework for Transmission System Planning

As competition and deregulation are strongly introduced into Korean electric power industry, it has been discussed that followings are necessary to make better transmission planning under the new competitive environment facing uncertainties in electricity market.

- Establishing rational and objective planning standard
- Developing transparent transmission planning process :
  (1) Sharing sufficient information on transmission planning between market participants and planner
  (2) Providing sufficient information on transmission expansion plan to market participants are necessary
- Improving efficiency on transmission investment by transmission planning :
  (1) Designing incentive mechanism for efficient transmission planning by transmission planner
  (2) Designing regulatory mechanism for transmission business

Developments of the electricity network must be planned with sufficient lead time to allow any necessary statutory consents to be obtained and detailed engineering design/construction work to be completed.

The electric resources development plan (ERDP) and the business plan for transmission network development (BPTND) are documents that describe the actual and predicted future changes and additions to the electricity network. These documents show the opportunities for future connections and indicate those parts of the transmission network most suited to new connections and to the transport of further quantities of electricity. This will assist in encouraging the promotion of competition and the development of the transmission network in a non-discriminatory manner.

The network planning committee (NPC) is a key element in the transmission network planning process ensuring that the requirements and proposals of the Korea Electric Power Exchange (KPX), other network service providers (NSPs) and users will be fully considered.

A. Network Planning Committee

In order to facilitate detailed input into the preparation of the transmission network development plan and to provide a forum for co-ordination of this plan with all interested parties the Transmission Asset Owner (TAO) will establish and chair a transmission network planning committee (NPC). The NPC will provide an informal forum for considering detailed developments to the transmission network. The membership of the NPC will include the KPX, other NSPs and users of the transmission network.

The NPC will not have any decision-making functions and its role will be only advisory. The responsibility for planning the transmission network rests completely with the transmission asset owner.

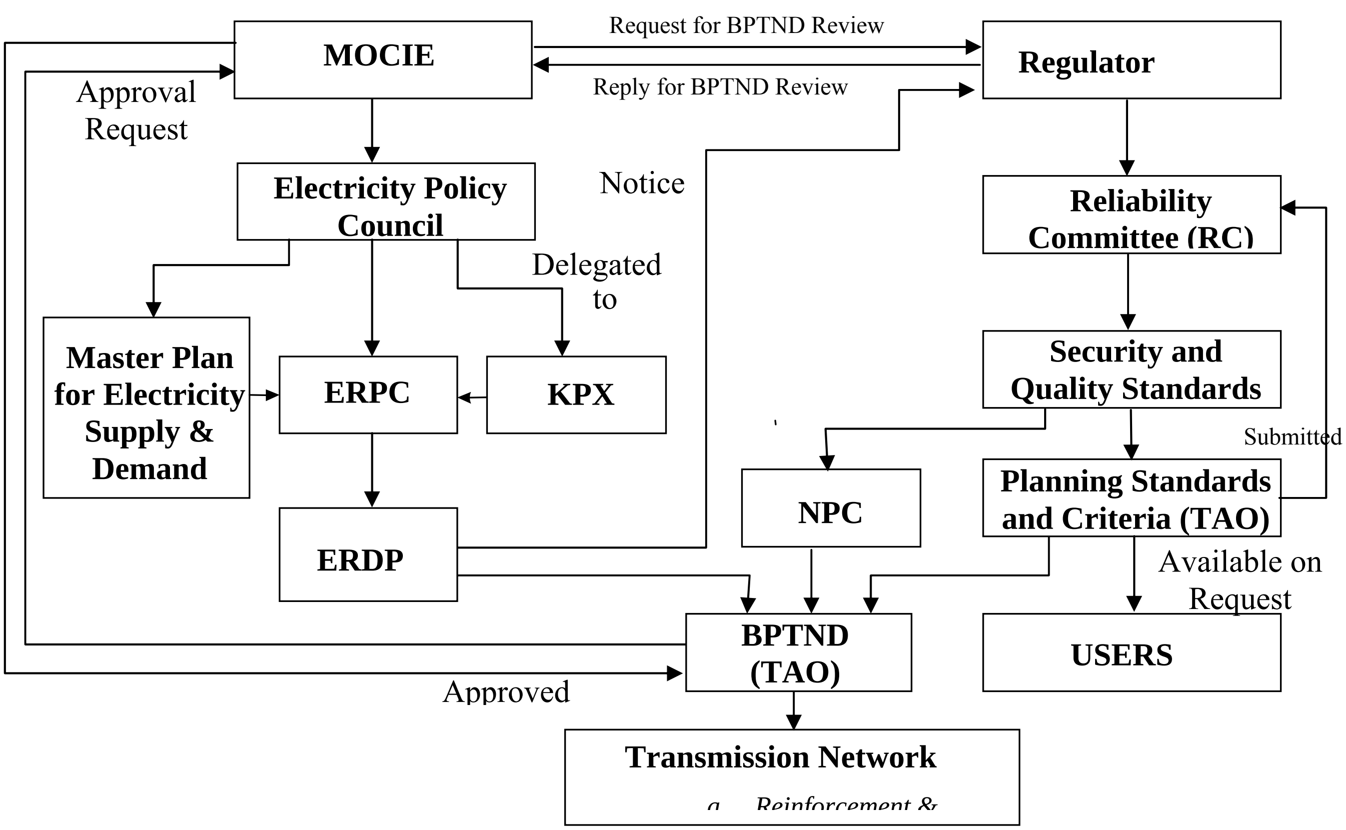

Figure 2. Transmission network planning flowchart

B. Business Plan for Transmission Network Development

Annually the TAO will prepare and issue the detailed BPTND for the next seven years. The BPTND will use the output of the ERDP and will be produced within three months of the publication of the ERDP. The BPTND will consider all the requirements outlined in the ERDP from the needs identified by the various parties represented in the ERPC and will describe how those needs are being or will be incorporated within the plan.

The TAO will be responsible for the preparation of the final version of the BPTND but the TAO will consult with the KPX and will take into consideration the needs of the other parties involved. The final version of the BPTND shall be submitted to Ministry of Commerce, Industry, and Energy (MOCIE) for approval.

Ultimately the TAO will be held accountable for the quality of the planning activities and planning results included in the BPTND. In the event of the KPX being unable to operate the system to the required standards as a direct result of a TAO decision not to make an investment, then the KPX will take the necessary operational measures to secure the system and protect electricity supplies. The TAO will meet any additional constraint costs that occur due to this.

The parties may conduct independent assessments to evaluate alternatives. The KPX may also identify and suggest needs for investment based on its operational experience, engineering practice and professional estimation.

The flowchart for the transmission network planning process is shown in Figure 2.

2.4 Background to Performance Criteria for Transmission System Planning

Based on regulating framework for transmission system planning, this paper describes the proposed performance criteria as a part of planning standard and criteria

A. Development of Performance Criteria

Performance criteria for transmission system planning is determined based on the extend that transmission system can keep supplying electricity to loads when a disturbance occurs. However, load supplying may be interrupted by the adopted strategy of its system operator as well as by <u>deterioration</u> of electricity supplied. So, performance criteria should consider both aspects of these.

In Korea, power system is operated at such a high reliability level that never allows the loss of load on systems other than the one where a disturbance (including the failure of 1 route(2 circuits) 345kV line) occurs Thus, in this paper, performance criteria for transmission system planning is proposed to assure this principle.

B. Performance criteria for normal state

Normal state is a such state that all system elements are in service after power system is adjusted to supply load following specified operating procedures, and no faults or outages occur. For this normal state, performance criteria should meet the normal operating criteria the system operator would apply to power system operation

C. Performance criteria for abnormal state

1) classifying performance level

Performance level is classified based on the allowable actions or conditions on systems other than the one where a disturbance occurs.

In this paper, considering the reliability criteria principle that is applied to Korean power system operation, any loss of load is not allowed in all performance level. Table2 shows each performance level classified by the allowable actions or conditions on system.

TABLE 2
PERFORMANCE LEVEL

Level Allowance	PA-1	PPA-2	PPA-3	PPB-1	PPB-2	PPB-3
Tripping Generator	NO	NO	NO	YES	NO	YES
Generation Output Adjustment	NO	YES	NO	NO	YES	YES
Temporary Loss of Load	NO	NO	YES	YES	YES	YES
Loss of Load	NO	NO	NO	NO	NO	NO

*Temporary loss of load : Case of that the dropped load being restored within a short period of the time by switching actions at the station where the load is supplied

In this Table, a “YES” indicates that the actions or conditions are allowed in a simulation test to meet the performance level, and a “NO” indicates that the actions or conditions are not permitted.

2) Classifying contingencies into performance level

Selections of the considered contingencies are based on probability of that contingency happening. Moreover, special considerations are given to characteristics of the Korean Power system.

In general, contingencies have different effects on power system according to importance of the transmission system where contingencies are occurred. Thus, in this criteria transmission system is divided according to its main function and its voltage level.

- Generator connection system : transmission facilities connected to connection point of generating unit
- Main system : transmission facilities connecting generator connection system and load supplying system.
- Load supplying system : transmission facilities connected to connection point of load

Table 3 shows contingency classification in each sectioned transmission system.

TABLE 3
CONTINGENCY CLASSIFICATION

Performance Level	Generator connection system [			Core system [kV]		
	154	345	765	154	345	765
PA-1	O	O	-	-	-	-
PA-2	-	-	-	O	O	-
PA-3	-	-	-	-	-	-
PB-1	-	-	-	OO	-	-
PB-2	-	-	-	-	OO	O
PB-3	OO	OO	O	-	-	-

Performance Level	Load supplying system [kV]		M. Tr [kV]		
	154	345	154	345	765
PA-1	-	-	-	O	O
PA-2	O	O	-	-	-
PA-3	-	-	O	-	-
PB-1	OO	OO	-	-	-
PB-2	-	-	-	-	-
PB-3	-	-	-	-	-

O : Failure of 1 circuit or 1 Transformer bank
OO : Failure of 1 route(both of 2 circuits) line

In Table3, failure of 1 route is not applied to 765kV transmission line under the assumption that its probability is too low to consider into designing the criteria.

3) Transient voltage criteria

a) Overvoltage

It was reported that over-voltage criteria is not required as a performance criteria[1], and is not recommended since it is usually related to a local problem

b) Undervoltage

Table 4 shows voltage dip criteria applied by WSCC to avoid uncontrolled loss of load[1]. In this table, the values were based on the estimated response of electronic equipment such as computers to voltage dips. In this paper, it is assumed that Korean electronic equipment has a similar characteristic at least, so the values of this table can be applied as an under-voltage criteria. But, only A and B steps in this table would be applied as a criteria since Korean power system does not allow any loss of load.

TABLE 4
VOLTAGE DIP CRITERIA COMPARING LOSS OF LOAD

Step	Instantaneous voltage drop	Maximum duration of V dip exceeding Min. drop	Loss of load
A	25%	20[cycle]	No
B	30%	20[cycle]	No
C	30%	40[cycle]	Critical
D	30%	60[cycle]	Yes

4) Transient frequency criteria

a) Over Frequency

Over-frequency problem is mostly associated to generators, but generators usually have local protection. So, it is reported that over-frequency criteria is not recommended[1].

b) Underfrequency

Under-frequency criteria is selected to coordinate with the operational strategy for UFLS(under frequency load shedding). UFLS is expected to arrest frequency decline and avoid the cascading as a result of a disturbance. To do this, UFLS relay is set to be coordinated with under-frequency protection of generators and any other actions planned to occur when frequency declines.

In Korean power system, UFLS relay is set at 58.8Hz. According to this strategy, automatic load shedding starts if system frequency declines below this value. In this paper, low-frequency criteria is proposed not to allow any loss of load considering this UFLS strategy.

5) Post transient voltage deviation

The criteria for post transient voltage deviation is set to provide some measure of the ability of system to recover to acceptable operating conditions following a disturbance[1]. It is also known that this criteria can provide some information about the incipient voltage collapse problem though it is not sufficient as a voltage stability criteria. 5-10% deviation is usually recommended for this[1].

2.5 Proposed Performance Criteria for Transmission System Planning.

A. Performance criteria for a normal state

A normal state should meet following performance criteria considering operating criteria of Korean power system.

- All transmission facilities should be kept within its thermal rating for normal state
- System frequency should be usually at 60Hz, and adjusted within 60±0.2Hz otherwise any exception occurs.
- Voltage in transmission system should be kept within following guidelines in Table 5.

TABLE 5

VOLTAGE CRITERIA FOR A NORMAL STATE

Voltage level	Voltage criteria	Remarks
154kV	156~164kV	Peak
	152~160kV	Off-Peak
345k	336~360kV	-
765kV	746~785kV	-

B. Performance criteria for a disturbance

A disturbance means fault or outage of system elements that is not expected. Response of transmission system to this has to meet its performance criteria. Table 6 shows the proposed performance criteria for each disturbance.

TABLE 6

PERFORMANCE CRITERIA FOR A DISTURBANCE

Performance level	Transient voltage dip(measured in a load bus)	Transient frequency(measured in a load bus)
PA-1	-Maximum voltage dip : 25% -Max. Duration of V dip exceeding 20% : 20cycle	-Minimum : 59.6Hz -Max. duration of F below Min : 6cycle
PA-2	Same as above	Same as above
PA-3	Same as above	Same as above
PB-1	-Maximum voltage dip : 30% -Max. Duration of V dip exceeding 20% : 30cycle	-Minimum : 58.9Hz -Max. duration of F below Min : 6cycle
PB-2	Same as above	Same as above
PB-3	Same as above	Same as above

TABLE 6

PERFORMANCE CRITERIA FOR A DISTURBANCE (CONTINUED)

Performance level	Damping	Post transient V deviation	Loading
PA-1	Positive	5%	Within nominated rating
PA-2	Positive	5%	Within emergency rating
PA-3	Positive	5%	Same as above
PB-1	Positive	10%	Same as above
PB-2	Positive	10%	Same as above
PB-3	Positive	10%	Same as above

2.6 Conclusion

As electric power industry undergoes restructuring in Korea, it has been discussed that reasonable regulation for guiding planning needs to be established, and the objective and rational criteria for transmission planning needs to be developed because a transmission company still remains as a type of monopoly after restructuring in Korea, and the investment into transmission system should be considered fairly and transparently. A transmission system determines a kind of infrastructure for trading electricity in electric power market, so we have to promote transparent and rational circumstances to induce the efficient investment. This paper reviews the progress of restructuring in Korean electric power industry, and describes regulating framework for transmission system planning. In addition, this paper examines the proposed criteria for transmission system planning. The proposed regulating frameworks provide various market participants with many chances to correlate them in planning transmission system, and the proposed performance criteria became an objective standard by which transmission system is planned and maintained in electricity market.

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3. POWER GENERATION AND TRANSMISSION PLANNING IN INDIA – METHODOLOGY, PROBLEMS AND INVESTMENTS

Subrata Mukhopadhyay, *Senior Member, IEEE*

Summary – India starting from an overall installed capacity of little above 1,300 MW at the time of its independence in late forties, through its successive five-year planning periods could achieve a level of about 110,000 MW with energy generation of the order of 600 billion units in five and half decades. Though initial generation was concentrated to meet load in urban areas, at present vast country side too has been covered under massive electrification program.

Due to thrust on hydro development for the purpose of both irrigation and power, fifties and sixties saw a good hydro-thermal mix in the generation front to meet the load along with the formation of Electricity Boards under the State Governments of the Republic of India and some river-valley project authorities for the implementation of projects. Due to the low level of load and shorter distance of haulage of power, grids hitherto had been restricted to 132 kV and seldom going up to 220 kV level. But with the setting up of quite a good number of mine-mouth large thermal power stations and few hydro power stations at the regional level by the Central Government-owned Companies starting from eighties, state grids were integrated to form the regional ones with simultaneous development of 400 kV networks for power evacuation from major stations as well as for strengthening of networks. Thus came into existence the five regional grids in the Northern, Western, Southern, Eastern and North-Eastern part of the country. At present out of these further integration has made it possible to connect North-Eastern, Eastern and Western synchronously. Other two continue to operate through asynchronous mode of interconnection (HVDC) with the combined one, both in the form of back-to-back and bulk supply links.

In the mean time with restructuring vis-à-vis reform taking place in the power sector from early nineties, some Independent Power Producers (IPPs) came into the arena and started feeding to the state grids coming under concerned regional grid. At the same time in order to improve efficiency and performance in general in certain states vertically integrated state utilities were unbundled to form generation, transmission and distribution companies. Though transmission sector was opened up for private sector participation in early 1998, it is yet to pick up. As traditionally in pockets generation and distribution activities were existing in private sector, only these saw further expansion through setting up of new generation plants and acquisition of distribution companies. Transmission as natural monopoly remains still under government-owned companies, both at central and state level, though right at the beginning of 1998 it has been opened to private enterprises to build, own and operate from point to point. With the open access in inter-state transmission to any distribution company, trader, generating company, captive plant or any permitted consumer as per recent order of Central Electricity Regulatory Commission (CERC) certain changes are, however, expected in future.

With Central Electricity Authority (CEA) of Ministry of Power of Government of India at the helm of affairs, the basic work of planning starts with load survey. State Electricity Boards (SEBs) at the grass-root level do the spade work with different agencies involved through collection of data concerning new demand in commercial, industrial, domestic, public service and irrigation areas and also the growth for the existing systems in the corresponding areas. CEA consolidates the projected figures on all-India basis by working in close coordination with the SEBs and forecasts load and work out total requirement of electric energy and peak load to be met for the next few five-year plan periods based on a combination of partial end use technique and trend analysis, and computing long term projection by extrapolating the energy requirement at power station bus bar. Various components, such as, Transmission and Distribution (T & D) losses (both technical and commercial), load factor, diversity factor, etc. are also taken into account state / system-wise along with growth rate. As the National Power Grid is under formation, long term projection takes care of regional diversity factor considering significant daylight time difference across the country from east to west. Recession in economy, restructuring of SEBs are the other pertinent factors that influence the overall scenario. These figures are, however, scrutinized by certain Departments of Government of India including Planning Commission keeping it mind the commensurate fund requirement vis-à-vis relative priority with respect to the other sectors of infrastructure of the country for investment under public sector.

Having made the blue print, CEA further works out the details of generation corresponding to various scenarios of load projected for few five-year plans ahead. In the last two decades in order to boost the economy, for rapid addition to generation, setting up of thermal generation plants was given much preference. Though side by side hydroelectric power stations were added, the balance tilted very much in favor of thermal to push it to the level of about 72% of the total capacity installed. This is primarily on account of long gestation period, as a result of rehabilitation and resettlement, and other environmental problems, inter-state river-water dispute, etc. and consequent cost and time overrun. Of late of course more attention is being paid to this type of generation of electric power to strike a balance, which otherwise too needed for proper grid operation efficiently with standard parameters and in most economic way.

With the opening of trade barrier, alternatives too are looked into, like, whether to import fossil-fuel or to produce indigenously. Exploration of new gas-wells as well as offshore drilling has lead to quick addition of gas-based plants, which of late are coming up and added to the grid with combined-cycle mode of operation. Thus under integrated resource planning, considering all possible sources to produce electricity in conventional ways including nuclear one, most optimum solution is attempted for meeting the load requirement. In the process of planning for addition of generation, issues of system improvement to minimize T & D losses, raising of plant load factor, Renovation and Modernization (R & M) of old but still running power plants and also generation from renewable and non-conventional sources, etc. are considered to augment overall supply. Having known the load points too, in the process it identifies the possible corridors of transmission of power vis-à-vis energy, though voltage level for it may be just an indicative one at this stage.

As applicable for the planning of any system, the basic philosophy of configuring transmission system is to achieve a level of operating performance with adequacy and security, which in turn requires a trade-off between cost and risk. It may be based on either deterministic or probabilistic approach. Though with enormous amount of operational data available vis-à-vis past experience latter mode may be adopted for investing further, in the scenario of rapid development of system one may have to bank upon still on deterministic approach very much or on a combination of both to expect ultimately acceptable system performance. Accordingly certain planning criteria have been evolved in India. Inputs in the form of possible generation sites with capacity available and so the loads in bulk, the process of transmission planning starts. It involves not only the corridors of transmission lines with voltage levels but also with the finding of locations of associated substations. Adequate transformation capacity in the substation with the possibility of future expansion, flexibility at the operation stage, etc. are the major guiding factors for such planning exercises. The systems so planned, hitherto on regional basis are then presented in Standing Committee of the concerned region. Decision is taken to firm up the addition with the identification of agencies in Central and State sector responsible for construction, owning and operation. As mentioned earlier, private entrepreneur is yet to have a stake in the matter, though the door has been opened.

The problems encountered in having the feasibility of generation especially for hydro development is enormous. In the southern part of the country, while harnessing has been quite appreciable, most of the new generations from this type of source are expected further in the Himalayan region in the northern and north-eastern part of the country. Besides rehabilitation and resettlement problem as mentioned earlier, issues concerning geological stability of the areas as well as consequent transportation of equipment and transmission of power to load centers pose great challenges.

Though in the thermal generation expansion, problem is somewhat less, indigenously available coal has high ash content resulting in somewhat unusually oversized designing of boiler and associated plants for large thermal sets. Of course with economy of scale not so an important factor, IPPs have come up with various sizes of units of different smaller sizes. But in the long run maintainability of equipment may require larger investment on accounts of spares. But due to high rate of growth in load, as inevitable for any developing country, in a shorter time frame, it is also highly desirable to add to the system larger units, particularly when solid fuel is used, to have quicker enhancement of installed capacity. However, this is being limited to some extent due to high-ash contained indigenous coal for use in thermal generation, as just mentioned.

On the other hand due to large population and environmental restrictions particularly due to forest coverage, Right-Of-Way (ROW) for the construction of Extra High Voltage (EHV) transmission lines is gradually becoming more and more difficult. In the early eighties due to the construction of single-circuit 400 kV lines quite a good amount of corridors have been lost with limited amount of flow of power. In fact subsequently with almost same amount of corridor width double circuit construction in hexagonal formation has paved the way for haulage of twice the amount of power. However, as a measure of enhancement of power flow, series compensation (both static and dynamic), is being implemented to increase the loading capability of these lines. Also with the development of loads at intermediate locations, hitherto operating long lines (above 400 km) are being broken to form new substations in between, thereby improving structural stability and other operating parameters of the system in addition to enhancement of loading through these lines. Similarly on certain corridors through forest multi-voltage multi-circuit transmission is being attempted. But still some bottlenecks may be existing in the transmission system on account of inadequate compensation of reactive power at lower voltages, leading to burdening EHV system to run at lower voltage and consequently unable to deliver active power of desired level. However, through various measures being attempted, situation is improving.

On the investment front, if one looks right from independence it may be seen whole power sector has been primarily nurtured with funding by state. Very little investment has come through private sources, that too concentrated in and around some of the large metropolitan cities only. Only since early nineties latter channel has become little active with the opening up of the sector. Though transmission is yet to pick up, for generation and distribution, some progress has been made. Issue of cross-subsidy for the domestic and agricultural areas through revenue earning from commercial and industrial areas could not produce enough revenue on net basis for future investment, resulting in poor financial health of power utilities of the states. Due to this background, it failed to attract private investment even when high rate of return was allowed. Under this category whatever investment has been made so far in the generation, it is restricted to thermal (mostly gas or liquid fuel based), barring one or two hydro projects.

In the power sector, like any other physical system, overall efficiency, in this case, right from generation to ultimate delivery to consumer is a point to be reckoned with. This naturally gives importance to distribution system too. After giving due attention to generation in the initial stages, followed by transmission system by always making it sure to link with every generating system coming up and in between for the improvement downstream as and when necessary, now distribution system is being revamped under accelerated development program with the public investment to a large extent through the states. Haphazard growth due to compelling requirement of delivering electricity to every place at the cost of deteriorating parameters resulted in system with high losses, which when accompanied by low collection of revenue lead to almost bankruptcy of suppliers, mostly the public sector power utilities. To some extent it lead private investors too to shy away from the scene of running the distribution systems. However, with the concept of individual center of profit introduced to some extent, gradually situation is improving with additional investment pouring in this vital part of power sector.

Source: "Sixteenth Electric Power Survey of India", Central Electricity Authority, New Delhi, India, Sep 2000, "Fifth National Power Plan", Central Electricity Authority, New Delhi, India, Feb 2001, "Manual on Transmission Planning Criteria", Central Electricity Authority, New Delhi, India, Jun 1994, "Perspective Transmission Plan 2011-2012", vol. I & II, Central Electricity Authority, New Delhi, India, Jun 1999, "Open Access in Inter-State Transmission", Central Electricity Regulatory Commission, New Delhi, India, Nov 2003 and various reports of studies carried out by the Central Electricity Authority from time to time

BIOGRAPHY

Subrata Mukhopadhyay was born in Asansol, India in 1947. He graduated in Electrical Engineering from Jadavpur University, Calcutta in 1968 and gained his Master's and Doctorate Degrees from Indian Institute of Technology, Kharagpur and Roorkee in 1970 and 1979 respectively. His employment experience of 33 years includes teaching and research in Roorkee and power system planning, design and operation with the Central Electricity Authority of Government of India. He has authored two books and twenty-five papers, and was awarded the IEEE Third Millennium Medal in 2000, the PES Delhi Chapter Outstanding Engineer Award & PES Asia-Pacific Regional Outstanding Engineer Award for 2001, and the 2002 RAB Leadership Award. He is a Fellow of the Institution of Engineers (India).

Rec’d 31 Jan 04

4. GENERATION PLANNING AND INVESTMENT UNDER DEREGULATED ENVIRONMENT: COMPARISON OF USA AND CHINA.

Felix.F. Wu, Fushuan Wen, Gang Duan, Center for Electrical Energy Systems The University of Hong Kong, Hong Kong, China.

Abstract-- The electric power industry all over the world has gone through a fundamental restructuring in recent years from regulated or state-owned monopolies to competitive markets. In many developed countries, such as the USA, where power companies are mostly investor-owned private enterprises, the changes are brought about in a large part because the generators of the independent power producers, originally introduced for environmental and conservation reasons in 1070’s, that use newer technologies, can compete favorably with the generation from the traditional power companies. As a matter of fact, the guaranteed rate-of-return regulation has resulted on oversupply of generation in many developed countries. The developing countries in Asia, such as China, on the other hand, with their rapid economic development, face totally different pressures. Economic growth has driven up even higher growth in electricity. These countries are hard pressed to come up with the necessary capital to build the huge demand of additional generators. As a result, countries are changing the laws and rules to encourage private investment in electric generation. Private generators are then demanding open markets for fair competition and potential higher return.

The promise of the competitive market is a more efficient and responsive industry. The electric power industry is an established industry. Its investment, especially in generation, is relatively high and takes a long period of commitment. Electricity plays a tremendously important and indispensable role in the modern society: in individual’s daily life and society’s economic well-being. Policy makers are straddled with the difficult issue of balancing the adequacy and cost of power supply. Different rules and processes have been devised for generation planning and investment as part of the experiment in restructuring. There is no clear winner of an ideal or optimal solution.

In this paper, after a brief introduction of the power industry and the current status of restructuring in China, we first discuss the process for generation planning and investment in the deregulated environment in the West, in particular, the USA, as well as in China and then compare the impact of such different approaches in terms of the goals of deregulation, i.e., efficiency incentive, economic signaling and risk distribution.

Index Terms—electricity market; generation planning; generation investment; generation adequacy; risk analysis

4.1 Introduction

Since the 1980’s, the electricity supply industry in the west and in South America has been undergoing rapid and irreversible change reshaping an industry that for a long time has been remarkably stable and had served the public well. A significant feature of these changes is to allow for competition among generators and to create market conditions in the industry, which are deemed necessary to reduce costs of energy production and distribution, eliminate certain inefficiencies, shed manpower and increase customer choice. While such restructuring also started in China several years ago, the situation is very much different from that in the west and other countries. As a result, a modified form of restructuring is occurring in China, driven by a need for rapid expansion of capacity in all three sectors, i.e. generation, transmission and distribution.

The power industry in China has rapidly developed in the past 25 years, and currently the generation installed capacity in China ranks the second in the world, only next to USA. Even so, the capacity is still not enough since the economics expand very fast. The annual electricity demand growth rate is around 15%-20% in the recent 3 years. In the summer of 2003, 19 provinces suffered electricity supply shortage, accounting for 2/3 of the provinces in China.

The power industry in China will keep a rapid development in the next 20 years. It is estimated that the annual increase of power consumption in China will be around 6.6 ~7% from 2003 to 2010. The total annual power consumption will be 2,700 TWh by 2010, and the total installed capacity in China will be 600GW then. The annual increase of power consumption will be 4.5~5.5% from 2010 to 2020, the total power consumption will be 4,200~4,600 TWh in China by 2020, and the total installed capacity in China will be 900GW then. With the projects being completed, such as the "Power transmission from the west to the east", the "Mutual transmission power between the north and the south" and the "Inter-connection of power grids over whole China", there will be a nation-wide power grid in China.

While the power industry restructuring represents a world-wide trend and the Chinese government has already decided to reform the power industry by separating the generation sector from the transmission/distribution sectors, there exist extensive debates concerning how competition and sustainable development of the power industry in China could be well balanced.

In fact, one of the key issues in restructuring of the power industry is to ensure that an adequate generating capacity will be available for reliable supply. Without sufficient supply, there will be no competition, and hence, the market will not work properly. This problem appears more serious in China since the load demand increases rapidly.

4.2 Reforming history of the power industry in China

The power industry in China used to be governed by the former Ministry of Electric Power with combined functions of regulation and enterprise practice before 1985. Due to rapid development of economy and hence increasing demand of electric power, electricity shortage became a very serious problem. However, at that time the government did not have much money to build power plants. To solve the problem, investment for power plants from different sources was encouraged by the government. To attract generation investment, the government guaranteed the recovery of generation investment and reasonable return. Specifically, there was a very stimulating mechanism for investment in generation plants at that time. For each IPP, the amount of electricity generated every year and the tariff associated were ensured by a long-term agreement signed by the governments. In general, the yearly return on investment was over 15%. With such a high and stable return and without investment risk, more and more capitals were raised for the power generation sector, and as a result, a large number of independent power plants (IPP) were built in China in the past 15 years.

In order to separate administrative functions from enterprises, the State Power Company of China (SPC) was established in 1997. It inherited from the former Ministry of Electric Power all the assets of power networks and around 50% of the generation installed capacity. By the end of 2001, SP had a total capital of 1,002.7 billion RMB, accounting for 72% of the total capital of China's power industry and ranking the sixtieth among the world 500 strongest enterprises.

In 2002, a significant reform with far-reaching influence was initiated for the power industry in China. The major objective of this round of reform is to make a break to the vertically integrated monopoly of the power industry, to introduce a market mechanism by organization restructuring, and to establish a regulatory system for the competitive electricity market.

For this purpose, it is necessary to break the assets of the SPC by separating power grids from power generation and the generation companies thus established must compete for supplying power in a competitive market. Five national generation group companies and two power grid companies have been established at the end of 2003, by following a fundamental principles: for each generation group company, the scale of assets and quality of installed capacity must be similar so that competition will be workable. With a rational geological distribution, they all have in principal a share of less than 20% in the regional electricity markets. In order to govern the operation of electricity markets, the State Electricity Regulatory Commission of China was established at the end of 2002. This committee is responsible for working out operating rules for the electricity market, regulating market operation and maintaining a fair competition among generation companies.

At the end of 2002, eleven power group companies were established in China, including two power grid companies – the State Power Grid Company of China and the South China Power Grid Company; five power generation groups companies – China Huaneng Power Company, China Power Investment Company, China Huadian Power Company, China Guodian Power Company, China Datang Power Company; four auxiliary companies – China Power Engineering Consultation Company, China Hydropower Engineering Consultation Company, China Water Resources and Hydropower Construction Company, China Gezhouba Company. The South China

Power Grid Company is composed of five provincial power grids – Guangxi, Guizhou, Yunnan, Hainan and Guangdong. The State Power Grid Company of China is composed of the rest of regional power grids – North China (including Shandong province), Northeast China (including the east part of Inner Mongolia), East China (including Fujian province), Central China (including Sichuan province and Chongqing City) and Northwest.

The present reform is only focused on the generation sector. It is expected that restructuring will be extended to the sectors of transmission, distribution and sales, but at this moment, the future picture is still not clear.

4.3 Generation investment

4.3.1 Generation Investment in the Traditional Power Industry

Before deregulation, it was the responsibility of utility companies to assure that enough generation capacity was available and usually there was a centralized generation planning and investment associated. The traditional approach to this was to build planning capacities based on the forecasted load, loss of load probability (LOLP) calculation and estimates of the value of lost load (VOLL), and allocate the costs of the generation capacity implicitly among consumers. The investment and planning were regulated by the government or the regulator. As a regulated monopoly, investment recovery and reasonable profits for utility companies were guaranteed by the government or the regulator, and as a result, utility companies did not have real risks on generation investment.

4.3.2 Generation Investment in the Restructured Power Industry

In the restructured power industry, generally there is no central planning for new generation capacity additions and no guarantee is made anymore for recovery of generation investment and return. On the other hand, generation companies do not have any obligation for ensuring sufficient supply of electricity in nowadays and in the future. Each generation company makes its own independent assessments of the profitability of new generation projects, as for any other industrial investments. Since electricity markets are more akin to oligopoly rather than perfect competition and there exists strong entry barriers, the supply tends to be less than the socially optimal demand. Hence, it is a problem of extensive concerns that how adequate generation capacity can be secured in the long run under the electricity market environment. The electricity market failure in California has brought this subject to the forefront.

Investment on new generation capacity additions is a commercial and risky activity and is expected to become more prudent under the deregulated electricity market environment. This is because investors are more interested in short-term investment return, and are reluctant to invest generation capacity which requires large investment and long recovery period and has increasing uncertainties on load variation, restructuring policy and market management rules which influence their benefits. Investors are expected to spend a considerable amount of time and effort in analyzing the interaction between investment and the decentralized decisions by participants. In making a generation investment decision, expectations concerning future electricity demand, spot market prices, variations of regulatory policies, as well as the financial status are major considerations. The locations, capacities and timing of new power plants are basically at the generation companies' own discretion although an indicative generation planning may be provided by the regulator to guide the investment and planning, as is the case in several South America countries such as Chile, Peru, Bolivia and Argentina.

It is believed by many people especially regulators around the world that energy markets are not mature enough and cannot be entirely relied on for securing a desired system adequacy so that some supporting mechanism is needed, at least in the near future, in order to ensure adequate generation capacity. As a result, in many operating electricity markets there exist different forms of capacity payments for ensuring sufficient supply in short and/or long terms. Up to now, there are basically three approaches for capacity payments as detailed below.

1) ***Capacity Obligation Model:*** In this model, a capacity obligation is imposed to customers by forcing them, explicitly or implicitly, to sign long-term contract with power suppliers. The regulators determine the amount of firm capacity that each one of the consumption entities has to buy, as well as the maximum amount that each generator is allowed to sell. In other words, a reserve is imposed on each load entity in proportional to its load. To meet this requirement, the load serving entity must enter into contracts with generation companies or procure its obligation through a 'capacity market' that is operated by an organization like ISO. This model is employed in Northeast of the USA including PJM, NYPP (New York Power Pool) and NEPOOL (New England Pool). In PJM and NEPOOL, capacity obligations are defined for "load serving entities" or participants. This is the recommended method in the standard market design (SMD) in USA.

A main advantage of this method is that system reliability can be assured according to well proved techniques and procedures that have shown to result in reliable system operation. A disadvantage is that some of the benefit of restructuring may be lost. One of the main problems of the traditional power industry is overinvestment since return-on-investment is guaranteed. By using capacity obligations based on forecasts, there is a risk of over-investment.

2) ***Administrative Payments for Capacity:*** In several countries such as Argentina, Chile, Colombia and Spain, administrative payments are employed with an explicit remuneration for the installed capacity as an economic signal intended to augment the volume of installed and available generation. Specifically, additional payment is made for available capacity during hours with high

demand to motivate capacity investment.

Generation companies are offered a capacity payment based on their availability no matter if they get dispatched or not. The capacity payments are collected from customers as a prorated uplift similarly to other uplift charges such as the transmission charge.

This method has several major disadvantages:

a) It is not easy to determine an adequate level of capacity charge for inducing optimal capacity investments. Basically, the administrative payment for capacity is based on the expected cost of lost load, which is difficult to obtain. Overestimating this cost would create artificially inflated demand for capacity and result in high capacity prices, which in turn will lead to overinvestment on capacity.
b) A fixed capacity charge does not adapt to a varying balance between supply and demand for capacity.

3) ***Explicit Capacity Adder Payment Model:*** In this model the capacity is priced separately from energy and consumers are not required to procure capacity. At the initial operation stage of the England & Wales (E&W) electricity market, this approach was employed. In the E&W market, the capacity payment is set to the value of lost load (VOLL) multiplied by the loss of load probability (LOLP) on half-hourly basis and paid to all available capacity. However, determining an appropriate level of VOLL is very difficult, and in the E&W market it is administratively managed by the regulator through estimating the annual marginal cost of capacity required to meet expected demand at the required reliability standard. This is included in the uplift which is added to the spot market clearing price as the power purchase price. No matter if a generator is dispatched or not, it will receive the capacity payment. When the reserve is tight, the capacity payment will be very high. As a result, the price is very volatile. In this model, the capacity payment is basically determined administratively.

This approach has been criticized for distorting the market price and for being particularly easy to manipulate. Large generation companies have sufficient incentives to withhold capacity so as to magnify the capacity payment as well as to increase the market clearing price for energy, and such manifestations have been observed.

Since the capacity payment is dependent on the system operating conditions and hence is uncertain in the future, this method may not be able to induce sufficient investment on new capacity.

Another major problem of this method is the reliance of capacity payments and capacity requirement on VOLL. It has been criticized repeatedly that VOLL is administratively set and has no market base. A possible way to get a reasonable VOLL is through demand side bidding. Another problem is with the simplified calculation of LOLP.

Although it is difficult to state which approach is the best since different market models are employed in different places, determination of capacity payments by a market mechanism is generally believed a better way than by an administrative pricing method which can not adequately reveal the value of capacity and may result in overinvestment as is the case in the traditional power industry.

How to fairly allocate capacity costs among market participants is also a key issue to address. In the last two methods introduced above, capacity payments are shared by customers at a flat rate, which is usually determined based on energy usage and maximum capacity required. In the first method, it is determined by auction.

4.3.3 Generation Investment in China

The California energy crisis makes the Chinese government more prudent in making the restructuring decision-making of the power industry, especially on generation investment issues. Although the generation sector has already been separated from the utilities in China, investment and construction of new power plants are still under strict control of the government.

According to current energy situation, Chinese government has worked out a strategy for the development of China power industry. That is, "to build up three channels in north China, central China and south China for power transmission from west to east, to further restructure the power generation to improve efficiency, to develop hydropower, to construct of mine-mouth coal-fired units, to shut down small capacity units, to properly develop nuclear power, to encourage heat-electricity cogeneration and power generation by wastes material and renewable resources.

Recognizing the fact that a huge amount of investment will be required in the next 20 years so as to meet the need of rapid economic development and the disastrous event happened in California in 2000-2001, Chinese government will employ a so-called "two-part tariff" for generation companies. As the name denotes, the two-part tariff includes a capacity price and an electricity price. The capacity price will be determined mainly based on investment and construction costs of new power units, while the electricity price will be "discovered" through a pool-based electricity market or long-term contracts. In order to improve the investment efficiency, it is expected that a uniform capacity price will be applicable to the same kind of generation units, at least in a same region (in different regions, the investment and construction costs for the same kind of units may be different) and the capacity price will only cover part (such as 80%) of the AVERAGE investment and construction costs of the same kind of generation units. In this way, the investor will have some degree revenue stability and it will be easier for them to obtain financing for new generation capacity additions. The government hopes that by providing capacity prices for generation units, the recovery of investment and construction costs could be guaranteed to some extent, and as a result, some incentive could be provided for generation investment.

As expected, the “two-part tariff” has suffered strong objections from academics since this does not match with the market mechanism. However, the Chinese government insists that such a policy is very necessary at least at the stage with rapid economic development, since it will be disastrous if serious electricity supply shortage occurs in the future.

According to development plan of the Chinese government, it is estimated that the installation capacities of hydropower, natural gas combined cycle, nuclear power, wind power and coal-fired generation will respectively be 200 GW, 80 GW, 38 GW, 12 GW and 570 GW in 2020.

In China, it has already been determined that the generation planning will be conducted by grid companies although generation investment will be from different sources.

4.4 Risks in Generation Investment

As already mentioned before, there is actually no investment risk for the utility companies in the traditional power industry. The SMD of USA actually leaves the investment risk to the load service entities (LSEs) since LSEs have capacity obligations. While in China, the “two-part tariff” is actually used to reduce the investment risk of investors.

However, in any of the above mechanisms the ultimate risks are borne by the customers and/or investors.

Let us have a comparison of the effects of the above three mechanisms from several aspects such as risk distribution, efficiency incentives and economic signals, based on three scenarios:

a) normal level of power supply
b) over-supply
c) under-supply.

4.4.1 Risk Distribution

The parts bearing higher risk under different supply scenarios with the above three mechanisms are listed in Table I.

TABLE I. RISK DISTRIBUTION

	Traditional method	The two-part tariff in China	Electricity market
Oversupply	Customers	Customers	Investor
Normal supply	No	No	No
Undersupply	Customers	Customers	Customers

4.4.2 Efficiency Incentives

The efficiency incentives of generation companies (utilities) under different supply scenarios with the above three mechanisms are listed in Table II.

TABLE II. EFFICIENCY INCENTIVES

	Traditional method	The two-part tariff in China	Electricity market
Oversupply	Low	Medium	High
Normal supply	Low	Medium	High
Undersupply	Low	Medium	High

4.4.3 Economic Signals

The economic signals through electricity tariffs under different supply scenarios with the above three mechanisms are listed in Table III.

TABLE III. ECONOMIC SIGNALS

	Traditional method	The two-part tariff in China	Electricity market
Oversupply	Weak	Medium	Strong
Normal supply	Weak	Medium	Strong
Undersupply	Weak	Medium	Strong

From the above comparisons, it can be concluded that the market based approach for generation investment could provide both high efficiency incentives and strong economic signals although investors have to bear higher risk. On the other hand, the approach employed in China through the “two-part tariff” is a mixture of regulation and competition, and a major difficulty associated with this approach is how to well balance regulation and competition and this is more a problem of art rather than science.

4.5 Concluding Remarks

A reliable and reasonably priced supply of electricity is critical to the functioning of a modern economy and society. To achieve this goal, it is important to secure adequate generation capacity in the long run. Without sufficient supply, a market cannot lead to maximized social welfare, and sometimes even cannot work at all.

As already happened in California, capacity shortage will probably occur in those markets using the energy-only market model. An adequate capacity payment, in one way or another, appears necessary for ensuring the system adequacy. However, it seems that there does not exist a generally applicable so-called “best” method to solve the generation capacity adequacy problem, since a best solution to this problem is related to many factors such as the past, current and future scenarios of the power industry studied, social and economic development status of the country or region concerned. These factors must be well taken into account in designing a workable electricity market.

The balancing of competitive opportunities and regulatory measures is of great strategic importance in the power industry restructuring and should not be overlooked since the power industry is an important national infrastructure whose failure will have severe social and political implications.

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Biographies

Felix F. Wu (Fellow, IEEE) received his PhD from University of California at Berkeley (UCB). He is now a chair professor of electrical engineering in the University of Hong Kong, and an emeritus professor in the Department of Electrical Engineering and Computer Science, UCB. His research interests are in power industry restructuring, power system investment planning, design of modern control centers, distribution automation, distributed processing etc.

Fushuan Wen received his B. Eng. and M. Eng. degrees from Tianjin University, and PhD degree from Zhejiang University, China, in 1985, 1988 and 1991 respectively, all in electrical engineering. He joined the faculty of Zhejiang University, China, in 1991, and had been a professor there from 1997 to 2003. He visited the National University of Singapore and the Hong Kong Polytechnic University from 1995 to 1997, and from 1998 to 2001, respectively. He is currently with the University of Hong Kong. His research interests are in power industry restructuring and fault diagnosis in power systems.

Gang Duan received his B. Eng., M. Eng. and Ph. D. degrees in power system and its automation from Tianjin University, China, in 1994, 1997 and 1999 respectively. Then he worked as a postdoctoral research fellow at Tsinghua University, China from 2000 to 2002. Currently he is a visiting scholar at The University of Hong Kong. His research interests are in electricity market, energy management system, operator training simulator, and power system planning.

5. INVESTMENT AND DEVELOPMENT PROBLEMS OF RUSSIA'S POWER INDUSTRY

L.S. Belyaev, N.I. Voropai, S.V. Podkovalnikov, V.V. Trufanov, G.I. Sheveleva, Energy Systems Institute, Irkutsk, Russia; A.R. Yankilevsky, Ministry of Energy, Moscow, Russia.

Abstract: The federal law "On electric power industry" establishes some principles of investment attraction. The system of measures and mechanisms of their implementation is needed. The structure of such a system is presented in the paper.
Keywords: Power Industry, Investment Attraction, Development Problems.

The federal law "On electric power industry" adopted in 2003 stipulates the basic principles of the state investment policy in electric power industry [1]. These principles need to be specified in the form of a system of measures and mechanisms of their implementation. The general structure of such a system is presented in Fig.1. Let us comment on the scheme.

The most important objectives of the state investment policy in the sphere of electric power industry are to build a positive investment image of the country and develop a market investment infrastructure (a share market and bank system). It is necessary to essentially increase the level of state guarantees to investors which is possible only with the appropriate legal framework, stability and predictability of the state policy in electric power industry development, available economic mechanisms for implementation of state guarantees, etc. These are the problems of Federal Assembly and Government of the country and their solution will help essentially decrease the investment risk components.

Another important objective is to create an effective system of investment risk insurance including the so-called market insurance (options call, etc.). The role of the state in this context consists in formation of a legal framework for creation of the insurance system that includes economic mechanisms to support it and provide its stability.

The solution of the problems will also be fostered by an increase in the investment attractiveness of power companies, particularly of the generating companies being formed now, which can be achieved by providing financial transparence of their activity, economic stability, predictability and transparence of the management actions, other corporative measures. The role of the state here is also very important as it should create the required legal framework to regulate the activity of the generating companies and their management. The framework should reflect the economic mechanisms that stimulate the management of the companies to act properly and employ economic sanctions in the case the regulating laws are violated.

Another aspect of the state regulation of market relations in electric power industry is the antimonopoly regulation that is carried out on the basis of the antimonopoly legislation by the Ministry of antimonopoly policy.

Elaboration of the state policy on electric power industry development and mechanisms of its implementation is a key problem and the role of the state in solution of this problem should be decisive. The government and, first of all, Ministry of energy should be in charge for the state policy elaboration. This activity employs the elaboration of state strategies and programs of the electric power industry development that could determine the scale and proportions of the industry development, based on the need of stimulating some energy technologies, solving certain social problems, etc. The mechanisms for implementation of the state policy on the electric power industry development are tax, credit, export-import and other economic mechanisms.

Federal and Regional energy commissions should play an important part in the system of providing investment and development of Russia's electric power industry. Their main objectives are presented in Fig.1.

The considered components create the required conditions for investing into electric power industry and for its development. The electric power industry development and the investments required should be substantiated in the frames of the management system of Russia's electric power industry and UPS development. This system includes:

- UPS and IPS expansion patterns that should be based on the system properties of the object;
- Strategic plans for expansion of electric power companies;
- Plans for commissioning of power facilities and investment programs;
- Programs for provision of shortage-free electric power industry development;
- Monitoring systems of investment programs.

All these lines require a methodology whose creation is an independent problem for further studies. Here let us focus on substantiating the elaboration of the programs to provide only the shortage-free development of electric power industry.

The above components of the state policy on attraction of investments into generating facilities of electric power industry call for a scrutiny. The complexity of their substantiation and implementation may result in inefficient and irrational decisions that will not lead to the desirable results in terms of external investment inflow. Besides under a free market the short-term objectives of the investors, including the generating companies themselves, dominate the long-term ones [2]. All this may lead to the inadmissible decrease in the reserves of generating capacities, generation shortage and, as a result, rise in electricity tariffs. Therefore there is a need for special measures to prevent from such situations.

The federal law "On electric power industry" envisages some short-term and long-term measures on prevention from power shortage and subsequent electricity tariff rise. The short-term measures include introduction of constraints on tariff rise (price caps) and introduction of regulation in the corresponding zone of the wholesale electricity market at generation shortage that may result in disappearance of conditions for competition.

The primary long-term measure in the considered context is creation of the state system of planning the additional generation expansion that could provide permanent availability of surplus generating capacities at the wholesale market and avoidance of their shortage. Nuclear energy which is entirely a property of the state can become a basis for development of such an “insuring” additional generation. Currently the nuclear energy has essential potentialities for commissioning additional generating units. Distributed generation, particularly small gas-turbine co-generation plants, may also play an important role as there are great potentialities for their construction.

The considered state system of planning the additional generation expansion should form economic mechanisms to stimulate the generating companies and external investors to invest into construction of new power plants. However the main line is creation of the State Foundation for development of energy and energy conservation. The proposal on creation of the Foundation was forwarded to Russian Government by Ministry of Energy, Federal Energy Commission and State Construction Committee in July 2003.

Creation of the Foundation is particularly topical in 2003-2005 which is related to Russia’s electric power restructuring. Further as the market relations grow stronger and the private investors appear the functions of the Foundation can be reduced to provision of system reliability and energy security of Russia.

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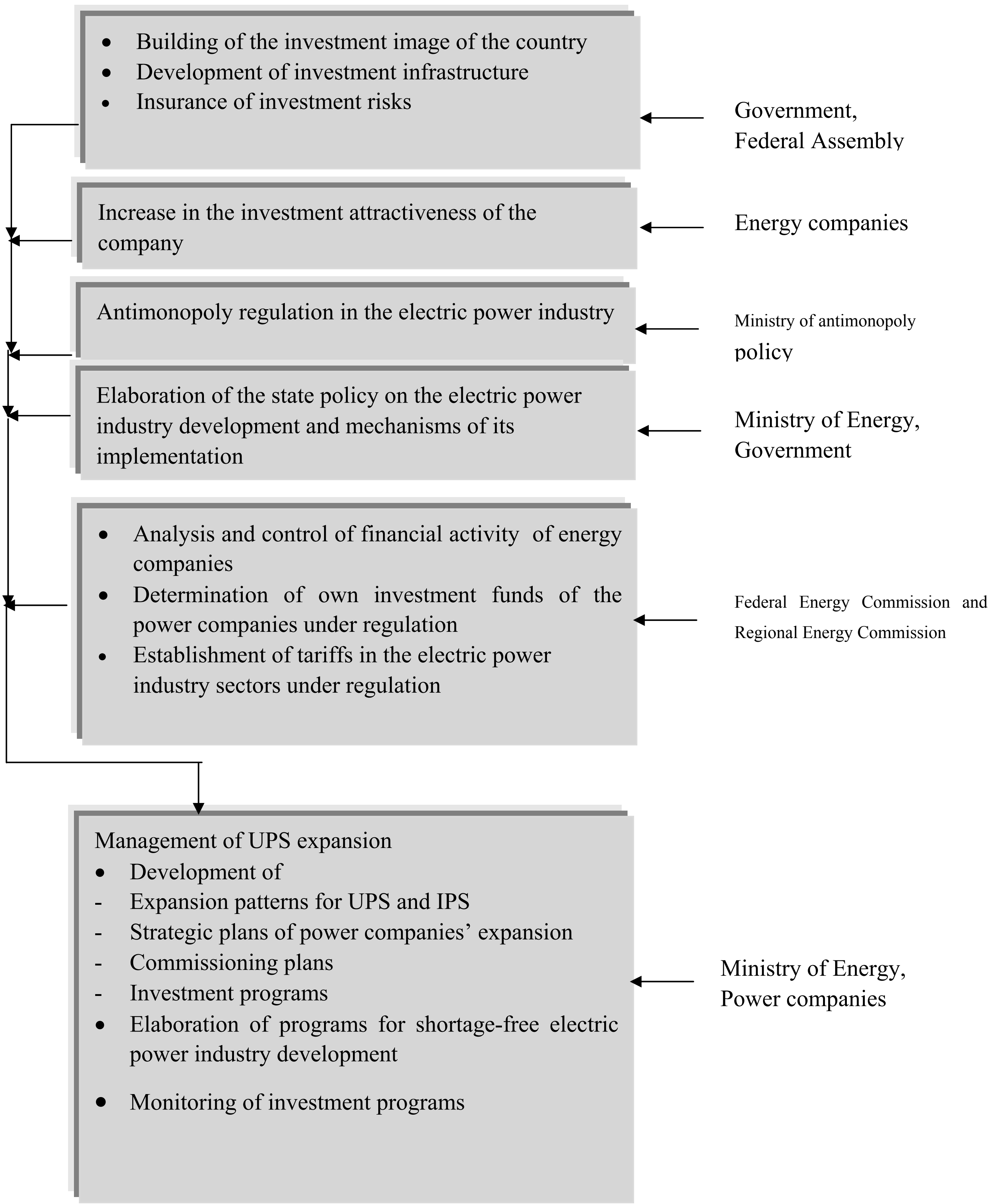


Figure 1. Structure of investment attraction and development of Russia's electric power industry

Lev S. Belyaev was born in 1928. He received an electrical engineer's degree from Moscow Energy Institute in 1950. He has been Doctor (since 1969) and Professor (since 1986) of Technical Sciences. Currently he is a Chief Researcher at Energy Systems Institute named after L.A. Melentyev (ISEM). In 1975-1976 he was with the Energy Program at the International Institute for Applied Systems Analysis – IIASA (Luxenburg, Austria). His main research interests are: development, simulation and optimization of energy systems including global ones, energy technology assessment, interstate electric ties, methodology of decision-making under uncertainty. He is the author and co-author of more than 200 scientific papers and books.

Nikolai I. Voropai is Director of ESI. He is also the Head of the Electric Power System Department of the Institute and Professor at Irkutsk Technical University. He was born in Belarus in 1943. He graduated from Leningrad Polytechnic Institute in 1966. N.I. Voropai received degree of Candidate of Technical Sciences in 1974 and Doctor of Technical Sciences in 1990. His research interests include: modeling power systems; operation and dynamic performance of large interconnections; reliability, security and restoration of power systems; development of national, international and intercontinental interconnections. N.I. Voropai is a Member of CIGRE, a Senior Member of IEEE and a Member of PES.

Sergey V. Podkovalnikov was born in 1958. He received an electrical engineer's degree from Irkutsk Polytechnic Institute in 1980. In 1989 he received the Ph. D. degree in electrical engineering. In 1993 he participated in Young Scientists Summer Program of IIASA (Austria). In 1997 – 1998 he was with Pace University (USA) as a Fulbright Scholar. Since 1999 he has been IEEE Member. Currently he is a Principal Researcher at Energy Systems Institute named after L.A. Melentyev (ISEM). His research interests are: interstate electric ties and interconnected power systems, expansion planing of electric power industry in market environment, electric power industry liberalization, methodology for decision-making under uncertainty and multiple criteria. He is the author and co-author of more than 70 scientific papers and books.

Galina I. Sheveleva was born in 1956. She received an economic mathematician's degree from Novosibirsk State University in 1978. Currently she is a Senior Researcher at Energy Systems Institute named after L.A. Melentyev (ISEM). Her main research interests are: development, simulation and optimization of electric power systems, methodology for investment process management in electric power industry. She is the author and so-author of more than 30 scientific papers and books.

Victor V. Trufanov was born in 1947. He received an economic engineer's degree from Irkutsk State Polytechnic Institute in 1970. Currently he a Principal Researcher at Energy Systems Institute named after L.A. Melentyev (ISEM). His main research interests are: development, simulation and optimization of electric power systems, methodology for decision-making under uncertainty and multiple criteria. He is the author and so-author of more than 100 scientific papers and books.

Andrey R. Yankilevsky, an advisor to the Deputy Minister of Energy of RF, was born in 1954. He graduated from Odessa Polytechnic Institute in 1977 and from Academy of Foreign Trade in 1990. The area of his interests covers the problems of attracting investments in the electric power industry development in a market environment and the problems of determining the rational participation of the state in regulation of the electric power industry development.

6. NORTH-EAST ASIA INTERCONNECTION SCENARIO MAP, AND POWER RESERVE STRATEGY IN SOUTH KOREA

Sang-Seung Lee, Member IEEE; Jong-Keun Park, Senior Member IEEE; Seung-Il Moon, Member IEEE; Seoul National University, KwanakGu, Seoul, Korea

Summary--The purpose of this paper is to obtain the reserve power for the future power shortages faced by the metropolitan areas of the Korean Peninsula and by the southeastern area of the South Korea in North-East Asia. The assumed scenarios will be proposed in the cases of without or with connection to the Sinpo nuclear power plant, which is to be constructed with 2,000MW capacity in the future. In this connection, the types of a power transmission for interconnection consist of the 765kV HVAC and the HVDC. In this paper, the various scenarios for providing the interconnection of the power systems among Far-East Russia, North-East China, North Korea, South Korea, and Japan are presented, and the resulting interconnected power systems are simulated by means of a power flow analysis performed with the PSS/E tool. The power flow map is drawn from the data simulated and the comparative study is done.

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. Therefore, the interconnection of the power systems within the Korean peninsula should proceed without delay in order to lay the foundation for a complete interconnection of the various power systems within North-Eastern Asia. As the substitutes for 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, five cases of scenarios as follows will be proposed according to the assumed scenario.

- The first case of the scenario involves 765 kV HVAC interconnection between Yangju bus of South Korea and Pyongsan bus of North Korea.
- The second case of the scenario concerns 765 kV HVAC interconnection between the Yangju bus of South Korea and the Pyongsan bus of North Korea to supply the Sinpo nuclear power plant which is to be constructed with 2,000MW capacity in the future.
- The third case of the scenario includes HVDC interconnection between the Busan area in South Korea and the Kyushu area in Japan to solve the power shortage in the Gyeongnam area of South Korea.

- The fourth case of the scenario consists of an HVDC interconnection between Sredne-Uchurskaya HPP in Far-East Russia and Wongi bus in North Korea without supplying Sinpo nuclear power plant in the future,
- In the fifth case of a scenario, the assumed scenario for an HVDC interconnection between Liaoning's power network in North-East China and Supung bus in North Korea will be proposed without supplying Sinpo nuclear power plant in the future.

A. Power System 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 demand for power 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. The reasons for upgrading the highest system voltage to 765kV are to improve distribution between the large power plants and the load centers, to provides a stable supply of electric power, to meet the rapidly increasing demand in the metropolitan area, to resolve the difficulties involving transmission routes and substation sites, to interconnect power plants having a large capacity, and to create the necessary backbone for the transmission system in and around the metropolitan area. 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 supply and demand for power is likely to become increasingly unbalanced, because the two regions in South Korea produce a much greater quantity of electricity than they consume. The 5th long-term power supply-demand study published in January, 2001 recorded a current total demand of 41,007MW which will likely increase to 60,718MW in 2010. The total power generation capacity will have to be increased each year to keep up with the growing demand, and will in fact be raised to 1.5 times the current level for a total of 74,611MW in 2010. It is predicted that the electrical load will attain the level of the current developed countries, sometime between 2020 and 2030, representing a total power consumption of over 80,000MW. This represents doubling of the amount of electricity produced, compared with the present level.

B. Power System in North Korea

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.

C. Power system in Far East Russia

Installed capacity of Sredne-Uchurskaya HPP in Far-East Russia has been estimated to be approximately 3,300MW and average annual output to be about 15TWh. Its total half-wave length is approximately equal to 2,500km. Interconnection between Sredne-Uchurskaya HPP and South Korea will pass through territories of Far-East Russia, North Korea, and South Korea. The problem of bulk power transport over very long distances of 2,000-4,000km can be solved with the help of EHV & UHV transmission systems in both DC and AC. There are two types of AC transmission systems (TSs) over very long distances, namely line compensation TSs and Half-Wave TSs. The former includes line, terminal substations and reactive power equipment, which are placed at several intermediate substations of line. Power transfer capability of line compensation TS is primarily limited by stability, and the basic function of the reactive power equipment is to secure this. Half-wave line keeps its reactive power balance for all conditions and there is no need to have compensation devices. Transition from double-circuit 2-pole line to single-circuit 4-pole one improves ecological and economical parameters of DC TS at the expense of some increase of risk of forced outage only under extreme contingencies as mentioned above. For traditional AC TS a separate 3-phase line is an independent unit regardless of type of faults (line-to-ground or complete faults).

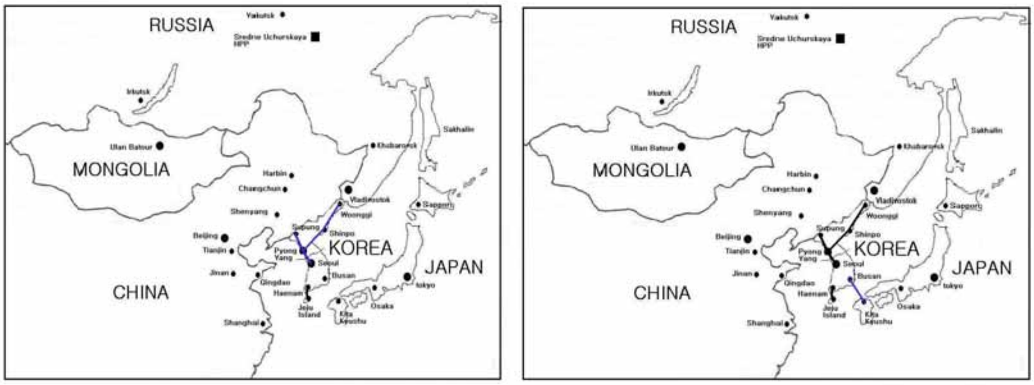
D. Liaoning region power system in North-East China

Liaoning's power network covering the 147,500 square kilometers of land is a modern power network with long history and full of vigor. From 1935 to 1941, the first 154kV and 220kV super-grid in China was formed in Liaoning province. This power network owns the first large 220kV-substation (Hushitai Substation) independently designed and constructed in China and the first extra-high substation (Dongjia Substation) in China that was independently designed and constructed, and adopted as domestic equipment. It installed the first 25MW fossil-fueled unit in China and the first set of domestic 200MW fossil-fueled unit. The 800MW unit with largest single-machine capacity in China has been put into operation in Suizhong Power Plant. In the province, there are five overlarge thermal power plants with an installed capacity of 1,200MW including Suizhong, Qinghe, Tieling, Jinzhou, and Dalian. Huaneng has four sets of supercritical condensing generating units, and fourteen sets of thermal generating units with single-machine capacity at or above 300MW. Power network of 220kV has covered nearly all cities above county level and power networks of large cities in the province have formed two rings. Hydraulic power units may adjust output automatically according to frequency. As a heavy industrial base of China, and with developed politics, economy, and culture, 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%. In Liaoning province, there are two hundred and one 220kV lines totaling 7,610km and five 500kV substations with a capacity of 6,000MVA. At present, there are two hundred and one 220kV lines totaling 7,610km, and ninety-four 220kV substations with a capacity of 18,426MVA.

E. Power system of Kyushu in Japan

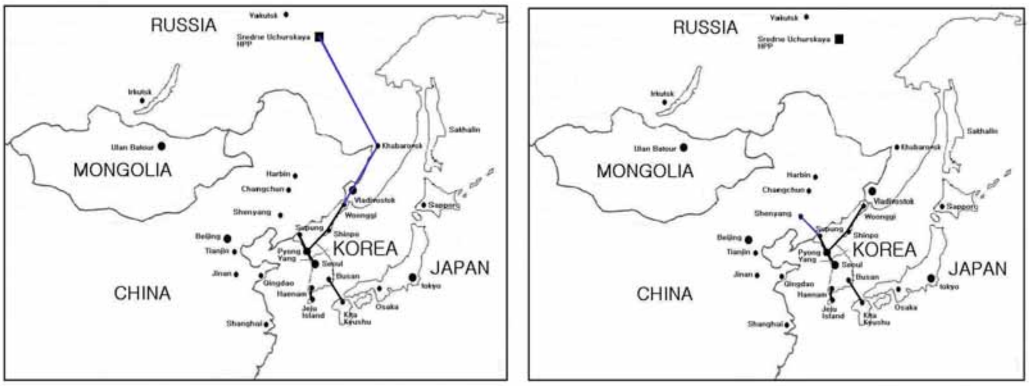
Japan's power system is divided into 9 regional companies serving the areas of Hokkaido, Tohoku, Tokyo, Chubu, Hokuriku, Kansai, Shikoku, Chugoku, and Kyushu, and transmission consists of 500kV, 220kV, 110kV, and DC250kV lines. The frequency used is 60Hz in the western part and 50Hz in the eastern part 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. The overhead transmission system consists of 46,692km of lines with a voltage of less than 110kV and 16,048km of lines with a voltage of more than 110kV and 19,324km of lines with a voltage of more than 187kV. The total length of these overhead lines is 82,065km. The underground system consists of 9,333km of cable with a voltage of less than 110kV, 909km of cable with a voltage of more than 110kV, and 624km of cable with a voltage of more than 187kV. The total cable length is a 10,865km. 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. Kyushu's infrastructure is composed of nuclear, thermal, hydro, and geothermal power generating plants. 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.

The four cases of maps will be drawn according to the assumed scenario as follows.



(a) Route for N.K., S. K. (b) Route for N.K., S. K., Japan.

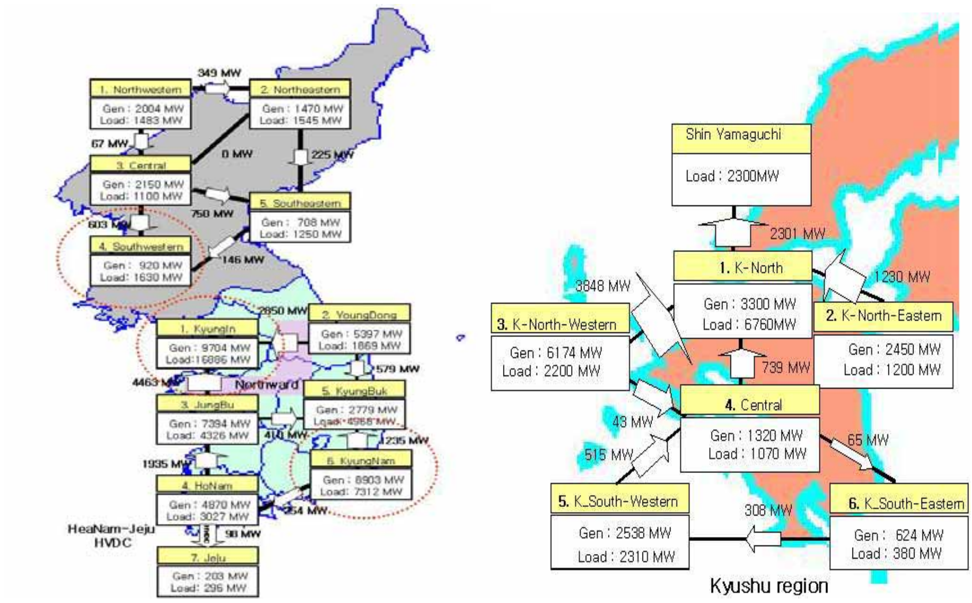
Figure 1. Scenario for Interconnection among N.K, S.K. and Japan



(a) Route for Russia, Korea, Japan. (b) Route for China, Korea, Japan.

Figure 2. Route among Far-East Russia, China, N.K., S.K., and Japan.

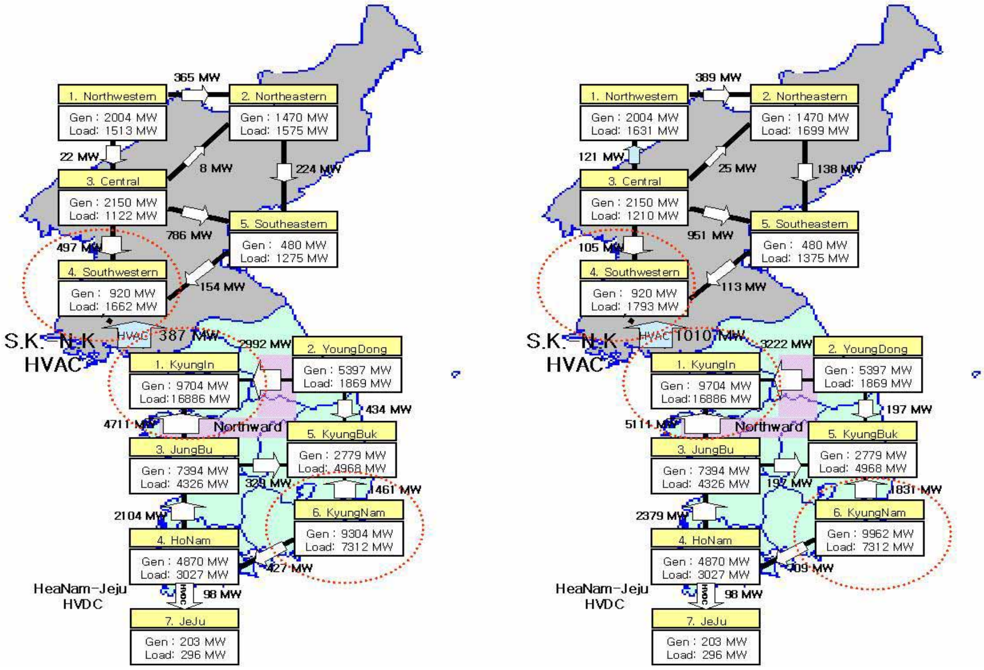
F. Isolated load flow between S.K. and N.K.



(a) Flow in N.K and in S.K (b) Flow in Japan

Figure 3. Isolated Flow Map for N.K-S.K-Japan.

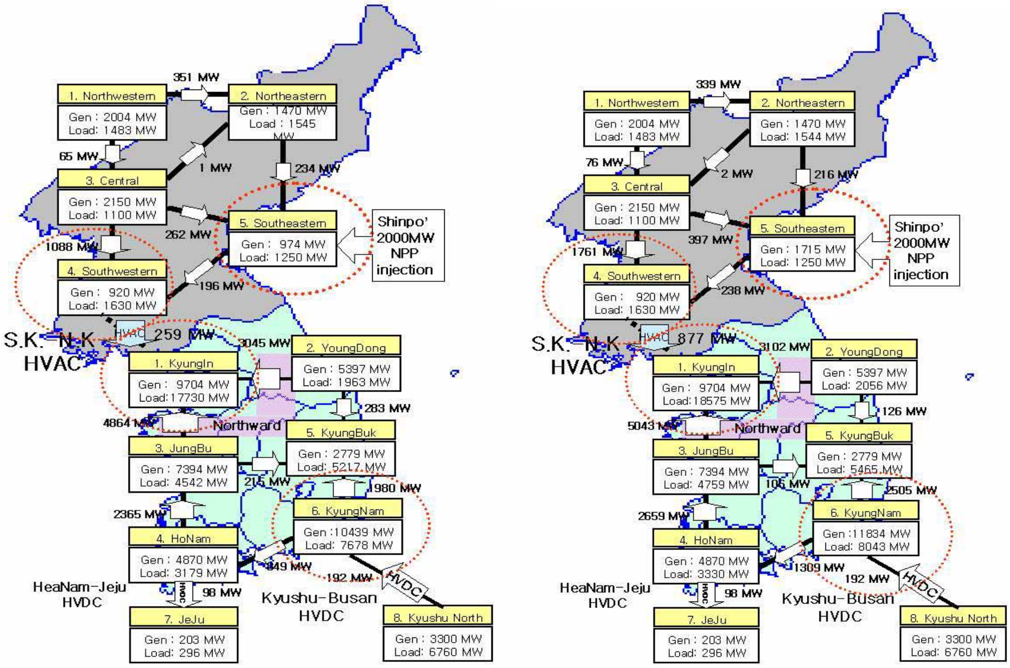
G. Northward Load Flow (S.K.→N.K.)



(a) 2% increase **(b) 10% increase**

Figure 4. Northward Flow Map between N.K and S.K.

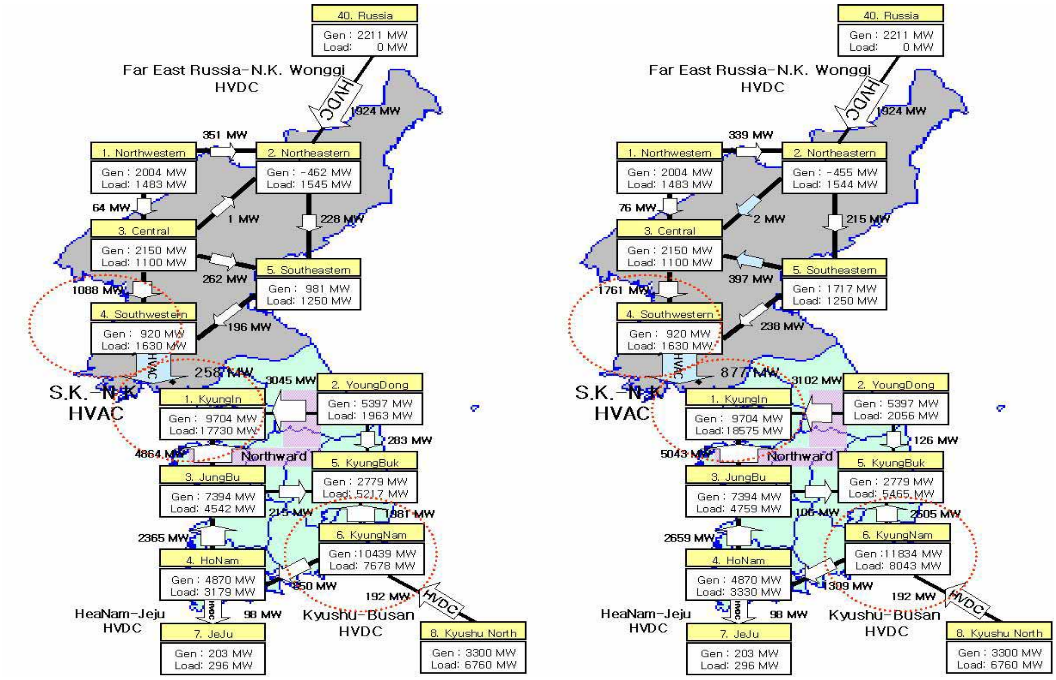
H. Southward Load Flow (N.K.→S.K.) with Sinpo 2000MW NPP Power Injection



(a) 5% increase **(b) 10% increase**

Figure 5. Flow Map between S. K. and N. K. with Sinpo 2,000MW.

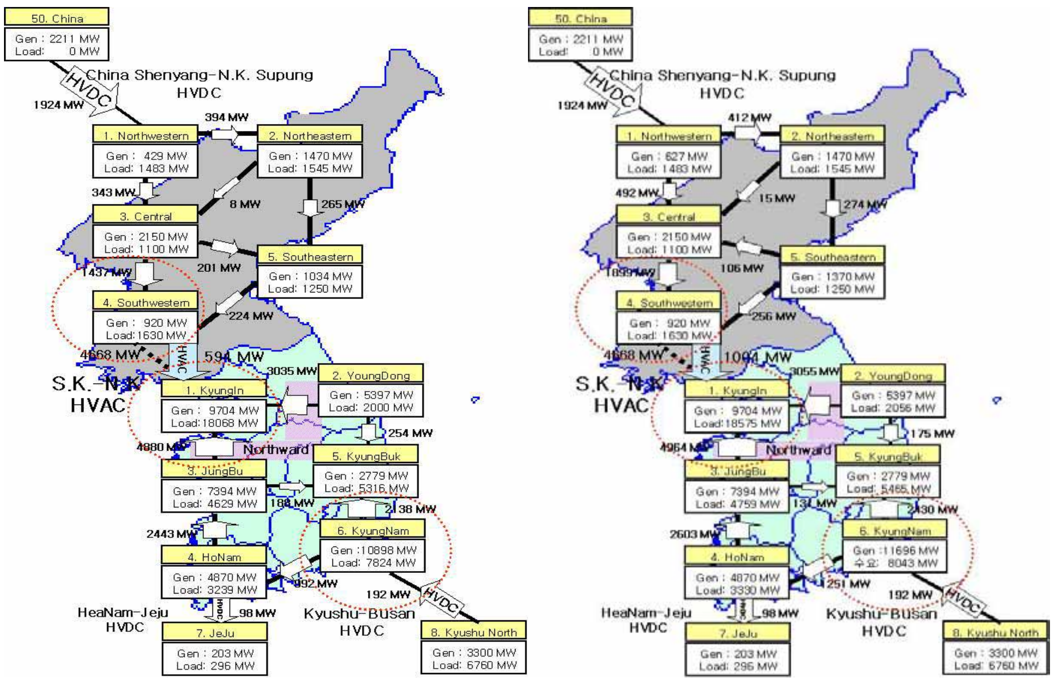
I Southward load Flow (S.K.→N.K.) for Far East Russia-Korea-Japan



(a) 5% increase (b) 10% increase

Figure 6. Load flow map for Far East Russia-Korea-Japan.

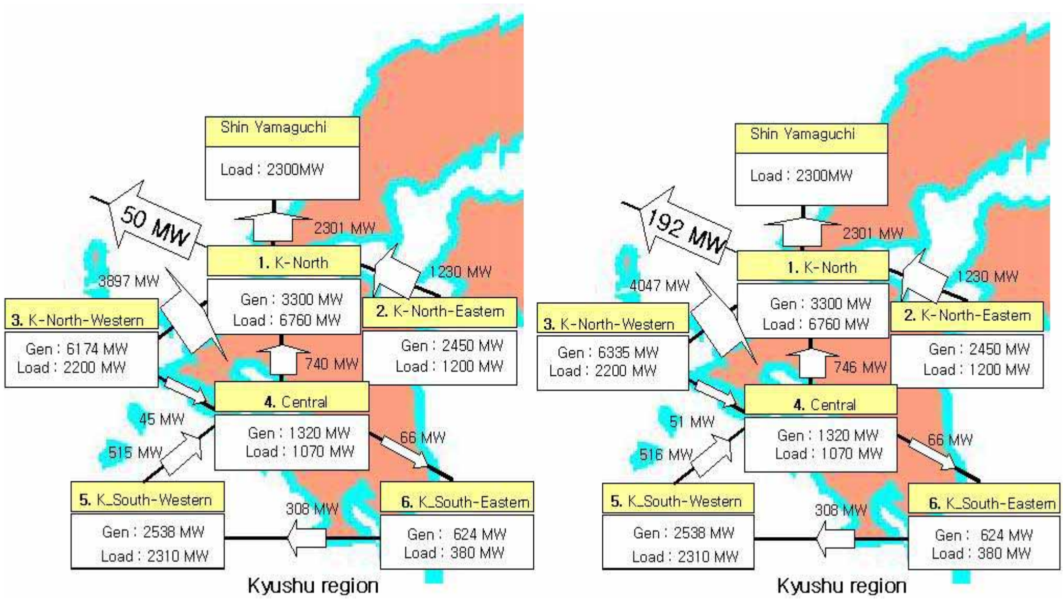
I. Southward Load Flow (S.K.→N.K.) for North East China-Korea-Japan



(a) 5% increase (b) 10% increase

Figure 7. Flow Map for North East China-Korea-Japan.

K. Southward Load Flow (S.K.→N.K.) after Interconnection between South Korea and Japan



(a) 50 MW transfer **(b) 200 MW transfer**

Figure 8. Flow map between South Korea and Japan.

L. Southward load flow result after interconnection in North-East Asia

TABLE I

LOAD FLOW RESULTS OF N.K. AND S.K. WITHOUT SHINPO' NPP INJECTION.

Load increase in N.K.	Result [MW] (S.K.→N.K.) [MW]
2%	387
5%	613
10%	1,017

TABLE II

LOAD FLOW RESULTS OF N.K., S.K. AND JAPAN WITH SHINPO' INJECTION.

Load increase in S.K.	Result [MW] (N.K.→S.K.) [MW]
5%	259
7%	506
10%	877

TABLE III

LOAD FLOW RESULTS FOR FAR EAST RUSSIA-N.K.-S.K-JAPAN.

Load increase in S.K.	Result [MW] (N.K.→S.K.) [MW]
5%	258
7%	506
10%	877

TABLE IV

LOAD FLOW RESULTS FOR NORTHEAST CHINA, N.K., S.K. AND JAPAN.

Load increase in S.K.	Result [MW] (N.K.→S.K.) [MW]
5%	318
7%	594
10%	1,004

TABLE V

LOAD FLOW RESULTS FOR S.K. AND JAPAN INTERCONNECTION (HVDC).

Power injection	Result [MW] (Kyushu→Busan)
50MW	50 (Kyushu→Busan)
200MW	192 (Kyushu→Busan)

Sang-Seung Lee was born in Goseong, Gyeongnam, Korea on April 2, 1960. He received Ph.D. degree in the School of Electrical Engineering at the Seoul National University, Seoul, Korea in 1998. Currently, he is the research leader of Power System Research Division (PSRD) of the Electrical Engineering and Science Research Institute (EESRI), 130-Dong, Seoul National University, Seoul, Korea. His interest areas are power system interconnection, control, power system economics and power distribution system plan.
Mail: ssLee@er.snu.ac.kr

Jong-Keun Park was born in YuSeong, Chungcheongnam-do, Republic of Korea, on October 21, 1952. He received his B.S. degree in electrical engineering from Seoul National University, Seoul, Korea in 1973 and his M.S. and Ph.D. degrees in electrical engineering from The University of Tokyo, Japan in 1979 and 1982, respectively. In 1982, Dr. Park worked as a researcher at the Toshiba Heavy Apparatus Laboratory. He is currently a professor of School of Electrical Engineering, Seoul National University. In 1992, he attended as a visiting professor at Technology and Policy Program and Laboratory for Electromagnetic and Electronic Systems, Massachusetts Institute of Technology. He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and Japan Institute of Electrical Engineers (JIEE). Also, he is presently acting as a fellow of the Institution of Electrical Engineers (IEE) and the Korean representative of the study committee SC 5 “Electricity Markets and Regulation” in CIGRE. (Seoul National University, School of Electrical Engineering, ENG420-020, 301Dong 615Ho, Shillim9-Dong, Gwanak-Gu, 151-744 Republic of Korea, Phone: +82 2 880 5016, Fax: +82 2 878 0100, E-mail: parkjk@snu.ac.kr)

Seung-Il Moon was born in Jeonnam, Korea on Feb. 1, 1961. He received B.S.E.E. degree in Electrical Engineering from Seoul National University, Seoul, Korea in 1985, and the M.S.E.E. and Ph.D. degrees in Electrical Engineering from Ohio State University in 1989 and 1993, respectively. Currently, he is an associate professor of School of Electrical and Computer Engineering and he has been with the School of Electrical and Computer Engineering of 301-Dong, Seoul National University, Seoul, Korea as a professor. His present research interests are power system modeling, analysis and control.
E-mail: moonsi@plaza.snu.ac.kr

7. GENERATION AND TRANSMISSION SECTOR IN KOREAN POWER SYSTEMS

Jong-Keun Park, Professor, Seoul National. University, Korea, Senior Member IEEE

Abstract

Throughout the world, restructuring and competition are being introduced into the electric power industry. In Korea, the act on the promotion of restructuring of the electric power industry was approved to allow the division of generation businesses on December 23, 2000. Furthermore, the Electricity Business Act (EBA) was amended in early 2002 so that it could mandate the establishment of an electricity trade market and the advent of a regulatory agency, Korea Electricity Commission. Amongst the radical changes since the restructuring, we are fleshing out our experiences associated with the investment and expansion planning in generation and transmission sectors. Indeed, we need to work out a long-term generation investment plan, taking into account scheduled and reasonably foreseen unscheduled outages as well as transmission installations. Also, construction, operations, and maintenance of the new facilities will be ensured by a closer examination of development plans for the network. **Keywords:** *Basic Plan of the Electricity Supply & Demand (BPE), Generating capacity construction, Transmission expansion planning*

Summary

1. Generation sector in Korea

Before the electricity industry restructuring, the government had established a Long-term Power Development Plan (LPDP) and the Korea Electric Power Corporation (KEPCO), a vertically integrated utility, had implemented this LPDP in order to secure the affordable and reliable electricity supply. Under the domestic requirements and international pressure, the Korean government decided to gradually restructure the electricity supply industry and to promote consumers' rights. With the electricity supply industry restructuring, the competitive market mechanism will be the crucial factor. In this context, the function of the former Long-term Power Development Plan inevitably started to make changes into non-binding guidelines or reference.

1.1 Restructuring Plan for Electricity Industry

The Korean electricity supply industry restructuring procedures are summarized in the following [1]:

- Generation Competition (2001-2003): Separation and privatization of KEPCO's generation assets into six generation subsidiaries and the introduction of competition in the generation sector
- Wholesale Competition (2004-2008): Separation and privatization of KEPCO's distribution assets and the introduction of competition in the wholesale electricity supply
- Retail competition (after 2009): Introduction of competition in retail electricity supply

The Korean government, in consultation with the Korea Power eXchange (KPX), biennially sets up the Basic Plan of the Electricity Supply & Demand (BPE) just as it had prepared the Long-term Power Development Plan. Here the KPX in Korea has three major functions [2].

- Facilitates operations of the electricity market by monitoring the process of bidding, metering and performing real-time dispatch to balance the supply and demand
- Ensures stable operations of the electric power system and security of electricity supply including maintaining the stability of transmission networks
- Supports the government in planning strategies to meet the demands for electricity by projecting market trends and forecasting demands for electricity

However, the BPE will be established not as a binding force but as a tool providing market participants with appropriate information and market-based solutions.

1.2 Investment in Generation Capacity

Speaking of the recent electricity supply and demand trend in Korea, the electricity demand has steadily soared in accordance with the nation's high economic growth and the increase in the standard of living over the last 30 years. In 2001, a peak demand of 43,125MW and electricity sales of 258TWh ranked Korea the seventh among the Organization for Economic Cooperation and Development (OECD) members [3].

Table 1 Trend of demand and load factor in Korea

(unit:MW)

Year	1999	2000	2001	2002
Peak Demand	37,293	41,007	43,125	45,773
Average Demand	27,320	30,328	32,552	34,974
Load Factor	73.3 %	74.0 %	75.5 %	76.4 %

Table 2 Electricity sales in Korea (unit: GWh)

Year	1999	2000	2001	2002
Residential	34,581	37,102	39,211	42,278
Industrial	120,859	132,260	135,791	144,454
Commercial	58,775	70,173	82,729	91,719
Total	214,215	239,535	257,731	278,451

In spite of such a high demand growth, the continuous construction of generating plants and the promotion of demand side management have led to a stable electricity supply. Although there was no severe shortage of electricity supply capacity, the Korean electric power system has experienced periodical excesses and shortages of the generating capacity. To overcome this fluctuation, the government offers basic policy directions of electricity industry including the reliability criteria, optimal fuel-mix, nuclear power plant construction policy, transmission and/or distribution expansion policy, the target of demand side management, and so on.

To sum up the directions of generating capacity construction, the government guides the investors to construct some generating capacity so that the reserve margin and energy resource mix can be satisfied and to adopt advanced generating technologies for additional capacity in order to cope with the strict environmental regulation. It is generally accepted that new generating plants are constructed at the existing sites as much as possible, and yet it is possible for them to be constructed in the vicinity of load centers, taking into the consideration the difficulties in the exploitation of land for transmission facilities.

In the event that the crisis of the electricity supply is predicted mainly due to the lack of generating capacity, the government will be ready to issue a contingency plan including generation capacity addition by the public company. In the near future, the government will reduce the regulatory intervention and organize the institutional foundations so that the electricity market can achieve the goal of the stable electricity supply and demand in the long run.

2. Transmission System in Korea

Improving transmission system operations will go a long way toward easing transmission bottlenecks by delaying or alleviating the need for construction of new transmission facilities. However, construction of new facilities cannot be avoided entirely. We must guarantee that needed facilities are identified in a timely fashion through open processes and that, once identified, they are constructed expeditiously.

2.1 Overview of Current Transmission Network

Transmission voltages in Korea are 765kV and 345kV for trunk lines and 154kV or 66kV for local networks, while the 66kV lines are being phased out. Also, the power transmission network on Jeju Island is connected to the mainland system by submarine high-voltage direct current (HVDC) cables [4].

Table 3 Transmission facilities in Korea (as of 2002)

Facilities	Line length (C-km)		
	Overhead	Underground	Total
765kV	662	-	662
345kV	7,335	162	7,497
154kV	16,501	1,643	18,144
66kV	1,398	4	1,402
180kV(HVDC)	30	202	232
Total	25,926	2,011	27,937

Now, we will focus on the expansion of transmission system in Korea. The objectives of the long-term transmission expansion planning are classified by the voltage levels:

- 765kV line: It will directly interconnect the generation plants to Seoul metropolitan area.
- 345kV line: It will be constructed for the interregional network and play a role as a bulk power source in the city area.
- 154kV facility: It will be constructed for the intercity network and serve as the supply source of electricity distribution.
- 66kV facility: The construction of new line will be restricted and affected under the consideration of load characteristics.

2.2 Transmission Expansion Planning

Several methodologies to improve the performance of transmission facilities are suggested as follows:

- To secure the stability of large-scaled transmission systems: timely expansion of transmission system and transmission voltage upgrades to 765kV
- To develop a countermeasure to the fault currents: strengthening of breaker standards and installation of series reactor
- To balance the supply and demand of reactive power: reinforcement of condenser for electric power, installation of shunt reactor and development of distributed generations

Most of all, the sizes and date of transmission line construction are determined in such a way that the lines provide sufficient transportation capacity intimately in conjunction with the ultimate generating capacity at the plant sites. In addition, enough has been said to find the authority that would answer the following question: What portion of the construction costs in building up the interconnection lines are charged to generators and/or transmission service providers? Further studies on this issue are needed and discussed in terms of various factors such as voltage level, economic assessment, and technology availability.

References

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[4] Korea Electric Power Corporation (KEPCO): www.kepco.co.kr.

Jong-Keun Park was born in YuSeong, Chungcheongnam-do, Republic of Korea, on October 21, 1952. He received his B.S. degree in electrical engineering from Seoul National University, Seoul, Korea in 1973 and his M.S. and Ph.D. degrees in electrical engineering from The University of Tokyo, Japan in 1979 and 1982, respectively. In 1982, Dr. Park worked as a researcher at the Toshiba Heavy Apparatus Laboratory. He is currently a professor of School of Electrical Engineering, Seoul National University. In 1992, he attended as a visiting professor at Technology and Policy Program and Laboratory for Electromagnetic and Electronic Systems, Massachusetts Institute of Technology. He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and Japan Institute of Electrical Engineers (JIEE). Also, he is presently acting as a fellow of the Institution of Electrical Engineers (IEE) and the Korean representative of the study committee SC 5 "Electricity Markets and Regulation" in CIGRE. (Seoul National University, School of Electrical Engineering, ENG420-020, 301Dong 615Ho, Shillim9-Dong, Gwanak-Gu, 151-744 Republic of Korea, Phone: +82 2 880 5016, Fax: +82 2 878 0100, E-mail: parkjk@snu.ac.kr)

Rec'd 17 June 2004

8. POWER SYSTEM AND POWER MARKET DEVELOPMENT IN CHINA ---- PROBLEMS AND PROPOSED ALLIVIATION MEASURES

Xiaomin Bai and Shuti Fu, China Electric Power Research Institute, Qinghe, Beijing 100085, China, bxm@epri.ac.cn eprifst@public.bta.net.cn

1. Introduction

The economy of China developed in a quite fast rate with an average of 9.5% increase of GDP from 1978 to 2000. Most of the time, power industry was under the pressure of the capacity shortage. Only in recent years (especially 1997-1999) most power systems experienced capacity adequacy. Generally speaking, in years of 2000-2002 the demand and supply in China were almost balanced, except in some minor parts of power systems. However, starting from the summer of 2003, 21 provincial power systems experienced energy shortage, the situation has been getting worse during the winter. In 2003 the yearly installed generation capacity (including thermal, hydro and nuclear) was 30,000 MW, we believe it is the fastest rate in the world; however, the rate of power consumption was still faster, it reached 15.3% in 2003. In 2004 37,000 MW of generation capacity will be installed, still more will be added in 2005 and 2006. According to experts' prediction, the energy shortage problem will probably be worse in 2004, and begin to be alleviated from 2005 to 2006.

The total installed generation capacity by the end of 2003 reached 384.5 GW, total yearly consumption reached 1,908 TWh, both numbered second place in the world.

The yearly total installed generation capacity in China from 1952 till 2020 is shown in Fig. 1. Nationwide interconnection of regional power systems in China in 2005 is shown in Fig. 2.

The rate of installation of transmission lines has been very fast too. The total length of 220 kV and above transmission lines by the end of 2002 reached 188,700 km, in which 37,000 are 500 kV lines. At present there are 6 large regional power systems and 5 provincial power systems (usually they are not interconnected with the main grid). These large regional power systems are only partly interconnected at present. By the end of 2005 these power systems in China will be interconnected into a huge nationwide power network linked by 500 kV and 750 kV HVAC/HVDC transmission lines, except Xinjiang and Xizang autonomous region and Taiwan. This would further alleviate the energy shortage problem.

Considering the changing status for power shortage and power surplus, some key issues related to power systems security and generation capacity adequacy are discussed. One important issue is how to coordinate system generation and power grid construction under the environment of power market with separated generation and transmission companies. Another issue is about how to setup power markets under the situation of continuously changing status of system generation capacity adequacy. In order to manage the generation adequacy problem, the basic conditions for the opening of a market and the requirement for market normal operation criterions are also discussed.

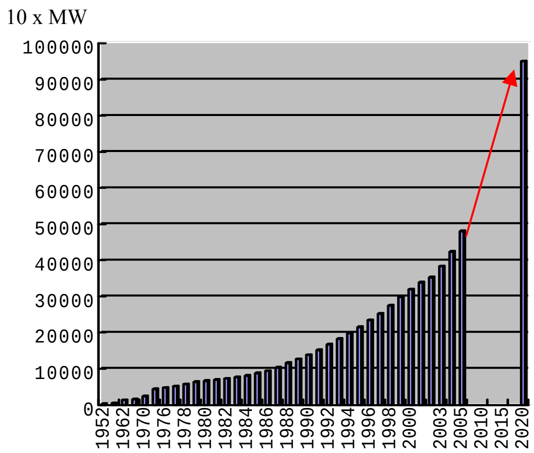

Figure 1 Yearly total installed

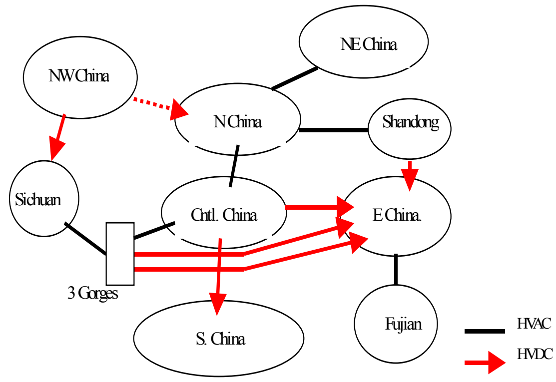

Figure 2 Nationwide interconnection of

Along with the introduction of nationwide power systems interconnection and power market development, the most important issues are how to improve procedures for generation planning and transmission expansion planning, how to procure investment for building new power plants and new transmission lines, and how to alleviate energy shortage problems under deregulation environment. These problems will be discussed below.

2. Power market development

Since the first implementation of deregulation of power sector in UK in 1990, more than 38 power systems in the world has restructured their power system and introduced competition in their electricity markets. There has been a lot of experience and lessons learned during their implementation, however, the restructuring of each later electricity market has been benefited from the experience and failures of former electricity markets.

China has implemented her experimental electricity markets during 1999-2000. Six provincial /municipal power systems have been restructured to implement electricity market, i.e. Shandong, Zhejiang, Shanghai, Liaoning, Heilongjiang and Jilin. Their experiences are:

- Ownership of power plants were not privatized, they were still owned by the state government or provincial government or foreign and domestic investors, but they were separated from the grid company and become independent power plants (IPP).
- About 80-90% of the demand are long-term bilateral contracts (usually one year) between IPPs and the grid company, the rest (10-20%) of the demand is under competition. This practice guarantees stable supply of energy to the user.
- They all established their power market support systems (including dedicated communication links, information system, bidding management system,

schedule application software, settlement management system), they were all developed by different Chinese vendors.

- They have been in operation successfully and improved the efficiency of IPPs. Since the price of users cannot change, so the grid companies have gained some revenues through competition.

However, there are some limitations of deregulation on provincial level, because deregulation on provincial level can only to optimize the utilization of resources in their own territory, they are not able optimize the utilization of resource in the whole region, even when there are cheaper, cleaner energy in neighboring provinces. So what should we do next? Shall we continue to establish electricity market in each province, or shall we establish electricity market for a larger scale?

After evaluation of experiences of deregulation in China and abroad, the State Government of China has made a decision in 2002 for restructuring of power industry: The former State Power Company will be broken into 5 large generation companies (Huaneng Group, Huadian, Guodian, Datang, Power Investment), and two grid companies (State Grid Company-SG, South China Grid Company-SCG). There are 5 regional grid companies under the SG (NE China, North China, NW China, Central China, East China) and 5 provincial grid companies under the SCG in southern part of China (Guangdong, Guangxi, Yunnan, Guizhou and Hainan). The National Electric Power Regulation Commission (NEPRC) was established to monitor and regulate the forming and operation of 6 regional power markets. The forming of 5 generation companies and 6 regional grid companies including the SGC have been completed in the end of 2003.

According to the new policy, each regional grid company should establish one or several dispatch and trading centers (DTC) in their region. How can we establish regional power markets under the present energy shortage condition?

Fortunately not all regions and provinces has energy shortage problems, for example, NE regional power system has no shortage problem, they are the first to establish their regional power market. After seriously planning and design, their power market support system has been in trial operation in the middle of January, 2004. Their special features are as follows:

- The regional DTC is responsible for all wholesale trading and dispatch of 500 kV transmission lines in their region. Provincial dispatch centers are responsible for the security of operation and retail trading in their provinces.
- The regional DTC begin to collect transmission service charges of 500 kV transmission lines.
- The regional DTC is responsible for yearly generation market (consists of about 80% of the yearly demand forecast), monthly market (about 20% of the remaining demand forecast), and a day-ahead market for competition, a real time balancing market, and ancillary services.

- A two part tariff system is implemented for IPPs, which include a capacity charge and an operation charge. The capacity charge would be paid to all available generators no matter whether it is dispatched or not, to compensate their equipment and installation cost. The operation cost would be only paid to those generators whose bidding price are lower than or equal to the system marginal price.
- Other functions are similar to former provincial power markets.

East China Regional Grid Company will be the second regional power market, it is scheduled to be in trial operation in June, 2004. Their special features are as follows:

- Provincial DTCs will coexist with regional DTC.
- The regional DTC will be responsible for day-ahead market and real-time market, provincial DTC will be responsible for long-term bilateral contracts (mostly one year contract between provincial DTC and IPPs in their provinces) and ancillary services.
- The regional DTC will be responsible for coordination between provincial DTCs.
- Other functions are similar to NE regional DTC.

The type of other regional markets will be similar to either NE China or East China. They are all in actively planning and design stage, and will be in trial operation in 2005-2006.

There is a National Control Center in China, their future mission would be coordination among 6 regional power markets, and settlement of 500 kV and above tie-line charges between regions.

3. Generation planning, transmission expansion planning and investment in China

Generation planning. In the past, generation planning and transmission expansion planning studies were usually done by electric power design institutes. Take a regional power system for example. The usually way is, the regional grid company (RGC) provides the load forecast (5 years or 10 years), and entrust a design institute (usually a large design institute in the same region) to do the generation planning and transmission expansion planning. Based on the load forecast, the entrusted design institute would make a study on how much generation capacity will be needed each year, where these generation plants should be located, how many transmissions corridors would be needed to transmit the power to the load. The design institute would propose several schemes, make technical and economic studies and compare the results. The final plan will be approved by the regional grid company and State Grid Company. Sometimes some very important planning projects (such as Three Gorges transmission project) can be entrusted to CEPRI to do detailed analysis, because CEPRI has advanced analytical tools and experienced experts.

If there are hydro resources available in the region, hydro generation planning would be entrusted to hydro-electric power survey and design institutes. They will make a survey on the water resources in the region, and make a proposal on the location and capacity of hydro stations to be built, and a yearly construction schedule. This proposal will be submitted to the regional grid company and Ministry of Water Resources as well as State Grid Company for approval. If it were a 5-year plan or 10-year plan, the hydro generation plan would be updated every year.

Transmission expansion planning. Usually regional grid companies are responsible for transmission planning between provinces (usually 500 kV or above), provincial power companies are responsible for transmission planning in their provinces (usually 220 kV). There are 6 large thermal power design institutes and 6 hydro-electric power design and survey institutes, one in each region, and small design institutes in each province, they do the planning works for the regional grid companies. For very large transmission projects (such as Three Gorges transmission project or Nationwide Interconnection Transmission Project), many design institutes, together with the General Electric Power Planning and Design Institute (GEPPDI) and China Electric Power Research Institute (CEPRI) are working together to do the planning. Based on local load forecast and the national economic growth rate, and generation planning in the whole region, they would work out several transmission schemes, such as pure AC or DC, or hybrid AC/DC, what voltage level should be adopted, etc. for each scheme, technical and economical analysis will be made, such as load flow analysis, n-1 security analysis, transient stability analysis and dynamic stability analysis, sub-synchronous analysis etc. By comparison of technical and economical results of several feasible schemes, the best scheme will be determined. Again, the final transmission planning proposal will be approved by the State Grid Company (former State Power Company).

After deregulation, we think the generation and transmission expansion planning procedure may not change much.

Investment. As for investment, in the past practically most of power plants and transmission construction were funded by the former State Power or former Ministry of Power, except some large industry owned power plants. Since the national budget was limited, so the investment problem has been a limiting factor for the growth of generation and transmission expansion in China. To overcome the energy shortage problem, in the mid eighties the "provinces take the main role" policy prevails, some were invested by local banks, some by foreign loans, and some BOT plants were built. Before the separation of generation and transmission, the former SP manages state-owned electric power assets (almost ½ of the generating capacity) and ran the country's national transmission networks. After reform, the ownership of power plants is distributed to 5 large generation companies. They will take the responsibility to invest new power plants. They have income from operating their IPPs, if necessary they may loan from local or foreign banks. As for which generation company may obtain the right to build new plants for a certain regional company, there are two possible options: by bidding, or by contract.

The investment for new transmission lines came from various sources. Usually the investment for tie lines (330 kV and above) between provinces were shared by provincial power companies. Investment for transmission lines (500 kV AC/DC) between two large regions usually was shared by the two neighboring regional grid companies. Investment for outgoing lines connecting the power plant to the main grid was usually included in the budget of power plant project. For very large power plant or transmission project such as Three Gorges project, the state government provides the investment, it was approved by the National Congress. We assume that the source of investment for new transmission line projects may continue to be so after the reform.

4. Energy shortage problems and proposed alleviation measures

In the introduction it has mentioned that China faced serious energy shortage problem in 2003. 21 provinces had to partly curtail their load which caused considerable damage to the industry and inconvenience to the social life. The cause of energy shortage is due to the following reasons:

- The rate of economic growth was faster than it was expected. The rate of economic growth for 2003 was planned at 7%, but the actual growth rate reached 9.1%, and the annual consumption of energy increased 15.3%. Of course energy shortage became inevitable.
- There was drought in some of the provinces, consequently hydro-stations can not produce enough power, which only make the energy shortage problem even worse.
- Although China produced 1.7 billion ton of coal in 2003, still can not provide enough coal for thermal power plants. This was another cause of the energy shortage.

The proposed counter measures are as follows:

1) To increase annual installed generation capacity. China will install 37,000 MW of generation in 2004, 48,000 MW in 2005[1]. It seems that the investment may not be a problem, because most provinces which suffered by energy shortage today are very enthusiastic to invest and install new power plants in their provinces. It is expected that the energy shortage problem will become alleviated in 2005-2006.

2) To increase the reserve capacity requirement. According to the present design guideline, the requirement for reserve capacity is between 20-30% (including 8-15% for maintenance schedule), usually 25% reserve is used for planning purpose. Since the long term load growth rate is difficult to predict accurately especially in a fast growing environment like China, it is recommended to use higher figure for planning purposes to avoid future energy shortages.

3) More reserve capacity may result in large number of power plants become idle if the rate of load growth is slower than predicted. However, in China we adopted a two-part tariff system in power market bidding. One part is capacity cost, which

just cover the average cost of investment per kW of power plant no matter whether the generator is dispatched or not. The other part is bidding price, it depends on the efficiency of operation of the generator. Two part pricing scheme is already experimenting in NE China Power Market. By application of this two-part tariff system the risk of investors for building new power plants can be considerably reduced.

4) To limit the investment for new fast growing, energy intensive and low efficient industries. The state government has made a decision to limit the new investment for steel, electrolytic aluminum, cement industries and construction of more luxurious houses. If the original schedule for installing of steel plants completed in the end of 2005, the yearly production capacity of steel in China would reach 330 million ton, it would be far more than necessary. The production capacity of electrolytic aluminum, cement industries are in similar situation, if not worse.

5) To shave the peak load, in East China and South China two-stage energy fare system have been implemented. It is likely more regions will adopt this system.

6) Demand Side Management (DSM). This technology has been implemented in Shanghai and other cities. A multi-stage energy fare system is applied for some industries. It implies that the higher the load, the higher the energy fare, which automatically encourage the user to reduce their own load. This measure is very effective to help reduce the load, experience in Shanghai has resulted reducing 2,000 MW in peak load.

7) Likewise, since the average unit production cost per energy consumption is high in China, about 0.15 kWh/RMB, which is 3 times as high as in USA, and 5 times as high as Japan. We propose that in industrialized part of China, a special fare can be added on each kWh of energy when the reserve capacity is lower than certain threshold, say 5%. The smaller the reserve capacity, the special fare would be higher. If there is no spare and curtail of load become inevitable, the fare would be still higher. This measure would encourage all users to save their energy, and this fare can be used for building new power plants.

8) Economic signaling in power market design. To encourage incentive of investment for building new power plants and transmission lines, we propose to use Long Term Marginal Cost (LTMC) combined with MW-KM price system which would give an economic signal for investors to select the best site to build new power plants. And we propose to use a two-part transmission service charge system, including a fixed charge to compensate the investment charge, and an operation charge to cover the operation charge. This system would encourage the incentive of investors to build new transmission lines.

9) Implementation of more sustainable new energy source. For instance, in summer time the air conditioning load becomes very high. In Central China, the air conditional load reached 30% in summer of 2003. If solar energy generators are encouraged to be installed on tops of all new buildings, it can be best utilized to feed air conditioning load, because the hotter the weather, the more power can be

generated by solar generators. In the winter, solar energy can be also be utilized for heating purposes.

5. Conclusions

1) China's economic growth rate has been very fast. The average rate of growth from 1978-2000 was 9.5%. But the average rate of growth of total installed generation capacity was only 7.8%, which was the main cause for energy shortage. Lack of investment was the limiting factor for installing more generation plants and transmission lines.
2) China started her deregulation in late nineties. 6 provincial power markets were in trial operation in 1999-2000. Restructure of Chinese power sector has been completed in 2003. 5 large generation companies and 6 regional grid companies were formed. NE China Grid Company has been the first regional power market in China, it is characterized as a sole wholesale power market in the region. The second regional power market is East China, it is characterized as a hierarchical power market, in which provincial power markets would coexist with regional power market. Other regional power markets will fall into either NE mode or East China mode.
3) Past generation planning and transmission expansion plan procedures in China is presented. Investment for expansion usually comes from various sources. Future procedures for generation and transmission planning and investment are discussed.
4) By installing more generation and transmission lines and limiting of investment for energy intensive industries as well as by implementation of various demand elasticity measures, it is predicted that the energy shortage problems will be alleviated by 2005-2006.

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Biographies

Xiaomin Bai: Received BS degree from Electrical Engineering Department in Tsinghua University, China in 1977, M.S and Ph.D. degree from Graduate School, EPRI, China (1982, and 1988 respectively). He is a Deputy Chief Engineer of China EPRI, Senior Member of CSEE, Member of IFAC and observer of CIGRE C5. His main research interest includes power system analysis and control, power market, EMS and DMS.

Shuti Fu (IEEE SM)**:** Received BS degree from Electrical Engineering Department in Tsinghua University, Beijing, China in 1948. He has been Deputy Chief Engineer for

China Electric Power Research Institute, now a consultant. His main research interest includes power market and EMS. He is a senior member of CSEE, former working group member of IFAC power system and power plant control subcommittee.

Panelists

1. Nikolai I. Voropai
Director
Energy System Institute
Russian Academy of Sciences
130 Lermontov Str.
Irkutsk 664033
Russia
E-mail: voropi@isem.sei.irk.ru
Tel. +7 3952 424700
Fax +7 3952 424444

Ekaterina Yu. Ivanova
Senjor Researcher
Energy System Institute
Russian Academy of Sciences
130 Lermontov Str.
Irkutsk 664033
Russia
E-mail:
Tel. +7 3952 423486
Fax +7 3952 426796

2. Dong-Wook Park
Vice-President
Korea Electrotechnology Research Institute
P.O. Box 20, Changwon,
Korea 641-600
E-mail: dwpark@keri.re.kr
Tel. 0551- 80-1300
Fax: 0551-80 – 1307

3. Subrata Mukhopadhyay
SMIEEE
PES Chapter Representative, Region 10 East
PES Region 10 Communications Coordinator
and IEEE PES-IAS Delhi Chapter Chair
Dll-62 Pandara Road, New Delhi – 110003
India
E-mail: pesdelhi@ieee.org
Tel: +91-11-23387501 & 23381502 (H)
Fax: 26170541 (W)
04GM0424

4. Felix F.Wu
Professor of Electrical Engineering

The University of Hong Kong
Pokfulam Rosd
Hong Kong
E-mail: ffwu@eee.hku.hk
Tel. 852- 2859 2709
Fax: 852- 2559 8738

Fushaun Wen
The University of Hong Kong
Pokfulam Rosd
Hong Kong
E-mail: fswen@eee.hku.hk
Tel. 852- 2859 2709
Fax: 852- 2559 8738

Gang Duan
The University of Hong Kong
Pokfulam Rosd
Hong Kong
E-mail: duangang@eee.hku.hk
Tel. 852- 2859 2709
Fax: 852- 2559 8738

5. Lev S.Belyaev
Chief Researcher
Energy System Institute
Russian Academy of Sciences
130 Lermontov Str.
Irkutsk 664033
Russia
E-mail: belyaev@isem.sei.irk.ru
Tel. +7 3952 425840
Fax +7 3952 426796

Sergey V.Podkovalnikov
Lead Researcher
Energy System Institute
Russian Academy of Sciences
130 Lermontov Str.
Irkutsk 664033
Russia
E-mail: spodkovalnikov@isem.sei.irk.ru
Tel. +7 3952 428930
Fax +7 3952 426796

Viktor V.Trufanov
Lead Researcher
Energy System Institute
Russian Academy of Sciences

130 Lermontov Str.
Irkutsk 664033
Russia
E-mail: trufanov@isem.sei.irk.ru
Tel. +7 3952 424677
Fax +7 3952 426796

Galina I.Sheveleva
Senior Researcher
Energy System Institute
Russian Academy of Sciences
130 Lermontov Str.
Irkutsk 664033
Russia
E-mail: trufanov@isem.sei.irk.ru
Tel. +7 3952 424677
Fax +7 3952 426796

Andrey R. Yankilevsky
Head of Department
The Ministry of Energy Russian Federation
7 Kitaigorodsky pr.
Moscow 109074
Russia
E-mail: yankilevsky@mte.gov.ru
Tel. +7 095 7105811
Fax: +7 095 2068221

6. Sang-Seung Lee
EESRI, 130-dong
Seoul National University
San 56-1 ShinLim 9 Dong
KwanakGu
Seoul, 151-742
Korea
Telephone: 82-2-880-5516
Fax numbers: 82-2-883-0827
E-mail: sslee@er.snu.ac.kr
Tel: +82-2-880-5516
Fax: +82-2-883-0827

. Jong-Keun Park
School of Electrical Engineering
301-dong
Seoul National University
San 56-1 ShinLim 9 Dong
KwanakGu
Seoul 151-742
Korea
Korea

E-mail: parkjk@snu.ac.kr
Tel: +82-2-880-7247
Fax: +82-2-883-0827

Seung Il Moon
School of Electrical Engineering
301-dong
Seoul National University
San 56-1 ShinLim 9 Dong
KwanakGu
Seoul, 151-742
Korea
E-mail: moonsi@plaza.snu.ac.kr
Tel: +82-2-880-1821
Fax: + 82-2-883-0827 Jae-Chul Kim
Seul-Ki Kim
Ho-Yong Kim
Korea

7. Jong-Keun Park
School of Electrical Engineering
301-dong
Seoul National University
San 56-1 ShinLim 9 Dong
KwanakGu
Seoul 151-742
Korea
Korea
E-mail: parkjk@snu.ac.kr
Tel: +82-2-880-7247
Fax: +82-2-883-0827

8. Xiaomin Bai
Electric Power Research Institute
Qinghe, Beijing 100085
China
E-mail: bxm@epri.ac.cn
Tel. +86 10 62918546
Fax +86 10 62913126

Shuti Fu
Electric Power Research Institute
Qinghe, Beijing 100085
China
E-mai: **eprifst@public.bta.net.cn**
Tel. +86 10 62916912
Fax +86 10 62913126

Panel Session Chairs:

Tom Hammons
Chair International Practices for Energy Development and Power Generation
Glasgow University
11C Winton Drive
Glasgow G12 0PZ
UK
E-mail: T.Hammons@ieee.org
Tel: +44 141 339 7770

Nikolai I. Voropai
Director
Energy System Institute
Russian Academy of Sciences
130 Lermontov Str.
Irkutsk 664033
Russia
E-mail: voropi@isem.sei.irk.ru
Tel. +7 3952 424700
Fax +7 3952 424444

E N D