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Status of Power Markets and Power Exchanges in Asia and Australia

Integration of electric power systems and power exchanges among countries, regions and companies is an objective tendency in world power industry development. The Asian region is rather promising in this respect since the sources of energy resources for electricity production are often very remote from the load centers. Besides, there are the so-called system effects from electric power systems integration that are beneficial for all the participants. The role of power exchanges increases still further under deregulated electricity markets particularly in terms of the possibilities to decrease the market prices of electricity.

The following viewpoints are discussed in this Chapter:

- Ideas of the different countries in Asia and Oceania of either the positive or negative role of power exchanges in a market environment;
- Estimations of potential limits in the power exchanges and substantiation of such limits if there are any;
- Concrete results of the studies on power exchanges in the feasibility studies of prospective projects of power exchanges.

9.1 Status of Reform and Power Exchange in India: Trading, Scheduling, and Real Time Operation Regional Grids

Though India opened up its power sector in nineties to private sector investment, initial impact was mainly in the form of generation addition and then with unbundling of generation, transmission and distribution, to some extent on the last segment also. Transmission as natural monopoly remains still under government-owned companies, both at central and state level, though right at the beginning of 1998 specifically it was 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 November 2003 order¹ of Central Electricity Regulatory Commission (CERC) certain changes are, however, taking place. Under such circumstance changes in methodology of generation scheduling to meet demand are also inevitable to take into account this very aspect from time to time considering role of various participants in power market. However, at the same time aspect of system security vis-à-vis stability is given due importance in real time grid operation, as envisaged also under Electricity Act 2003².

9.1.1 Development of Indian Power System^{3,4}

India has a federal structure with 28 States, 7 Union Territories and a Central Govt. Present installed capacity of India is 112 GW with 25% of hydro besides nuclear, gas, wind and conventional thermal plants. For the purpose of power system, the country was demarcated into five geo-political regions in the year 1964 and gradually different states within the region got integrated and by the 1980s five mature regional grids were under operation. In 1992 Eastern and Northeastern regions were interconnected. In 2002 the Northeast, East and West with a span of 2800 km. of synchronous grid became operational. There are four HVDC Back-to-Back stations of 500 / 1000 MW capacity each and three Bi-pole HVDC long lines for carrying bulk power. Indian power system also has multiple connections at different voltage levels with neighboring countries, like, Nepal and Bhutan. Cross border power exchanges are progressively increasing. There is wealth of experience regarding expansion of the grids and experience of operating large grids.

Resources are unevenly spread with hydrocarbon deposits in the East and Central parts of India and huge hydro potential in the Northeastern and Northern part of the Northern Grid. There is a promising availability of gas on the long coastal lines. The load growth has also been uneven with widely varying per capita income in different states. This calls for transfer of large blocks of power over long distances.

Central Electricity Authority, a statutory organization produces the national plans. Integrated resource planning approach is adopted. Transmission system expansion is coordinated for achieving a most optimal plan with least investment. Perspective plan and the long-term forecasting are also carried out by the Authority.

The Legislations on Electricity in India traversed a long distance and all the old act since 1910 onwards have been merged and recast in the form of a consolidated Electricity Act 2003. Indian Electricity Grid Code (IEGC) and the State Electricity Grid Code (SEGC) are in place after public debate. The Regulators, Authorities and the state utilities are framing rules and Regulations. The Central Electricity Authority is developing metering codes.

Indian Electricity Act 2003 envisages Electricity Regulators at State level (State Electricity Regulatory Commission, SERC) to take care of intra-state affairs while the Central regulator (Central Electricity Regulatory Commission, CERC) to take care of inter-state matters. The tariffs, codes and directions on Open Access are now being issued by the Regulators in a fair and transparent way and the Government is distancing itself.

Transmission has been recognized as a separate activity in 1998 by the legislation. In line with the federal structure the Central Transmission Utility (CTU, at present Power Grid Corporation of India) and the State Transmission Utilities (STU, at present Transmission / Grid Company TRANCO or GRIDCO of the concerned state) have been created for coordinated development of the transmission segment. Transmission being a natural monopoly is a regulated entity and barred from trading as per the law. Transmission system in India has developed from 132/220 kV and now well-meshed 400 kV mature grid forms the backbone of Indian Grid. A rapid development is envisaged by the year 2012 matching with load growth and generation addition of 100,000 MW.

By and large the GENCO (Generating Company), TRANSCO and DISCO (Distribution Company), STU, CTU, SLDCs (State Load Dispatch Centers), RLDCs (Regional Load Dispatch Centers) and CERC structure has been followed while progressing with reforms and unbundling. There are variations in the models being adopted by different states. Some of the states have already privatized their distribution systems.

The Indian sub-continent with its vast geographical distances and diverse resources is struggling to achieve cost reduction through 'Economy of Scale'. The large size generators of 660 MW are being added as 500 MW sets have already stabilized and are dominating presently. For transferring large blocks of power, 765 kV transmission system has been envisaged overlaying 400 kV meshed network.

Private participation in generation by way of IPPs (Independent Power Producers) and Mega Power Projects supplemented with Government investment is envisaged. So far the transmission has been through the State / Central Government companies. Joint venture and IPTC (Independent Power Transmission Company) route have also been launched to attract private investment in the transmission segment. With unbundling and demarcated distribution companies, niche market is being created for private participants to enter into the field of Distribution. With Open Access, investment in captive power plants is likely to get a boost, as they would have access to enter the Indian power market.

765 kV transmission systems connecting the regions and the resource-rich areas and load centers would form a super highway for wheeling of power from source to sink. A massive capacity addition plan of 50,000 MW of hydro and 100,000 MW of thermal power has been launched and expected to yield result by the year 2012.

The variety of diversities between the different regions of India and its neighboring countries open a vast potential for coordinated expansion and operation to take care of time, season and resource diversity prevailing in the sub-continent. It would also enable to level the diversity caused by various uncertainties, like, investment, load growth, etc.

9.1.2 Grid Operation

The Indian Electricity Grid Code (IEGC) lays down rules, guidelines and standards to be followed by the various participants in the system to plan, develop, maintain and operate the power system in the most efficient, reliable and economic manner while facilitating healthy competition in the generation and supply of electricity. The IEGC covers roles of different organizations and their linkages, planning codes, connection conditions, operating codes, scheduling and dispatch codes, metering and management of the grid code.

The regional grids in India are operating as loose power pools in which the constituents have full autonomy and have the total responsibility for scheduling and dispatching their own resources, arranging any bilateral inter-change and regulating their drawl from the regional grid.

The Regional Load Dispatch Centers coordinate the entire activity of day-ahead scheduling. For the purpose of scheduling and settlement a day is divided into 96 blocks of 15 minutes

each. The shared generation resources declare their availability and RLDCs communicate the entitlement to all the stakeholders. Based on the load-generation availability and economics, all the constituents furnish their requisition from the shared resources that are aggregated by the RLDCs and communicated to the shared generators. These are based on the long-term contracts and allocation normally done by the Central Government in consultation with the State Governments.

On day-to-day basis the utilities enter into bilateral agreements of different kinds. The SLDCs and RLDCs incorporate the same in the schedule provided there is no network congestion. In case of congestion the same are moderated by the SLDCs / RLDCs. There is an elaborate time line for the scheduling and dispatch procedure. Provisions also exist for revising and modifying the schedules by any of the participant in case of contingency for which at least six time blocks, i.e., one and a half hour notice is required. The scheduling is carried out through a web-based scheduler and all the revisions are posted on the web in a transparent way. At the end of the day the final schedule becomes the datum for calculation of 'Unscheduled Interchange' as well as payment of energy charges. In other words the schedules are Commitments / Contracts and payment of energy is decided and finalized based on the finally implemented schedules.

At present there are few Traders licensed to operate in the Inter-state Trading. Traders are given different categories of license depending on the volume of transactions and the Regulatory Commission assesses the financial capacity and other parameters of the Traders before issuance of license. Traders are to file the periodic Returns to the Regulator furnishing the details of the transactions.

The Open Access Regulations stipulated by the Commission and the Procedures framed by the Central Transmission Utility is followed by the Open Access customers, which are primarily the Traders. The Open Access Regulations enacted in 2003 are undergoing speedy refinements based on the experience of various stakeholders including the Operators. The volume of trading has grown phenomenally and huge number of transactions has already taken place.

Load Dispatch Centers have been declared as an apex body both at the State level and at Regional level, i.e., SLDCs and RLDCs. The National Load Dispatch Center (NLDC) has also been conceived to take care of inter-regional and cross boarder exchanges. Load Dispatch Centers are also barred from trading activity and are 'no profit no loss' centers with fees and charges being determined by the Regulators. Since both transmission and system operation are neutral to the market and barred from trading activity, at present Indian power system is having synergy with transmission and Grid operation. The Load Dispatch Centers both at Regional and State levels have been upgraded with state-of-the-art technology.

Each region acts as a pool. Control areas are demarcated with each state and shared generators being separate entity and there are many participants in the pool. After much debate and in consonance with the federal structure, India has opted for loose power pool and decentralized market.

The settlement system has undergone drastic evolution in recent years. A new scientific settlement system popularly known as 'Availability Based Tariff' (ABT) has been introduced in all the five regions in the country in a staggered fashion. The new mechanism has three parts, viz. capacity charges linked to the availability of the generation, scheduled energy charges based on the requisition and the schedules by the control areas.

The unique and the third component is termed as 'Unscheduled Interchange' (UI), which is deviation from the schedule and its pricing is linked to frequency. The UI mechanism has a self-healing property, brings in equilibrium and emulates all the properties of 'Non-Cooperation Game Theory' automatically. The mechanism while causing economy also complements reliability, yet maintaining the sovereignty of the utilities giving choice and freedom.

Besides long-term (25 years) and short-term day-ahead, spot / balancing market by way of UI mechanism where the prices are linked to the frequency has been created. The spot prices are linked to frequency that is said to be collectively controlled and effectively stabilized. It does not require elaborate calculations. Regulators tinker the UI vector from time to time in order to achieve economy and reliability by creating a pseudo competitor.

Unlike other Pools the Pricing Mechanism of Unscheduled Interchange, i.e., Schedule minus Actual is linked to frequency. The Central Regulator after public hearing and debate notifies the UI price curve. The slope of the curve, kinks, upper and lower ceilings are arrived at by the Regulator with a view to cause overall economy as well as quality in the grid.

The fundamental theory of equilibrium and the negative feedback has been adopted while deciding the UI price curve. As UI price is linked to frequency and as it is known that frequency deviations represent surplus and shortage situation, accordingly the UI price varies with real-time shortage or surplus. In other words, as the surplus emerges, frequency rises and the UI price starts coming down. Similarly, with shortage the frequency starts falling and the UI price rises. The participants in the Pool seeing the rise and fall take corrective action that acts as a negative feedback and dampens fluctuations and system reaches equilibrium. The beauty of the scheme is that the Pool price needs not be calculated. It is totally transparent. The mechanism encourages 'Merit Order Operation' in a distributed fashion as virtually all the generators compete with the prevailing UI price that keeps sliding.

The marked difference in the scheme expects the frequency to fluctuate in order to give a signal to the generators to adjust their output. A distributed optimization is effected. The mechanism is also akin to Non Co-operative Game Theory through which the best prices are achieved. The most interesting feature is that while economy is achieved the mechanism also compliments reliability. In UI Mechanism utilities while economically gaining also contribute to reliability. This makes the approach absolutely novel.

Trading of power has been recognized as a separate, distinct licensed activity by the legislation. There are variety of products being invented by the Traders and the prices are being discovered however with a benchmark of prevailing UI prices fixing the virtual roof and floor.

With the formulation of power pool, settlement system, trading, in 2003 Regulators introduced Open Access in the inter-state transmission. The plan is to progressively introduce Open Access for embedded and captive power plants. The Open Access has been primarily categorized as 'long-term' and 'short-term'. The detailed speaking orders with elaborate procedure has been put in place for calculation of transmission charges, obligation of losses, prioritization of allotment, etc.

The transmission development management is a coordinated activity and by and large there is not much of intra-regional congestion. However with increase in inter-regional flows congestion has started surfacing in the inter-regional links. Regulators have devised bidding procedure to take care of the congestion. Augmentation of Inter-Regional links capacity to 30,000 MW is envisaged by 2012.

9.1.3 Power Exchange

At present there is no formal 'Power Exchange' operating in India. However, the Buyers, Sellers and the Traders meet periodically in the various coordination meetings and deals are negotiated. Some of the constituents have also opted for tendering and bidding for power procurement through Traders in a competitive way. With continuous oversight by the Regulators the resource scheduling and turnover of power by trading is improving and causing economy to the sector while giving much desired choice to the utilities.

Basically the concept of a Power Exchange is that of a platform that enables market participants to go about their business of bidding, pricing, scheduling and settlement of transactions on a real-time basis. In the Indian context, Power Trading Corporation (PTC) of India, formed in the year 1999 in the public sector, was initially conceived as an intermediary with a primary focus on managing credit risk for the Mega Power Projects. However soon it recognized its larger mandate of creating a vibrant power market. The concept of an exchange gets subsumed in this mandate, and it came up with the statement of purpose as to be a frontrunner in developing a Power Market and striving to correct market distortions.

The frontrunner has conceived a roadmap for setting up a power exchange in the country. While shaping the concept, the frontrunner has the onus of visualizing the phasing of various activities and corresponding investments as also educating various market participants, existing and prospective, about the potential benefits. All this has to be dovetailed to the Indian context, with its own peculiarities and consequent capacity to absorb change.

With the initiative taken for the first time in 2001, few market participants took part utilizing the concept of exchanging surplus power with entities that have complementary deficits at a market determined rate. The structure of these transactions was simple, with seller entities supplying power on a round-the-clock basis for periods varying from a few months to one year to buyer entities. While seller entities benefited by the enhancement of cash flows due to better capacity utilization, the buyers got reliable supply at an economic, market-determined rate. At the same time, various linking entities in the supply chain like the CTU, STUs, RLDCs and SLDCs were able to make adjustments in their processes to allow these market determined exchange transactions to overlay existing long-term, bilateral transac-

tions. The participants experienced the benefits of exploiting complementary surplus-deficit situations arising from an annual or seasonal time-epoch.

As market participants and the linking agencies gained confidence from the demonstration of success in these early transactions, more participants were initiated into the market. At the same time, the experience curve benefits started accruing to the participants and their power planning and operational processes became geared to take on shorter response time. At this stage, it was felt that the time was ripe to initiate services that exploited complementary demand-supply situations arising from shorter time-epochs, like even a one-day period. Therefore in 2002, new products were introduced that allowed flow of power for limited hours during a 24-hour period, like 'Morning Peak', 'Evening Peak', 'Off-Peak' and various combinations like '18 Hours Supply'. As all participants benefited by utilizing these trading opportunities for shorter durations, many participants experienced the unique position of reversing roles from buyer to seller during the same 24-hour period. At the same time, implementation of Availability Based Tariff was started with the Western Region (WR), and PTC as Trader looked at opportunities arising from this situation. Therefore, 'ABT' Power arising from the need of the utilities in WR to balance schedules and optimize their revenues was sold to utilities in the Southern Region (SR) at a fixed rate (the regime in SR had until then not changed to ABT). This transaction, though small in terms of the volume traded, was a pre-cursor to 'As-and-When-Available' power, a product evolved later in 2003 when all participants became subject to the ABT regime. During 2002, with the acquisition of long-term contracts for trading of power from Chukha and Kurichhu projects in Bhutan it has been possible to diversify the supply portfolio. The participants' confidence in the evolving market mechanism is perhaps best symbolized by the structuring of trading transactions for the sale of power from the 86 MW Malana HEP for periods ranging from one to three years, in effect making it the first plant in India to operate on the merchant power plant business model.

In the quest for greater efficiencies through a market based exchange mechanism, the 'As-and-When-Available' power as a product where sale and purchase is planned on a day-ahead basis in 2003 was introduced. At the same time, the Electricity Act was instituted, and it formalized a very important principle on which these transactions were structured, namely 'Open Access' in transmission. Participants and transactions grew manifold, and about 30 participants were active in the market at any point of time during the year. Several transactions that involved use of transmission systems of four, and even all five-power regions of the country were structured successfully. Hence, new participants that came into the market were unique in their position. Some of them did not have significant sizes, but were in a position to relieve power system congestions, or help other participants in managing resources better because of the timing of the trading opportunities offered.

The challenge in moving ahead to the long-term scenario of an exchange is to reduce the response time from a 'day-ahead' level to a real-time environment. While, even in the present scenario, it has been possible to effect transactions in periods as low as 6 hours from the user's request, a power exchange aims to reduce this window to the minimum time required by the System Operator. This part of the journey, possibly, presents the greatest challenge in terms of integrating the evolution process to an exchange-like platform to the

changes taking place in the industry, post Electricity Act 2003. In order to meet this challenge a number of steps are contemplated that cover various aspects of the development of an exchange.

A successful exchange platform requires rewards for efficient operation to be accruing to participants equitably. This in turn, depends on the number and type of participants in the market. Efforts are being made for a further diversification of the market participants' base. As a result entry of prospective participants, like, Captive Generators, Co-generators, Industry Associations, energy intensive process industries, is expected into the market as Open Access customers. However, with all these there may be requirement of change in regulatory structures that would promote development of a market as well as wider participation in the market. This is a crucial component in the strategy towards implementation of an exchange.

The backbone of an exchange is an information repository. While all other components would require investment of time and buy-in of participants and linking entities, this is the key component that also requires a significant capital investment. The features of this information platform would include a single application that allows tracking of bid-to-bill (B2B) aspects of all transactions, enables validation at transaction and business levels, supports high volumes (typical range 500 to 5000 transactions in a year). The applications also have to be flexible in that they need to adapt to additional / specific markets. While initially the trading platform is envisaged more in the form of bulletin boards or an effective B2B platform, the same will evolve into a power exchange with real-time capabilities over a longer term. This is the correct approach to setting up a power exchange, as presently all the participants do not have online connectivity with even aggregate level scheduling and dispatch data available with the RLDCs.

Further to enable customers to adapt to an online environment in a phased manner, as a next step it is also necessary to initiate a Customer Relationship Management tool that would enable both availability of information at the market participants' desktops as well as allow capture of operational information. As the market matures, this would evolve into a B2B platform, or alternatively, integrate with an existing B2B platform. In fact the B2B platform would be a pre-cursor to a fully functional, real-time exchange.

Thus, with lot of changes taking place in the Indian power scenario, due to unbundling of generation, transmission and distribution and subsequent regulation providing Open Access of transmission, de facto Power Exchange is in place in grid operation. Scheduling of generation with Open Access of transmission system to meet demand is done keeping in mind trading of power involved on short-term and long-term basis. Under real time Grid Operation, system operates with the principle of Availability Based Tariff taking care of Un-scheduled Interchange, of course subject to the constraint of system security and stability.

9.2 The Influence of Transmission on Further Development of Power Exchange in the Australian National Electricity Market

The national electricity market (NEM) is the market for the wholesale supply and purchase of electricity in five Australian states and territories - the Australian Capital Territory, New

South Wales, Queensland, South Australia, and Victoria - together with a regime of open access to the transmission and distribution networks in those states and territories⁵. Tasmania intends joining the market following completion of Basslink.

The market was launched on 13 December 1998.

The objectives of the national electricity market are that:

- the market should be competitive;
- customers should be able to choose which supplier (including generators and retailers) they will trade with;
- any person wishing to do so should be able to gain access to the interconnected transmission and distribution network;
- a person wishing to enter the market should not be treated more favorably or less favorably than if that person was already participating in the market;
- a particular energy source or technology should not be treated more favorably or less favorably than another energy source or technology; and
- the provisions regulating trading of electricity in the market should not treat intrastate trading more favorably or less favorably than interstate trading of electricity.

9.2.1 Description

The NEM is based on a single dispatch model. Generators are dispatched every five minutes on the basis of bid price in \$/MWh. An ancillary services market also operates simultaneously with the energy market to maintain the level of operating reserve.

The NEM spans more than 4000km. The long distance transmission between load and generation centers can require restricting the dispatch of generators to avoid overloading transmission. Presently, the NEM is divided into several pricing regions. The market can thus be described as a limited nodal pricing model. The resulting dispatch rules accommodate the effects of marginal inter-regional loss factors and inter-regional operating limits. The control center dispatch software, based on a Linear Programming algorithm, minimizes the cost of meeting the load subject to many variables including generator upper and lower operating limits, inter-regional line limits, and minimum reserve levels.

The inter-regional transmission system has been augmented several times since market inception, including connection of Queensland in 2000 through the Direct link dc link and the QNI ac link, then in 2002 with the Murray link dc interconnector between Victoria and South Australia. In November 2005, the Tasmanian and Victorian systems was interconnected for the first time by a 300km undersea HVdc cable.

Figure 9.1 shows the connection arrangement including the nominal interconnector limitations between regions.

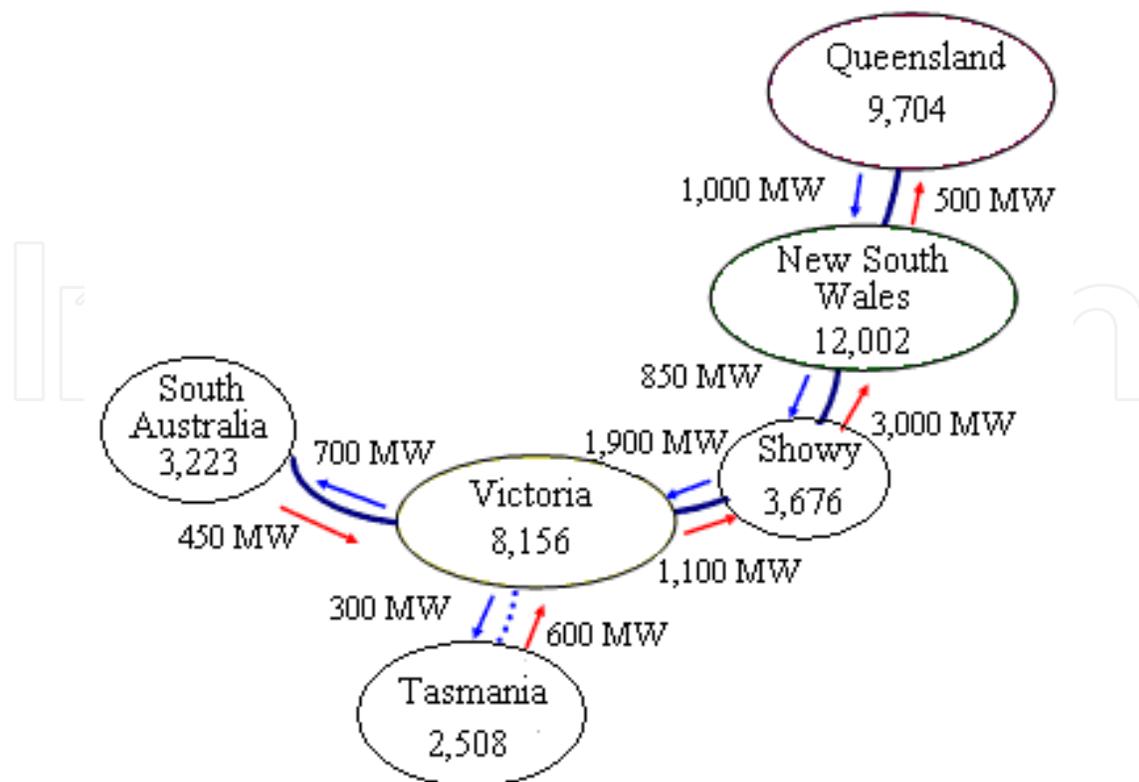


Figure 9.1. Generation and transfer capabilities (Summer 2004/05).

9.2.2 Issues

9.2.2.1 Generation utilization

Prior to and since market inception, the forced outage rates of generating plant have reduced substantially. This has allowed the margin between supply and demand to reduce without compromising reliability. The result of these efficiency gains has been to increase the dependence of reliable market operation on inter-regional interconnections.

The general reduction in the gap between annual installed capacity and annual half hourly peak demand over time is shown in Figure 9.2. While net generation of nearly 4000MW has been added since the start of the NEM due to market forces, the summer peak demand has increased by more than 6000MW. The data is for the mainland states only, but includes a net injection of equivalent generating capacity of 600MW from Bass link starting in 2005-06.

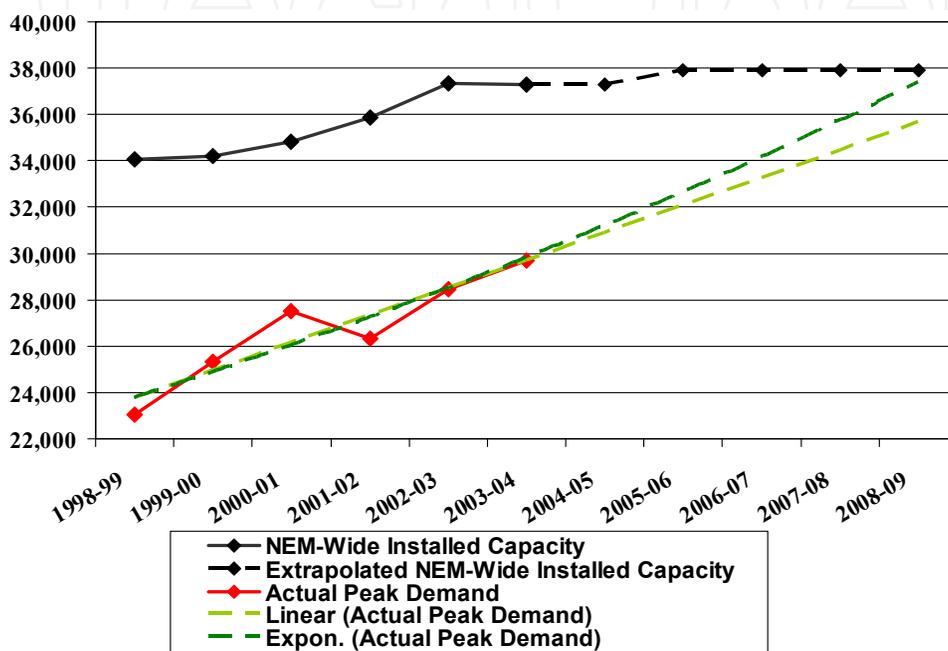
9.2.2.2 Resource Development

Growth, with accompanying pool price increases, is the main driver for the development of new generation.

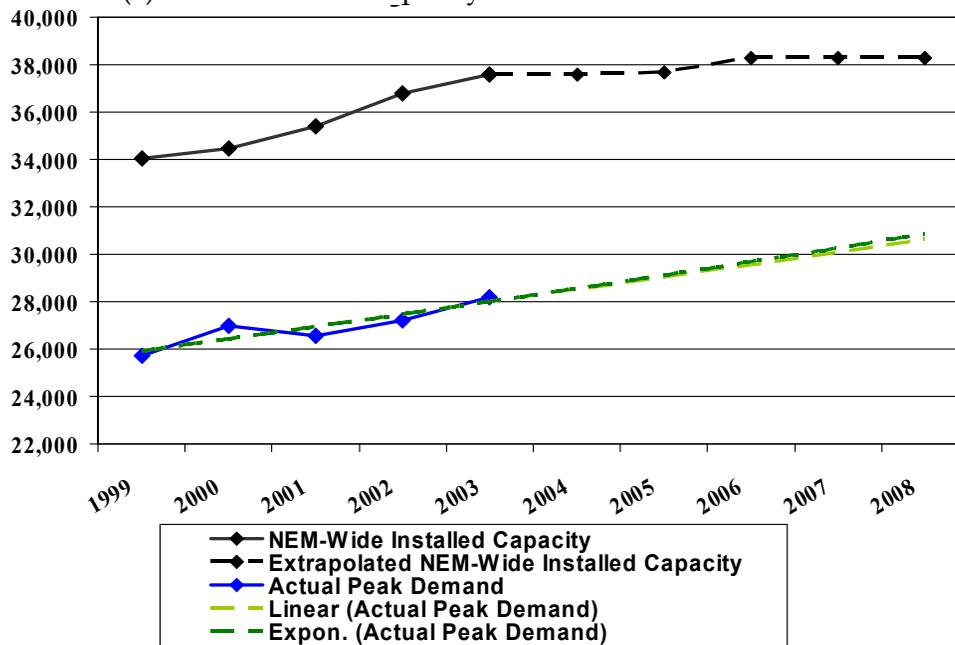
At the same time, environmental factors are influencing the development of the market through restrictions on permitting plants that do not meet the highest levels of performance available for that fuel.

Several mechanisms are in place to encourage development of renewable or low emission generation within a market context:

- Commonwealth initiatives such as the 2% Mandatory Renewable Energy Target (MRET) scheme for additional renewable energy
- State initiatives such as the Queensland 13% gas scheme and the NSW Greenhouse Abatement Certificate (NGAC) scheme, both of which are aimed at enhancing efficiency, and development of lower emission plant such as gas.



(a) Installed Capacity and Summer Peak Demand



(b) Installed Capacity and Winter Peak Demand

Figure 9.2 Supply and demand

With the impending exhaustion of opportunities to gain further performance improvements from existing generation, many new plans are being developed by market participants to introduce new generation, predominantly gas, black coal, brown coal, wind and biomass. Wind resources dominate in the southern regions, while biomass tends to dominate in the northern regions.

Major gas pipelines are planned from Papua New Guinea and the Timor Sea, both north of Australia. If these projects eventuate they are of the scale to introduce major changes to the generation mix and utilization of transmission.

The Bass link project will add 2500MW of storage hydro generation to the existing mainland hydro (predominantly the 3676MW Snowy Mountains hydro), and introduce further dynamics to the hydrothermal interactions.

9.2.2.3 Transmission utilization

Flows are significantly different from the pre-market situation. While pre-NEM flows were dominated by issues within state boundaries, plus defined interchanges based on operating agreements, the market has expanded trading across interconnectors on the basis of bids by all generation including renewables.

This has tended to use transmission to a higher degree, resulting in increased incidence of operation at or near transmission limits.

The increasing incidence of transmission constraints resulting in price separation between regions with generation constrained off or down in the exporting region(s) has created the opportunity for further augmentation. However, since transmission is a regulated service, additional transmission augmentation has to be justified on the basis of reliability or cost reductions. Proposals are in place, however, to relax the conditions for regulated augmentations by accounting for other defined market benefits. This could open the way for expanded interconnections and/or new interconnections between existing regions.

Unregulated transmission can be built by a proponent seeking to recover its investment based on market revenues. So far, several such transmission links have been built, all based on HVdc technology and connecting regions with potential price differentials sufficient to justify the investments. One of these, Murray link, has since successfully applied for conversion to regulated status.

The potential for additional transmission connections to other regions and/or countries is reduced by the relatively small loads and long distances involved. The largest unconnected region is the 4000MW South West Interconnected System (SWIS) in Western Australia, which is approximately 2000km from the nearest connection point to the NEM. Since Western Australia has an abundance of energy available from the North West Shelf gas fields in the north of the state, and coal fields in the South West, there is no economic justification for a NEM-SWIS link at present.

Several smaller grids are operating in Australia - in North West Western Australia (the North West Interconnected System, of about 400MW, and several other unconnected generators with an additional several hundred MW), in the Northern Territory (approximately 400MW), and in North West Queensland (approximately 400MW). These may be linked to the NEM or to each other as part of anticipated resource developments, including gas pipelines from the Timor Sea and/or PNG.

9.2.3 Market Developments

The strict conditions associated with development of the NEM have resulted in a robust and successful electricity market. This market has succeeded in accommodating substantial load growth, while accommodating several thousand MW of new merchant plant of various types and sizes. There has also been withdrawal of some generation due to market forces.

The success of the NEM can be put down to several factors, including:

- A single body/organization overseeing the market
- Multiple parties looking at system operation to look after commercial interests
- Careful specification and description of network limitations, resulting in a general increase in network utilization.
- expanded tools to improve analysis, which are used by market operators, participants and regulatory authorities.
- A uniformity of approach in the application of standards for connection and access, which previously did not exist.
- Transparency and governance strictly according to the National Electricity Code and National Electricity Law. High levels of transparency tend to ensure good governance.
- Active involvement at the political level as well as the industry level
- The high quality of staff in market operation
- The high level of horizontal and vertical disaggregation of the industry exposes the risks of markets and therefore drives commerciality. This tends to drive out the benefits in each part of the industry.
- The rules and regulations support and facilitate market operation.

9.2.4 The Way Forward

Since market inception, grid development has been minimal compared with the extensive changes to the operating regimes of existing generating plant and the new generating plant that has been developed.

This has resulted in increasing tension between regulated grid development and generation.

Planning and implementation of changes to the grid have been underway in several critical areas.

Grid companies will need sufficient incentives to consider augmentation to meet the imperatives of economic resource development in an environment that is likely to include further and stricter emissions limitations from generation sources.

9.3 Technical and Market System Effectiveness of Intersystem Power Exchanges in Russia

Historically the formation of large electric power systems and their interconnection into the Unified power system (UPS) of the country was related to the objective positive factors. Creation of Russia's UPS enhanced essentially the economic efficiency and reliability of power supply as compared to separately operating regional power systems. The influence of the system effect casts no doubt among energy specialists. A great number of publications have been dedicated to the analysis of different aspects of system efficiency of electric power systems.

This section deals with the notions of the potential effect of integration of electric power systems (EPS) and the effect realized in a market environment. The estimation technique is presented. The effect is estimated on the example of Russia's UPS.

9.3.1 Technical System Effect

The system effect in electric power industry is of a multi-factor character. Traditionally the following technology-based components of the intersystem effect have been set off at integration of power systems^{6,7}.

A "capacity" effect

- A decrease in demand for installed capacity of power plants by bringing into coincidence the load maxim, reducing the operating reserve, decreasing the reserves for routine maintenance;
- An increase in firm power of hydro power plants by raising the total firm power owing to asynchronous run off in different river basins and use of long-term regulation of water reservoirs to the benefits of neighboring power systems;
- A more complete use of commissioned capacity by decreasing the unused capacity in a large system.

A "structural" effect:

- Rationalization of power system structure by: using cheap (but economically inefficient in terms of transportation) energy resources at power plants with power transmission to neighboring systems; increasing the use of peak and free power of hydro power plants;
- A better use of hydropower in the high water years;
- An opportunity to construct power plants successively with the use of temporary surplus powers in the other power plants;
- Saving in the construction of electric networks for power supply to the areas of individual power systems connection.

A "frequency" effect

A Frequency Effect implies a lesser impact of an individual energy unit or a consumer in a large electric power system (EPS) on the system frequency as compared to a smaller system. The frequency effect allows the unit capacity of energy facilities to be chosen without constraints on the system requirements.

An “operation” effect

An Operation Effect implies a decrease in operating costs by optimizing the operating conditions of power plants in the integrated system, increasing the total density of load curves of power systems at integration, by widely using the cheap fuels.

An “environmental” effect supposes improvement of the environmental situation due to redistribution of power generation at power plants with its decrease in the areas with unfavorable environmental conditions.

All these components have objective material (technological) nature. However currently the assessment of these components only seems to be insufficient.

9.3.2 Market System Effect

At present the process of operation and expansion of power systems involves many subjects of relations in electric power industry: power companies, individual power plants, Governmental authorities (federal and regional), electricity consumers (production and agricultural consumers, transport sector and population). These subjects have different interests. For power companies as for the wholesale market subjects the main criterion is profit. The criteria of the governmental authorities include profitability of the sector (incomes to the budgets), impact of the electric power industry on the industrial production volumes, employment and living conditions of the population, environmental impact, energy security, etc. The consumers are interested in the level of electricity and heat tariffs, reliability and quality of power supply. In particular the decisions efficient from the viewpoint of a federal or “national economic” level can be unacceptable for the other subjects. Many decisions cannot be made until the interests of all the parties concerned are coordinated and the required compromise is achieved.

Thus, the traditional estimation of power systems efficiency with account for only technological factors corresponds currently only to its technically feasible limits. Let us call them technical system effects (TSE).

The fact that many subjects have different interests and affect the decision making on expansion and operation of power systems does not change the set of components of the effect but leads to variations in the set for different subjects of relations and to different estimations of the same components of the effect by different subjects of relations.

Consider the main factors that determine the system effects for different subjects of relations in a market environment (let us call them market system effects (MSE)) as applied to Russia’s current electric power industry structure that consists of competing generating and selling companies, network companies as natural monopolies, electricity consumers.

The bids of generating companies for electricity supply to the wholesale markets build the function of a supply which is then related to the function of a demand for electricity on the part of selling companies and consumers. This relationship is used to determine the equilibrium price of electricity at the wholesale market. Profit, being the main criterion for the generating companies under competition will make them decrease the costs of electricity production by loading, first of all, the most efficient generating capacities. Thus, the market

mechanisms will decrease the equilibrium electricity price at the wholesale market. This is possible at joint operation of generating companies in a system with no network constraints. Here the account should be taken of the constraints on participation of generating units in covering load curves and on provision of power supply reliability and power quality.

The relationship between the MSE and the above TSE components shows that the formation of equilibrium electricity price at the wholesale market involves realization of practically all the TSE components. However the extent of their realization is determined by the efficiency of the competing market mechanisms. Bearing in mind the fact that the ideal competition in electric power industry is practically unachievable due to a limited number of market subjects we can expect that the MSE will be smaller than the potential TSE.

Similar market mechanisms should operate at competition of selling companies at the consumer electricity markets that will result in realization of additional MSE components at this level.

Network companies (federal and distribution regional) play an auxiliary role in the considered market processes. They render the required services on power transmission from suppliers to consumers, on provision of power supply reliability and power quality, thus being conducive to the enhancement of MSE as a result of electricity market operation.

It is necessary to emphasize that in a short-term context the competing mechanisms at the wholesale and consumer electricity markets may decrease the electricity prices even below the level which is determined by the complete realization of TSE, as a result of price bids of the generating companies below the electricity production cost with account for its components. However, in a long-term context this situation is fraught with negative consequences that may take the form of inadmissible reduction of reserve capacities, decrease in funds to maintain the equipment in service state, to update and replace it. This will result in disappearance of conditions for competition at the electricity markets. The trend may appear toward a sharp increase in the electricity prices that will call for their regulation.

The interests of consumers expressed through their main criteria imply the interest in efficient operation of the electricity markets, i.e. maximum realization of MSE and, thus decrease in the electricity prices.

The interests of the authorities are to a certain extent contradictory. For example, the electric power industry will be highly profitable at high profits of power companies and these high profits are possible at high electricity prices. At the same time the efficiency of the industrial production, the living conditions of the population and other interests call for decrease in these prices. However, on the whole the authorities are certainly interested in the efficient operation of electricity markets, i.e. in maximum MSE realization.

It should be noted that for the subjects of relations the real effect from the measures on intensification of power systems integration depends on the system of economic management in the country. The system of management to a considerable extent affects the

redistribution of the real effect among the subjects of relations and can both foster and hinder the TSE realization.

9.3.3 Principles of Estimating the System Efficiency

When estimating the potential TSE we consider UPS of Russia as a technically and technologically single object disregarding the forms of property. In this context this estimation is objective and single-valued. Comparatively simply we determine the base for such estimation, i.e. the conditions the effect is estimated for. Here we should use the approaches and recommendations that were developed for the centrally managed electric power industry. In a certain sense the model of the centrally managed electric power industry facilitates the full realization of the potential TSE.

The TSE components for UPS as a whole were estimated, depending on the aspect of consideration, based either on the conditions that do not suppose realization of the effect (for example isolated operation of regional power systems) or on the existing level of the UPS integration.

The approaches to the estimation of MSE are less obvious. When analyzing UPS expansion for a long-term future they apparently should be maximum independent from the conditions and principles of legal-normative framework. We should orient to the situation when the legal-normative framework fosters the full realization of TSE. When considering short-term prospects it is necessary to take into account the active legal-normative framework.

For a qualitative estimation of the system effect it is necessary to use existing and develop new mathematical models for: estimation of individual TSE components; integral estimation of an effect (such models are necessary as the net present value is not a simple sum of individual components); estimation of effects for federal and regional authorities and energy consumers that include the assessment of budget efficiency, levels of electricity tariffs, level of employment, level of living conditions, etc.

A complex integral estimation of the TSE involves the optimization model of electric power system expansion "SOYUZ"⁸⁻¹⁰.

9.3.4 Case Study

Below presented are the results of estimating the system efficiency of Russia's UPS expansion for the time horizon 2010-2030.

It is very complicated to fully estimate all the TSE components, therefore only the main ones were estimated: the "capacity" effect, excluding the effects of equipment maintenance optimization and use of asynchronous run off in the rivers of different water reservoirs; the "structural" effect disregarding the environmental components, the effect of successive construction and construction of transmission lines at the point of connection of adjacent power systems; the "operation" and "frequency" effects. The model "SOYUZ" was applied for the estimation.

In the analysis of MSE the changes in EPS profit, cost of electricity produced, customer profits, payments to the federal and regional budgets were evaluated from the standpoint of subjects of the wholesale market, authorities and customers.

Comparison was made by the variant that envisaged expansion of the UPS generating capacities without expansion of the intersystem electric network, whose transfer capabilities between interconnected EPSs (IPs) remained at the existing level. The basic variant to be estimated was the variant of the UPS expansion that was recommended by design institutions with optimization of transfer capabilities of tie lines between IPs.

UPS in the model was described by a 7-node network (by IPs). Two time levels were modeled: the years 2010 and 2030.

Adaptation of the structure of generating capacities to different expansion conditions was foreseen by the necessary changes in capacity commissioning at condensing power plants. The main calculation results are presented in Table 9.1.

The Table shows that the expansion of intersystem tie lines over the time span to 2010 is effective. The discounted costs for the UPS operation and expansion in this variant are \$340 million lower than in the variant without their expansion, the required installed capacity of power plants is 990 MW lower, the saving of investments makes up \$1.8 billion, the annual expenditures decrease by \$110 million per year.

Indices, million doll.	Efficiency	
	2010	2030
Discounted costs, total	340	2760
Including: Power plants	440	3080
Transmission lines	-110	-320
Capital investments, total	1810	12890
Including: Power plants	2510	14720
Transmission lines	-700	-1830
Installed capacity, MW	990	8740
Annual expenses	110	1220
Including: Power plants	130	1320
Transmission lines	-20	-100
Fuel costs	-50	-30
Payments to the budget	49	510
Net profit of power companies	88	900
Cost of electricity production	130	1320

Table 9.1 Basic components of the efficiency of UPS integration

Expansion of the intersystem tie lines “Siberia – Ural” and “North-West - Center” is the most effective. The effect of expansion of the intersystem tie lines depends primarily on the “capacity” components when connecting the IPS of Siberia due to coincidence of load maxim and power exchanges of IPSs in emergency situations; capacity commissioning at power plants in Siberia decreases with partial compensation for this decrease by the capacity commissioned in other systems and increased use of existing power plants.

Decrease of operating costs is determined mainly by the decrease in fixed costs as a result of decrease in the total installed capacity; the fuel costs even somewhat increase due to the change in the structure of fuel burnt. Decrease in the cost of electricity production is accompanied by the growing profit of power supply systems and growing payments to the budgets of different levels.

The calculated value of the effect over the time horizon to 2030 (see Table 1) is considerably higher (3-4 times) than to 2010. The effect value is much higher than the expenses for its realization by construction and maintenance of intersystem tie lines. One dollar invested in expansion of transmission lines saves \$2.5. The relation between decrease in discounted costs and increase in costs for transmission lines is equal to 3.1. One dollar invested in expansion of transmission lines decreases the cost of electricity production by 19 cent, increases an annual profit in UPS by 12 cents, and brings 7 cents to the annual consolidated budget.

Thus, the studies performed confirm a high efficiency of measures on strengthening the integration of Russia’s UPS. The estimates obtained are conservative enough, since they cover not all the components of the system effect. In particular, the possibilities for formation of UPS expansion conditions that are optimal in terms of gaining the highest system effect were not analyzed. The system effect within IPSs in terms of interaction between the power systems comprising it was not considered as well. Account for this internal effect can raise the obtained estimates by a factor of 1.5-2.0. Nonetheless, even such conservative estimates point to an absolute efficiency of EPS integration. It can be achieved by the proper implementation of the required principles of economic management and the provisions of the legal-normative-legal framework.

9.4 Deregulation of power systems in Asia: special considerations in developing countries

Power industry is undergoing restructuring throughout the world¹¹⁻¹⁷. The traditional vertically monopolistic structure has been deregulated and replaced by gencos, transcos and discos with competitions introduced to gencos and discos in order to reach higher efficiency in electricity production and utilization. A lot of R&D work has been conducted on power markets¹⁸⁻²⁴. However for different countries, the principal objectives and considerations of power system deregulation are different. In the developed countries, areas with higher electricity prices would like to introduce competitions so that electricity prices are able to reduce and social welfare can be maximized. In some countries, electric power supply sector is a regulated public utility, and the government would like to privatize the electric power industry so as to reduce government commitment and functions. In this regard, gencos, transcos and discos are formed with competition introduced to gencos and discos to stimulate

their incentives in efficiency improvement. When efficiency grows up and electricity price goes down, it can in turn promote GDP growth. In the developing countries, the power system deregulation and power markets are to establish fair competition among gencos so as to encourage investments to power industry from various resources, such as foreign investments, local investments and IPPs etc.

The diversified resources attracted to power industry can well meet the requirement of fast growing electricity demand induced by blooming economy in the developing countries. This might be the main reason for Asian developing countries to promote deregulation in power systems.

Although power system deregulation is widely conducted in the world, it is not easy to successfully reach the initial targets set for the deregulation. Both experiences and lessons are obtained in practice. Considering that power industry is a significant infrastructure and in order to realize sustainable development of power systems at high efficiency, how to realize optimal system planning and reliable operation at acceptable electricity prices with qualifies service and how to transit to the market environment smoothly at lowest costs and lowest risks should be considered thoroughly in the market environment. This is actually an important task for the developing countries in Asia.

9.4.1 Considerations on Power System Deregulation in Developing Countries

9.4.1.1 Targets of deregulation

In Asian developing countries, power systems are usually owned by the state or provincial government before deregulation and operated as a vertical monopoly. Unified dispatch is applied to individual power grids with limited power exchange to external grids. Hence the interconnections among grids are relatively weak. Because of fast economic development, the electricity demand is growing rapidly and the power system expansion becomes a severe economic burden of the governments and a bottleneck of overall economy sustainable development. Investments from companies other than governments to power systems through approaches such as Build-Operation-Transfer (BOT) etc. are not so attractive. It is urgent to launch power system restructuring and deregulation and to establish power markets with fair competition so as to attract more investments from various resources to power industry. Moreover it is found that in some countries the monopolistic operation of power systems can also lead to low efficiency and even corruption for non-transparency and lack of surveillance in operation. It is clear that the power market is able to solve most of the problems appropriately.

Based on the facts mentioned above, the targets of power system deregulation and power market establishment in Asian developing countries can be outlined as follows with certain priority.

* To attract various investments to power systems through open-access and fair competition so that power supply can meet the fast growth of demand in developing countries.

* To reduce government commitment to power industry, which is a severe burden to the governments of developing countries concerning huge amount of investment to the infra-

structure construction; and to mitigate government functions in power industry so that the government can focus attention to significant issues of entire society.

* To encourage efficient electricity production and utilization through competition and electricity pricing mechanism. The energy resources can be saved. The production costs can be reduced and hopefully the electricity price can decrease. It can in turn increase social welfare and benefit to national GDP growth. Thus sustainable development of power industry can be realized.

* Through competition, the market-clearing price (MCP) of electricity can provide clear economic information for future power system development use; power supply services can be improved; gencos' profits may increase through higher operation efficiency; and the government tax return from power industry can be raised.

However the realization of the targets are not easy because power system deregulation involves the benefits of various parties and each party will try hard to protect its own interests and add influence to the power market policies and rules. To keep a large genco can make it possess noticeable market power to get more profits. To define a MCP with or without congestion management consideration will lead to totally different profit distributions. To organize a small provincial market or a large regional power market may bring about significantly different social welfare. In order to construct power markets with fairness, justice and transparency, thorough considerations should be made to various aspects, which will be discussed below.

9.4.1.2 Considerations on the scheme of power system deregulation

The overall power market scheme is usually considered by the government. It includes several aspects described below.

* According to the targets set for deregulation, it is very important for the government to consider carefully at the beginning on: how many markets should be organized throughout the country; who should be responsible to organize the power markets, how to organize gencos, transcos and discos; what are their functions; who is responsible for market operation and/or system operation; how to develop market rules; who is responsible for market surveillance; how to transit from current regulated market to future competitive market; etc. A timetable should also be developed for execution. It is clear that a lot of negotiations and government decisions should be made at this level in order to make deregulation process successful. International consultant might be helpful, however for the different economic and technical backgrounds, it is more important to rely on own conditions and experts to make final decision.

* After the fundamental decisions in launching the deregulation, the market rule development is a key step. A lot of lessons have been obtained in this aspect. For developing countries, copying power market rules of other countries or other markets such as natural gas etc. might lead to severe results. The market rules should be different from market to market with only principles unchanged. Therefore all market participants (suppliers, consumers, brokers, operators etc.) should have rights to join or examine rule development with consideration on all economic, technical and physical backgrounds, conditions and trends. The rule should try to be a perfect set on market organization, market functions, goods to be exchanged and services to be provided, sub-markets definition (futures, forward, option,

day-ahead, and balancing markets for electricity as well as the markets for transmission service and ancillary service, etc.), pricing mechanism, participants and relevant regulation, market operation and system operation rules under normal and emergency cases, settlement, surveillance, etc. The rule should be revised from time to time to meet new requests and evolve gradually.

* Another important task in power market operation is to develop a reliable computer supporting system to manage bilateral contract records, day-ahead market bidding and MCP - power selling/buying calculation, congestion management, and market information announcement etc.

It should be pointed out that different markets have different potential risks in operation, to which special attentions should be paid. The issue is discussed below.

9.4.1.3 Consideration on risks and their mitigations

To realize successful running of the power markets, a significant issue is to examine carefully the potential risks existing in a specific power market. The risks include natural resource types, amount and relevant risks, economic development in the market area, gencos and consumers' features, grid characteristics, potential market power, risk in power markets of single-buyer mode, special reliability and security issues in power system operation, power system planning/expansion in market environment, possibility of power exchange with adjacent power markets and relevant issues, and possible local government interference, etc.

For a power market operating very well for years, we should not say the market is perfect until it operates very well under extremely severe market conditions and can also keep power system sustainable and efficient development for a relatively longer time horizon. Some risks, which are often appeared in the developing countries, will be discussed briefly in more detail below.

Unbalanced economic development within the market area. When a power market covers both rural area and industrial area, the power generation in rural area usually has lower electricity price than that in industrial area if there is no power exchange between the two areas or if special price policy is applied to the rural consumers. When they are in the same market, discriminating price or proper measures should be taken to protect rural area consumers. Otherwise, industrial area users would like to sign bilateral contract with gencos in rural area at lower prices and the electricity price in that area will rise and have negative impacts to rural users.

Hydraulic resource and hydrothermal dispatch in market environment. When a certain area has a higher hydraulic capacity ratio and/or the hydraulic resources should also be used for navigation, irrigation and flood control purposes controlled by the government agent, the risk of hydraulic power generation may occur. Basically there are several ways to dispatch hydropower: central dispatch with priority for hydropower taking care of peak load to maximize social welfare, thus all hydropower can get maximum benefits. However this might have negative impacts on thermal power generation profits especially when water resource is rich in certain years. However if hydraulic power plants bid in the same way as thermal power plants, the hydraulic resources might not be used efficiently. Besides

some compensation should be provided to hydraulic power plants for their loss caused by diversified usages of water resources. Therefore certain rules should be developed to manage the case to make both thermal and hydraulic power companies have proper profits with incentives to make further investment to the power markets when load grows.

Market power. When a market has few power generation companies, the company with large market share is able to control the price and get high profits from it. Such market power is harmful to consumers and may reduce social welfare noticeably. Therefore market share and/or capacity limits should be applied to any gencos. Grid congestion is another source of market power. Improperly defined transmission rights or congestion management rules can be utilized by market participants and strengthen the locational market power. In peak load condition or when large units are under maintenance, some machines become 'must-run', the market power can be severe. In addition to well-defined market rules to manage congestion and mitigate market power, market power existence and severity should be supervised constantly. Market surveillance and certain penalty should be applied to solve the issue.

Reliable and secure power system operation under market environment. This is the most significant issue in deregulation. The power system deregulation should not sacrifice the system operation reliability and security. However the risk does exist. Lots of reasons can cause the issue, such as lack of reserve capacity, lack of reactive power supply and voltage control, poor organization of real-time power balancing market, poor emergency control and restorative control, wrong load forecasting and/or poor generation and transmission expansion planning which in turn leads to inadequacy of capacity, etc. In developing country, the grid construction may lag behind the generator installation and the resultant stressed network may cause severe problems under large and small disturbances.

Centralized dispatch is highly recommended in such case to make full use of system-wide resources to avoid system instability and collapse. In principle, the economic issue such as various transactions should be determined by market rules before real time operation. Even if the resource/service is used/provided in real-time, it should be scheduled beforehand regarding to time, price, quantity, and the way to use/provide. However secure and reliable system operation should be realized in real-time absolutely through central dispatch and control and the system operator should have the authority to make decision according to load demand, power quality and security requests etc. under normal and emergency conditions. The difference of system operation with or without power market existence is that in power markets the operator should dispatch/use the available resource according to bilateral contracts, day-ahead market, ancillary service market outcomes determined beforehand.

Considering former monopolistic operation condition, existing EMS and operation experience, it is recommended to have two computer systems for market operation and system operation respectively but with real-time link to each other for information exchange, software/database sharing and necessary mutual support. The same institute will manage both computer systems to realize cost-effective operation and well

coordination. A system operator should get some training on market operation and vice versa so that he/she can understand the impacts of market environment on system operation very well.

Electricity pricing and demand elasticity. Pricing is a core issue in power markets. Bidding strategies are worked out based on pricing mechanism. For most power markets, MCP is used to determine day-ahead market price and electricity production amounts, which are then revised according to congestions if any. If the pay-as-bid principle is used in spot pricing, the ISO of a single buyer market can get significant benefits.

A disco, who buys electricity from the market and sell it to the end users, may suffer from fixed electricity price for end users. The load elasticity is very important in power markets. Market failure might happen when the energy supply price is extremely high while end user cannot see it.

Other merchandises in power markets should have their prices well defined as well. However at the beginning stage, the market rules should be simple and practical. Some services, such as reactive power supply and voltage control, reserve capacity, AGC etc. can be considered as a whole by the ISO and then distribute the cost to users as a lumped 'uplift'. The users' bill will not show the price for each service. This can be improved gradually when the technology is mature.

Smooth transition to the market environment. This is also an important point in deregulation. A violent transition should be avoided. Usually when a market has adequate generation capacity and the supply is a little greater than demand, it is a good time to start power markets. The price will be smooth in transition and market rules can be tested under normal conditions first. Operators can practice in the real market environment. In this case, reliable and secure system operation can usually be ensured. Otherwise risk will appear in the test operation of power markets.

Power system planning in market environment. Under market environments, generation and transmission network expansion are vital to power industry sustainable development. Accurate load and fuel price forecasting and correct estimation of profits are very important. Government policy and market rules in power system planning also play an important role in system expansion. In order to attract enough generation investments, a key point to developing countries, some rules with bias to gencos have to be applied. A typical price policy is two-part electricity price including capacity price and energy price, which can greatly reduce gencos' risks in capital return and encourage generation investments effectively. This price policy is now used in NE China regional power market. In the meantime, to let grid company (which may also be the operator of both power market and power system) have enough income as transmission network capital return and for future development, transmission service price can be set at a relatively higher level.

In power system planning, it is important to have an authorized institute to make centralized optimal planning with participation of market participants based on the

information of economic development, load forecasting, energy resources available etc. Interested companies can then bid for power plant expansion and construction. However the transmission network expansion is a problem since it is difficult to get investment back in a short period through transmission service charge. The incentives to invest transmission line construction are therefore unclear. And the stressed network may lead to system instability under disturbances and even blackout under cascaded faults. Special measures and policies should be applied to solve the problem.

9.4.1.4 Other considerations

To ensure fairness, justice and transparency in market competition, government should have minimum interference to the markets. But special purpose committees can be organized to manage the overall power industry policy, energy planning and investment consideration, market surveillance, etc.

The market rules should also define duties, rights and benefits of individual market participants; include extraordinary operations of markets such as emergency stop, termination and re-start conditions and procedures.

In order to promote power exchange and obtain more economic benefits and social welfare, transaction between markets are highly encouraged which include hydrothermal coordination across the markets, emergency support to reduce reserve capacity cost, and peak-load-time-difference utilization, etc.

In certain area, special policies on electricity tariff are applied to special users, such as compensation to rural area users and special local industry, etc. This policy may exist at the beginning stage of power markets. It will be reduced and eliminated gradually when market is mature.

In general power system deregulation is a kind of 'system engineering', which is relevant to various aspects including economy, politics, society, engineering and technology. The success of power system deregulation will have great impacts on overall society and national economic development.

9.4.2 Power Markets in NE and NW China

China is a developing country in Asia with fast economic development in recent years. By the end of 2004, the total generation capacity reaches 447 GW, ranking at No. 2 in the world. Its electricity is still in short supply for the fast blooming economy.

Huge population, fast economic development and electricity demand growth cause severe burden of the government under traditional vertically monopolistic operation mode, in which the government is responsible for the investment of main power plants and transmission grids. In order to attract diversified resources to invest power industry, power system deregulation and power market establishment to ensure fair competition is the best and sustainable way to solve the problem.

The main steps in power system deregulation in China are as follows²⁵⁻²⁸. In Dec. 1998, the State Council of China announced to launch power industry reform in China. In the first stage, the restructuring was focus on forming independent power companies and grid companies. Five provincial power markets and Shanghai power market were built up and tested as pioneers. Competition was introduced to gencos and the markets were in the single buyer mode. However the provincial power markets only covered small areas, which strongly limited the power exchange across the provinces and the goal of optimal use of resources over a wide region could not be realized. In Feb. 2002, the State Council of China announced a new document of 'The Scheme of Power System Reform'. In this document, it is declared that to form regional power markets will be the future direction of power industry restructuring in China. In Dec. 2002, two independent grid companies were formed. They are S. China Grid Company and the State Grid Company. The latter includes 5 regional grid companies. They are Northeast, Northwest, N. China, E. China and Central China Grid Companies. The traditional government owned power plants were reformed into five generation-group companies with their individual shares in each regional power market less than 20%. In March 2003, the State Power Market Surveillance Commission (SPSC) started to work. Under the leadership of SPSC, Northeast and East China regional power markets were built up and committed to test operation in January and May of 2004 respectively. In the meantime all original provincial power markets were asked to stop operation. Other regional grid companies are actively making R&D to ensure well design and optimal operation of future regional power market and avoid any potential risks.

The power market in NE China and R&D work in NW China will be discussed below.

9.4.2.1 Northeast Regional Power Market in China

The Northeast region covers three provinces (Hei-long-jiang, Ji-lin and Liao-ning) of NE China and East of Inner-Mongolia with the population of 100M and generation capacity of 41GW (85% thermal power and 15% hydropower) at the end of 2003. The rich coalmines in the north and heavy load in the south cause a long transmission corridor from N. to S. of the region. In addition, a short power transmission corridor exists in mid-region from west (thermal power) and east (hydraulic power) to central part. The NE has been interconnected to N. China to sell their electricity.

From the Northeast Regional Power Market, we can see some rules which are typically defined based on developing country conditions and significant to secure operation and sustainable development.

* The NE Grid Company owns the regional transmission network and runs the regional power market and power system in parallel. It is also responsible for organizing generation planning and transmission planning according to the load forecasting although the Grid Company is not responsible for the construction of power plants.

* The NE Grid Company keeps main hydraulic power plants in hand (10% in capacity) for frequency control and peak load dispatch to avoid sky-high prices under heavily loading conditions.

* Two-part electricity pricing is used, in which capacity price and energy price are separate. The capacity price is defined by the State Tariff Department, while energy price is generated

through competition. This is good to encourage future investment in power generation and solve sunk-cost issue.

* The market in its first stage adopts single buyer mode. For long-term contract, pay-as-bid rule is applied for settlement, which can protect the benefits of the Grid Company and consumers. For day-ahead spot market, MCP is used. In general major energy transactions are through forward contract (round 80-90% of total power exchange); only a small amount is exchanged through spot market. Besides the generation option market is under organization to reduce gencos' risks.

* All transmission and ancillary services are centrally dispatched and the cost is distributed to consumers as a 'transmission cost' in average cost nature, which is also examined by the state Tariff Department. In order to avoid high service price, each power plant should provide certain reactive power and reserve power and join voltage and frequency regulation without payment. Later on a compensation method will be worked out.

* Bilateral transaction is limited to large consumers and power plants as test right now. It will be gradually increase. Currently only machines at or above 200MW are in the market. Later on it can be generators at or above 100MW.

* Ancillary service market is under consideration. Competition among discos and the transition of the market from single buyer to whole sale modes are also under consideration. But these will commit only when the current market operates well and experiences have been cumulated enough.

9.4.3 R&D for Future Northwest Regional Power Market

The Northwest Grid covers four provinces or autonomous region. They are Shan-xi, Gan-su, Ning-xia and Qing-hai. Its area is about one seventh of China. By the end of 2003, the total generation capacity was 20 GW with 65% thermal and 35% hydraulic power. However the economic development is quite unbalanced in the region, relatively rich in Shan-xi and poor in Qing-hai. Hence the electricity prices are quite different in the two areas. The upper Yellow river provides rich hydraulic resources. However the request of nevegation, irrigation and floor protection, which is controlled by certain official organization, may significantly reduce the profits of hydraulic power plants and bring about difficulties in day-to-day dispatch. Another issue is caused by larger area and lower population density, which means more transmission system investment. The western area hydraulic power and eastern area thermal power can be dispatched properly to yield most economic benefits. The peak load time difference between western and eastern areas also asks for large amount of power transfer between east and west parts. However currently relative weak network may lead to severe congestion and relevant market power if power market is committed. The region is going to interconnect to N. China and Central China Grids to sell electricity to the two regions.

Based on the facts mentioned above, NW Grid Company is actively conducting R&D towards future power market operation. Three R&D projects have been implemented with the help of universities. The three projects covered the following three aspects respectively (i) overall market structure, market operation mode and market rule etc.; (ii) pricing mechanism and grid average transmission cost estimation; and (iii) potential risks and their mitigations in the NW Regional Power Market. The last project was jointly implemented by the University of Hong Kong and NW Power Grid Company.

All the R&D projects examined the characteristics of the Grid thoroughly and made valuable qualitative and quantitative suggestions on future power market operation. Experiences and lessons from world power market practices are also considered in-depth, which laid a solid foundation for future successful operation of the power market and secure and reliable operation of the power system.

9.5 East China Power Market Development and TRIAL OPERATION

East China Power Grid (ECPG) covers the geographical areas of Shanghai Municipality, Jiangsu, Zhejiang, Anhui and Fujian Provinces. By the end of 2003, the total installed capacity in East China Power Grid had reached 81,300MW, with total annual electric energy consumption of 453TWh. There are 45 substations and power plants at 500KV level. The length of 500KV AC transmission lines had reached 7460 Km. 500KV DC transmission lines connect the East China Power Grid with Central China Power System where Three Gorge Power Station, the largest in the globe, is located. The large scale East China Power Grid offers an excellent platform for the trading of energy-related commodities.

The region East China Power Grid covers is one of the fastest economically growing and most prosperous regions in China, with a two digit annual GDP increases in recent years. The population accounts for 1/6 of China's, consuming 1/5 of electric energy in China, and having 1/3 of China's total economic production. The average per capital GDP in this region is over 1.7 times of domestic average level. The continuously fast economic growth has triggered two-digit increases in both energy consumption and peak load for some consecutive years. The fast economic growth, together with the dynamic market activities in other sectors and relatively advanced market management experience, provide a rather suitable external environment for the development of East China Power Market (ECPM).

Before industry restructuring, East China Power Grid, the parental company of four provincial grid companies, had a long tradition of executing inter-provincial energy transactions. These transactions range from centrally planned proportional allotment, residual energy transactions, to bi-lateral contracts. In general, provincial grid companies participate in such transactions while individual generators do not. In particular, the bi-lateral trading among the provinces is booming in these years. The bi-lateral trading energy has reached 4.855 TWh in 2001, 11.836TWh in 2002 and 25.594 TWh in 2003, with an average increase rate 129.6%. From a historical viewpoint, these inter-provincial energy trading laid a solid foundation for the development of the East China Power Market.

During the period from 2000 to 2003, a number of provinces in east China region have opened free electricity markets in a provincial level. These markets were criticized because they offer competition only in provincial level. This motivated the idea of inter-provincial markets, which is of much the same flavor of Regional Transmission Organization (RTO) in USA.

Traditional wisdom suggests that the construction and development of the regional power market is a process of learning both international experiences and lessons that have been accumulated over times. It is also a process of reaching agreement and increasing awareness of the market initiatives. From June 2003, when the East China Power Grid was selected as one of

the regional power market pilots, to May 18th, 2004 when trial market operation started*, it took almost one year to complete the initial market preparation and construction. The major milestones can be listed below:

- In March 2002, China government issued Power Industry Institutional Reform Plan (Policy No. 5), which outlines the direction of China's Power Industry reform. Generation business has been separated from transmission business and five major generation companies have been formed. The establishment of the regional power market is given the top priority.
- In June 2003, State Electricity Regulatory Commission (SERC) presided a meeting in Shanghai and clearly addressed the intention of establishing a pilot power market in East China.
- According to the Policy No. 5, East China Grid Company Limited (ECG) was established on September 28, 2003, which bears leading responsibility for developing ECPM.
- In November 2003, SERC issued the ECPM Pilot Plan, which is the blue print of the power market development.
- In April 2004, SERC issued the ECPM Codes.
- On May 18th, 2004, ECPM trial operation was commenced. This is the largest regional power market pilot in China.

9.5.1 The Development of the Market

9.5.1.1 Guidelines

The Policy No. 5 guides the development of ECPM. The market development has to respect the unique characteristics of power industry, and international experiences are exploited. It starts with the separation of generation from transmission functions, which aims at optimal resources allocation by introducing competition into wholesale market. The market is expected to facilitate a sustainable and healthy development for power industry in East China Region to satisfy the requirement of regional economic growth as well as the needs of people's life.

The objectives of ECPM Development include:

- ◆ Introducing competition, breaking down market barriers and achieving optimal resource allocation in the East China region;
- ◆ Encouraging power industry to improve management, efficiency and service standard etc;
- ◆ Establishing a unified, open, competitive and stable regional power market under government regulation.

9.5.1.2 The principles of market design

The institutional structure of ECPM is judiciously chosen taking into account the characteristics of energy resources and consumption types within the region, technical requirements, the current institutional structure, and local economic conditions²⁹.

* In the language of Chinese power community, "trial operation" is the first step towards a competitive market, followed by "pre-operation", and "official operation". In trial operation, market dispatch is performed based on bids, settlement is performed but financial transaction is not executed. In "pre-operation", financial transaction is executed but the market can be suspended if certain condition (say, extremely hot weather) is met. In "official operation", market can not be suspended in general.

In the pre-restructuring model, the buyers and sellers are limited only to the provincial power companies serving as either single buyers or single sellers who trade for surplus or deficit of their own provinces. In the new market, all the market entities are competing on the same regional market platform. This design is expected to produce a better outcome in terms of resource allocation over a wider area.

In the preliminary stage of the ECPM, five buyers (four provincial power companies and Shanghai Municipal Power Companies), 171 sellers (conventional coal-fueled generators with capacity over 100MW) will participate in the centrally controlled regional power market.

A 500KV transmission network that connects the provinces and Shanghai Municipality has formed, which facilitates the inter-provincial energy trading. The separation of generation from transmission was largely completed by 2004. Shanghai Municipality and Zhejiang Province who managed province-based power market pilots have accumulated some experiences for the development of the regional market.

9.5.1.3 The stage objectives

In accordance with the principles of integrated design and phase-in implementation, ECPM development shall be implemented in three stages.

- Stage one objective: Let most of the generation companies participate the competitive market, and a portion of the energy be centrally traded in the ECPM platform. Investigate to allow large customers to directly purchase from generation companies in a controlled fashion. Establish legal and regulatory framework for the operation of ECPM. Reform and improve pricing mechanisms for electricity. Establish an ECPM coordinated by the region and its provinces.
- Stage two objectives: Let gradually more generation companies participate in the market, thus increase the level of competition; start bi-lateral trade between large customers, independent distributors and generation companies, set up ancillary services market and transmission rights market, increase trading products; Establish a well functioning market regulation framework and a market under unified operational control.
- Stage three objectives: Introduce competition into retail segment of the industry, and allow all eligible customers directly participate in the market competition with more flexible trading arrangements and products. Establish financial market for energy and form a unified, open, competitive and orderly ECPM under government regulation.

9.5.1.4 The trading arrangements

At initial stages of market development, market trading is a combination of contract trading and physical trading. Contract trading will be the major trading pattern, supplemented by physical trading. A small portion of the energy generated by generators is traded in monthly market and day-ahead market, the remaining energy is sold to network companies through annual contracts for difference (CfDs) and physical contract. Ancillary service is not included in this market at this stage. Non-market generators are expected to sign contracts with network companies under the guidance of SERC.

In the short term, ECPM trading includes annual contract, monthly contract, day-ahead market and real time balancing mechanism. With the development of the market, other forms of trading could be introduced such as quarterly competition and weekly competition. At initial stages of market development, approximately 85% of energy is determined by annual contract; the remaining 15% or so is traded in the market. Depending on the progress of market development, the portion of energy exposed to market competition can be increased.

9.5.1.5 Bidding and market clearing mechanism of monthly market

The monthly market of ECPM, the first market to go under trial operation, was divided into two segments. One is for the peak hours trading with a price cap 482 RMB/MWh, the other is for the off-peak time with a price cap 321 RMB/MWh. Both markets follow the familiar market clearing mechanism while transmission constraints are taking into consideration. Mathematically, the market clearing is represented as the following linear program in which the mathematical symbols are self-explanatory:

$$\begin{aligned}
 & \text{Max} \quad \sum_{p \in \text{Prv}} \sum_{i \in \text{PrvBlock}_p} \text{PrvPrice}_{p,i} \times \text{PrvBid}_{p,i} \\
 & \quad - \sum_{g \in \text{Gen}} \sum_{j \in \text{GenBlock}_g} \text{GenPrice}_{g,j} \times \text{GenOffer}_{g,j} / \text{GLF}_{g,j} \\
 S.T. \quad & \sum_{p \in \text{Prv}} \sum_{i \in \text{PrvBlock}_p} \text{PrvBid}_{p,i} - \sum_{g \in \text{Gen}} \sum_{j \in \text{GenBlock}_g} \text{GenOffer}_{g,j} = 0 \\
 & 0 \leq \text{PrvBid}_{p,i} \leq \text{PrvBidMax}_{p,i} \\
 & 0 \leq \text{GenOffer}_{g,j} \leq \text{GenOfferMax}_{g,j} \\
 & \sum_{i \in \text{PrvBlock}_p} \text{PrvBid}_{p,i} - \sum_{\substack{j \in \text{GenBlock}_g \\ g \in \text{GenPrv}_p}} \text{GenOffer}_{g,j} < \text{PrvInMax}_p \\
 & \sum_{\substack{j \in \text{GenBlock}_g \\ g \in \text{GenPrv}_p}} \text{GenOffer}_{g,j} - \sum_{i \in \text{PrvBlock}_p} \text{PrvBid}_{p,i} < \text{PrvOutMax}_p
 \end{aligned}$$

Implicit in the above formula is a zonal transmission model; each province (Prv) is considered as a transmission zone. The duals of the above linear program form the zonal marginal prices³⁰.

9.5.2 The trial operation of the market

According to a SERC order, ECPM trial operation, which started on May 18th, 2004, only involves monthly competition. The monthly competition simulates the following processes: generator unit registration, bidding, price ranking and information publishing.

In this trial operation, both supplier and buyer should bid and offer for their intended energy. The price and volume that will be cleared in the monthly market is determined by the bidding and offering curve from both generators and provincial buyers respectively, although, it will not be settled during the trial operation period.

However, the provisions of the ECPM Code on market administration and network operation shall be strictly implemented even during the trial operation period in order for the

safer operation during simulation stage. Market administration comprises market participant management, unit registration, market suspension, etc.

9.5.2.1 Simulation results

Results of June 2004

ECPM cleared at total electricity 4.503 TWh with an average price 369.5 RMB/MWh in June 2004. Respectively, in peak load time the cleared quantity is 3.326 TWh, accounting for 73.86%, the cleared price is 406.8 RMB/MWh; in off-peak load time the cleared quantity is 1.177 TWh, accounting for 26.14%, and the cleared price is 273.1 RMB/MWh (see Table 9.2 and Table 9.3 below).

Unit: RMB/MWh; MWh				
Provinces	Clear Price	Supply	Demand	Export
Shanghai	406.8	538.020	143.220	394.800
Jiangsu	406.8	11895.460	1621.200	274.260
Zhejiang	406.8	248.220	1275.960	-1027.740
Anhui	389.0	568.680	0	568.680
Fujian	406.8	75.600	285.600	-210.000
Aggregation		3325.980	3325.980	0

Table 9.2 The simulation results of peak load time in June 2004

Unit: RMB/MWh; MWh				
Provinces	Clear Price	Supply	Demand	Export
Shanghai	273.1	266.100	600	265.500
Jiangsu	273.1	292.200	0	292.200
Zhejiang	273.1	132.000	708.300	-576.300
Anhui	272.2	434.100	277.800	156.300
Fujian	273.1	52.800	190.500	-137.700
Aggregation		1.177.200	1177.200	0

Table 9.3 The simulation results of off-peak load time in June 2004

The market clearing of on peak and off-peak hours are further illustrated in Figure 9.3 and Figure 9.4.

Results of July 2004

ECPM cleared at total electricity 6.820 TWh with an average price 405.4 RMB/MWh in July 2004. Respectively, in peak load time the cleared quantity is 4.849 TWh, accounting for 71.09%, the cleared price is 468 RMB/MWh; in off-peak load time the cleared quantity is 1.972 TWh, accounting for 28.91%, and the cleared price is 289.3 RMB/MWh (see Table 9.4 and Table 9.5 below).

Unit: RMB/MWh; MWh

Provinces	Clear Price	Supply	Demand	Export
Shanghai	468.0	1014.258	954.366	59.892
Jiangsu	449.0	2139.620	2070.180	69.440
Zhejiang	468.0	607.600	1059.828	-452.228
Anhui	416.4	687.890	186.186	501.704
Fujian	468.0	399.280	578.088	-178.808
Aggregation		4848.648	4848.648	0

Table 9.4 The simulation results of peak load time in June 2004

Unit: RMB/MWh; MWh

Provinces	Clear Price	Supply	Demand	Export
Shanghai	289.3	865.520	0	865.520
Jiangsu	289.3	458.490	193.130	265.360
Zhejiang	289.3	244.280	1399.030	-1154.750
Anhui	289.3	288.610	199.950	88.660
Fujian	289.3	115.010	179.800	-64.790
Aggregation		1971.910	1971.910	0

Table 9.5 The simulation results of off-peak load time in July 2004

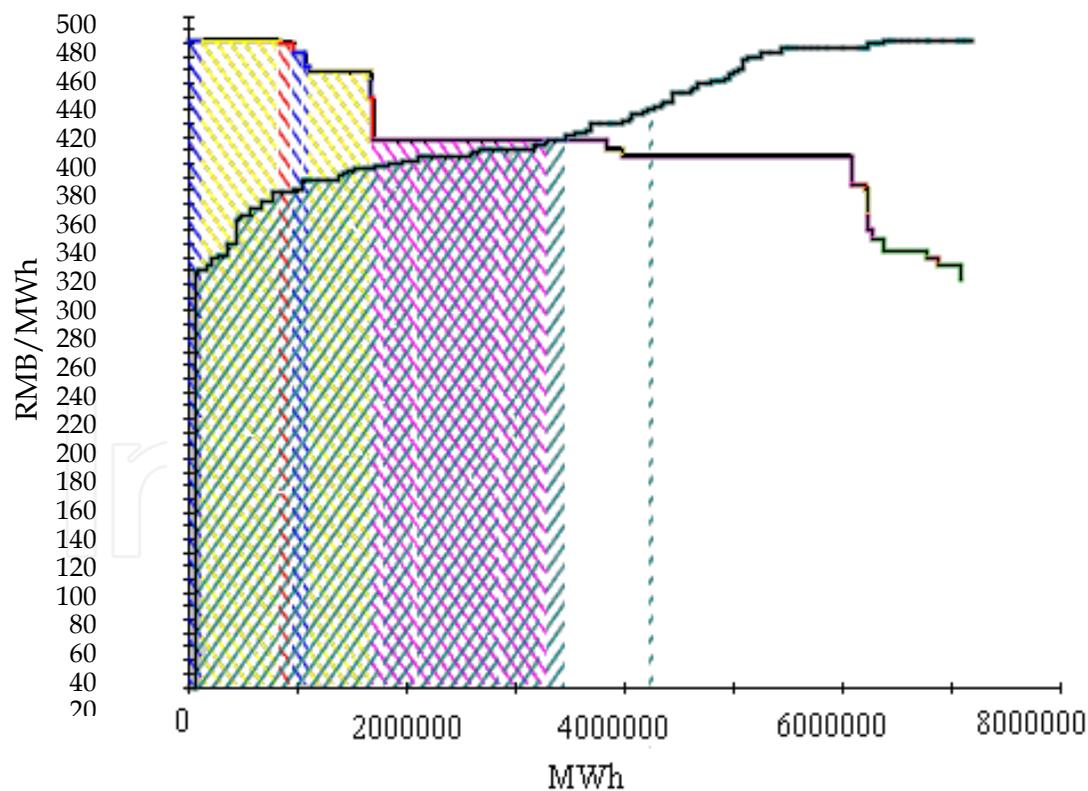


Figure 9.3 The merit curve of peak load time in June 2004

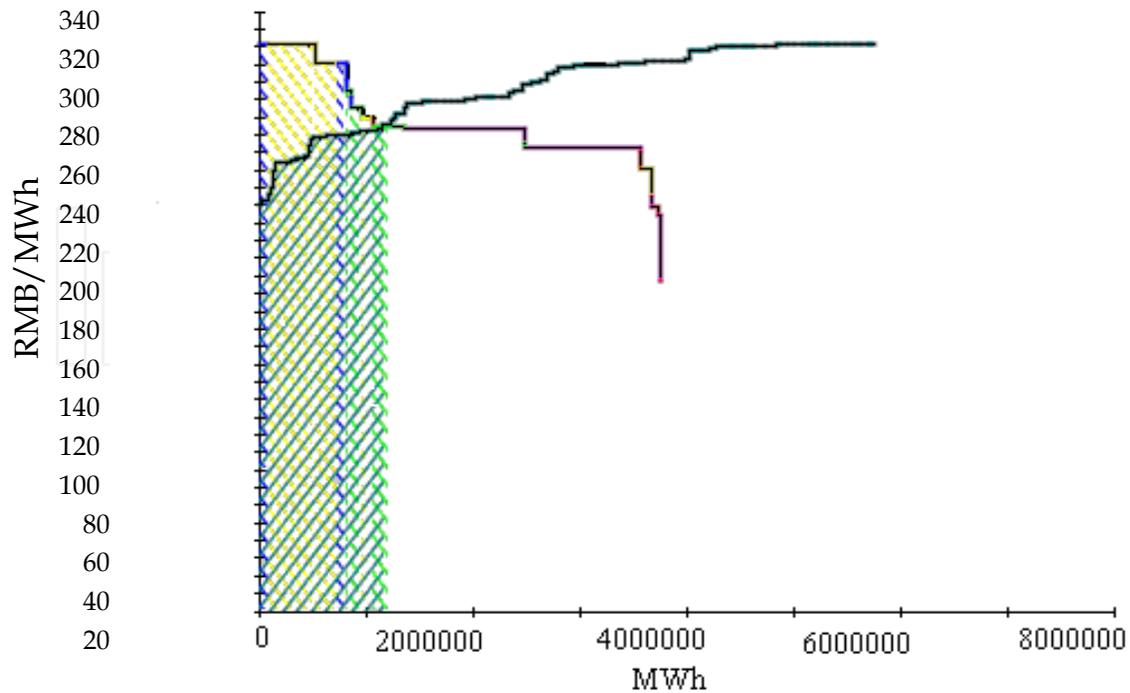


Figure 9.4 The merit curve of off-peak load in June 2004

The market clearing of on-peak and off-peak hours are further illustrated in Figure 9.5 and Figure 9.6.

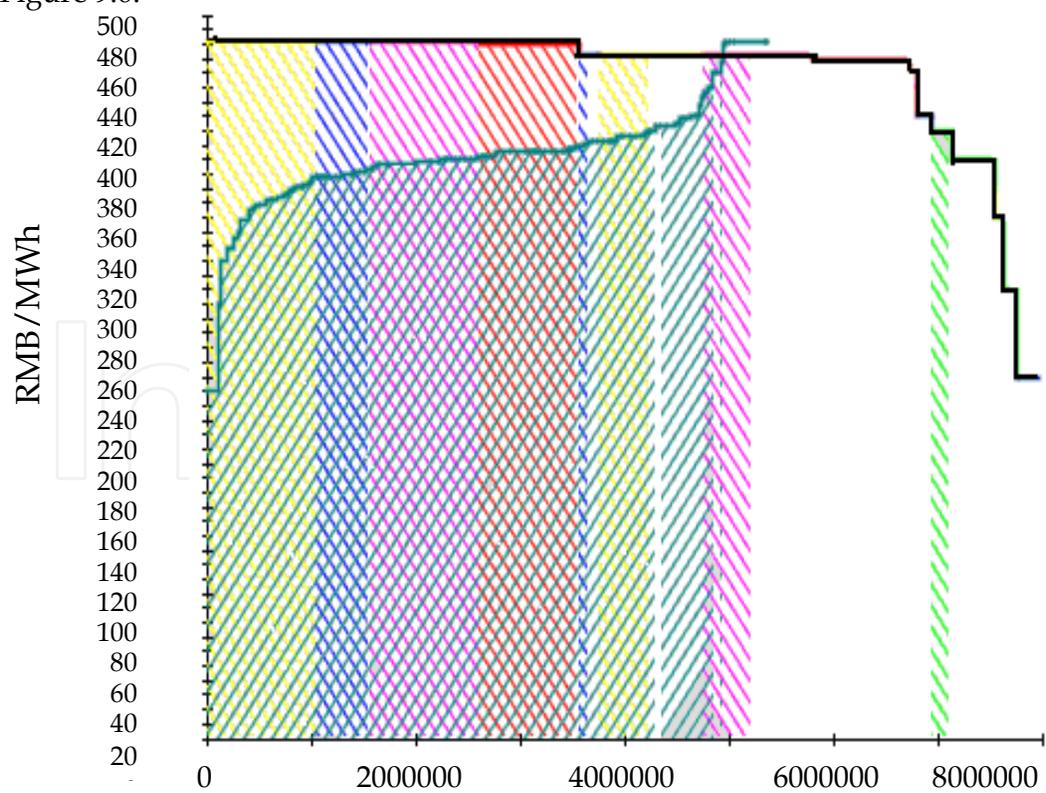


Figure 9.5 The Merit curves of Peak Load Time in July 2004

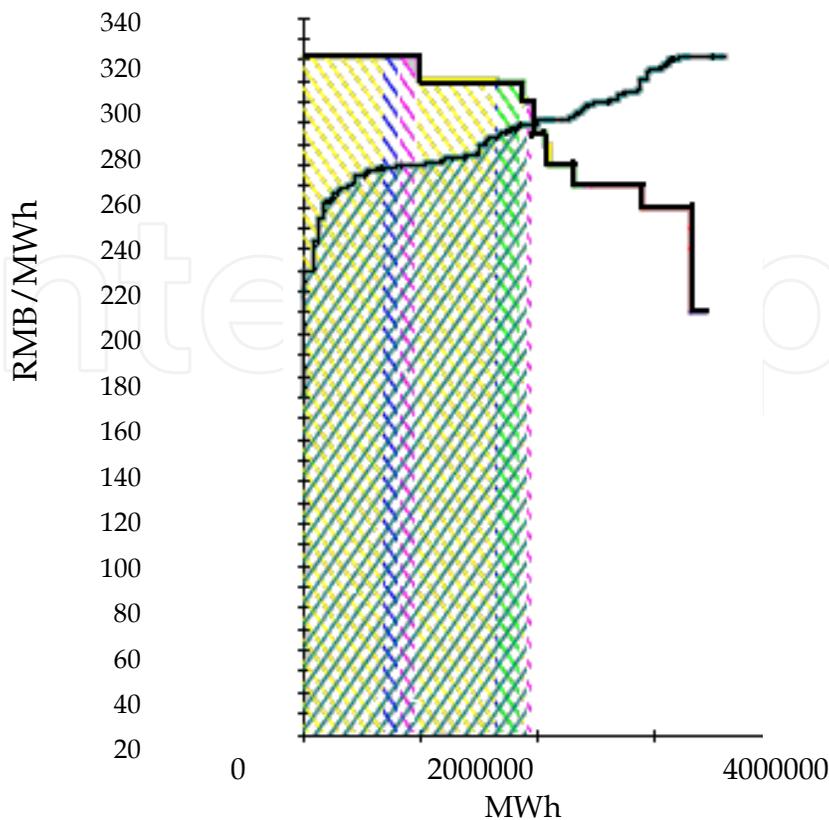


Figure 9.6 The Merit Curves of Off-peak Load in July 2004

9.5.2.2 Results analysis

The significance of the regional power market lies in optimizing resource allocation over a wider area, compared to the previous provincial power market. The problem is how to quantify the significance. In what follows we give a preliminary solution to this question.

The significance can be represented by the market efficiency. According to the principle of economics³¹ the market efficiency can be quantified by the total surplus, which is the sum of consumer's surplus and producer's surplus. In the regional power market, the Tie Line Flows among the provinces has a significant impact over the market efficiency. Assuming the transfer limits of the Tie Line Flows are zero, actual market flows and infinite respectively, the efficiency of the provincial market, actual regional market and ideal regional market can be calculated, the results are included in Table 9.6.

From Table 9.6, it can be seen that the market efficiency of the actual regional market is 774 million RMB, while the province's is 574 million RMB. The regional power market proved to be maximizing the market efficiency. Figure 9.7 further illustrates the relationship between tie-line transfer capacities and market efficiency.

	Unit: million RMB		
	Provincial	Regional	Regional (ideal)
Off-peak, June	23	52	52
Peak, June	149	232	235
Off-peak, July	44	93	93
Peak, July	357	397	411
Aggregation	574	774	791

Table 9.6 The regional market efficiency compared with the provinces

Certainly, provincial markets with zero tie-line capacities are rather idealized markets. The transactions exist among provincial markets help to improve (provincial) market efficiency. However, the difference between an inter-provincial market and a group of provincial markets with transactions is fundamental.

Another issue that is receiving attention is the simulated deficit of network companies. As a result of the tight supply situation, the network companies' payment in the wholesale market has increased on a large scale. The analysis on trial operation revealed that the increased payment is 171 million RMB in June, and 334 million RMB in July respectively. The total increased payment, 505 million RMB, is far beyond the network companies' budget. This tendency has been one of the major concerns of the regional market.

We complete this section by summarizing the trial operation of the monthly market in Figure 9.8, where ISO means Independent System Operator.

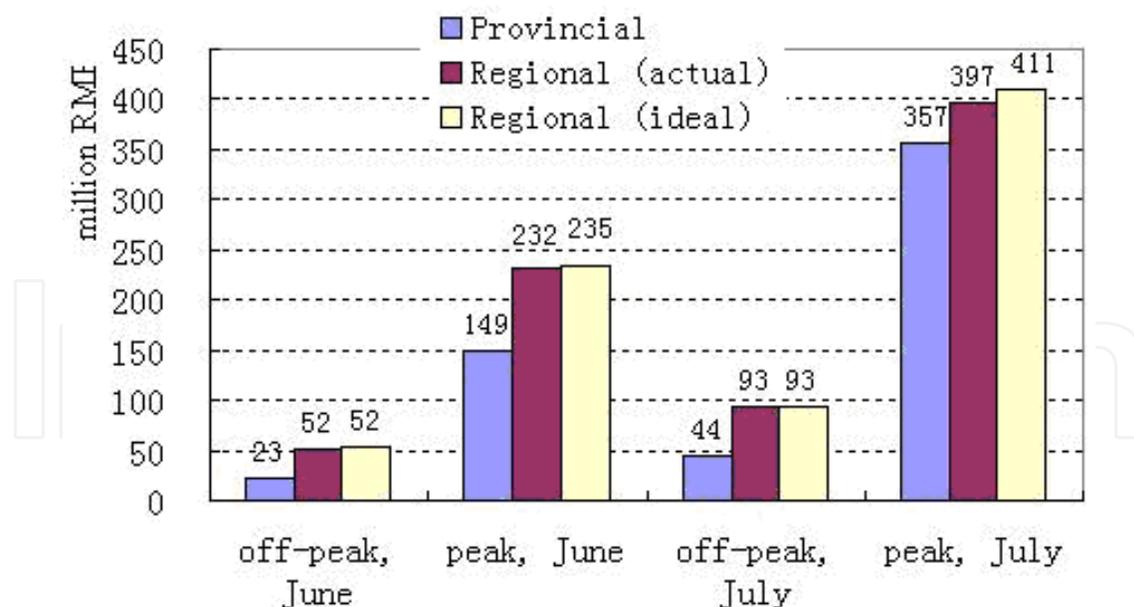


Figure 9.7 Tie line flows affecting market efficiency.

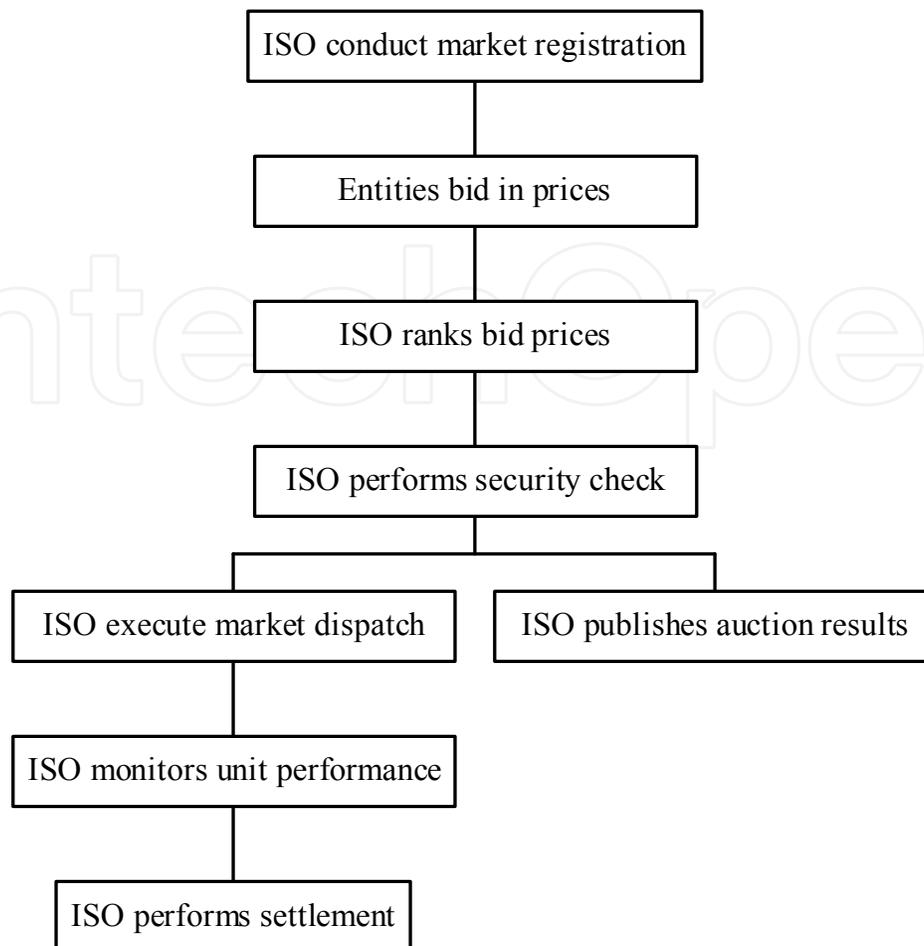


Figure 9.8 The Monthly Market Operation.

9.5.3 Lessons and Recommendations

Despite of the success of the trial operation, there are lessons and recommendations worth mentioning. They are summarized in this section.

9.5.3.1 Regulations and policies need to be improved

The ECPM pilot is developed and operated in a trial fashion under the condition of lacking relevant regulations and policies. With the pilot work going, however, improving market regulations and policies becomes extremely important. The Electrical Regulatory Ordinance has not come forth, the electricity transmission tariff has not been established, and the retail prices has not been linked with the wholesale price. The immaturity of legal environment has limited the success of ECPM pilot.

9.5.3.2 The supply-demand gap threatens the safety of the power system

The East China Power Grid has a wide supply-demand gap for the time being. The Month-ahead market has affected the electricity balance of the provinces, and changed the Demand Side Management of the region. Those provinces, which failed to purchase energy in market, will lead to heavier pressure on their power supply responsibility. This kind of pressure will threaten the safety of network operation because it makes the buyer more irrational also

brings the native provincial governments more challenges. A favorable macroscopic environment with the understanding and support of the whole society is necessary for changing the power industry from the planned economy to the market economy.

9.5.3.3 The tight supply situation results in market price rising rapidly

Opening the wholesale market under the tight supply situation, will certainly lead to the market clear price rising rapidly. This has been proved by the trial operation of the monthly ECPM. It was forecasted that the peak supply gap would reach 18,000MW in East China Power Grid in summer 2004, further more, the severe condition would continue to develop until 2005. The price rising reflects the gap between supply and demand, but the fixed retail price makes the final consumer not be aware of the market signal, and on the other hand, makes the Grid Company take much financial risks. This is just the story of Pacific Gas and Electricity of USA in 2000 market crisis.

9.5.3.4 Risk mitigation methods need to be studied

A free market is just like a sword with two blades. One blade optimizes the allocation of resource, while the other brings enormous risks. Under the environment with incomplete regulation and intense situation between supply and demand, the power market risk is magnified and focused on transmission utilities. In the first two months of trial operation in ECPM, the increased payment of the transmission utilities has been 5.05 hundred million in total, which has broken the balance between generation and transmission presently and has gone beyond the finance capacity of the transmission utilities. The risk mitigation methods need to be studied deeply.

9.5.4 Concluding Remarks

As one of the pilots of regional power market, ECPM has renovated the provincial power markets to the regional platform with uniform codes, realized the inter-provincial competition under the multiple control area model, and optimized the resources allocation within a wider area. Despite of the institutional complexities, the monthly market competition, which adopts a two-way bidding mechanism, maximized the market efficiency and enhanced the social welfare.

The trial operation of the regional market has converted administrative relationships between the market participants into contractual relationships. The responsibilities and obligations of the market participants are declared by the market codes definitely. At the same time, the regional market clearing prices as signals indicate investments on the generation and transmission sectors. In addition, the ECPM model offered a good example for further restructuring of China power industry.

Although the ECPM faces a lot of difficulties and disadvantageous situations, it is believed that market reform will bring positive changes to social welfare and should be pursued down the road. To this end, international experiences such as those of Australia, North America are exploited. It is likely that the concept of pool-based market, widely accepted in the above countries, will be followed in the future market design. Although the suitability of Standard Market Design³² remains skeptical, a day-ahead market with zonal marginal prices calculated centrally is envisioned.

Another question that ECPM faces is whether or not it is feasible to centrally manage a market with rapidly increasing installed capacity. The total installed capacity of the market will exceed 100,000MW in 2011. An extra-large scale market presents challenges to fundamental control center functions such as but not limited to security analysis, real-time dispatch, unit commitment, ancillary service provision, and AGC. This is in fact a question of common interest in the power community³³.

9.6 Status and Perspective of Electric Power Industry in Korea

In recent years, the electric power industry in which monopoly had been taken for granted, has experienced drastic shifts. These changes have triggered active movements toward competition through industrial restructuring and liberalization. In step with this trend, Korea has gradually carried out privatization in the state-monopolized industry. Our objective is not only to overcome management inefficiency but also to restructure it in a way to more effectively benefit the market competition. To begin, the generation sector has been divided into six separate segments according to the similarity of fuel composition and generation capacity. Also, the Korea Electricity Commission (KOREC) was established as a regulatory body and the Korea Power Exchange (KPX) was opened in 2001.

9.6.1 Korea Power Exchange

FOR decades, the electric power industry of Korea had been monopolized by the state-run Korea Electric Power Corporation (KEPCO). However, deregulation of the industry became indispensable so as to establish a competitive electricity market in which electricity can be traded as a commodity. In this context, a market in which electricity can be bought and sold has formed and competition among generation companies has commenced since April 2001.

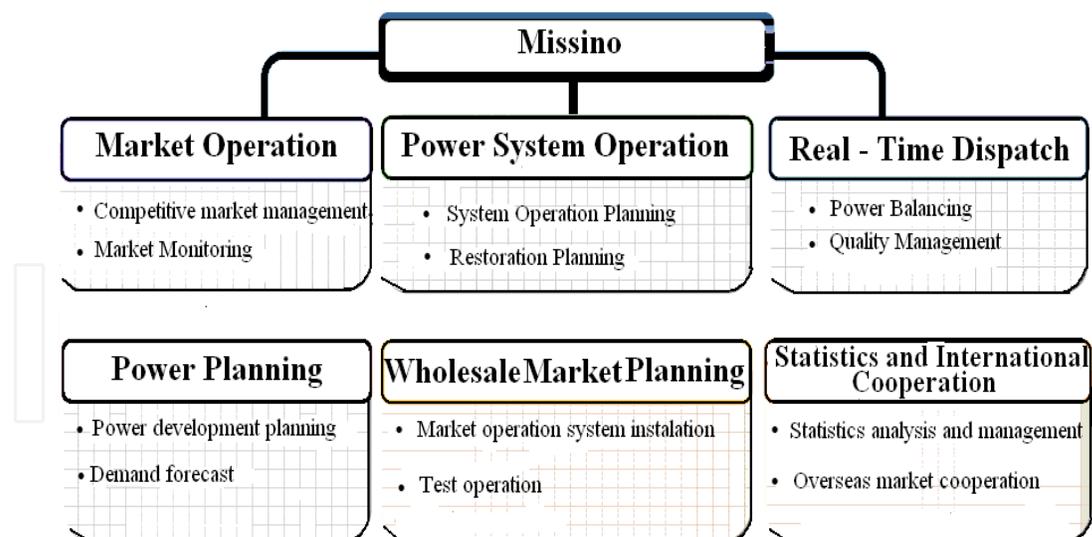


Figure 9.9 KPX's main functions

The Korea Power Exchange (KPX) was introduced on April 4, 2001 as a non-profit independent organization in accordance with Article 35 of the Electricity Business Law to perform main functions, that is, market and system operations, settlement, revision of market rules, administration for regular and associate members, load forecast and establishment of a power development plan, and so on. The KPX's mission can be briefly described in Figure 9.9.

The futuristic reform of the electricity market will be addressed as a transition from the generation competition market to the wholesale competition and finally the retail competition market³⁴. Accordingly, the structure will be changed from Cost-Based Pool (CBP) to Price-Based Pool (PBP) and eventually to Two-Way Bidding Pool (TWBP) in Figure 9.10.

At the generation competition stage, the principles of reform include the adoption of the free competitive environment among the subsidiary generation companies, separation of the distribution business, privatization, establishment of independent regulatory authorities and the bilateral power exchanges available only to large customers. At the wholesale competition stage, the distribution and the sales business will be monopolized on a regional basis and the consumers' right in choosing the electricity supplier will be gradually elevated. In the long run, at the retail competition stage, the regional monopoly of distribution business and sales companies will not be prevented until 2009. There will be new sales companies such as the consumer associations and the expert power sales companies, which will reflect prospects from consumer-oriented viewpoint. The application of PBP and TWBP will be timely made subject to the change of the situation in the market structure.

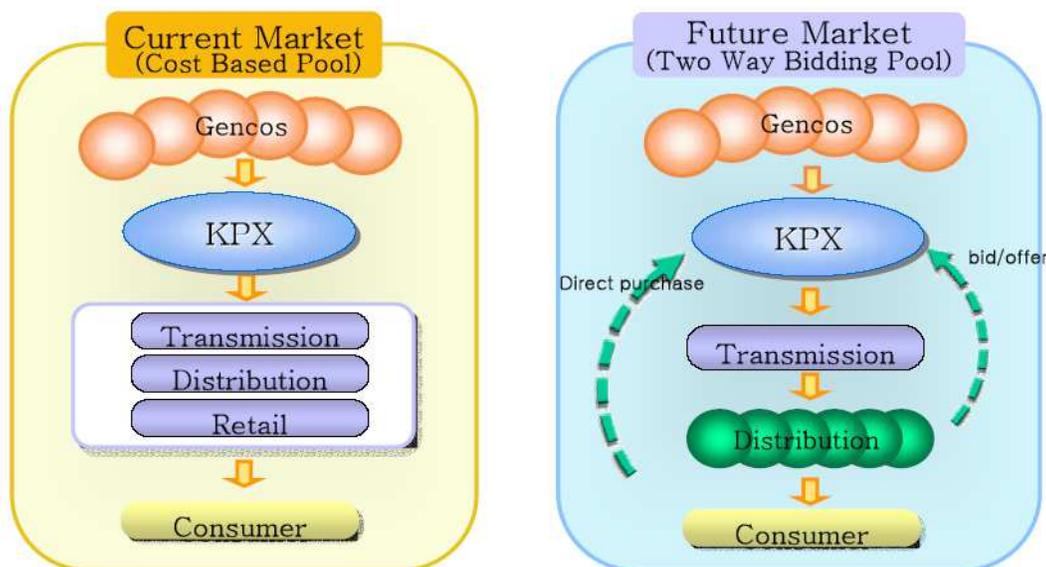


Figure 9.10 CBP vs. TWBP.

9.6.2 Overview of Korean Electricity Industry

Due to the increasing demand of electricity with a growth rate of over 7.5% per annum, the industry had the total electricity generating capacity of 56,053 (MW) in 2003. In 2015, the capacity will be approximately 1.5 times as much as current capacity, which will come to 77,023 (MW) and be expected to sufficiently meet the forecast load-demand. Figure 9.11 shows the installed capacity according to the source of power and individual generating companies, respectively.

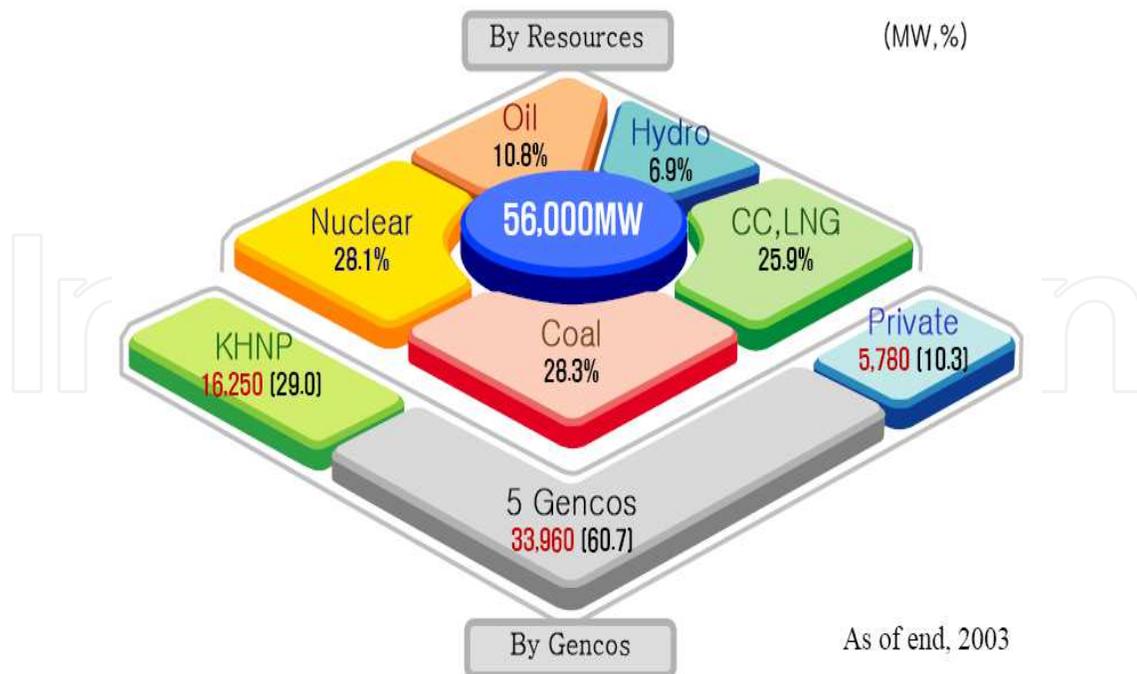


Figure 9.11 Installed generating capacity according to resources and GENCOS

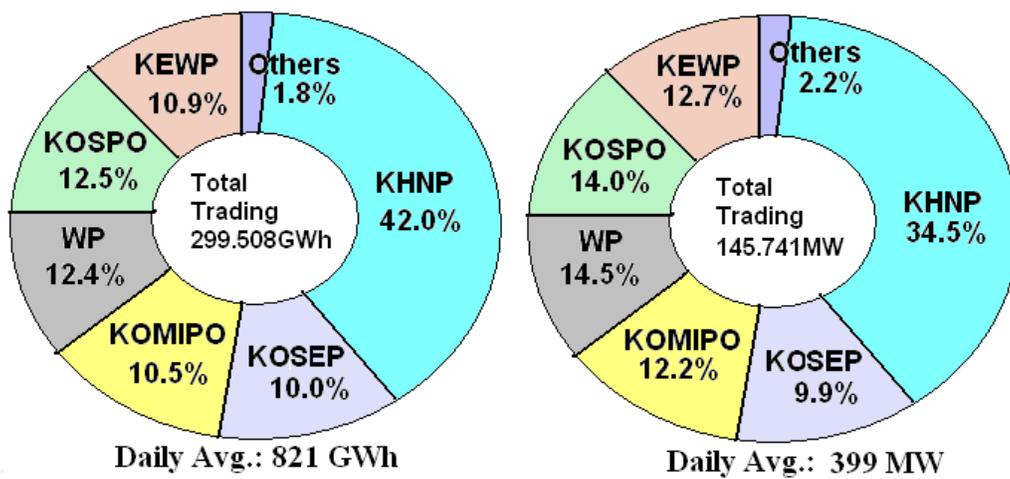


Figure 9.12 Daily average trading volume.

In April 2001, KEPCO's generation sector was split into six power generation subsidiaries including one big hydro and nuclear power company (Korea Hydro & Nuclear Power company, KHNP) and five thermal power companies (Korea East-West Power Co., LTD., Korea South-East Power Co., LTD., Korea Midland Power Co., LTD., Korea Southern Power Co., LTD., Korea Western Power Co., LTD.) on an equal basis in terms of commercial and technical aspects. Particularly, KHNP will remain as a public entity in consideration of nuclear safety, the characteristics of power supply and demand, nuclear power development, and the capability of building new plants, while the other five power generation companies, consisting of fossil and pump storage power plants, will be privatized in the near future. Figure 9.12 depicts the daily average trading volume and we have seen a 15 percent increase of the trading volume in 2003 compared to the same period in last year, as shown in Figure 9.13.



Figure 9.13 Total trading amounts from 2001 to 2003.

During the generation competition, the power plants under construction were built as planned to keep the capacity reserve margin above 15% by 2005. At the same time, the Demand Side Management (DSM) will be strongly implemented to reduce the peak load as illustrated in Figure 9.14. To secure the investment resources needed for activating the DSM program as previously planned, the collection of "Electricity Supply Industry Foundation Funds" for DSM program is legitimized pursuant to article 49 of the Electricity Business Act.

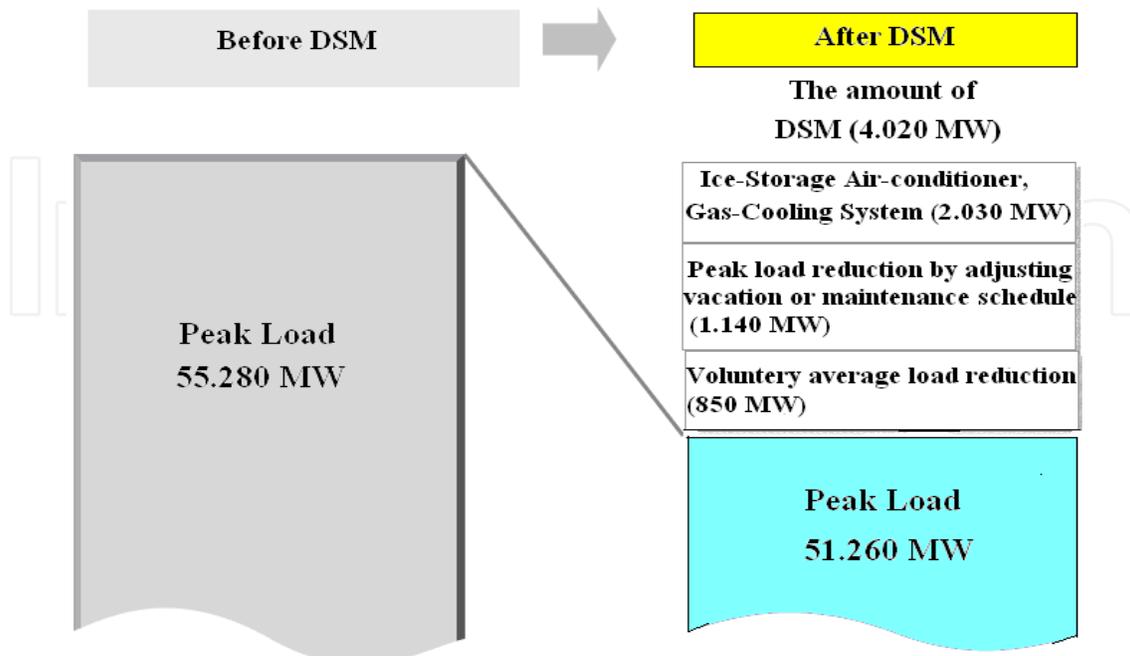


Figure 9.14 Positive effect of demand side management program

In Korea, the seasonal load-demand pattern can be characterized as follows (See Figure 9.15):

- Summer: annual peak load (12:00 ~ 13:00) due to cooling load
- Winter: peak load (23:00) due to heating load
- Spring: the lowest load of a year without consuming neither cooling nor heating loads Besides, Figure 9.16 and Figure 9.17 represent the summer peak load (47,385 MW on August 22, 2003) and the winter peak load (46,387 MW on February 5, 2004), respectively.

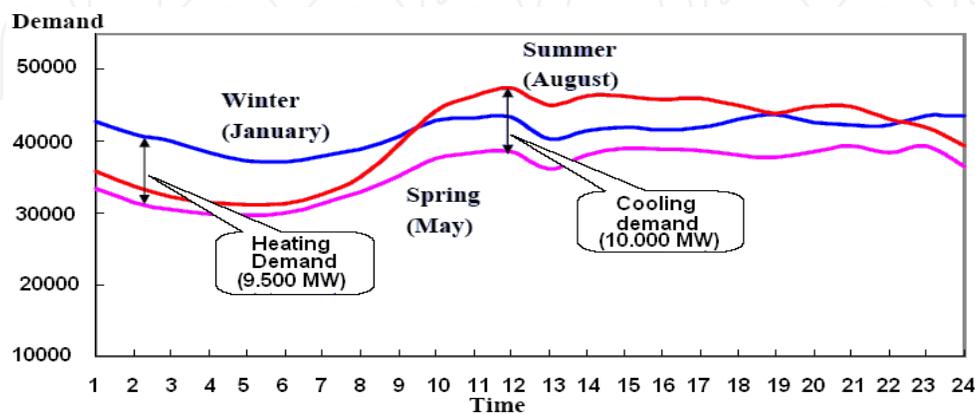


Figure 9.15 Seasonal load-demand pattern

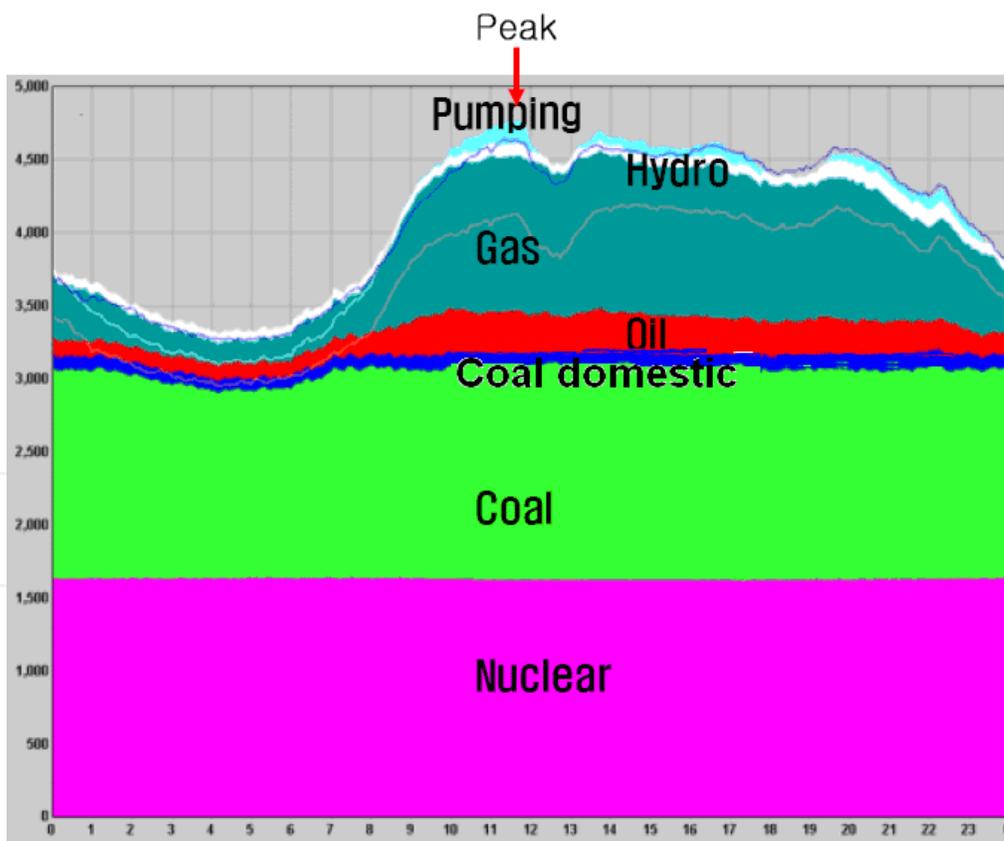


Figure 9.16 Hourly load curve for summer peak load on August 22, 2003.

Table 9.7 summarizes the transmission and distribution facilities in Korea³⁵. The transmission lines including both overhead and underground have a length of 28,260 (km) and the installed transformers totaled 1,672 in 2003. In addition, the distribution lines run radially for a length of 376,454 (km).

Classification		2000	2001	2002	2003
Transmission line (c-km)	765 kV	595	662	662	662
	345 kV	7.281	7.345	7.497	7.740
	154 kV	16.747	17.576	18.144	18.595
	664kV below	1.727	1.540	1.402	1,031
	DC180kV	232	232	232	232
	Total	25.582	27.355	27.937	28.260
Transformer capacity (MVA)	765 kV	-	1.110	7.110	7.110
	345 KV	53.115	63.577	69.078	75,660
	154 KV	70,886	78.119	83.364	89.228
	66 KV below	1,699	1.473	1.286	1.068
	Total	125.700	144.279	160.838	173.066
Distribution Facilities (km, 1.000Set, EA)	Route				
	Length	351.264	358.328	366.938	376.454
	Supporter	6.439	6.695	6.875	7.171
	Transformer	1308.947	1428,510	1546.088	1618.889

Table 9.7 Facilities of transmission and distribution in KOREA

9.6.3 Measures in Power System Operations

Figure 9.18 is a schematic showing six routes connecting metropolitan regions and others as well as a large amount of real power flows through the designated “flowgates”³⁶. More than 40% of system load is in the metropolitan region, while the majority of generation is in the non-metropolitan regions. Further, most generating units with low generation costs are scattered all over the non-metropolitan regions.

For the purpose of economic benefits, therefore, real power generation in non-metropolitan regions increases in parallel with the consumption level, resulting in the power transfer from the south and central parts of the Korean electric power system to the northwestern part through one of the most critical corridors of the grid.

Even more striking is the concept of transfer capability that would be eventually bounded by applicable line ratings, reactive support, and dynamic limitations because greater volume of power flows into a region in normal states can give rise to cascading failures in the N-1 steady-state security criteria^{37, 38}. After privatization of generators, power system engineers in Korea emphasize that the trend of heavier real power flows into the metropolitan region will continue or become profound, and that the constraint of the interface flows will be vital to our national-interest transmission bottlenecks, leading to congestion that significantly decreases reliability, restricts competition, enhances opportunities for suppliers to exploit market power, increases prices to customers, and increases infrastructure vulnerabilities.

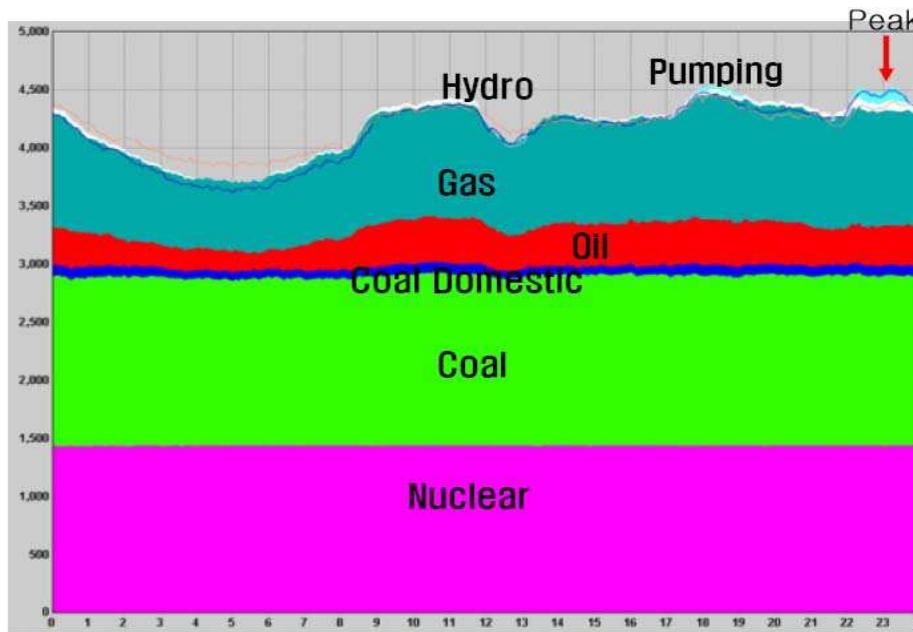


Figure 9.17 Hourly load curve for winter peak load on February 5, 2004.

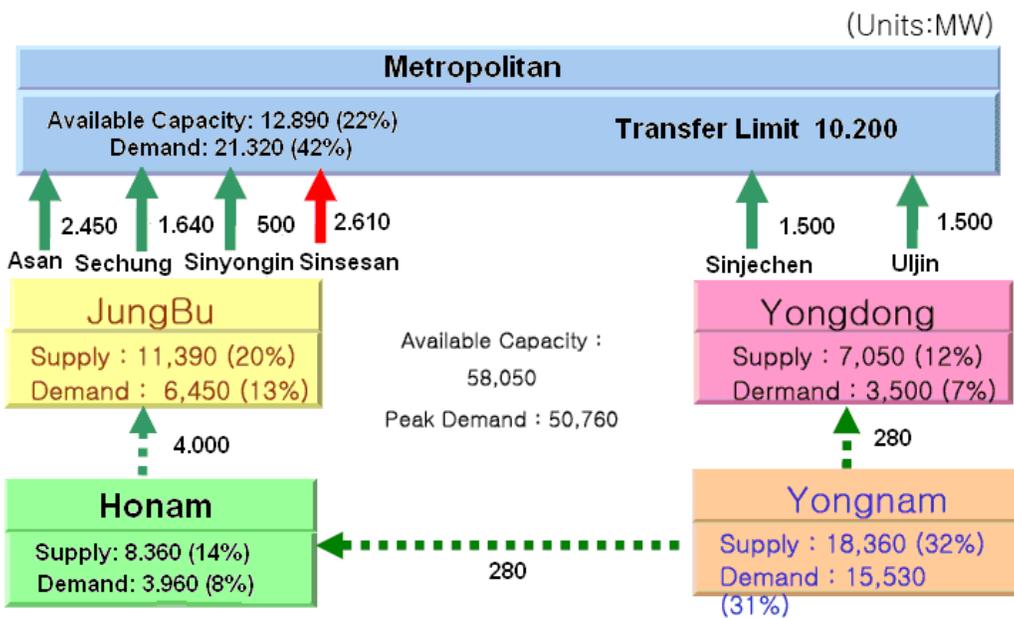


Figure 9.18 Total transfer capability in tie lines between metropolitan region and adjacent regions.

Typically the transmission network planning approach includes a set of fundamentals, some realistic events, under which the system must be able to operate and specified consequences that are accepted under the operation³⁹. As the electricity sector is getting more and more liberalized, a number of questions have been raised regarding the grid planning, e.g., does the market opening require network reinforcement and can the market requirements be an argument for that reinforcement? The network planning approach now involves a set of additional parameters like market prices, transmission pricing, and investment policies.

Thus the transition from monopoly to an open electricity market is a global process, which has been going on for several years. In an overall perspective the open electricity market means liberalizing the sector to create competition in power generation and supply. The introduction of the competitive electricity market has resulted in new frameworks and considerations in power system planning and operations.

9.7 Outlook for Power Exchange between Russia, DPRK and ROK

Since the 1990s, many papers have been published dealing with power system interconnection between Northeast Asian countries. Electricity trading through NEAREST offers mutual benefits, and can be a good countermeasure to solve the environmental and technical problems caused by the independent system operations of each country. Power exchange between countries contributes the infrastructure to open trading markets, while interconnected systems between NEA countries will have more technical and economic advantages when compared with independent system operation conditions. However, this power system interconnection could not become a reality until now due to social, economic and political regime differences. Basically, the ROK, the DPRK and Russia have the most powerful potential in NEAREST, when their status and future prospects are considered. These three countries have different situations and backgrounds on power system interconnection from technical, economic and political viewpoints. The ROK power system is an island, having been isolated from the DPRK network in 1945. Also, the ROK is very poor in natural resources and must import 97.4% of the total primary energy consumed domestically. Also, the ROK has difficulties relating to generation sites. Since the 1980s, the DPRK has suffered from a deficiency of electricity supply and wants to be supported by the ROK. After the summit between the DPRK and the ROK in 2000, the DPRK has requested electricity support with a short-term capacity of 500MW, and a long-term capacity of 2,000MW from the ROK government. Conversely, East Russia, FER (Far East Russia) and ES (East Siberia), have plenty of coal, gas and hydro resources. Also, Russia has surplus power plants and generation potential due to the economic decline since 1990. Russia has plenty of power export potential. Therefore, this section evaluates the prospect of power exchange considering future demand/surplus supply plans and exchangeable power in technical and economic aspects.

9.7.1 Power interconnection scenarios for “RFE – DPRK - ROK”

Many scenarios on NEAREST have been published by institutes working on power interconnection topics, including as ESI, KERI, and others⁴⁰⁻⁴². Most of these scenario analyses, however, have simply estimated the rough parameters of interconnection scenarios, including voltage level, capacity, and line length of inter-ties. The basic contents and concepts covered by these scenario analyses have been largely similar to each other. The main scenarios either under discussion, or currently being studied, are as follows.

9.7.1.1 Potential local interconnections under discussion

Russia has a plan to interconnect its power grid with that of the DPRK. This interconnection might ultimately be extended to the ROK. A number of problems, however, including obtaining financing, pose significant barriers to this project. Table 9.8 describes the general ratings of this interconnection plan. This project will include a 380km, ± 500 kV DC line between VLADIVOSTOK and CHEONG-

JIN. This interconnected line will be operated at 220 kV AC during the first stage of the project, and will be changed to 500 kV AC operation after the 500 kV line between "CHUGUEVKA-NAHODKA-VLADIVOSTOK" is put into operation. In its final stage, the line would be modified as a ± 500 kV HVDC line in the future.

Power volume to be transmitted (mln. kWh)	1500 - 2500
Load to be transmitted (MW)	300 - 500
Frequency (Hz)	50
Voltage (kV)	220/500
Length of line in Russian territory (km)	250
Length of line in DPRK territory (km)	130
Cost of construction (mln. USD)	160 - 180
Period of construction (years)	3 - 4
Period of investment repayment (years)	8 - 10

Table 9.8 Overview of interconnected system between FER-DPRK

Also, the ROK and the DPRK are seeking to develop an industrial complex at GAESUNG, near the shared border of the two countries (but inside the DPRK). The required electricity for the GAESUNG industrial complex might be supplied by the ROK. This project is utterly dependent on the political situation between the two parties. At the first stage, the ROK and the DPRK agreed to construct two distribution circuits rated 2×10 MW, which are now under construction. Finally, the basic rating of transmission line supplying electricity for the GAESUNG industrial complex is 154 kV, 200 MW with a length of 40 km.

9.7.1.2 New scenarios including KEDO N/P

Basically, KERI investigated new six interconnection scenarios for the "RFE-DPRK-ROK" interconnection⁴⁰. "Russia-DPRK-ROK" interconnection can present various scenarios according to the following factors and hypotheses.

- i. Whether KEDO nuclear power plant is included in NEAREST or not.
- ii. Accomplishment of "VLADIVOSTOK-CHEONGJIN" local interconnected system under disconnection to the DPRK system, and the future possibility of re-connection to the DPRK system of CHEONGJIN load.
- iii. Power supply plan to GAESUNG industrial complex under disconnection to the DPRK system and future possibility on re-connection to the DPRK system.
- iv. Capacity and voltage of the interconnected system.

For example, in order to include the KEDO N/P in a power interconnection network, we can consider the interconnection route "VLADIVOSTOK-SINPO" as a tentative hypothesis. This scenario is somewhat different from the existing scenario for a "VLADIVOSTOK-CHEONGJIN" interconnection that is under discussion between Russia and the DPRK. The "VLADIVOSTOK-SINPO" scenario could be one of the alternatives for the effective utilization of the KEDO N/P. If this scenario is implemented, after the commissioning of KEDO N/P, by means of the interconnection the DPRK can earn revenues by trading seasonal surplus electricity, or can be supported with electricity imports at times of seasonal shortages of

electricity. This implies that all of the interconnected countries in this scenario can reap benefits by trading seasonal surplus electricity.

9.7.2 Estimated prospective export/import potential

9.7.2.1 Power industry of the ROK

Table 9.9 describes the present status and future projections for installed generating capacity in the ROK according to the 1st power supply/demand plan after restructuring. The installed capacity is expected to rise to 77,024MW by 2015. In terms of the plant mix, the share of oil and coal plants are projected to decrease over the next 12 years, while the share of nuclear capacity is projected to increase.

Table 9.10 describes the present and future total electricity production in the ROK. As shown in this table, the expectation is that the total generation portion provided by nuclear power plants will rise slightly in the future. In contrast, the fraction of generation provided by thermal plants such as coal- and oil-fired units will decrease.

Year	Nuclear	Coal	Gas	Oil	Hydro	SUM
2002	15716 (29.2%)	15931 (29.6%)	13618 (25.3%)	4660 (8.7%)	3876 (7.2%)	53801
2005	17716 (28.6%)	18165 (29.4%)	16814 (27.2%)	4667 (7.5%)	4485 (7.3%)	61847
2010	23116 (29.3%)	24265 (30.7%)	20437 (25.9%)	4817 (6.1%)	6385 (8.1%)	72635
2015	26637 (34.6%)	22240 (28.9%)	19550 (25.4%)	2212 (2.9%)	6385 (8.3%)	77024

Table 9.9 Present and future projected generating capacity in the ROK (MW)

Year	Nuclear	Coal	Gas	Oil	Hydro	Etc.	SUM
2002	122.8 (43.2%)	117.9 (41.5%)	29.7 (10.4%)	26.7 (2.8%)	6.0 (2.1%)	- (0.0%)	344.8
2005	134.1 (40.6%)	132.7 (40.2%)	45.6 (13.8%)	24.8 (2.9%)	6.7 (2.0%)	1.4 (0.4%)	399.0
2010	166.7 (42.1%)	175.2 (44.3%)	26.5 (6.7%)	17.9 (4.5%)	8.5 (2.2%)	1.0 (0.3%)	435.0
2015	210.3 (47.2%)	165.4 (37.1%)	49.0 (11.0%)	12.0 (2.7%)	9.3 (2.1%)	-(0.0%)	445.9

Table 9.10 Present and future projected electricity production in the ROK (TWh)

Although the projections shown in Table 9.9 indicate that nuclear power's share of future ROK installed capacity and electricity production are expected to be higher than they are at present, it should be noted that these projections should be considered just as long-term targets. Factors such as the shortage of land in the ROK suitable for nuclear plant construction, and public resistance to building power plants, especially nuclear plants (the "NIMBY", or "not in my back yard" movement) will likely make these targets difficult to achieve. As a

result of the "NIMBY" movement in the ROK, and the public fear of atomic energy, construction of new nuclear power plants faces difficulties. Furthermore, building thermal power plants fueled with coal, oil and gas is problematic because of the constraints on GHG emissions specified under the Kyoto protocol. Therefore, as a matter of government policy, it is necessary to establish a future general plan and countermeasures that will help to assure that future electricity demand is met, while still reducing GHG emissions.

9.7.2.2 Power industry of DPRK

Even though we have some DPRK power industry and power system data, most of the DPRK data is quite uncertain⁴³. The DPRK had been suffering from electricity deficiency since the 1980s and most of its hydro/thermal plants are out of date. Because of this, the DPRK had not published formal statistics since the late 1990s, so we could not use existing outdated formal statistics when evaluating the prospect of the DPRK power balance. We could only estimate and treat the DPRK system as a black box.

9.7.2.3 RFE power balance and export potential

A study of the power export potential of East Russia (ER), including East Siberia (ES) and Russian Far East (RFE), up to 2020 was done in ⁴⁴. In Tables 9.11-9.13, min/max value is based on the future minimum/maximum domestic demand. Three categories of power export potential are identified. The first one is power that can be additionally generated by existing power plants up to 2005. The second category of power export includes power from power plants that can be additionally generated during the summer season. The third category of power export potential includes power generation from power plants that should be additionally constructed in ER for export purposes.

Tables 9.11, 9.12 indicate power balances for the RFE interconnected power system compiled using data prepared by ESI for NEAREST DB. Hydropower capacity is supposed to be significantly developed in the RFE, according to power balances in Tables 9.11, 9.12. Bureyskaya HPP, with total capacity of 2000 MW (6×333 MW) and average yearly generation of 7.1 TWh, is constructed, with a third unit phased in by the end of 2004. Three more units were planned by 2009. Nizhne-Bureyskaya HPP, with total capacity of 428 MW (4×107 MW) and average yearly generation of 1.6 TWh, is the second stage of the Bureysk cascade of HPPs. It is supposed to be completed by 2010. Cascade of Nizhnezeyesk HPPs, of an installed capacity and average power generation of 349 MW and 2,12 TWh/year respectively, will be completed in the period 2010-2012. Additionally Urgalsk HPP-1, with a power generation of 600 MW and 1.8 TWh/year, and Dalnerechensk hydropower complex, with a generation capacity of 595 MW and 1.4 TWh/year, are supposed to be introduced by 2015-2020, depending on scenarios of rates of electricity consumption growth in the RFE. Steam TPPs are not supposed to be developed in the RFE. In fact, they are planned to retire, and new steam TPP capacity is not to be commissioned. Development of co-generation TPPs is mainly determined by the demand of heat consumers.

Capacity, peak load and transfer	2001	2005		2010		2015		2020	
		Min	Max	Min	Max	Min	Max	Min	Max
Hydro	1.33	2.2	2.2	4.0	4.0	4.7	5.3	4.7	5.3
Steam turbine	2.61	2.5	2.5	2.4	2.4	2.5	2.5	1.6	1.6
Co-generation	3.17	3.5	3.5	3.6	3.8	3.8	4.3	5.4	5.4
Nuclear	-	-	-	-	-	0.6	0.6	1.3	1.3
Total capacity	7.11	8.2	8.2	10.0	10.2	11.6	12.7	13.0	13.6
Peak load	4.74	5.33	5.77	5.80	6.74	6.33	7.96	6.93	8.85
Power transfer to adjacent regions	0.04	0.32	0.35	0.85	0.85	0.85	0.85	0.85	0.85
Peak load and power transfer	4.78	5.65	6.12	6.65	7.59	7.18	8.81	7.78	9.7
Capacity reserve rate, %	48.7	45.1	34.0	50.4	34.4	61.6	44.2	67.1	40.2

Table 9.11 Capacity balance for RFE IPS, GW

Power generation, electricity consumption and transfer	2001	2005		2010		2015		2020	
		Min	Max	Min	Max	Min	Max	Min	Max
Hydro	4.85	8.9	8.9	13.7	13.7	16.3	16.3	17.0	19.0
Steam turbine	6.05	6.8	6.8	5.2	6.6	4.9	7.7	1.2	3.0
Co-generation	14.6	14.5	16.6	17.1	19.9	17.7	22.8	18.9	21.6
Nuclear	-	-	-	-	-	-	-	3.8	7.8
Total generation	25.5	30.2	32.3	36.0	40.2	38.9	46.8	40.9	51.4
Electricity consumption	25.2	28.5	30.6	31.5	35.7	34.4	42.3	37.4	46.9
Electricity transfer to adjacent regions	0.29	1.7	1.7	4.5	4.5	4.5	4.5	4.5	4.5
Electricity consumption and transfer	25.5	30.2	32.3	36.0	40.2	38.9	46.8	41.9	51.4

Table 9.12 Electricity balance for RFE IPS, TWh/year

As can be seen from Table 9.13, power export potential, which does not require additional capacity commissioning (apart from that required for meeting domestic power loads), and, therefore, additional investment, can be quite sufficient, exceeding 4 GW of capacity in summer, and 2 GW in winter, and 16-18 TWh/year of power generation in the beginning of the period under consideration. At the end of the considered period, export potential declines to about 2.5-3.0 GW of capacity in summer only (because of exhausting existing excessive capacity), and 5-6 TWh/year of power generation.

	Potential	2005	2010		2015		2020	
			Min	Max	Min	Max	Min	Max
Capacity, GW	Winter	2.4	1.2	0.4	0.7	0.0	0.0	0.0
	Summer	4.3	3.3	2.8	3.0	2.9	2.5	3.2
Power generation, TWh		18.1	11.5	7.4	8.6	5.8	5.0	6.4

Table 9.13 Total RFE Power Export Potential of Existing Plants

	Power plants	Installed capacity, GW	Annual average generation, TWh	Years of commissioning
Hydro	Bureysk (together with Nizhne-reysk)	2.428	8.7	By 2010
	Cascade of Nizhnezeysk	0.349	2.12	By 2015
	Dalnerechensk	0.595	1.4	By 2015
	Urgalsk-1	0.6	1.8	By 2015
	Subtotal	3.972	14.02	-
Nuclear	Primorye	1.3	9.75	By 2020
	Total	5.27	23.77	-

Table 9.14 Power plant capacities to be commissioned in RFE by 2020

	Power plants	Installed capacity, GW	Average yearly generation, TWh
Hydro	Urgalsk-1	0-0.6	0-1.8
	Gilyuisk	0.38	1.15
	South Yakutian hydropower complex, including:	5.0	23.45
	Cascade of Sredne-Uchursk and Uchursk HPPs	3.7	17.2
	Cascade of Idjelsk and Timonsk HPPs	1.3	6.25
	Khingansk	1.2	5.8
	Subtotal	6.58-7.18	30.4-32.2
Thermal	Sakhalin (Gas)	4.0	26.0
	Sakhalin (Coal)	2.0	13.0
	Urgalsk (Coal)	1.2	7.5
	Subtotal	7.2	46.5
Nuclear	Far East	2.5	18
	Total	16.28-16.88	94.9-96.7

Table 9.15 Power Plant Capacities to be commissioned in RFE after 2020

Table 9.14 and Table 9.15 shows prospective power plants, which can be constructed within (or close to) the area of the RFE IPS in and beyond 2020. As can be seen from Table 9.15, the total power potential of the third category can exceed 16 GW and 95 TWh/year. In addition to this potential, construction of the Tugursk tidal power plant, with a capacity of nearly 7 GW and a yearly power generation of 17 TWh, can be possible beyond 2025-2030.

9.7.3 Admissible Interconnected Capacity in Technical Viewpoints

9.7.3.1 Evaluation of maximum exchangeable power

An evaluation of maximum exchangeable power was performed by KERI^{45,46}. It can be evaluated by taking into account the following technical aspects, such as ROW (Right of Way) and system constraints. ROW constraint means the geographical constraints that the interconnected line should pass through. Also, system constraints include technical problems, such as load flow and stability analysis. The study results of technical aspects are as follows.

ROW constraint: Considering the geographical situation between Russia and the Korean peninsula, a two-bipole system having a capacity of 7 GW can be built.

Load flow analysis: There is no violation of overload and voltage in a steady state up to 7 GW of inflow power. However, in N-1 contingency, some violations happen as the inflow power exceeds 4 GW. Therefore, 4 GW seems to be the maximum exchangeable power.

Dynamic analysis: The power system frequency of the ROK can keep the standard when losing 2 GW of power. However, loss of more than 3 GW of power makes frequency violate the standard. Considering a one-bipole trip, 4 GW is the maximum exchangeable power.

Finally, we can say that 4 GW of power exchange is the maximum exchangeable power from a technical viewpoint between Russia and the ROK at present status, and this result could satisfy the security points.

9.7.3.2 Evaluation of minimum exchangeable power

Minimum exchangeable power is evaluated through a comparison of total costs and benefits of the interconnected line during its life cycle span of 30 years. The total cost of interconnected lines, life cycle costs, consist of initial investment and operating costs. Initial costs include the construction cost of transmission lines and converter stations, operating costs means the maintenance costs of transmission lines and converter stations. The benefit of interconnection comes from the electricity tariff difference between the ROK and Russia. The electricity tariff difference in 2000 was \$0.0383/kWh, but this difference has been getting decreased because the annual rate of increase for electricity tariffs in Russia will be higher than that of the ROK. Table 9.16 shows the total cost and benefits of interconnected lines. If 1 GW or 2 GW of power is exchanged between the ROK and Russia, the total cost is much more than the accrued benefits, a situation that cannot assure an economic advantage. However, more than 3 GW of exchange power can guarantee the interconnection project will be in the black. Therefore, we can propose that minimum exchangeable power, from an economic viewpoint, will be 3 GW.

Exchange power	Cost (billion \$)	Benefit (billion \$)
1GW	4.13	3.16
2GW	6.60	6.33
3GW	7.82	9.49
4GW	10.56	12.65

Table 9.16 Total cost and benefits

Benefits are affected by a decrease in the rate of electricity tariff differences between the ROK and Russia. The lower the decreasing rate is, the more we can expect benefits. Figure 9.19 shows the sensitivity of benefits with variations of the decreasing rate. In this figure, the horizontal axis is the decreasing rate and vertical axis shows benefits. In the case of 1GW of exchange power, the benefit is \$5.24billion, with a 1% decreasing rate, but the benefit is reduced to \$2.11billion with a 9% decreasing rate. With a 5% decreasing rate, more than 3GW of exchange power is needed to assure economic feasibility. More than 1GW of exchange power, with a 1% decreasing rate makes the interconnection project beneficial, but if decreasing rate increases over 7%, the cost is larger than the benefit with 1 GW to 4 GW of exchange power. Figure 9.20 shows the Benefit/Cost ratio with a 5% decreasing rate. In this figure, the horizontal axis means exchange power and vertical axis means B/C ratio. As exchange power grows, B/C ratio also increases up to 3 GW. However, B/C ratio decreases from more than 4 GW, as shown in Figure 9.20. So, we can say that ranging from 3 GW to 4 GW is a more reasonable exchange power in economic terms.

As a result, the minimum exchangeable power is about 3GW, and optimal exchangeable power range, considering technical and economic viewpoints, is expected to 3~4 GW.

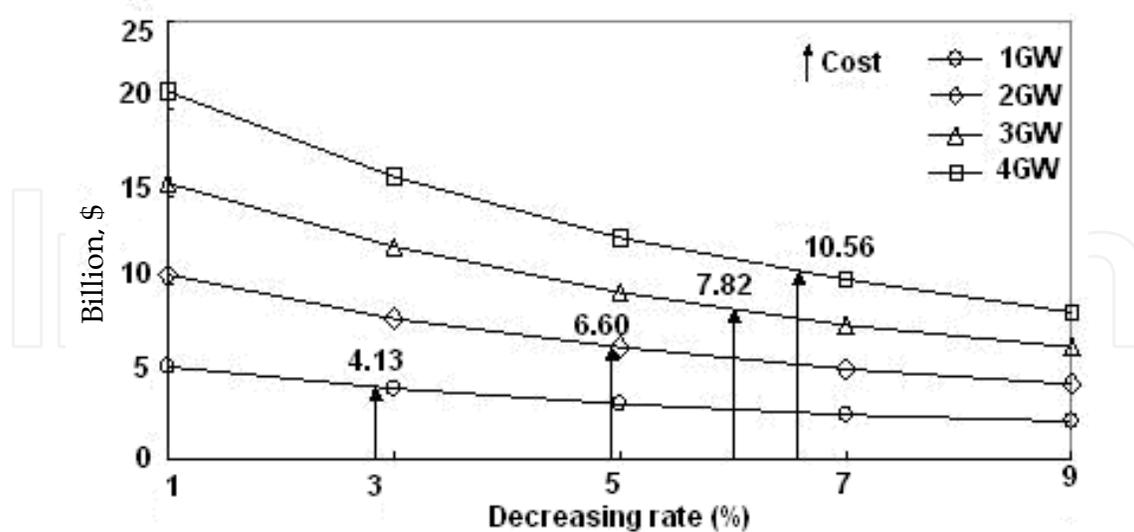


Figure 9.19 Sensitivity of benefit to variations in decreasing rate.

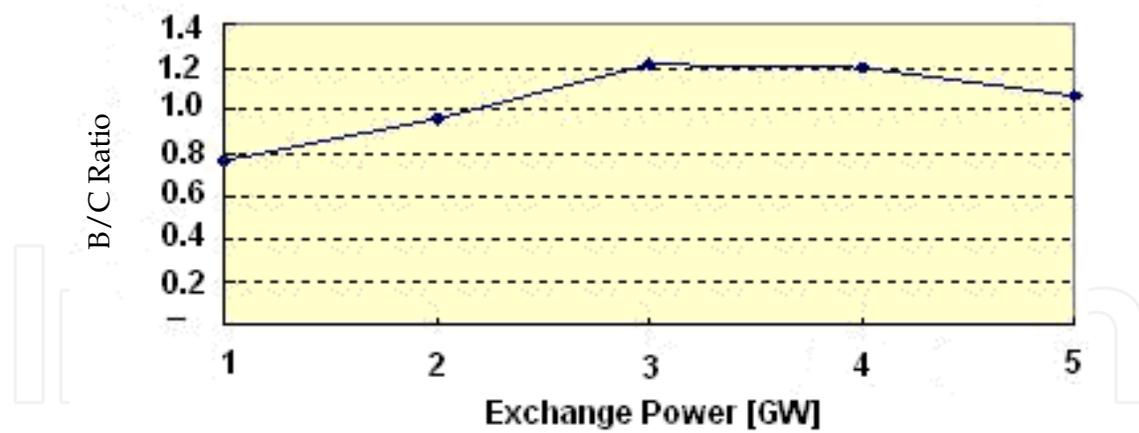


Figure 9.20 B/C Ratio with a 5% decreasing rate.

Thus, above study examines the future outlook of exchange power between the ROK, the DPRK and RFE from technical and economic viewpoints. The main results of this study on power system interconnection are as follows.

1. Excessive capacity and power generation for the RFE system was estimated in the paper. Power export potential, which does not require additional capacity commissioning and, therefore, additional investment, can be quite sufficient exceeding 4 GW of capacity in summer, 2 GW of capacity in winter, and 16-18 TWh/year of power generation at the beginning of the considered period. At the end of the considered period, the export potential declines to about 2.5-3.0 GW of capacity only in summer (because of exhausting existing excessive capacity) and 5-6 TWh/year of power generation. The total power exports potential, including new commissioning plants can exceed 16 GW and 95 TWh/year. In addition to this potential, construction of the Tugursk tidal power plant, with a capacity of nearly 7 GW and yearly power generation of 17 TWh, can be possible beyond 2025-2030.

2. The maximum acceptable exchange power between Russia and the ROK at present status, from a technical viewpoint, is 4 GW and this result could satisfy security points. In addition to maximum exchangeable power, the minimum exchangeable power, by comparing total costs and benefits of interconnected lines, is evaluated at 3GW. At this time, we can say that the range of 3 GW to 4 GW seems to be a reasonable power exchange level between the ROK and RFE systems.

3. This study is based on a hypothesis, and research concepts, not on practical engineering projects. Therefore, more detailed engineering work from the technical and economic viewpoints are required for the realization of NEAREST. Above all, we could not estimate the prospect for the DPRK system because we have no accurate DPRK power industry data and, consequently, the exact details are uncertain.

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

Economical and technical considerations are usually the underlying factors for interconnecting electric power systems. Among some of the benefits that may be realized are plant capacity savings, in-

terchange due to diversity, emergency power interchange, spinning reserve savings. Development of such ties in the future can result in more effective utilization of power stations installed capacities, fuel economy, to improvement of ecological situation in a region.

However, the planning of interconnection is a demanding task and needs to meet a wide range of technical aspects. The interconnection of the power systems among North-East Asian countries (Russia, China, Mongolia, Japan, and Korea) has been proposed on numerous occasions, but little progress has been made due to the complicated political issues and economical problems involved. Interstate electrical ties of power systems of the Northeast Asia countries now practically are not developed. Now, the necessity for this power system interconnection is increasingly being felt due to the benefit of each country. Because of these reasons, Korea peninsula takes the role connect a bridge between different areas of North-east Asia, such as Russia, Mongolia, China, and Japan⁴⁷⁻⁵¹. The problem of utilizing 2,000MW power output after the successful construction for the Sinpo nuclear power plant in future has been studied, and a 765 kV HVAC interconnection between South Korea and North Korea has been discussed with several papers⁵²⁻⁵⁸.

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

However, most of the large-scale power plants have been constructed in the southern part of South Korea. Consequently, the existing power grid includes multiple routes designed to supply the metropolitan area so that, by and large, the direction of power flow is toward the north. The future substitutes are to relieving the problems of power imbalance and the shortage of power in the Seoul metropolitan areas in South Korea and the Pyongyang metropolitan areas in North Korea.

In this Section, we present various scenarios and the accompanying power flow analyses considering on seasonal load patterns, in order to provide the interconnection of the electric power grids. A distribution map of the projected power flow will be drawn by the results of simulations performed using the PSS/E tool.

9.8.1 Power System Status and Seasonal Load Patterns in Northeast Asia

In this Subsection, we will explain the general characteristics and the seasonal load patterns of the existing power systems used in South Korea, North Korea, Russia, China, and Japan⁵⁹⁻⁶⁶.

9.8.1.1 Power system and seasonal load patterns in South Korea

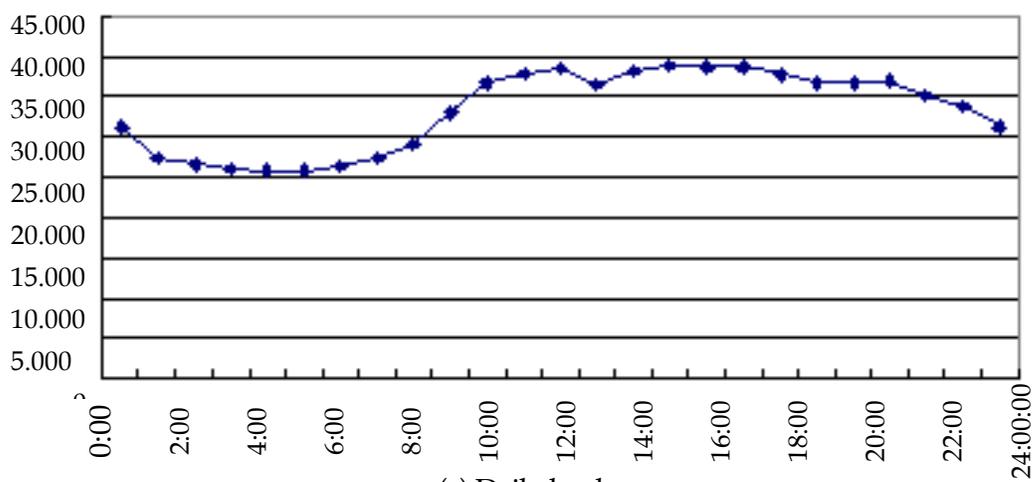
The South Korean electricity generation system can be divided into 7 geographical areas that take geographical boundaries into account. The transmission voltages used are 345kV for the major networks, and 154kV or 66kV for the local systems. Most 66kV lines are now either being removed or replaced by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

tween the large power generation plants and the areas where the consumers are located. Figure 9.21 represent the load curve for day and the load curve for month in South Korea.

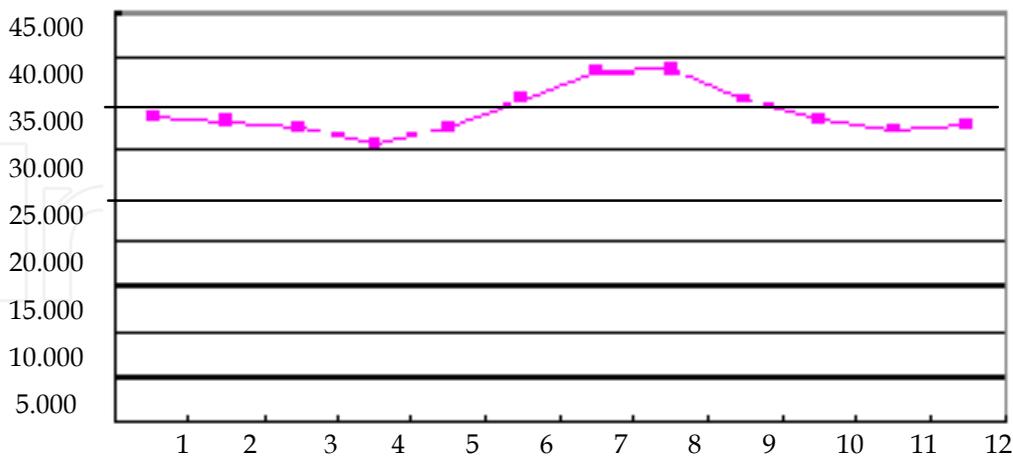
Table 9.17 shows the current status of KEPCO's transmission grid facilities at the end of 2001. Table 9.18 represents a mid-to-long term forecast in demand and supply. Table 9.19 shows a power capacity of 6 generating companies in South Korea, 2002. (The bellow data had obtained from KEPCO in Korea) Figure 9.22 represents a load demand and a generating facility capacity for districts.

9.8.1.2 Power system and seasonal load patterns in North Korea

Figure 9.23 represents the load curve for day and the load curve for month with the assumed material in North Korea. As shown in bellow Figure, the pattern of a curve has a flat and small variation.



(a) Daily load curve



(b) Monthly load curve

Figure 9.21 South Korea load curves for day and for month.

(At the end of 2001)

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

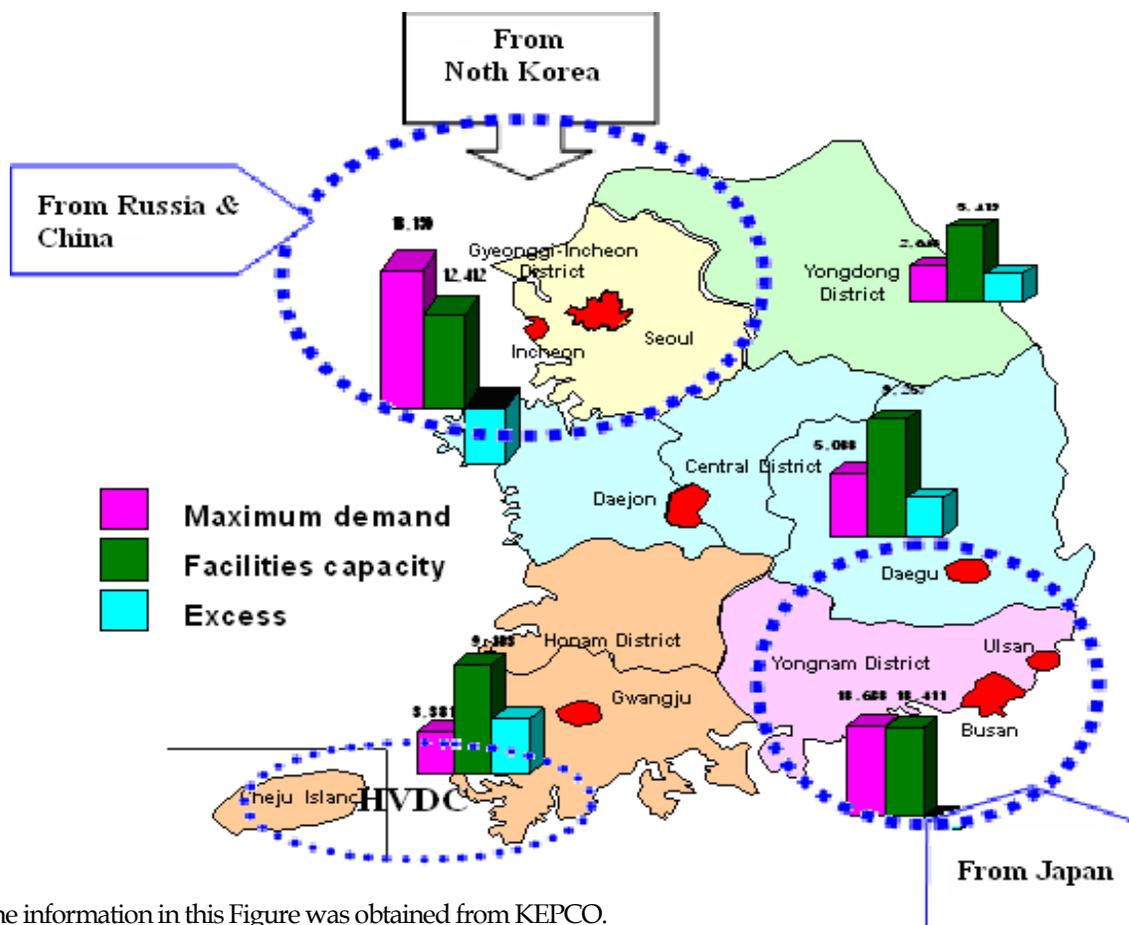
Table 9.17 Current status of KEPCO's transmission grid facilities

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

Table 9.18 Mid-to-long term forecast in demand and supply

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

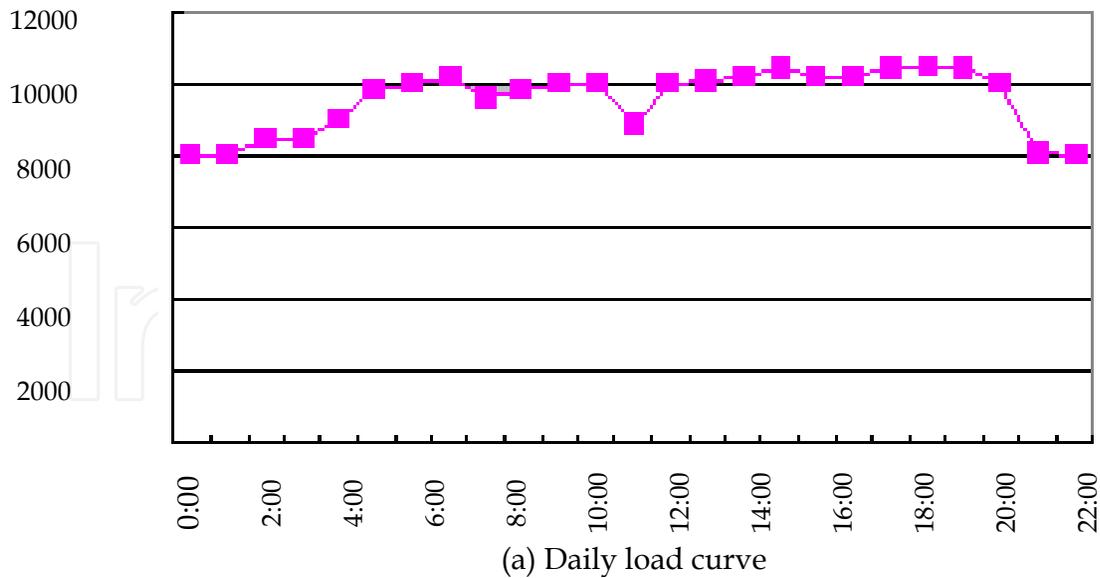
Table 9.19 Power capacity for generation companies in South Korea, 2002



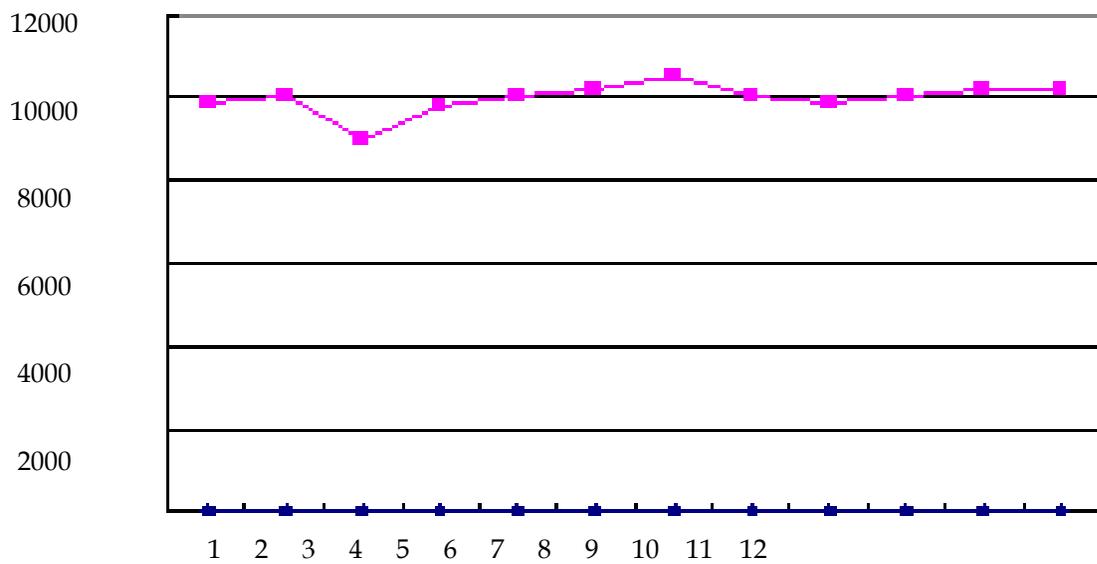
* The information in this Figure was obtained from KEPCO.

Figure 9.22 Demand and facility capacity by regions

At present, the data about transmission system of North Korea are insufficient and are not arranged well. There are only a little data from Russia, UN, CIA, the Korean Board of Unification, etc. Accordingly, the previous researches of interconnection in the Korean Peninsula have just focused on the analyses of the present data and scenarios. This study assumes that the power system in North Korea is divided into 5 areas. The power system in North Korea is smaller than that in South Korea. Most of the hydroelectric power plants are located in the hilly region of the northern areas in North Korea and most of the thermoelectric power plants are located in the metropolitan area. Moreover, power capacity in North Korea has been estimated to be approximately 7,000MW. Currently, it is known that transmission line voltage is composed of 110kV and 220kV.



(a) Daily load curve



(b) Monthly load curve

Figure 9.23 North Korea load curves for day and month (Assumed Material)

9.8.1.3 Power system and seasonal load patterns in Far East Russia

The above data had been obtained from SEI in Russia. Table 9.20 represents a present seasonal data of power in Russia (2001). Table 9.21 is a present seasonal data of power in East Siberia (2001). Table 9.22 shows a present seasonal data of power in Russian Far East (2001).

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

Table 9.20 Present seasonal data of power in Russia (2001, TWh)

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

Table 9.21 Present seasonal data of power in East Siberia (2001, TWh)

Unified Power System (UPS) of Russian East provides with the electric power the most inhabited and industrially developed regions of the Russian Far East. UPS of Russian East consist of seven large regional electric power systems: Amur, Far East, Kamchatka, Magadan, Sakhalin, Khabarovsk and Yakutsk. Now the Amur, Khabarovsk and Far East electric power systems are united on parallel operation, in parallel with them the southern part of the Yakut electric power system is working also. The maximum of electric loading in UPS falls at winter and makes about 5.8 GW (based on the data for 2001). The minimum of electric loadings makes approximately half from a maximum and falls at the summer period. The maximum of in UPS was in 1990 and made approximately 30 billion kWh. In 2000 value of electrical energy consumption has made approximately 24 billion kWh, in 2001 this value has made 25.5 billion kWh. It was planned, that by 2005 consumption will make about 28.7 billion kWh by 2010 - 32 billion kWh, and by 2025 will make about 50 billion kWh.

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

Table 9.22 Present seasonal data of power in Russian Far East (2001, TWh)

The current consumption is distributed non-uniformly. More than 40 % of the electric power is consumed in the Far East electric power system. The rest of 60% are distributed between the Khabarovsk, Amur and Yakut electric power systems. Backbone electrical network of the UPS consist of 220 and 500 kV transmission lines. General extent of 500 kV lines makes about 2000 km The total installed capacity of power stations (nuclear, thermal and hydro) make about 11 GW⁵⁹. Figure 9.24 represents the HVDC interconnection lines in Siberia and Far East Russia⁵⁰.

9.8.1.4 Power system status in North East China

Figure 9.25 represents the seven regions and power consumption map in China. This Figure was obtained from EPRI in China.

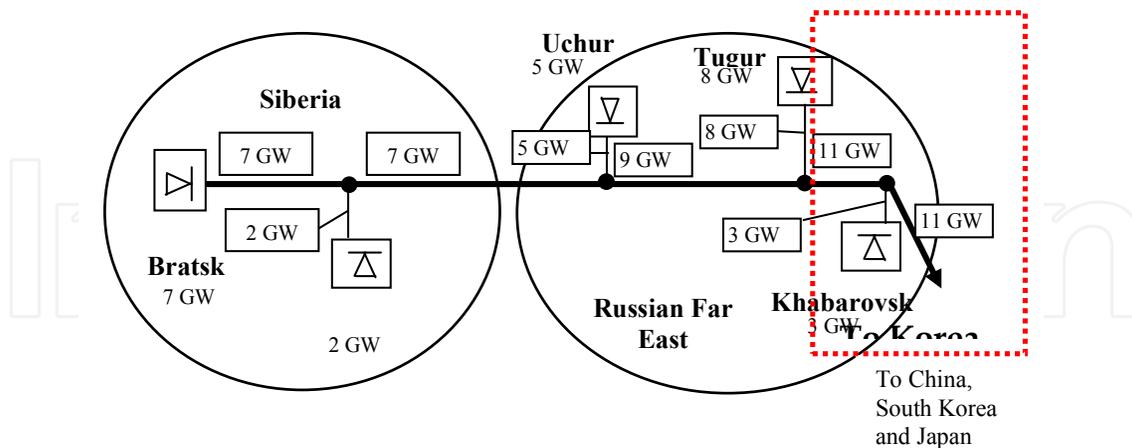


Figure 9.24 HVDC Interconnection Lines in Siberia and Far East Russia

This map shows an overview of the different regional grid systems within China, showing year 2002 generating capacities and outputs in each region, as well as indicating interconnections between regional grids. In China, Liaoning’s power network covering the 147,500 square kilometers of land is a modern power network with long history and full of vigor.

Liaoning province is the power load center in Northeast China. It has one 500kV line and six 220kV lines to connect with the power network in Jilin province. It also has two 500kV lines and one 220kV line to connect with eastern part of an Inner Mongolia. By the end of 2000, the total installed capacity in Liaoning province was 15,185MW (hydro power: 1,156MW; thermal power: 12,559MW). The total installed capacity of the wholly-owned and holding power generation plants of Liaoning Electric Power Co., Ltd. is 2,854MW (hydro power: 456MW; thermal power: 2,398MW) and takes up 18.8% of the total installed capacity of the whole province. The independent power generation company has a total installed capacity of 10,861MW (hydro power: 488MW; thermal power: 10,373MW) and takes up 71.5%. The local self-supply power plants have a total installed capacity of 3,006MW, taking up 19.8%. The installed capacity of the plant at Sino-Korean boundary river is 545MW, taking up 3.6%.

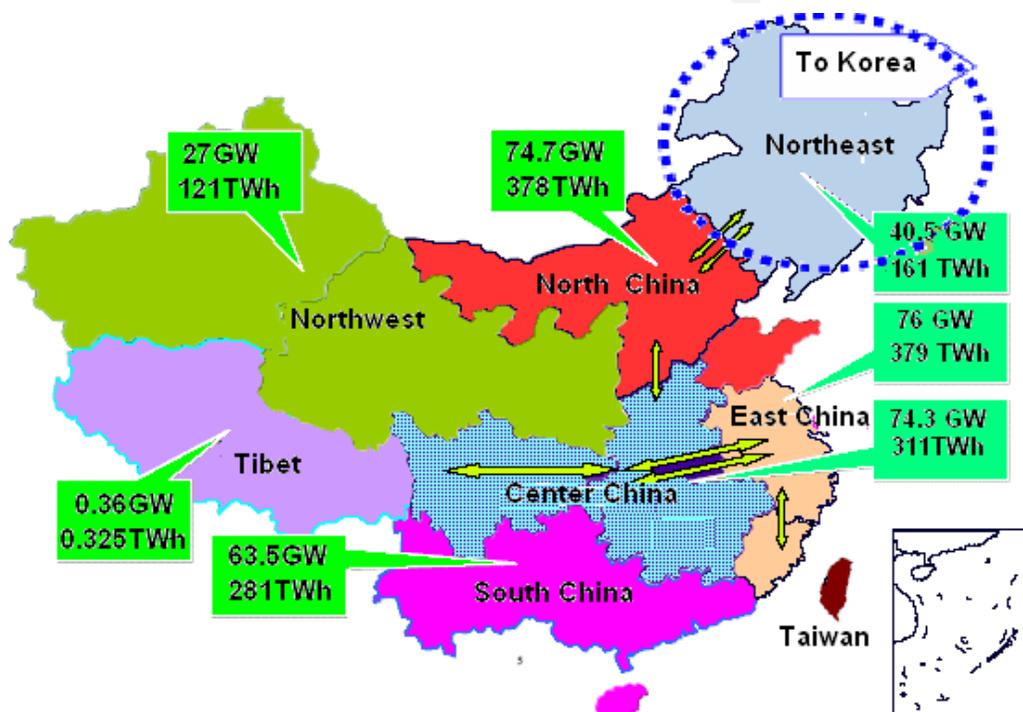


Figure 9.25 Regional power consumption map in China

9.8.1.5 Power System Status and Seasonal Load Patterns of Kyushu in Japan

Japan's power system is divided into 9 regional companies serving the areas of Hokkaido, Tohoku, Tokyo, Chubu, Hokuriku, Kansai, Shikoku, Chugoku, and Kyushu, and transmission consists of 500kV, 220kV, 110kV, and DC 250kV lines. Figure 9.26 shows a cascade power flow map in Japan. The information in this Figure was obtained from ⁶⁵.

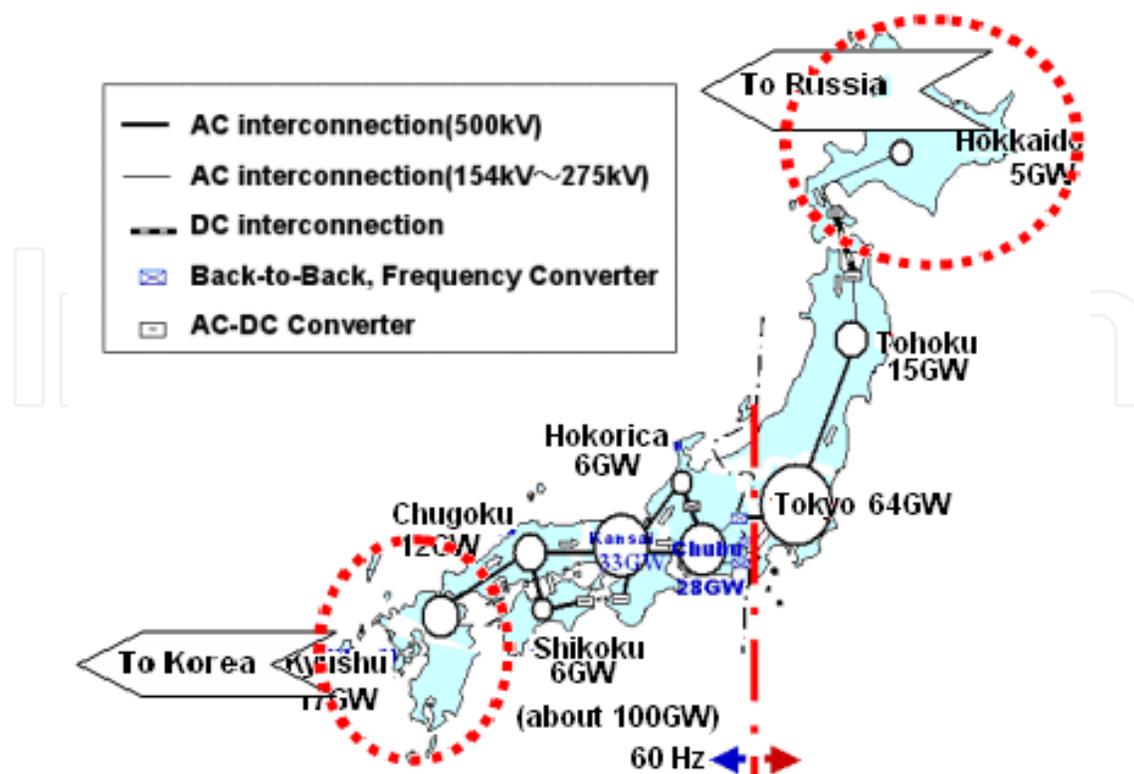


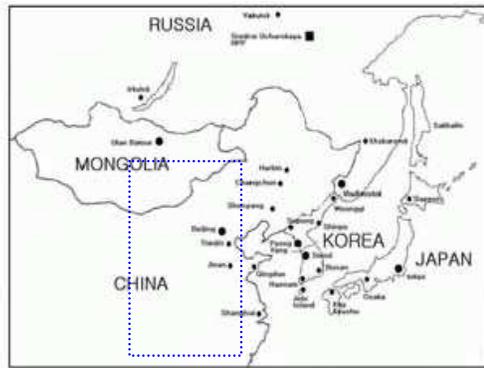
Figure 9.26 Cascade power flow map in Japan

The frequency used is 60Hz in the western part and 50Hz in the eastern part of the country. According to statistics published in 2001, the total generating capacity of the nine power companies is 33,765MW due to hydropower, 118,112MW due to thermal power, and 42,300MW due to nuclear power. The total capacity is therefore 194,177MW.

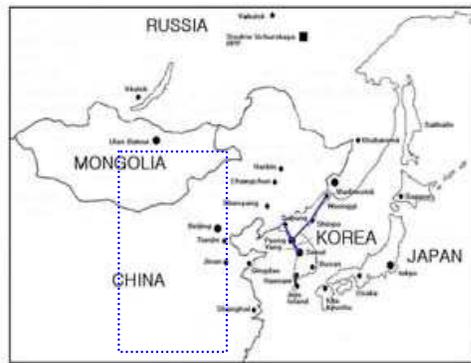
Kyushu's infrastructure is composed of nuclear, thermal, hydro, and geothermal power generating plants. In Kyushu region of Japan, 2001, summer peak has 16,743[MW], and winter peak has 12,961[MW]. The nuclear power plants are located both in the southwest coastal region and at the furthestmost tip of Kyushu's northwest coast. The thermal power plants are located mainly on Kyushu's northeast and the northwest coasts. The hydro power plants are randomly distributed within the north and south central regions. The geothermal power plants are located in the north and south central regions. Among these regions, Kyushu has a total land area of 42,163 km² 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.

9.8.2 Assumed Possible Interconnection Scenarios in North East Asia

Several cases of maps are drawn according to the assumed scenario in Figure 9.27, which has possible scenarios among Russia, China, North Korea, South Korea and Japan.



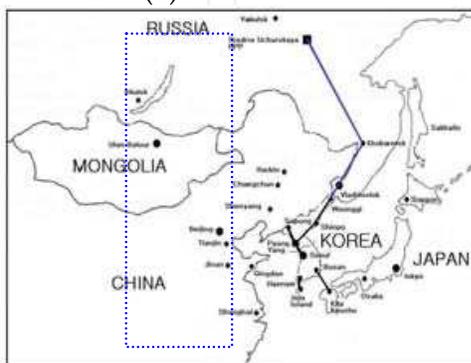
(a) Separation for North Korea and South.



(b) North Korea-South Korea



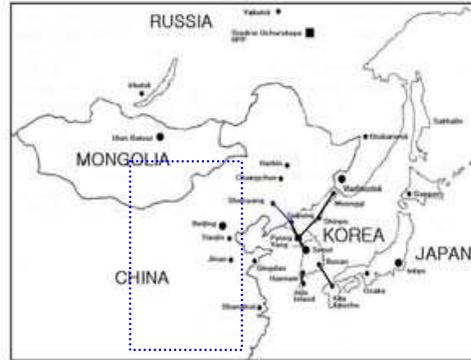
(c) North Korea-South Korea-Japan.



(d) Russia-North Korea-South Korea-Japan



(e) Russia-Mongolia-China-South Korea-Japan.



(f) China-North Korea-South Korea-Japan



(g) Russia-Mongolia-China-South Korea-Japan.



(h) Russia-Mongolia-China-South Korea-Japan

Figure 9.27 Possible scenarios among Russia, China, North Korea, South Korea and Japan

9.8.3 Assumed Seasonal Power exchange Quantity for Power Flow Calculation

Table 9.23 represents the assumed peak load data for summer and winter in South Korea, 2005. To simulation the PSS/E package, the load was decreased with 2,000MW in summer season and decreased with 1,000MW in winter season. Table 9.24 has the assumed peak data for summer and winter in North Korea, 2005. All the load and supply patterns were assumed with constant quantity. Table 9.25 is the assumed peak data for summer and winter at Kyushu in Japan, 2001. Table 9.26 has the assumed export power for summer and winter in Far East Russia. Table 9.27 represents the assumed export power for summer and winter in North East China.

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

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

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

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

Table 9.23 Assumed peak data for summer and winter in South Korea, 2005

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

Table 9.24 Assumed peak data for summer and winter in North Korea, 2005

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

Table 9.25 Assumed peak data for summer and winter at Kyushu in Japan, 2001

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

Table 9.26 Assumed export power for summer and winter in Far East Russia

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

Table 9.27 Assumed export power for summer and winter in North east China

9.9 Acknowledgements

This Chapter has been prepared by Nikolai I. Voropai, Professor, Corresponding Member of RAS, Director of Energy Systems Institute, Irkutsk, Russia. Contributors include colleagues at the Institute and Members of the IEEE PES W.G. on Asian and Australian Electricity Infrastructure.

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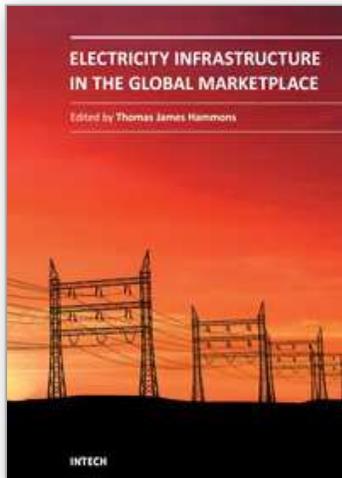
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This book discusses trends in the energy industries of emerging economies in all continents. It provides the forum for dissemination and exchange of scientific and engineering information on the theoretical generic and applied areas of scientific and engineering knowledge relating to electrical power infrastructure in the global marketplace. It is a timely reference to modern deregulated energy infrastructure: challenges of restructuring electricity markets in emerging economies. The topics deal with nuclear and hydropower worldwide; biomass; energy potential of the oceans; geothermal energy; reliability; wind power; integrating renewable and dispersed electricity into the grid; electricity markets in Africa, Asia, China, Europe, India, Russia, and in South America. In addition the merits of GHG programs and markets on the electrical power industry, market mechanisms and supply adequacy in hydro-dominated countries in Latin America, energy issues under deregulated environments (including insurance issues) and the African Union and new partnerships for Africa's development is considered.

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