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2011 Modularization of Korea's Development Experience:

National Power Grid Development Project For Stable Power Supply

2012

Ministry of Knowledge Economy

KEPCO KOREA ELECTRIC POWER CORPORATION

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National Power Grid Development Project for Stable Power Supply

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Preface

The study of Korea's economic and social transformation offers a unique opportunity to better understand the factors that drive development. Within one generation, Korea had transformed itself from a poor agrarian society to a modern industrial nation, a feat never seen before. What makes Korea's experience so unique is that its rapid economic development was relatively broad-based, meaning that the fruits of Korea's rapid growth were shared by many. The challenge of course is unlocking the secrets behind Korea's rapid and broad-based development, which can offer invaluable insights and lessons and knowledge that can be shared with the rest of the international community.

Recognizing this, the Korean Ministry of Strategy and Finance (MOSF) and the Korea Development Institute (KDI) launched the Knowledge Sharing Program (KSP) in 2004 to share Korea's development experience and to assist its developing country partners. The body of work presented in this volume is part of a greater initiative launched in 2007 to systemically research and document Korea's development experience and to deliver standardized content as case studies. The goal of this undertaking is to offer a deeper and wider understanding of Korea's development experience with the hope that Korea's past can offer lessons for developing countries in search of sustainable and broad-based development. This is a continuation of a multi-year undertaking to study and document Korea's development experience, and it builds on the 20 case studies completed in 2010. Here, we present 40 new studies that explore various development-oriented themes such as industrialization, energy, human capital development, government administration, Information and Communication Technology (ICT), agricultural development, land development and environment.

In presenting these new studies, I would like to take this opportunity to express my gratitude to all those involved in this great undertaking. It was through their hard work and commitment that made this possible. Foremost, I would like to thank the Ministry of Strategy and Finance for their encouragement and full support of this project. I especially would like to thank the KSP Executive Committee, composed of related ministries/departments, and the various Korean research institutes, for their involvement and the invaluable role they played in bringing this project together. I would also like to thank all the former public officials and senior practitioners for lending their time and keen insights and expertise in preparation of the case studies.

Indeed, the successful completion of the case studies was made possible by the dedication of the researchers from the public sector and academia involved in conducting the studies, which I believe will go a long way in advancing knowledge on not only Korea's own development but also development in general. Lastly, I would like to express my gratitude to Professor Joon-Kyung Kim for his stewardship of this enterprise, and to his team including Professor Jin Park at the KDI School of Public Policy and Management, for their hard work and dedication in successfully managing and completing this project.

As always, the views and opinions expressed by the authors in the body of work presented here do not necessary represent those of KDI School of Public Policy and Management.

May 2012

Oh-Seok Hyun

President

KDI School of Public Policy and Management

Prologue

It has been more than 100 years since the power industry emerged in Korea. After the first electric light bulb was turned on in the Gyeong-bok Royal Palace of Chosun dynasty which existed from 1492 to 1910, several regional power companies were founded. They operated throughout the Chosun dynasty, the Japanese colonial period, the Liberation period, and the Korean War. In 1961, the 3 companies were merged as the Korea Electric Power Corporation (KEPCO). Throughout the development phase of the national economy, the power industry has made great contribution to supplying reliable electric energy for the economic growth. Since then, power facilities have been expanded to about 30 thousand kilometers of transmission lines, 190 GVA of transformer capacity, and 400 thousand km of distribution lines. The growth history of the power industry can be called the history of KEPCO and the history of modernization and industrialization of Korea. Transmission, distribution technologies and the power quality reached the world-class level with multiple loop transmission networks, voltage upgrade to 345kV, 765kV, HVDC power network interconnection between Jeju Island and the main land, and un-manned automated operation of substations via the supervisory control and data acquisition system.

Transmission and distribution networks are vulnerable to unexpected disturbances from natural disasters, and additional construction of power facilities and maintenance of current power system should be continuously undertaken to cope with the steady growth of power demands. KEPCO has made utmost efforts to supply reliable power with good quality and at affordable price, and set the long-term power network expansion plans. The power industry needs enormous capital investment for the long term. And it is a very risky business which is exposed to uncertain management conditions such as unforeseeable future demands and fuel costs. Moreover, in the aspect of the power network operation, the power company has to maintain the proper reserve margin to keep supplying reliable power to consumers. While overcoming those difficult problems, the power networks have been largely expanded since 1970s. Multi-faced efforts to develop network operation technology and quality control of materials to overcome new problems arising from the extension of the networks such as reduced supply capacity, increased power loss, and equipment failures have been implemented.

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Summary

1. Progress of the Study

The study of "National Grid Development Project for Stable Power Supply" was financed by the Korean Government, Ministry of Strategy and Finance, and executed under the supervision of "KDI School of Public Policy and Management". A Steering Committee as a task force team was formed to oversee the study, comprising members from KIET (Korea Institute for Industrial Economics and Trade), Ministry of Knowledge and Economy. The study commenced with an initial kick-off workshop in Seoul, Korea on April 4th, 2011. KEPCO carried out the studies using its statistic data and worked in close collaboration with the steering committee, which made an invaluable contribution to the study. The presentations and discussion meetings for evaluation of the study were held in KIET, Seoul. The aim of the study was to ensure knowledge sharing between the developing countries and the Republic of Korea.

2. History of Korean Power Industry

In the early stages of economic development, South Korea's energy supply situation was very poor and power supply was among the worst, far from meeting the demands. In July 1, 1961, three existing power companies were merged into The Korea Electric Power, Ltd in order to promote power resources development and power grid development. At the end of 1960's, the power generation facilities had capacity of approximately 360MW, but it increased 200 fold to 76,080MW by the end of 2010 in terms of power supply. At the same time, the power grid facilities for transporting electricity (transmission and distribution) expanded significantly.

Due to the nature of power business, a huge amount of long-term investment is required. In particular, power generation is a very risky business, given that the future demand, fuel costs, and other business factors are quite unpredictable. In terms of power grid development and management, power suppliers have to build the optimal facilities for a stable and consistent power supply for customers. Also, those suppliers have to secure extra facilities with a prediction of adequate reserve power which they have to manage effectively.

With a huge lack of natural resources, the biggest national task of Korea was to reliably produce and transport electricity-the most important source of energy for industrial development-without failure to customers. In Korea's power industry, the resources development had transitioned from hydropower which utilized water resources and then to steam power that relied on petroleum with relatively low prices before the oil crisis. Then eventually, nuclear power and coal were the primary source of power resources development, in accordance with the promotion policy of resource variation. In terms of power grid development, the initial focus was on supply expansion-as shown in rural electrification project-and afterwards, more economical and highly reliable grid development and more effective grid management were promoted, as construction of facilities expanded nationwide.

From 1960s to 1970s, in an attempt to obtain funding without difficulty, commercial loans as well as grants were used to deal with shortages of domestic resources and skyrocketing demands, and large-scale steam power plants using petroleum were beginning to be constructed as a main priority.

In the mist of the oil supply crisis, variation of power generation fuel was needed. The government curbed construction of oil-fueled power plants-which were predominant at the time-in order to focus on developing energy resources less-dependent on petroleum. The government also strived to localize power generation technology and equipments which were highly dependent on imports.

In April 1978, Kori Nuclear Unit 1-our first nuclear power plant-began commercial operation, which clearly marked the beginning of Korea's nuclear age. In addition, a total of eight nuclear power plants-including Kori Unit 2 and Wal-Sung Unit 1-were built in this period.

At first, power grid facilities were operated with various voltages of 154kV-66kV-22kV-6.6kV (3.3kV) and therefore, equipment and materials, the construction and management system for each facility were different. In connection with the urgent expansion of power supply regions, development of power grid was being promoted on an ongoing basis, but transporting and supplying produced electricity incurred a big loss and dealt a devastating blow to the financial management of the power company.

In addition, it was imperative to prepare a blueprint for the national power grid for a stable power supply and for effective management of grids. However, distribution facilities were being managed with various facilities of 3.3kV, 5.7kV and 6.6kV in different regions and each voltage was different in terms of equipment and materials, and the construction and management methods, which made it hard for Power Company to increase the effectiveness in establishing and managing the power grid.

In the 1980s, the development of power resources was adjusted, following the low-growth demand, based on the economic situation at the time. The new focus was on developing energy sources less dependent on petroleum-which had been promoted since the 1970s-and Nuclear Unit 5 of 950MW was built in 1985, the first project of Korea's power company, and an oil-fired power plant was remodeled into a natural gas power plant. Particularly at the end of 1982, the total capacity of power facilities surpassed 10 GW as a result of four 5-year Power Resources Development Plan.

At the end of 1989, nine units of nuclear power plants accounted for 36.3%, and coal-fired plants accounted for 12.8% of the total power generating capacity of 20,997 MW. And the previously promoted construction project of 154kV and 345kV facilities was almost completed, along with 22.9kV power facility and rural electrification project. It was a period when the goal of nationwide expansion of power supply regions was almost accomplished, with the previously established blueprint for the national power grid as the framework.

In around the 1980's, the power grid's transmission facilities were simplified by functions with 154kV-354kV, and distribution facilities were operated with standardized voltage of 22.9kV and 220/380V line. It led to the introduction of standardized construction methods for each facility, and transmission and distribution facilities had a loop pattern.

3. Efforts to Overcome

3.1 Power Resource Development Sector

Power Resources Development project was consistently promoted from 1961 to 2010, in order to meet the increasing power demands. The power resources development, starting with The First 5-year Plan in 1961, leading up to the completion of the Fourth Plan in 1981, along with nuclear power generation project which was introduced to solve natural resource shortages. In 1961, based on the estimated peak demand of approximately 430MW, the first plan estimated the average growth rate of annual demand at 12% for five years, and the power demand in 1966 at approximately 840MW, considering the previous growth trend and the future economic indicator. However, with a lack of experiences, the first long-term plan showed occasional flaws, such as its estimation of power demands, and some problems with the implementation under the changing circumstances-domestically and internationally-hence the plan was revised multiple times. In this period, eight projects were completed, including the newly-built power plants of approximately 350MW, and there was a total increase of 430MW in power supply capacity with repair work on the existing plants.

Based on experiences and technologies obtained from the previous 5-year plan, a new power resources development plan was beginning to be established in May 1965, which materialized in the Second 5-year Power Resources Development Plan (1967~1971). When the power supply was on the right track, comprehensive research and study were underway in order to stabilize the production of electricity-an essential tool for national development-and to carry out the power resources development plan in better environment in the long run.

In that period, predominantly large-scale, oil-fired steam power plants were constructed. It was because oil prices stayed the same, or temporarily declining in the international market, while coal was considered to be an inadequate power generation fuel with declining production, considering prices and other issues.

During the Third 5-year Power Resources Development Plan in 1972 and after, the previous policy of petroleum-focused resources development was revised, following the international oil price hike in 1973, and fuel diversification was being emphasized, leading to the active construction of nuclear power plants.

In addition, at the end of 1976, there was a need to develop power resources less-dependent on petroleum, as the ratio of energy resources was dominated by petroleum at 92.3%, and hydropower and coal only accounted for 7.7%. The issue of energy source diversification-which had been previously unnoticed-started to be actively pursued in the Power Resources Development Plan, and there were aggressive efforts to change the paradigm with a renewed focus on nuclear power and coal-fired steam power, as a long-term measure, while the fourth and the fifth plan were being established.

During the promotion of four 5-year Power Resources Development plans, the construction of nuclear power plant was in the spotlight. With construction of the first nuclear power plant (Kori Unit 1) on April 1978, Korea embraced the era of nuclear power generation as the 21st country holding nuclear energy in the world. Afterwards, in March 1979, the U.S. experienced an accident in one of its power plants, raising a safety issue on the domestic and the international front, but Korea stepped up its effort to develop nuclear power after two oil crises with a lack of natural resources. When nuclear power was first introduced, it was developed on a contract with a turnkey system through a foreign business. From then on, with promotion of technological independence and localization, a lot of efforts were being made to develop manpower and technology in the nuclear power sector, which laid the groundwork for independent nuclear technology by the 1980s.

3.2 National Grid Construction

According to the information on the power grid expansion plan of 1960s, the average annual growth of power demand was estimated to be 12%, based on The First 5-Year Power Resources Development Plan. With the long-term power resources development plan established in 1962, the construction of large-scale power plants was being promoted, and the power grid planning was in full swing.

In accordance with the government's economic development plan, a power resources development plan was established in an effort to solve severe power shortages, but under the economic circumstances, private investment funds and technology had to be dependent on foreign loans and assistance for power grid configuration as well as previously-mentioned resources development plan. Therefore, in 1962, Korea turned to the U.S. for assistance for establishing a basic plan for the national power grid.

From the mid 1960s, with the successful promotion of economic development plan, a heavy chemical industrial zone was created in the 1970s, industrial facilities with mass power consumption rapidly increased, and power demands skyrocketed with rising average standard of living. Therefore, in order to enhance the supply capacity, development of long-distance mass power transport system was necessary, with the expansion of distribution facilities as the first priority.

From the late 1970s, the existing 154kV facilities were beginning to be used for regional loop grid or a distribution substation supply, and 345kV facilities were being actively expanded as the main grid, connecting the power plant complex and the high demand regions. Therefore, with the operation of mass power generator such as nuclear power, the grid stability as well as power flow had to be considered in the grid expansion planning, which includes facility expansion for a power supply, loop grid configuration for a reliable supply and development of long-distance mass power transport system. Also, as the economy was growing, the grid voltage system of 345kV-154kV-22.9kV-220/380V was actively being promoted; it was because new facilities expanded with demand growth, and facility reinforcement work such as boosting was in full swing in order to solve supply shortages.

The plan's basic idea was to shift the main facility of the mass power grid from the existing 154kV line to 345kV line, and keep expanding 154kV as the regional power supply grid, and continue building and improving 22.9kV and 220/380 V distribution lines for high quality electricity. Between the 1970s and the 1980s, the development of power grid and the expansion of transmission facilities were being actively promoted for a reliable power supply, and 154kV facilities were beginning to be used for a regional load supply. Also, the main line construction of 345kV facilities with three northern and southern roots and three eastern and western roots was completed.

3.3 Efficiency Improvement

Power Grid loss is an inevitable phenomenon that is in proportion to the square of power current for transmission, substation and distribution facilities where electricity passes through. In order to reduce the power loss, it is important to first carefully analyze the configuration of the grid distribution losses and to examine which part requires facility reinforcement and look for any areas for improvement in power grid management. The Korea Electric Power Co. Ltd, which was merged with three power companies, estimated that the transmission and distribution loss rate of 1961 was nearly 30%. At the time, low voltages of 100V, 3.3kV, 6.6kV, 22kVand 66kV composed the main line of power grid, and particularly in 1961, illegitimate power usage loss was nearly 11%, which indicated the high proportion of power loss in non-technical areas. After that, power loss prevention activities were intensified, such as boosting the grid voltage, replacing obsolete equipments and cracking down on illegitimate power usage. As a result, power loss rate dropped to less than 10% since the late 1970s, and illegitimate power usage loss was estimated to be 0.48% in 1980, evidences that the power loss prevention activities actually paid off.

Illegitimate power usage was a critical challenge for reducing power loss as well as maintaining social order, protecting power facilities, and securing power company's profits. The rising electricity rates caused by the nation-wide electrification project, steady increase of power demands and the rising oil prices could trigger illegitimate power usage, and it called for stronger prevention activities.

In order to detect illegal power use, monthly power consumptions of all customers were examined, along with inspections on randomly-chosen customers. All staff members were required to monitor the electricity sales and conduct a field research in their designated areas. If an illegitimate power usage was detected, the customer had to pay a fine of three to five times the normal amount for the maximum of six months. In the worst case, he or she had to pay a penalty of 30 times the one month's usage, and if they refused to pay, they could be charged with theft. Also, an incentive of 15 to 30% of the bill was provided to staffs who reported illegitimate power usage or to people who reported their neighbor's illegitimate actions. In addition, the illegitimate power usage prevention activities-as a responsible business indicator for performance evaluation-were conducted to encourage the project director to care more about loss reduction and illegitimate power usage prevention activities in order to reduce losses.

With the rising power demands, a large number of new substations were built and power supply facilities significantly increased. The operation and management of such complex facilities require state-of-the-art technologies. Since the existing management systems that relied on facility operator's judgments and intercommunications had limited capabilities in terms of accident processing capacity and speed, there was a strong need to develop centralized automation system that could perform comprehensive assessment and control of the entire grid quickly and accurately.

With industrial development, more and more customers were producing high-precision products and they were vehemently demanding high-quality electricity (no power failure, constant voltage and frequency), and power suppliers had to be responsible for manufacturer's losses caused by interruption of power supply. Meanwhile, with extensive supply of electronic products and the general public's increasing dependence on electricity, the customers' demands and interests in high-quality power were heightening. These phenomena led to the introduction of more advanced power control system with state-of-the-art technology.

At the time, as electronic industries were rapidly growing, Korea saw a dramatic improvement of calculators and word processing software capabilities, followed by the expansion of supply, stabilized prices and the increasing demands; it led to the rising needs for more reliable, remote monitoring control system. In developed countries, computerized power facility automation, remote monitoring, and practical operation of control devices were already in place, and they were about to be introduced to Korea.

4. Implication

4.1 Overview

Korea has been solving various tasks in different periods while conducting the national grid development project since 1961. Due to the insufficient power generation at the time, a blueprint for the national grid was necessary for systematic power resources development and grid construction; it was imperative to expand the grid to supply sufficient electricity for the economic development while slashing the power loss.

After the 1970s, there was a need to diversify the energy resources needed for power production in the mist of oil crisis, and to establish a foundation for the domestic power industry, in order to economically supply electrical equipments that had been dependent on imports.

In addition, Korea had to strive to provide more reliable power rather than just focus on expanding power supply regions. After the 1980's, Korea beefed up its effort to efficiently to manage the power facilities that had significantly expanded, following the economic growth. In this part, we will look at the implications associated with solving the tasks in each period and the possibilities of applying them to developing countries in the future.

4.2 Implication and Application Possibilities

For power resources development and the national grid development project, a basic blueprint should be prepared on a national scale for effective economic and industrial development and a reliable power supply-it is better than multiple, small projects. Throughout the Japanese occupation and the Korean War, there were practically no industrial facilities, not to mention a funding and human resources needed for economic development, and the power industry's production and transport situation were very poor.

However, Korea did not get frustrated or give up. Based on the 5-year-Economic Development Plan created by the government in 1962, master plans were created in the various economic and industrial sectors, including the power industry that established a basic scheme for power resources development and the national grid development.

As previously mentioned the master plan for the national grid development was created with America's technological assistance and funding. The plans for 345kV, 154kV, 22.9kV facilities which were the foundation for the current power grid were established back then, leading to the development of the national grid, such as power supply for industrial complex, the rural electrification project and the grid connection between power plants and the Metropolitan areas.

In the early stages of Korea's power industry development, skilled workers and technologies were in short supply as well as funds for importing equipments to implement the project, so the projects were executed with assistance from developed countries such as the U.S. and the international organizations. However, as shown in the 765kV grid construction project, Korea was able develop itself independently from international assistance in a short period of time and gradually localized the foreign technologies, leading to the level of implementing the national grid development project independently.

In addition, the distribution automation technology was initially imported, but it was gradually localized and, eventually, Korea was able to export it to the overseas market. In this aspect, the implications for developing countries are that Korea has also experienced catastrophic economic difficulties in the aftermath of colonial rule and the war just like many of them, and the problems appearing in their power grids are quite similar to the issues that Korea was grappling with in the 1960s or the 1970s.

The problems inflicting the developing country's power industry are as follows: shortage of power supply; tremendous grid loss rate, dealing a severe blow to the power company's financial management; and low reliability of power supply caused by frequent power failure and long recovery time.

However, these issues or tasks can be actively addressed by securing a proper basic scheme and funding, and training workers and developing technologies, as well as executing the scheme, as Koreas has accomplished through its national power grid development project. Furthermore, it can be used as a role model with a high possibility of success.

5. Preview of the Report

Chapter 1 describes the history of Korean electric market from 1961 to present. In 1961, on the first day of July, KEPCO was founded when three pre-existing electric utilities merged. Since then, KEPCO made a comprehensive effort to develop the energy source and to construct electric power network.

Typically, massive investment must be made to electric industry for a long term to maintain the electric energy supply to customers in one country. Because it is very difficult to predict the future energy demand and fuel price, there is higher-than-usual uncertainties in the industry compared to others. Accordingly, the energy industry involves the risk of investment.

From the respect of network management, it is also difficult to maintain reserved capacity for supplying reliable electric energy to customers. Before 2001, Korean electric industry was vertically integrated structure. One company undertook the generation, transmission and distribution. This structure was established because it is thought that it is more efficient for one vertically-integrated company in the electric supply chain to produce, transmit and distribute the electric energy which is indispensible for the economic development.

In this structure, the electric company became a monopoly in electric industry, and the government was involved with the electric industry by regulating the investment and retail prices. However, the scale of electric industry grew bigger and the socio-economic environment changed. For this reason, the vertically-integrated structure was not considered to be efficient any more. Externally, the pressure of opening Korean electric market from OECD (Organization for Economic Cooperation and Development), IBRD (International Bank for Reconstruction and Development) and APEC (Asia Pacific Economic Cooperation) increased, and internally the deregulation and market-oriented economic environment made the private sector to take part in the electric industry.

Especially in 1998, Korean economy suffered from liquidity problem for a short time. It was hard to reject the IMF (International Monetary Fund) policy which encouraged the foreign private investment. After considering the deregulation in electricity market, Korean government announced the plan for restructuring of electricity market and privatization of KEPCO on July 3rd, July, 1998. In 2000, “deregulation in electricity market” was enacted and “the act of electricity industry” was revised. Finally, the generation department was for the first time separated from KEPCO for a partial privatization process. Today, KEPCO undertakes the construction, maintenance and operation of power electric network.

Chapter 2 covers the effort for power resource development of electric power. Power Resources Development project was consistently promoted from 1961 to 2010, in order to meet the increasing power demands. In this part, we will look at the power resources development, starting with the First 5-year Plan in 1961, leading up to the completion of the Fourth Plan in 1981, along with nuclear power generation project which was introduced to solve natural resource shortages.

Chapter 3 describes the construction of national power grid. To begin with, the planning process from 1961 to present is explained. In a sense, the planning is a process to lay out the plan of investment and operation for supplying the electric energy produced at power plant, transmitting and distributing the energy to final customers.

Korean electric power network mostly consists of 22.9kV, 154kV, 345kV and 765kV facilities. In 1961, a variety of voltages were led to undermining reliability. Most of distribution and transmission facilities are now standardized into four different voltage facilities. The facilities of 3.3kV, 6.6kV and 11.4kV were upgraded into 22.9kV for distribution. Other transmission facilities like 20kV and 66kV were replaced with 154kV and 345kV facilities. To extend the capacity of transmission keeping with the economic growth, KEPCO constructed 765kV facilities for the first time in Asia. Around 1980s, the facility management system became automatic for efficiency. In the part of the process, the SCADA (supervisory control and data acquisition) and DAS (distribution automation system) were adopted into operation system. In addition to this, associated technologies were researched and developed during that time.

Chapter 4 explains the implication of the efforts KEPCO made from 1961 and describes the applicability of KEPCO's effort to the developing countries. The electric energy is known as the indispensible source for economic development. In the first, KEPCO constructed the electric power network timely as the Korean economy developed. For this reason, most factories or residential houses did not suffer from the shortage of energy even though there was a limited supply. For about 50 years of history, KEPCO researched and developed a lot of technologies including construction, maintenance, operation and automation. With this achievement, KEPCO undertook many overseas projects around the globe (Egypt, the Philippines, Paraguay, Saudi Arabia, Indonesia, Libya, Dominican Republic, Haiti, Ukraine, Uzbekistan, Kazakhstan, Mexico, UAE, Ghana, Myanmar, Bangladesh, etc).

Chapter 1

Overview of Tasks and Power Industry

Overview of Tasks and Power Industry

1. Overview

In the early stages of economic development, South Korea's energy supply situation was very poor, and power supply was among the worst, far from meeting the demands. In July 1st, 1961, three existing power companies were merged into The Korea Electric Power, Ltd in order to promote power resources and power grid development. At the end of 1960s, the power generation facilities had capacity of approximately 360MW, but it increased 200 fold to 76,080MW by the end of 2010 for power supply. At the same time, the power grid facilities for transporting electricity (transmission and distribution) expanded significantly.

Due to the nature of power business, a huge amount of long-term investment is required. In particular, power generation is a very risky business, given that the future demand, fuel costs, and other business factors are quite unpredictable. In terms of power grid development and management, power suppliers have to build the optimal facilities for a stable and consistent power supply for customers. Also those suppliers have to secure extra facilities with a prediction of adequate reserve power which they have to manage effectively. With a huge lack of natural resources, the biggest national challenge of Korea was to reliably produce and transport electricity-the most important source of energy for industrial development-without failure to customers.

In Korea's power industry, the resources development had transitioned from hydropower which utilized water resources to steam power and then to steam power that relied on petroleum with relatively low prices, until the outbreak of the oil crisis. Then eventually, nuclear power and coal-burning was the primary focus of power resources development, in accordance with the promotion policy of encouraging power source variation.

In terms of power grid development, the initial focus was on supply expansion-as shown in rural electrification project-and afterwards, more economical and highly reliable grid development and more effective grid management were promoted, as construction of power facilities expanded nationwide.

Meanwhile, as for the structure of power industry, the generation and power grid sector were vertically integrated within a power company which established and managed the generation and grid facilities from 1961 to 2001. It is because vertical integration system where a single company produces (generation), transports (transmission) and supplies (distribution) electricity-which is essential for economic development-was considered to be more effective and reasonable. Based on this thinking, South Korea's power industry has been a monopoly system. However, the government also got involved in the power business in order to regulate facilities investment plan and the rates for the benefit of the public. However, as the social and economic environments were changing,-such as increasing scale of power business-separation of generation sector was widely considered to be more effective and economical than such vertically integration system. On the international front, developed economies were putting more and more pressure on the Korean government to open its power market, mainly through international organizations under the trend of globalization. On the domestic front, private participation in monopoly firms was encouraged, as the regulation on overall economic activities was reduced and national preference shifted to market economy. Also, the market principle of competition and choice was applied to the power business with the demands from The International Monetary Fund and foreign investors. Considering all those factors, the government announced its plan to restructure the power industry as well as its decision to privatize the public enterprises on July 3rd, 1998.

On December 23th, 2000, "Promotion Act of Power Industry Restructuring" was established, and the "Power Business Law" was revised. On April 2nd, 2001, the power generation sector was separated from KEPCO, which indicated that a partial competition was introduced to the power production market which had been under the vertical integration system for over 40 years. In this part, we will look at the situation of the power generation and grid development project in each period, in connection with the Korea's economic and industrial development situations. Also, we will look at the tasks that had to be accomplished for a reliable supply of electricity at the time.

2. In the 1960s~1970s

2.1 Economic Situation

In 1945, Korea was just liberated from Japanese colonial period, and it was in dire economic situation where capital, technology and manpower, which were essential to economic development, were extremely hard to come by. To make matters even worse, the Korean War broke out on June 25th, 1950, only 5 years after liberation from Japan. Thus Korea almost ended up losing the drive to develop the economy with tremendous damage inflicted in properties, infrastructure and industrial facilities. Although a lot of efforts were put into reconstructing industrial facilities with restoration projects after the end of the Korean War in 1953, the government had tremendous financial difficulties and turned to the U.S. and international organizations for grants in order to get the economy back on track. Meanwhile, the government's first priority in 1960s was to get out of poverty through economic development, and established a five-year economic development plan which was carried out from 1962. At the time, the government strived to expand national industrial facilities and infrastructure with the goal of export-driven industrialization for economic development. However, under the Korea's economic circumstances, the financial situation of the government and the private sector was very poor just like before 1961, and technology was at a dismal level with the related manpower in short supply.

In order to obtain investment funding for the expansion of such infrastructure and to secure industrial technology and manpower, the Korean government actively introduced foreign technical assistance and grants. In addition, various efforts were made to establish power generation facilities and power grid, in connection with the expansion of supply regions in the power industry sector, in accordance with industrialization policy of the government.

2.2 The Situation and Tasks of Power Industry

2.2.1 Development of Power Resource Sector

On July 1, 1961, when the Korean government merged Cho-sun, Kyung-sung and Nam-sun power companies for economic development, the capacity of our power facilities was approximately 360MW. It was far from meeting the demands of approximately 430 M, and our power production was highly dependent on hydropower and domestically-produced coal. In order to solve the power shortage at hand, the government abolished the interrupted power supply on April 1st, 1964, as an emergency measure. In late 1960s, in attempts to secure smooth financing, commercial loans as well as grants were used to deal with shortages of domestic resources and skyrocketing demands; also, the government started to focus on building large-scale steam power plants using petroleum. Meanwhile, the government established a policy to introduce private capital to the power generation sector in order to effectively deal with supply shortage, which led to the construction of steam power plants for the first time.

Meanwhile, in 1970s, variation of power generation fuel was needed in the mist of oil supply crisis. The government curbed construction of oil-fired power plants-which were predominant at the time-in order to focus on developing energy resources less-dependent on petroleum. The government also strived to localize power generation technology and equipments which were highly dependent on imports. In April 1978, Kori Nuclear Unit 1-our first nuclear power plant-was began commercial operation, making the beginning of Korea's nuclear age. In addition, a total of eight nuclear power plants, including Kori Unit 2 and Walsung Unit 1, were built during this period.

2.2.2 Power Grid Sector

In around 1961, power grid facilities were operated with various voltages of 154kV-66kV-22kV-6.6kV(3.3kV) and therefore, equipment and materials, the construction and management system for each facility were different. In 1965, the power grid's transmission and substation facilities had a radial pattern across the regions. It is shown in [Figure 1-1].

Figure 1-1 | The National Grid in 1965

The main transmission and distribution lines for transporting massive amounts of electricity consisted of 154kV, 66kV and 22kV lines. In late 1960s, foreign aid funds, financial and commercial loans were used to obtain funding for supplying electricity in the industrialized regions such as Seoul and Busan-the two major cities in Korea.

During the First and Second 5-year Power Resources Development Plan (1962-1971), the scale of transmission and distribution facilities increased 48%, and the capacity of substation facilities achieved total increase of 265%.

Meanwhile, Han-Sung (the predecessor of Korea Electric Power Corporation)-the first power company in Korea-supplied electricity with 3.5kV distribution facilities and adopted 3.3kV as the standard supply voltage and 100V for a household supply. In order to meet the increasing demands for electricity, ongoing efforts were being made to raise the voltages. In fact, distribution facilities of 5.7kV was first introduced in 1960 and significantly expanded until 1965, which made it possible for the power company to meet the power consumption. In 1970s, 6.6kV distribution facilities-which replaced 5.7kV-became predominant nationwide.

In connection with the urgent expansion of power supply region, establishment of power grid was being promoted on an ongoing basis, but transporting and supplying the produced electricity at a low voltage incurred a big loss and dealt a devastating blow to the financial management of the power company. In addition, it was imperative to prepare a blueprint for the national power grid for a stable power supply and for effective management of grids. However, distribution facilities were being managed with various facilities of 3.3kV, 5.7kV and 6.6kV in different regions and each voltage was different in terms of equipment and materials, as well as the construction and management methods, making it hard for the power company to increase the effectiveness in establishing and managing the power grid.

3. In the 1980's

3.1 Economic Situation

In the 1980s, the Korean government turned to the policy of pursuing "growth on top of a stable foundation", rather than the previous growth-driven policy. The previous policy of growth-driven industrialization and focus on export was replaced with the policy of revitalizing the private sector, and stability was more emphasized than growth in the 1980s. The 1970s saw a consistent high-annual growth rate of 7% on average, and continuous investment in the heavy chemical industries and export-driven industries. However, due to the oil crisis in the late 1970s, the early 1980s saw economic stagnation. Therefore, the skyrocketing power demand began to gradually drop in the 1980s, following the government's policy trend, and brought a policy change to the power sector.

3.2 Situation and Tasks of Power Industry

3.2.1 Development of Power Resource Sector

In the 1980s, the development of power resources was adjusted, following the low-growth demand, based on the economic situation at the time. The new focus was on developing resources less-dependent on petroleum, which had been planned and promoted since the 1970s. In 1985, Nuclear Unit 5 of 950MW was built as the first project led by Korea's power company, and an oil-fired power plant was remodeled into a natural gas power plant. Particularly at the end of 1982, the total capacity of power facilities surpassed 10 GW as a result of four 5-year Power Resources Development Plan. At the end of 1989, nine units of nuclear power plants accounted for 36.3%, and coal-fired plants accounted for 12.8% of the total power generation capacity of 20,997MW.

In the early 1990s, with the growth of domestic economy and the hosting of 1988 Olympic Games, the demand for electricity skyrocketed, which led to an unstable supply and failure to secure adequate reserve rate. As an emergency measure, twenty units of composite gas turbine plants of approximately 300MW were built which required a relatively short amount of time and modest investment costs.

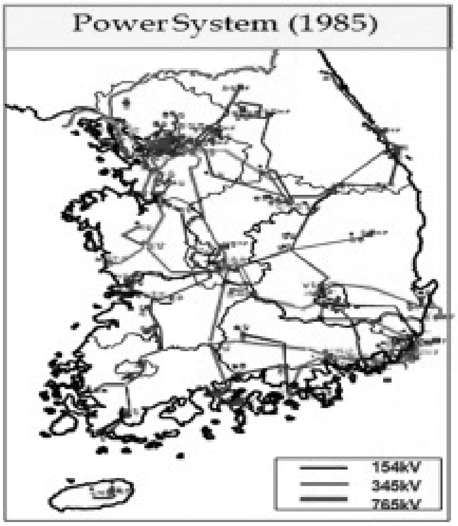
In addition, six obsolete steam power plants were disposed, and around in the 1970s, the constructions to extend the life expectancy of existing plants and to improve the functions of over 50-year-old hydropower plants were completed.

3.2.2 Development of Power Resource Sector

In the 1980s, the previously promoted construction project of 154kV and 345kV facilities was almost completed, along with 22.9kV power facility and rural electrification project. It was the period during which the goal of nationwide expansion of power supply region was almost accomplished, with the previously established blueprint for the national power grid as the framework.

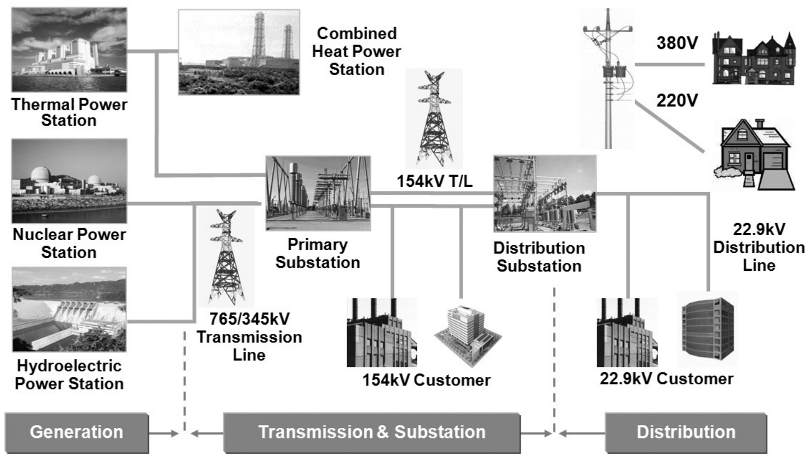
In around the 1980s, the power grid's transmission facilities were simplified by functions with 154kV-354kV, and distribution facilities were operated with standardized voltage of 22.9kV and 220/380V line. It led to the introduction of standardized construction methods for each facility, and the transmission facilities had a loop pattern, depending on the regions in 1985, as shown in [Figure 1-2].

Figure 1-2 | The National Grid in 1985



The main line of transmission facilities for transporting massive amount of electricity was operated with 345kV line, and in specified areas, 154kV line was used. As the New Cities were being developed, the Metropolitan areas were being congested. Therefore, it was imperative to build new facilities that could transport higher amount of electricity from the power plant regions (Korea's central and southern regions) to the Metropolitan areas than the 345kV line. Previously, financing was a big challenge, but in this period, the Korean government and power companies were able to obtain their own funding, and scale of power facilities increased at a slower pace from 1980 to the 1990s than it did before. However, unlike the previous period, the power energy demands were becoming more sophisticated, and high-tech industries were in the spotlight instead of simple production industries. Therefore, in terms of power quality, stable supply and management of grid, the issue of effectiveness was raised during this period.

Figure 1-3 | Power System Configuration



4. Statistics of Power Facilities by Year

From 1961 to 2010, the statistics of power plants and grid (transmission, transformation and distribution) are shown in the following tables:

Table 1-1 | Transition of Power Plant Capacity

(Unit: MW)

Year	Hydro power	Steam Power					Composite	Internal combustion	Nuclear power	Integrated energy	Total
		Domestic Coal	Coal	Crude Oil	LNG	Sub-total					
1961	143	223				223					367
1971	341	675		1,360		2,035					2,628
1981	1,202	750		6,062		6,812	920	314	587		9,835
1991	2,444	1,020	2,680	3,663	2,550	9,913	760	378	7,616		21,111
2001	3,879	1,125	16,340	4,349	1,538	21749	14,716	246	16,716		59,958
2010	5,429	1,125	23,674	5,804	887	29,571	19,100	351	17,715	3,964	76,130

Table 1-2 | Scale of Power Supply

Year	Peak Demand	Total Plant Capacity	Supply Capacity	Supply Reserve
1961	306	367	322	5.2
1971	1,777	2,628	2,391	34.9
1981	6,144	9,835	7,602	23.7
1991	19.124	21,110	20,148	5.4
2001	43,125	50,858	48,699	12.9
2010	71,310	76,130	75,750	6.2

Figure 1-4 | Transition of Transmission Facilities by Voltage

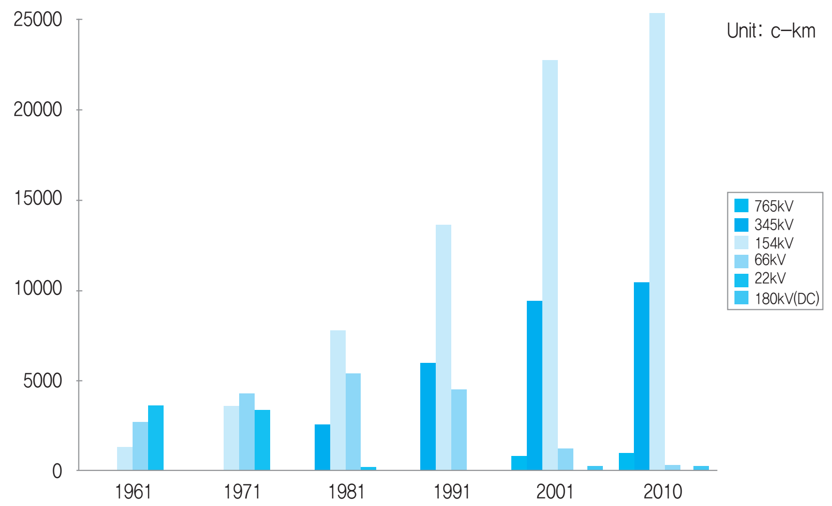


Table 1-3 | Transition of Substations by Voltage

(Unit: MVA)

Year	765kV	345kV	154kV	66kV	22kV	Total
1961			(5) 372	(70) 519	(216) 316	(291) 1,209
1971			(33) 2,539	(137) 1,265.8	(260) 603	(430) 4,409
1981		(8) 7,333	(100) 10,966	(150) 2,209	(105) 754	(363) 21,263
1991		(18) 24,171	(205) 29,767	(81) 2,235	(17) 589	(321) 56,763
2001	(3) 7,110	(71) 75,580	(500) 88,892	(19) 831	(10) 237	(603) 172,650
2010	(6) 25,115	(85) 104,929	(611) 118,563	(9) 433	-	(711) 249,040

( ) indicates the number of substations

Table 1-4 | Transition of Distribution Facilities

Year	Power Lines(c-km)			Substations	
	High Voltage	Low Voltage	Total	Number of Units	Capacity (MVA)
1961	5,478	3,694	9,172	52,967	649,491
1971	18,985	12,703	31,688	80,127	1,753,030
1981	72,943	56,259	129,202	228,345	7,508,528
1991	113,208	130,493	243,701	669,175	21,522,863
2001	182,046	192,080	374,126	1,612,799	75,956,835
2010	213,126	215,133	428,259	1,990,577	101,692,247

Chapter 2

Promotion of Power Resources Development

Promotion of Power Resources Development

1. Overview

The Power Resources Development Project was consistently promoted from 1961 to 2010, in order to meet the increasing power demands. In this part, we will look at the power resources development, starting with the First 5-year Plan in 1961, leading up to the completion of the Fourth Plan in 1981, along with nuclear power generation project which was introduced to solve natural resource shortages.

At the time, the government's financial situation was very weak, which made it difficult to solely rely on domestic funding to build power facilities. So the government pursed economic recovery through grants from the U.S. and international organizations. The following table is key information on loans received after 1961 for construction funding.

Table 2-1 | Funding for Power Facility Construction

Date	Funding Source	Loan Amount	Purpose
1962.4.4	USAID	20 million $	Construction of Gamcheon Thermal Power plant
1970.10.23	USA, England	150 million $	Construction of Kori Nuclear Power Plant
1976.6.4	USA	58.5 million $	Construction of Youngwon and Gunsan Thermal Power plant
1977.1.18	England	116 million $	Construction of Kori Nuclear Power plant 2
1979.5.28	USA	78.9 million $	Construction of Samcheonpo Thermal Power plant
1979.12.12	IBRD	115 million $	Construction of Gojung Power plant
1986.3.31	IBRD	230 million $	Construction of Transmission and Distribution lines

2. The First 5-year Resources Development Plan (1962~1966)

2.1 Establishment and Revision of the Plan

In 1961, our power generation facilities were far from meeting the demands as mentioned earlier, and therefore there was practically no reserve power. The First 5-year Power Resources Development Plan, which had been aggressively promoted since 1962, was focusing on securing electricity-the stepping stone to national economic development. In accordance with the plan, Korea's power industry sector established a full-fledged and bold power resources development plan, rather than the minimal construction and management of power facilities.

Based on the estimated peak demand of approximately 430MW, the first plan estimated the average growth rate of annual demand at 12% for five years, and the power demand in 1966 at approximately 840MW, considering the previous growth trend and the future economic indicator. However, with a lack of experiences, the first long-term plan showed occasional flaws, such as its estimation of power demands, and some problems with the implementation under the changing circumstances-domestically and internationally-and the plan was revised many times.

Table 2-2 | Original and Final Plans of the First Power Resources Development

Distinctions	Original Plan (In 1960)	Ultimate Plan (At the end of 1965)
Demand Estimation Methods	Based on the peak demand in 1960, a growth rate of 12% for five years was estimated.	Based on the sold electricity until the end of 1965, peak power demand was estimated.
Peak Demand in 1966	842MW	705MW
Plant Capacity in 1966	Hydropower: 207MW Steam Power: 746MW	Hydropower: 215MW Steam Power: 554MW
Financial Loan	Foreign Capital: 112,000,000 USD	Foreign Capital: 57,968,000 USD

Later on, the First Power Resources Development Plan was revised four times during implementation, materialized the delayed construction of power plants, and lowered the peak demand. At the time, the power demand forecast was dependent on suggestions from foreign consulting firms, which were unable to consider the special circumstances of Korea when estimating the power demand, and that was essentially why the peak estimate of the demand was lowered. The comparison of the original and the final revision of the plan is shown in <Table 2-2>.

In addition, in order to build urgently-needed power facilities in a short amount of time, and carry out uninterrupted power supply, "emergency power measures" were established, which included introduction and installation of a floating power station, Resistance Arc, and expansion of internal power plants.

2.2 Primary Accomplishments

The First 5-year Power Resources Development Plan was finalized with the construction of Sum-Jin River Hydropower Plant in 1965. In this period, eight projects were completed, including the newly-built power plants of approximately 350MW, and there was a total increase of 430MW in power supply capacity reserves with repair work on the existing plants.

In particular, the uninterrupted power supply after April 1964 stabilized the power grid management and surpassed the estimated demands, until the year of scheduled plan completion, by increasing the business opportunities in each industry sector. While the plan was implemented, nine power plants were built (seven steam power plants and two hydropower plants), and $ 6 billion of domestic capital and $50 million of foreign capital were invested.

3. The Second 5-year Power Resources Development Plan (1966~1971)

3.1 Establishment and Revision of the Plan

The successful execution of the First 5-year Power Resources Development Plan, which was the master plan of Korea's power industry, made possible uninterrupted power supply two years earlier than expected. Based on the experiences and technologies gained from the first plan, the Korean government decided to establish another power resources development plan in May 1964, which was the Second 5-year Power Resources Development Plan (1967~1971).

With the confidence that the power supply was on the right track, comprehensive research and study were underway in order to stabilize the production of electricity-an essential tool for national development-and to carry out the power resources development plan in better environment in the long run. For that matter, Thomas Research Team from the U.S. was invited. It provided consulting on Korea's power demand and resources development plan for six months from October 1964 and suggested "Plan #4BR." However, it failed to be adopted as a plan because of differences in perspectives regarding the estimated power demands among others.

Instead, the EBASCO's consulting results were accepted by Korea to establish a power plant construction plan. At the time, not only did EBASCO provide an outline of the national power grid which is considered as the blueprint for the recent power grid, but it also suggested an accurate proposal that could be directly used in the power sector at the time.

The Second 5-year Power Resources Development Plan was established with the EBASCO's suggestion, and was incorporated to the government's 5-year Economic Development Plan after several revisions. At that time, the peak estimate of demand and the new power plant in 1971 were approximately 1,630MW and 1,170MW respectively; combined with the existing plants in 1966, a new plan was established to secure total capacity of 1,940MW.

However, the year of 1967 saw an unexpected, sharp increase of power demands at nearly 30% every year with uninterrupted power supply and stunningly high-growth of industries. Under these circumstances, the construction of two hydropower plants raised concerns, and the power supply had to be temporarily interrupted in some areas due to the drought of 1968. As a countermeasure, gas turbine and diesel power plants were immediately introduced, since they required a relatively short amount of construction time and modest costs.

3.2 Primary Accomplishments

The Second 5-year Power Resources Development Plan completed in 1971 developed new power resources of approximately 1,910MW, which increased the nation's power supply capacity by approximately 3.4 times, compared to five years earlier in 1966. However, with a lack of hydropower and a tendency to rely on petroleum with a short supply of coal, the ratio of hydropower and steam power was approximately 13:87 at the end of 1971. In that period, large-scale, oil-fired steam power plants were predominantly constructed. It was because oil prices stayed the same, or temporarily declining in the international market, while coal was considered to be inadequate power generation fuel with declining production, prices and other issues. Also, foreign commercial loans were actively introduced to finance power resources development, unlike the First 5-year plan which deeply depended on financial loans.

Also, more importantly, a basic research was underway in this period for the construction of nuclear power plants-a very pioneering sector at the time. The construction project of nuclear power plants had been promoted since the late 1960's, and it was launched in June 1970 with its proved feasibility. It greatly helped solve the oil shortages which began in the late 1970.

Meanwhile, in this period, with the rapid growth of domestic industries, the Korean government substantially increased its investment in the heavy, chemical industry and as a result, it was not fully able to finance the power resources development. So the government established a policy of attracting private capital to power resources development, and actively encouraged private corporations to participate in the construction of power plants, and indeed several of them were built by private corporations. It contributed to the variation of power resources and expansion of supply capacity to meet the demands, but it also led to the saturation of power facilities in the early 1970s.

4. The Third 5-year Power Resources Developments Plan (1972~1976)

4.1 Establishment and Revision of the Plan

The Second 5-Year Power Resources Development Plan, completed at the end of 1971, had started with a 5-year plan, and then expanded into a 10-year plan which actually included The Third 5-Year-Plan later on. Therefore, whenever the second 5-year-plan was revised, the third 5-year-plan was automatically revised. During the Third 5-Year plan that lasted until the late 1976, the ultimately-confirmed capacity of new power facilities was approximately 2,920MW, which far exceeded the actual power demands. It was because there was a significant discrepancy in demand forecasts during the establishment of second and third plans, and resulted in a surplus of power facilities. Also, it led to an undesirable result of readjusting the demand forecasts and delaying the construction schedule.

During the Third 5-year Power Resources Development Plan after 1972, the previous policy of petroleum-focused resources development was revised to cope with the international oil crisis in 1973, and fuel diversification was being emphasized, leading to the active construction of nuclear power plants. In this period, the surplus of power facilities at the end of the second plan, coupled with a slow growth of power demands, led to the excessive power supply, which threw a devastating blow to the overall power industry in Korea.

However, by 1976, as the economy recovered, Korea saw substantial growth of export industries, leading to the rapid growth of power demands, going far above the estimated figures. As a result, the power supply reserves dropped to 3.9% by the end of 1976 and posed a serious threat to the stable power supply.

4.2 Primary Accomplishments

In this period, the economic circumstances surrounding the power industry were changing very rapidly. But the nature of power business-responsible for producing, transporting and supplying electricity-prevented it from responding to the fluctuating demands with flexible short-term measures in its planning, construction and management.

However, those circumstances provided an opportunity to build new power plants of the right scales, considering the nationally balanced arrangement of power plants, and to develop hydropower, instead of the previous emergency measures of introducing diesel or gas turbine power plant, or small-scale generator.

In addition, at the end of 1976, there was a strong need decrease dependence on petroleum, as the ratio of energy resources was dominated by petroleum at staggering 92.3%, while hydropower and coal only accounted for 7.7%. The issue of fuel diversification–which had been previously unnoticed-started to be actively included in the Power Resources Development Plan, and there were aggressive efforts to change the paradigm with a focus on nuclear power and coal-fired steam power, as a long-term measure, while the fourth and the fifth plan were being established.

5. The Fourth 5-Year Power Resources Development Plan (1977~1981)

5.1 Establishment and Revision of the Plan

Since the fourth plan, Korea had been continuing its high economic growth and firmly laid the groundwork for the development of the 1980s, which led the power industry sector to focus on deeply enrooting the system and expanding the facilities. As a result, numerous, mass-scale nuclear power, hydropower, pumped-up water and steam power plants were built at the same time-more so than ever before. In particular, the policy of energy diversification away from petroleum was actively implemented, and the base supply facilities were fueled by nuclear power instead of steam power using petroleum.

In addition, there were aggressive efforts to change the overall process of planning, such as introducing and utilizing WASP, computer software for establishing a long-term power resources development plan. The Fourth and The Fifth 5-Year Power Resources Development Plan, completed in 1981, had two goals of staying away from petroleum and localizing the equipment and materials. Also, in this period, 4,810MW facilities were newly built, in addition to the 4,710MW power facilities at the end of the Third Power Resources Development Plan, increasing the power supply reserve to 33.2%.

5.2 Primary Accomplishments

In this period, one of the biggest accomplishments, in terms of power plant construction, was to avoid importing equipments in bulk or ordering them for each construction from abroad. With accumulated construction experiences and domestic industrial technologies, foreign turnkey methods were replaced completely with indigenous ones, and main equipments were domestically supplied without foreign funds, which raised the average rate of localization to 40~45%.

6. Introduction of Nuclear Power

6.1 Overview

During the four 5-year Power Resources Development plans, the construction of nuclear power plant received much spotlight. With construction of the first nuclear power plant (Kori Unit 1) in April 1978, Korea entered the era of nuclear power generation as the 21st country operating nuclear power plant in the world. Afterwards, in March 1979, the U.S. experienced an accident in one of its power plants, sharply raising a safety issue on the domestic and the international front. However, Korea stepped up its effort to develop nuclear power in the aftermath of two oil crises due to its chronic lack of natural resources.

When nuclear power was first introduced, it was developed on a contract with a turnkey system through a foreign company. From then on, a lot of efforts were made to develop human resources and fuel technology in the nuclear power sector with technological independence and localization, which laid the groundwork for independent nuclear technology by the 1980’s.

6.2 Process of Promotion

Korea’s nuclear power project was initiated with the establishment of “Nuclear Power Task Force” in 1962, followed by “Nuclear Power Promotion Plan” based on the feedback from representatives’ meetings in the government and public institutions. It included the construction of nuclear power plant in the early 1970 with acquisition of related technology and the training of necessary personnel.

The basic research into the first nuclear power plant construction site was underway for one year, starting at the end of 1964. The research was carried out with cooperation from various public institutions, and it selected nine candidates among several construction sites, and conducted a preliminary research. After that, three areas were selected and the secondary research was done to examine the population density, proximity to the adjacent areas, transport conditions, the ground and geology. The third research evaluated the previous research results in cooperation with the International Nuclear Energy Agency's site investigators, and a further research was recommended.

In December 1966, a nuclear power research committee, consisting of the government and public institutions, was established again and conducted a feasibility study. The committee suggested that a new organization should be established in order to promote the future nuclear power development project on a full-scale during the feasibility study, but it led to a debate with Korea Electric Power Co. Ltd, who insisted on taking charge of nuclear power, claiming it belonged to the power generation project. In March 1968, for the research project, Burns&Roe was selected as the consulting company.

After a 5-month feasibility study, starting in October 1968, the company concluded that 500MW power plant had to be built in around 1974, in terms of economical efficiency, technology and safety, and chose "Kori" as the optimal construction site. In addition, The Nuclear Power Research Committee unequivocally decided on Korea Electric Power Co. Ltd as the main body for the previously-discussed nuclear power project.

6.3 Construction of Nuclear Power Plant

The construction of Kori Nuclear Power Station was launched in March 1971, and was completed in April 1978, after 87 months of construction. Its capacity was approximately 580MW, and foreign capital of approximately $170 million and domestic capital of $71.7 billion was invested-the biggest-scale project undertaken in Korea up to the time. The primary sources of funding were the Export-Import Bank of America and The British Lazards Financial Group. The main contractor of the construction project was Westinghouse of the U.S. which was in charge of the overall construction, and provided the key technology and equipments, and the engineering works were assumed by EEW Inc of the U.K.

Several domestic construction companies also participated and greatly contributed to the localization of nuclear power technology. The original plan for the Kori Power Station was to build a 500MW power plant first by 1974 during the Second 5-Year Power Resources Development Plan, and then to build another power plant in 1976. However, the plan was changed several times and was revised to build just one power plant during the Third Power Resources Development Plan.

Table 2-3 | Transition of Power Generation Resources

Period	Problems	Change in Resources	Effects
1st Power Resources Development Plan [1962~1966]	Lack of generation led to the interrupted power transmission	Expansion of hydro and thermal power generation	- Construction of thermal power plants led to the expansion of generation capacity in short term. - Unlimited power supply of 1964 laid the groundwork for economic growth.
2nd Power Resources Development Plan [1967~1971]	Lack of hydropower and coal supply	Expansion of petro-thermal power stations	- Developed new power resources of 1,910MW - Increased the power supply capacity by 3.4%, compared to 1966
3rd Power Resources Development Plan [1972~1976]	International oil price hike of 1973 increased the costs of petro-thermal power generation	- Variation of power generation resources - Construction of nuclear power plant	Power plants with proper scales were built, considering the nationwide arrangement and development of hydro power generation
4th Power Resources Development Plan [1977~1981]	Higher proportion of nuclear power generation, due to two oil price hikes	- Implementation of non-petroleum and energy variation policy - Initiation of nuclear power generation	- Development of new power resources of 4,710MW - Expansion of power supply reserve to 33.2%

Chapter 3

Promotion of National Power Grid Development

Promotion of National Power Grid Development

1. Establishment of Policy for National Power Grid

In 1961, Korea saw very low power consumption of only 52kWh per person. However, it rose rapidly in the 2000s with the economic growth. Stable power supply is extremely important for industrial production and everyday lives of people, and it is a main contributing factor for economic development.

Also, electricity is an absolutely essential energy which cannot be stored, and therefore, the supply should not be interrupted even for a short time. Moreover, it has almost no substitutes. Considering these characteristics of energy, transporting and supplying it as well as production are significantly important in the power industry sector. In Korea, three power companies were merged into one as part of power business restructuring project in 1961 when the power plant restoration project was completed.

In accordance with the government's economic development plan, a power resources development plan was established in an effort to solve severe power shortages, but under the economic circumstances, investment funds and technology had to be imported from industrialized countries for power grid construction as well as previously-mentioned resources development plan.

In 1962, Korea asked the U.S. for assistance regarding a national power grid establishment scheme. In response, America's EBASCO (consulting firm), and Burns&Roe provided consultations for Korea's power grid establishment policy; the key points are as follows.

Policy	Contents
EBASCO Consulting	First, in order to transport massive amount of electricity, simplifying the various kinds of voltage to 345kV-154kV was suggested. Second, in order to improve the management efficiency of 154kV facilities, changing the grounding method was suggested, and in order to improve the reliability of power supply, stable power grid configuration was also suggested. Third, the method of unifying the various kinds of distribution voltage, including 3.3kV, 5.7kV, 6.6kV and 11.4kV into 22.9kV was suggested. Fourth, boosting the low voltage facility of 100/200V, which had been supplied to the general public, to 220/380V was discussed.
Burns&Roe Consulting	First, the future transmission grid expansion should be done with 154kV, and 66kV facilities should not be expanded, except for special circumstances. Second, the Metropolitan areas should be equipped with a loop grid using 154kV 2 phase transmission lines which should be established near the load center.

1.1 Early Stage of Power Grid Development

According to the information on the power grid expansion plan of 1960s, the average annual growth of power demand was estimated at 12%, based on the First 5-Year Power Resources Development Plan. With the long-term power resources development plan established in 1962, the construction of large-scale power plants was being promoted, and the power grid planning was in full swing.

The First Power Resources Development Plan's transmission and distribution facilities plan included the expansion of facilities, improvement of power grid, modernization of power facilities and creation of new demands. As a main facility responsible for power transmission, 154kV loop grid conveying electricity to remote place (long-distance areas) in Korea was being planned, along with the construction of new plants. Furthermore, for a regional load supply, 154kV substations were built in Seoul, Jun-Buk, Jun-Nam and Kyung-Nam provinces, and the construction of transmission lines was being planned. For major cities in Korea, 66kV transmission line loop grid was used, and there were plans to step-up the voltage of 22kV transmission facilities to 66kV, and to increase the construction of 22kV and 66kV substation.

In order to secure the necessary investment funds for such large-scale facility expansion, a financial loan application was sent to the USAID in February 1963. In response to its request, a feasibility analysis and a management evaluation of Korea Electric Power Corporation's were conducted by EBASCO, an outsourcing company in the U.S. As a result, the company made various proposals, and the ones regarding the transmission sector had a huge influence on Korea's power grid configuration, voltage variation and distribution voltage boosting.

EBASCO's Detailed Suggestions:

■...

For a stable power supply in Seoul-the capital city with political, economical and societal significance-a loop grid of 154kV and 66kV should be established in the outskirts of Seoul.New facilities with 66kV grid should be curbed, and 154kV should be expanded.

■...

Reinforcement work on 22kV grid in the Metropolitan areas should be done with transformers of 154 /22kV, 40 MVA.

■...

The capacity of 22kV circuit breaker is recommended at 5 GVA.

■...

Two transformers of 154 / 22kV, 60 MVA at substations should be operated separately.

■...

Future power plants should be equipped with 154kV loop connected to 154kV grid.

■...

The existing 154kV double-circuit transmission lines, connecting Seoul and Kang-Won Province can transport 75MW per each line with a supply of VAR at receiving end and intermediary substation.

■...

Effective grounding should be done on 154kV grid.

■...

The current 3.3kV, 6.6kV Đ grid in the distribution sector is not economical, since it requires many substations and power lines.

■...

Multiple grounding system of 12kV or 23kV is the most economical one; it is very flexible with its large distribution capacity, and provides additional benefits, including voltage reinforcement, power loss reduction and construction simplification.

■...

There should be a construction standard for all voltages.

■...

Instead of building 3.3kV or 6.6kV substations, as mentioned in the loan application, the voltage of transmission lines should be boosted.

Based on the EBASCO's suggestions, a loan agreement was made in December 1964, which led to the aggressive promotion of national power grid development in the late 1960's. Meanwhile, under The Second Power Resources Development Plan, the focus was on expanding the154kV grid facilities, and the second USAID loan application was submitted in June 1966 to secure the investment funds with a consulting from Burns&Roe's.

The long-term power grid construction plan established in June 1967 emphasized that Korea's Metropolitan areas and south eastern regions should be equipped with 154kV 2 phase loop grid, and a power grid, connecting the Metropolitan areas and the South Eastern power plant regions should be constructed. For the remainder of the plan, EBASCO and Burns&Roe's suggestions were directly reflected. Meanwhile, a "Rural Electrification" project was discussed with a 5-year promotion plan.

1.2 Developing Stage of Power Grid Development

Following the successful execution of economic development plan from the mid 1960s, the power demands were rapidly growing with higher standards of living, heavy chemical industrial zones, and industrial facilities that consumed large amounts of power in the 1970's. Therefore, in order to increase the supply capacity, it was necessary to establish long-distance mass power transport systems, and expand the distribution facilities as the first priority.

From the late 1970s, the existing 154kV facilities were beginning to be used for regional loop grid or a distribution substation supply, and 345kV facilities were being actively expanded as the main grid, connecting the power plant complex and the high demand regions. Therefore, with the operation of high capacity power generator such as nuclear power, the grid stability as well as power flow had to be considered in the grid expansion planning, which includes facility expansion for a power supply, loop grid configuration for a reliable supply and establishment of long-distance mass power transport system.

Also, as the economy was growing, the grid voltage system of 345kV-154kV-22.9kV-220/380V was actively being promoted; it was because new facilities expanded with demand growth, and facility reinforcement work such as voltage stepping-up was in full swing in order to achieve the system stability. The plan's basic idea was to shift the main facility of the mass power grid from the existing 154kV line to 345kV line, and keep expanding 154kV only as the regional power supply grid, and continue building and improving 22.9kV and 220/380 V distribution lines to ensure high quality power.

Also, in the principal areas such as the center of the Metropolitan areas, underground facility construction was on the rise from 1976 in order to maintain the aesthetic appearance of the city. At the same time, underground line conduit and equipment were constructed to allow easier installation of future electrical facilities during the road construction.

1.3 Final Stage of Power Grid Development

Between the 1970s and the 1980s, power grid development and transmission facility expansion were actively executed to bring about a reliable power supply, and 154kV facilities were beginning to be used for a regional load supply. Also, the main line construction of 345kV facilities with three northern and southern roots, and three eastern and western roots was completed.

In addition, loop grid configuration around the Metropolitan areas, and 345kV underground line and indoor substation construction were conducted, and future voltage stepping-up was being considered. In a nutshell, there was a significant development of power grid at the time. However, securing a site for expanding transmission facilities was becoming more and more difficult, faced with complaints from the land owners and residents in the adjacent areas, as well as limitations on the land use.

As a result, the constructions were taking much longer, and it was increasingly difficult to expand facilities in a timely manner. It led to some 154kV grid overload and sharp increase of investment costs for underground line expansion. Particularly in Metropolitan areas, which accounted for 40% of the nationwide demands due to the numerous high-rise buildings and residential facilities, mass power line construction had to be consistently executed to connect the high demands with power resources located far away.

The key points of the 1990's power grid plan are as follows:

- After the ultra-high voltage stepping-up was first examined in 1979, the final voltage was set at 765kV in July 1991, based on the technology and opinions from many different people, and the target sections for grid configuration and construction were the areas connecting the new mass power resources and demand regions. As part of the plan, some power grids with 345kV facilities were shifted to 765kV.

- A 765kV power grid connecting the Metropolitan and South Eastern regions will be built in 1998, which will be initially operated with 345kV, and eventually shifted to 765kV with construction of 765kV substations in 2002.

- A large-scale coal-fired steam power plant of over 1MW will be built in an island near the Metropolitan areas, and 345kV transmission line for this plant and a nearby plant will be built in shallow sea in 1999 and 2003.

Also, KEPCO examined where to develop new power resources, regional supply and demand, the Metropolitan area's grid configuration, and fault capacity in order to ensure affordability and efficiency for grid configuration. It was based on the available land space, population growth and Japan's power demand trends, along with a prediction that Korea's peak demand would reach nearly 90 million kW in 2031.

The Metropolitan areas accounted for 44.4% of the nation's power demands in 1991, but the figure gradually increased and was expected to be around 48% in 2031; so it was predicted that 345kV substation should expand to 34 units in 2031 instead of 7 as in 1991 and that 765kV facilities would be necessary for power grid configuration, as the existing 345kV loop grid's supply capacity reached its limit; these predictions led to an establishment and promotion of a new scheme.

2. Construction of Power Grid

2.1 Construction of 154kV and 345kV transmission lines

In 1961 when the three power companies were merged, Korea's power grid utilized 154kV lines for transmitting long-distance mass power; for a middle-distance, medium-scale power 66kV lines were used, and for a short-distance, small-scale power 22kV lines were utilized as three different kinds of power transmission facilities. However, the grid was equipped with a grounding system, which made it difficult to manage the grid system in a reliable fashion.

Until 1968, when the direct grounding system was adopted, 154kV lines were all equipped with grounding or ungrounded system from three-phase three-wire arc suppressing reactor, making it difficult to detect and prevent faults, and the long duration raised the voltage of grid with no faults and ended up spreading the damage.

Various efforts were being made to improve the management of 154kV line grounding system, the essential tool for power transmission since the 1950s. Finally, the 154kV line's grounding system was modified in October 1968 with concrete plans and preparations after the 1960s.

A direct grounding system connects the grid transformer's neutral point to the ground with metal lines, and makes it easier to detect earth fault without raising the voltage of normal transmission lines. Therefore, it reduces the duration of damage and facility costs for power grid.

The successful completions of the First and The Second Economic Development Plan starting in 1962 made it possible to meet the rapidly rising power demands at an annual growth rate of 20%. Also, large-scale power facilities significantly increased the amount of power produced in a single unit, making it difficult to solely rely on 154kV transmission facilities, which led to the implementation of 345kV facility establishment project.

A detailed feasibility study for 345kV facility introduction was conducted with technical assistance from the U.S. It was used as the standard throughout the 345kV facility establishment project. Meanwhile, the equipment and materials used for the project were imported from Germany and the UK, and KEPCO engineers received technical training from those two countries regarding the details of imported equipments; they cost nearly $6,260,000 and were utilized during the first 345kV establishment project, along with domestic equipments worth approximately 52.3 billion Won.

345kV facility construction was planned and designed with outsourcing from Commonwealth Associates of the U.S. and the early stages of construction was done with foreign technology and capital using loans on a turnkey system. In April 1974, the first 345kV facility establishment project was launched and was completed on March 10, 1978. Then 345kV facilities started to play a main role in transmitting electricity across the country, and mass power plant construction was underway, with the economic growth. Also, as the power demands were steadily growing, the second and the third project plans for 345kV facility expansions were being examined from 1974, and were completed in 1981. So in January 1977, transmission equipment contract was made with Japan for the second 345kV facility establishments. In March 1977, the Barclay Bank's loan was used to introduce foreign equipments through an equipment supply contract with GEC of the U.K, and the second 345kV project was launched in March 1977.

During this project, the project management, equipment and material supply, and securing skilled construction workers and large-scale equipments were a big challenge. However, the introduction of mechanized constructions that used equipments changed the construction methods. At the same time, the 345kV equipment localization was in full swing, utilizing the foreign technologies obtained during the construction. The 345kV facility establishment project not only made it easier to transmit electricity, but it also greatly contributed to the technology of the incoming 765kV facility establishment project.

2.2 Construction of 765kV transmission lines

2.2.1 Overview

Korea's economic growth is commonly referred to as the "Han River's Miracle," which was largely achieved through aggressive expansion of infrastructure such as electricity, roads, harbor and railroads. In particular, the intensive constructions of large-scale nuclear power and steam power plants allowed for sufficient power facilities, which contributed to the economic development. These plants were mainly constructed in the sea shore due to fuel supply and water issues, and it led to the steady expansion of transmission grid for transporting the produced electricity.

In order to smoothly transport the increasing electricity, a power grid was established by raising the voltage from 154kV to 345kV in 1976.

In the late 1970s, as Korea's power demand was growing at an annual rate of nearly 20%, and the peak demand was expected to reach 25 GW in 1991, experts predicted that higher voltage facilities would be necessary in the early 1990s. So, in June 1978, an overseas education plan was established to study voltage step-up technology, and two technicians from Westing House in the U.S. and the Ministry of Power in Sweden came to Korea to offer technical training from May 1979 to April 1980 to nineteen KEPCO engineers in eight fields of grid planning, management, insulated transmission, conductor selection, insulated substation and machines, grid protection and communications. However, as the power demand growth plummeted after the second oil crisis in the early 1980s, the voltage step-up project was tentatively delayed. But the growth rate rebounded once again to over 10% from the late 1980s, and the imbalance of power demand and supply between the Metropolitan areas and power resources became stronger with over 40% of the nation's power demand concentrated in the Metropolitan areas.

Furthermore, finding a site for transmission and substation constructions was getting increasingly difficult in small, overpopulated Korean peninsula, and three sides of its terrain surrounded by ocean isolated the power grid, making it difficult to connect. In an attempt to solve these problems, upgrading the transmission voltage was on the top of the agenda. The existing 345kV facilities were not fully able to solve these issues, which raised a need to upgrade the voltage to 765kV with higher transmission capacity. Finally, after the thorough preparations in the early 1990s, 765kV transmission line construction was launched in January 1996 and completed in May 2002.

2.2.2 Promotion of Equipment Localization

Voltage stepping-up was not just for mass power transmission, but it also meant that a country's power technology upgraded overall. So, 765kV stepping-up improved the domestic technology such as high-voltage designing, equipment production technique, development of various equipments and construction methods, system designing, control and protection technique.

However, at the same time, the voltage stepping-up came with high development costs and technological risks. In addition, there were not many demands of that technology in both domestic and overseas markets, making it unappealing to manufacturers. Among the countries operating the upgraded 765kV facilities, South Africa, Brazil and Venezuela all introduced equipments from abroad-except for the U.S., Canada, Japan and Russia. However, in terms of 765kV project, a consensus was formed toward the localization among policymakers and experts in the government, Korea Electric Power Corporation, research institutes and manufacturing companies.

Furthermore, since Korea's electrical equipment manufacturers were fiercely competing with developed countries, importing 765kV equipments would have led to stagnation of domestic heavy electrical market, which had been growing significantly. The import could also lead to subordination of domestic technology to developed countries, which meant that domestic technology development had to gain a competitive edge instead of importing.

So, from 1991, domestic 765kV equipment designing and manufacturing technology were being developed with the government's leadership, the power company's predominant financing, and manufacturers' and research institute's collective participation and development. The development and production of similar kind or 500kV machinery-although they are not the same kind-was fairly easy. In fact, the project contributed to the export of 500kV machinery and technology.

2.2.3 Effects of 765kV Facilities Construction

The impacts of such 765kV voltage stepping-up are as follows:

First, the 765kV's stable transmission of generated power from the long-distance mass power complex to the Metropolitan areas, which accounted for 40% of the national demands, solved the imbalance of supply and demand, and established a stable power supply system. These achievements were translated into the nation's financial benefits by reducing the cost that could come from the Metropolitan area's power plant construction (765kV's transmission capacity is 4.8 time higher than 345kV).

Second, the Asia's first commercial operation of 765kV boosted the technological competitiveness, and particularly the purely domestic engineer's execution of research, development, designing and construction firmly laid the groundwork for independence of power grid technology. As the nation's first project with no related technology, it was conducted with utilization of the earlier overseas training, research findings from developed countries and 345kV construction and operation experiences. Also, in the process of design and construction, new technology and construction methods were developed and applied, achieving the advancement of power technology.

Third, the localization of all the equipments and materials as well as construction equipments-except for very few items with no domestic commercial viability-saved nearly 380 billion won.

Fourth, the construction of 765kV transmission line had an impact of replacing five 345kV transmission lines, which could eventually reduce the location problems associated with additional transmission facilities, and allow for more efficient use of the country's limited land.

Fifth, transmission loss rate dropped. Since power loss is in inverse proportion to the square of voltage, 745kV facilities reduced the transmission loss rate by approximately 20%, compared to 345kV.

2.3 Construction of 22.9kV Distribution Facilities

2.3.1 Training for Distribution Construction Personnel

Over the course of Japanese occupation and the Korean War, the technicians needed for construction and maintenance of power facilities were in short supply. Building and maintaining distribution facilities required outstanding personnel of KEPCO and its partnership companies, and led to the training of skilled workers. KEPCO's distribution technician training started with the first electrical engineering course at the Employee Training Center on November 1st, 1965. The vocational training lasted 26 weeks with technical and mental training to foster a sense of responsibility, cooperation, and teamwork, producing the competent workforce.

Table 3-1 | Status of Technician Training

Class	Year of Completion	Training Periods	Number of Trainees	Class	Year of Completion	Training Periods	Number of Trainees
1	1976	26	218	20	1998	16	29
2	1976	26	183	21	1998	16	29
3	1977	26	147	22	1999	16	30
4	1977	26	154	23	1999	16	30
5	1978	26	126	24	2000	16	30
6	1979	26	241	25	2000	16	30
7	1980	26	275	26	2001	20	17
8	1981	26	150	27	2001	20	20
9	1981	26	150	28	2002	20	18
10	1982	26	196	29	2002	20	20
11	1983	26	124	30	2003	20	23
12	1984	26	96	31	2003	18	24
13	1987	26	98	32	2004	15	24
14	1988	26	99	33	2004	15	25
15	1989	26	53	34	2005	15	35
16	1990	26	58	35	2006	15	19
17	1996	24	54	36	2006	15	30
18	1997	16	26	37	2007	15	30
19	1997	16	30	Sum			2,941

2.3.2 Introduction of New Technologies for Distribution Construction

The skyrocketing power usage amid industrial growth required a swift distribution of construction projects among contractors and KEPCO was in charge of executing its national power grid establishment project.

In the early 1980s, some contractors introduced machinery such as cranes to building poles, and expanded the mechanized operation to the overall distribution construction for heavy equipment, such as transformer, in the late 1980s.

In November 1989, KEPCO began cost estimation associated with mechanized operations, which became prevalent after 1988, and with live-wire operations, conducted by electrical construction companies under the new systems for distribution construction.

In particular, the uninterrupted power operations of 1994 were expanded to all branch offices in 1995.

2.3.3 5.7kV Distribution Voltage Boost

Korea used 3.3kV as the standard distribution voltage until the Korean War after 3.5kV was adopted by Kyung-Sung Electric Co. Ltd in 1917. With a war restoration project in place, power demands increased gradually. There was an urgent need to reinforce facilities, due to a tremendous voltage drop and power loss caused by shortages of power generation, transmission and distribution facilities.

One of the most economical countermeasures reviewed was the three-phase four-wire step-up system-implemented in developed countries such as the U.S.-which could increase the facility capacity by 1.7~2.9 times with the same power line of 3.3kV equipment; so 5.7kV distribution system was adopted.

In 1965, there were as many as seventy 5.7kV lines across the country. As of 1981, only ten of those 5.7kV power lines remained, in accordance with the recycling policy of discarded equipments during the 6.6kV, 11.4kV and 22.9kV step-up process. After that, distribution voltages were simplified to 6.6kV and 22.9kV in 1989 with completion of 5.7kV step-up in 1988, and 3.3kV in 1989.

2.3.4 6.6kV Distribution Voltage Boost

6.6kV distribution line was first used for Apnok River's hydropower construction line in 1938. At the end of Japan's colonial period, it was used as Korea Explosives' power line exclusively, located far away from Incheon substation. By 1961, there were seven distribution lines for such particular regions.

Afterwards, 6.6kV step-up with ungrounded system was beginning to be examined in 1961, due to the problems with 5.7kV distribution systems. During the establishment of

Power Resources Development Project, 6.9kV equipment was chosen for distribution, and 6.6kV step-up with ungrounded system was underway. However, it faced a stumbling block, with suggestions favoring 11.4kV or 22.9kV distribution voltage step-up. Then in around 1970, 6.6kV step-up was put into place nationwide as originally planned, since the construction financing for 22.9kV distribution voltage stepping-up was problematic, following an investment growth of rural electrification project. There were two regions where 6.6kV distribution line was used for quite a while due to the regional characteristics.

One of them is Seoul Metropolitan areas where Korea's central communication facilities are concentrated, thus making it difficult to solve the inductive interference with multi-grounded neutral distribution system through a neutral conductor. Also, installing transformers for ungrounded lines was a challenge. So 6.6kV system remained for general distribution, and an increasing number of high-rise buildings began to be equipped with 22kV ungrounded system; this grid was neutral resistance grounding system where a fast detection of earth fault accidents was quite difficult. Another area where 6.6kV system had to remain was Jeju Island where research findings indicated that it is impossible to keep the earth resistance low enough to have multi-grounded neutral system.

2.3.5 Construction of 22.9kV Distribution Facilities

The 22.9kV facility establishment project was initially financed with the first USAID loan, followed by the second USAID loan, Japanese funds with three commercial loans in 1968, 1969 and 1970, West Germany Restoration Bank's two loans, and Asia Development Bank's loan.

Then with usage of 23kV domestic insulator in 1974, 22.9kV facility establishment project was more aggressively promoted. In terms of annual 22.9kV facility capacity, it was 100 MVA in 1973, then it increased to 112 MVA in 1974, 173 MVA in 1975, and 184 MVA in 1976 and then it soared to 212 MVA in 1977. By the end of 1993, the accumulated stepping-up capacity was 3,844 MVA. New customers were supplied with 22.9kV as well as industrial zones and rural areas. During the expansion of 22.9kV regions, the focus was on new installation regions such as industrial zones and rural areas, which increased the proportion of extra-high voltage distribution and reduced the number of 3.3kV, 5.7kV and 6.6kV facilities.

2.3.6 Construction of 22.9kV Facilities in Central Seoul and Jeju Island

With a pilot project that boosted 22kV transmission line to 22.9kV distribution voltage in Kyung-Buk Province in 1965, the stepping-up project that shifted 6.6kV to 22.9kV was in full swing from 1969. However, the central Seoul and Jeju regions were excluded from the project in 1974. It was because the central Seoul areas faced communications line guidance obstruction and location problems with installation of insulated substation for stepping-up.

Jeju Island region had difficulties securing low earth resistance, suitable for multi-grounded, suitable for multi-grounded neutral system because of its geological characteristics. Due to the difficulties with stepping-up construction, caused by communication interference and the downtown congestions, the central Seoul area's stepping-up was delayed twice, but all the other regions saw completion of 22.9kV stepping-up in 1986, except for Jeju and rural areas. Soon after that, 22.9kV service area also expanded to all the 11.4kV supply regions in 1989.

2.4 220V Voltage Boosting Project

2.4.1 Background of 220V Boosting Project

Korea started to consider stepping-up from 110V to 220V from 1963. As mentioned before, unlimited power supply began in 1964 and with the steady growth of power demand, new way to supply electricity to customers was under consideration. The conclusion was that a step-up to 220V would be necessary to secure economical power supply facilities, and the project would be beneficial for domestic electronics' international standardization, because IEC standard voltage was 220V.

Table 3-2 | IEC International Standard Voltage

Phase Distinction	Series ⅰ	Series ⅱ
Single Phase	220V	120V,120/240V,240V
Three Phase	220/380V 500V,600V	120/208V,240/415V 277/480V,600V

2.4.2 Main Circumstances of the Project

Prior to the execution of the stepping-up in August 1964, Korea asked for feedback from Korea Electrical Association and Korea Electrical Engineering Association. In response, Korea Electrical Association stated that 220V should not be adopted, citing safety issues with the lack of domestic development of circuit breaker. Korea Electrical Engineering Association suggested that safety issues should be resolved first before adopting 220V, adding that it would not cause any trouble for indoor construction. Meanwhile, in order to investigate various technological issues with stepping-up, and examine the requests from the head of Commerce and Industry Ministry which was responsible for power business, and to make recommendations in the future, "Distribution System Improvement Committee" was established in March 1967, followed by"Korea Voltage Booster Committee"of Korea Electric Power Co, Ltd.

After that, with an approval from the Ministry of Commerce and Industry, pilot project of 220V supply was conducted on a trial basis for approximately 400 households in new power supply regions from July 1965 to December of the same year. However, without the supply of 220V appliances, inconveniences of power use and compensation for 100V products became a new issue. In an effort to solve these problems and smoothly implement the stepping-up plan, a new organization was established for preparation and execution of the project. Also some employees were sent to Thailand and Japan to collect relevant information and know-how's. Finally, in order to decide on boosting voltage, economical calculations were carried out by distribution systems, and various types were examined; it was predicted that 220V three-phase four-wire system-the most widely used system in developed countries-would be most beneficial. Based on the results, 220V stepping-up project was underway from 1965, and KS standard of 220V electronic products was set, followed by a system overhaul, banning production of 100V products.

But as the number of appliances per household increased with higher incomes as a consequence of economic growth, the compensation costs for 100V products skyrocketed. To solve the problem, KEPCO reported the phenomenon to the government authorities, and decided not to remodel customer's indoor facilities in most cases. As one of the counter measures, KEPCO provided either small transformers or two types of voltage (110/ 220V), and in 2005, low voltage stepping-up was completed.

2.4.3 Economic Efficiency of Voltage Boosting

The economical efficiency of boosting can apply to both the power company and customers. At the time, the power company, KEPCO, saved the investment costs of low voltage facilities, and lowered the selling price of electricity by slashing power loss, which also greatly contributed to solving technological problems (voltage drop and variation rate). In terms of benefits for customers, they were conveniently able to use large-scale appliances without changing their power facilities.

3. Management of Power Grid Loss

3.1 Analyses of Power Loss Rate By Year

Power Grid loss is an inevitable phenomenon that is in proportion to the square of power current for transmission, substation and distribution facilities where electricity passes through. In order to reduce power loss, it is important to first carefully analyze the configuration of the grid distribution losses and to examine which part requires facility reinforcement and to look for any areas for improvement in power grid management.

In Korea, the grid system is divided into sending, distribution and selling end for estimation of power loss rate, and statistics are compiled from the losses of the entire grid (transmission and distribution loss rate), transmission losses within the grid and the distribution losses.

$$\text{T\&D Loss rate (\%)} = \frac{\text{sending end power-selling end power}}{\text{sending end power}} \times 100\ (\%)$$

$$\text{Transmission Loss rate (\%)} = \frac{\text{sending end power-distributing end power}}{\text{sending end power}} \times 100\ (\%)$$

$$\text{Distribution Loss rate (\%)} = \frac{\text{distributing end power-selling end power}}{\times\ \text{distribution end power}} \times 100\ (\%)$$

In 1961, when three power companies were merged into Korea Electric Corporation, the transmission and distribution loss rate amounted to 29.35%. At the time, low voltages of 100V, 3.3kV, 6.6kV, 22kV, and 66kV formed the main power grid, incurring technical losses of 18.5% with obsolete facilities and non-technical losses of 10.84% with illegitimate power usage, leading to the high transmission and distribution losses of 10.84% with illegitimate power usage, leading to the high transmission and distribution losses.

After that, power loss prevention activities were intensified, such as boosting the grid voltage, replacing obsolete equipments and cracking down on illegitimate power usage. As a result, power loss rate dropped to less than 10% since the late 1970's, and illegitimate power usage loss was estimated to be 0.48% in 1980, which showed the power loss prevention activities actually paid off.

3.1.1 Before 1961

Right after the Korean War blackout, there was a period of turmoil when the transmission and distribution loss rates exceeded 40%, with tremendous damages of facilities and insufficiency of power transaction systems; at the time of merger in 1961, the power grid loss was 29.3%, of which 11.2% came from transmission losses, and 18.2% came from distribution losses. Out of distribution losses, power machinery accounted for 7.3%, and illegitimate power usage accounted for as much as 10.9%.

3.1.2 In 1960s

Right after the merger of three companies, thanks to the power loss analysis and loss prevention efforts, the power loss was greatly reduced to 11.84% by 1970, out of which transmission and distribution accounted for 6.91% and 4.93 % respectively; the proportion dropped to approximately 60% and 30% respectively, compared to 1961. In terms of facility loss, which inevitably occurs due to electrical characteristics, they dropped approximately 44% from 18.5% to 10.34%, and in terms of illegitimate power usage loss, which happens in transactions, they fell approximately 83% from 10.9% to 1.86%. In other words, transaction improvement (prevention of illegitimate power usage) was far more effective in reducing losses than facility improvement for the first five years.

3.1.3 In the first half of 1970s

Despite the intensive investments in power facility expansion from the end of 1960's and illegitimate power usage prevention activities, power loss rate remained unchanged for five years in the first half of 1970's. It dropped only 0.5% from 11.84% in 1970 to 11.31% in 1975, and illegitimate power usage losses stayed almost the same, shifting slightly from 1.86% to 1.78%. As for facility losses, the expansion of transmission and distribution facilities increased the power supply to meet the skyrocketing demands, but it did not get to the point of reducing the power loss. Also in terms of illegitimate power usage and other losses, the prevention efforts were not really paying off.

3.1.4 In the late 1970s

As the power loss rate decreased approximately 6% after a minimal reduction in the first half of the 1970s, it reached almost the same level as developed countries. In particular, illegal use of power dropped significantly, although prevention efforts of illegal use of power seemed to reach their limits. According to an analysis, the power loss in this period actually dropped, due to the introduction of 345kV grid facilities, tremendous expansion of 154/22.9kV substation facilities and growing number of customers for 154kV and 66kV ultra-high voltage sold in the upper-voltage class. The reduction of losses from illegal use of power was influenced by the fact that normal power usage was emphasized with a terminology change from "theft" prevention to "illegal use of power" prevention.

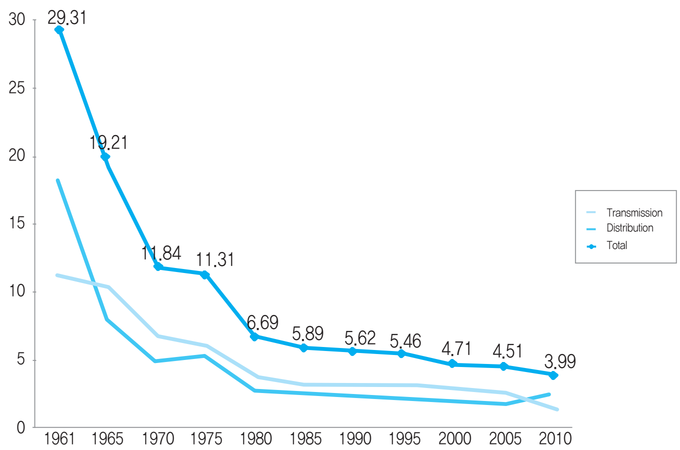
3.1.5 In the 1980s

Boosting of 22.9kV that had been steadily conducted since 1965 greatly reduced the power grid loss, which dropped steadily to 10% range in 1977. In 1985, it stood at 5.89%, comparable to developed countries. However, distribution loss rate showed fluctuations between 2.71%~2.60%, although it decreased 0.11% over five years, with 2.71% reduction in 1981, 2.61% in 1982, 2.68% in 1983, 2.61 % in 1984 and 2.60% in 1985.

3.1.6 Since the 1990s

Despite the steady promotion of 22.9kV boosting for distribution lines, the loss rate showed fluctuations between 2.66%~2.34% from 1986 to 1993, just like the first half of the 1980's. In other words, although the power loss was quite comparable to developed countries, it seemed to reach its limits, since it continued to fluctuate despite the steady power loss prevention activities such as boosting of 22.9kV distribution voltage.

Figure 3-1 | Transition of Power Grid Loss



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Technical Losses

Power grid loss is caused by all the facilities that carry or process electricity. In particular, there are several kinds of facilities that have a severe impact on power loss. Although facilities such as switch and circuit breaker carry large amounts of electricity, the amount of their losses is minimal. However, facilities that generally carry a lot of resistance such as conductor and transformer cause significant losses.

■

Non-technical Losses

Technical losses occur when electricity goes through a conductor, and it is fairly an inevitable phenomenon. However, non-technical losses happen during electrical transactions, and they can be significantly reduced with more systematic and reasonable policies. Major sources of non-technical losses are as follows:

- Illegitimate power usage loss
- Watt-hour meter's errors
- Flat rated streetlight's errors and improper management
- Inaccurate meter-reading
- Issuance of inaccurate bills
- Improper bill-collecting and unpaid amount
- Adjustment of customer rates
- Errors in calculations of distributed and sold power

3.2 Power Loss Prevention Activities in Transmission Sector

In an effort to reduce transmission losses, the following projects were put into place in order to improve the efficiency of large-scale transformers at substations and to lower the load current and the equivalent resistance, which are the main parameters of power line losses. Although the project was aimed at boosting the grid stability, it also contributed to power loss reduction.

3.2.1 Voltage Boosting of Power Grid

The existing 22kV and 66kV transmission facilities were mostly destroyed or reduced and instead, 154kV, 345kV, 765kV voltage upgrading projects were conducted, along with an overhaul of power facilities. Such project played a significant role in reducing the transmission losses. After the large expansion of 154kV power grid and the first overhaul of grid voltage in the late 1960s, the transmission losses dropped 45% in 1976, compared to that of 1966. In 1981 when the first and the second construction project of ultra-high voltage facilities-which were launched in the late 1970s-were completed and operated in 1981, the power loss dropped 29%, compared to 1976, which showed that the effects of voltage upgrading were tremendous.

3.2.2 Configuration of Loop-type Grid and Multiple Circuits

The loop-pattern configuration of 154kV and 345kV grids and multiple circuits of transmission lines reduced the load current and the equivalent resistance that caused power grid loss. With a load increase of 185% from 1986 to 1991, transmission losses dropped to 3.16%, although power line losses jumped 3.4 times (1.852). From 1991 to 1996, transmission losses climbed to 3.27% from 3.16%,although power line losses went up 3.1 times with a load increase of 175%.

3.2.3 Configuration of Loop-type Grid and Multiple Circuits

By installing grid facilities that can adjust the phase between voltage and current, the reactive power and transmission losses dropped, and the grid voltage was maintained. The capacity of shunt reactor-which was installed in December 2010-reached 10,262MVar and the capacity of power condenser was 14,583MVar.

3.2.4 Improved Efficiency of Large Scale Substation Transformer

At substations that always operate more than two main transformers, the combined operation of lightly-loaded transformers and another non-operating transformers on low demand days (holidays) decreased the frequent core losses of lightly-loaded transformers.

3.3 Power Loss Prevention Activities in Distribution Sector

3.3.1 Replacement of high-voltage Distribution Wires and Three-phased Distribution Wires from Single-Phase

Low voltage compensation constructions that replaced obsolete and overloaded electrical wires with thick aluminum stranded wires were conducted, with the first priority in low voltage wires with the biggest drop, and the entire grid construction contributed significantly to reducing the losses.

Also, the replacement of distribution wires expanded to the drop wires with high capacity electrical wires as well as middle and low voltage distribution wires. Meanwhile, with the expansion of rural electrification project and the growth of power consumption, the long-distance single-phase distribution lines in the rural areas and outdoors-where low voltage and losses were big problems-were three-phased and it greatly reduced the losses and imbalance in the distribution lines.

3.3.2 Three-Wired Low Voltage Lines from Single Phase

In order to effectively install and manage the low-voltage distribution wires, the configuration system was modified to allow single-phase three-wired supply system by combining 100V single-phase two-wire normal wires and electric lighting power wires from the additional pole-type transformers. Also, to supply electricity for lighting and power at the same time, the system was transformed into a three-phase four-wire system to reduce the number of pole-type transformers and low-voltage lines, as well as power line accidents, voltage drops and power loss.

3.3.3 Installation of Power Condenser

When distribution line's power factor drops, supply of the power current has to expand, and it lowers the voltage and increases the power loss. As a countermeasure, power condenser was installed in the areas that required compensation for power factor of distribution lines, and installation of power condenser was mandated even for customers who received electricity for power.

Also, the regulatory standard power factor rate for customers was initially set at 85%, and in 1999, it was highly adjusted to 90%. In addition, with facility reinforcement, the power factor was improved, and for customers who did not meet the regulatory power factor, premium rates system was enforced. Also, manufacturers of fluorescent lamps-one of the major appliances with low power factor-were required to install condensers first. Such installations of power condenser improved the selling end's total power factor from less than 80% to over 90%, which actually cut the power loss.

3.3.4 Reduction of Pole Transformer Loss

Since core losses accounted for nearly 2.31% among all the pole-type transformer losses, transformer usage was beginning to rise with common-use power supply system in place. In 1970s, the losses were cut by half and as of now, they are only 0.86%, with almost complete replacement of obsolete transformers made from costly materials with low-loss transformers.

3.3.5 The Medium and Low Distribution Voltage Boosting

Losses caused by distribution voltage boosting fell to approximately 1/12 with boosting of high-voltage for supply (6.6kV to 22.9kV), and 1/4 with low-voltage boosting (110 to 220V). As a result of the first voltage boosting and the expansion of 154/22.9kV substation facilities, the average distances between distribution lines shortened and the distribution losses significantly dropped with repair work on the detour of power lines and equal distribution of line loads. Also, boosting of low-voltage for supply was completed in 2005, and it greatly reduced the power loss.

3.3.6 Reinforced Metering Management

In order to prevent illegitimate power usage and improve the accuracy of transactions with careful measurement of power consumption, the following power loss prevention activities were aggressively carried out.

- First, active promotion of double-inspection on effective meters and quick replacement of faulty meters
- Second, nation-wide wattmeter inspection on mass power customers
- Third, double-check on converter capacity for mass power customers
- Fourth, installation of indicators that display measuring of P.T fuse melting
- Fifth, inspection on connection status to prevent illegitimate power usage with improper connection of meters

3.3.7 Prevention of Illegitimate power usage

Illegitimate power usage was a critical issue for reducing power loss as well as maintaining social order, protecting power facilities, and securing power company's profits. The rising electricity rates caused by the nation-wide electrification project, steady increase of power demands and the rising oil prices could trigger illegitimate power usage, and it called for stronger power prevention activities. In order to detect illegal power use, monthly power consumptions of all customers were examined, along with inspections on randomly-chosen customers. All staff members were required to monitor the electricity sales and conduct a field research in their designated areas.

Table 3-3 | Penalty Policy

Penalties	Period of Paying Penalties
3~5 times the normal amount	6 months (When the duration of illegitimate power usage is unknown)

If an illegitimate power usage was detected, the customer had to pay a fine of three to five folds of the original payment for the maximum of six months. In the worst case, he or she had to pay a penalty of 30 times the amount of the one month's usage, and if they refused to pay, they could be charged with a theft. Also, an incentive of 15 to 30% of the bill was provided to staff who reported illegitimate power usage or to people who reported their neighbor's theft. In addition, the illegitimate power usage prevention activities-as a responsible business indicator for performance evaluation-were conducted to encourage the project director to care more about loss reduction and illegitimate power usage prevention activities in order to reduce losses.

Another important policy for loss reduction was quantification of flat-rate customers. In 1961, approximately 400,000 households in Korea were flat-rate customers on a contract. Although they accounted for 51% of the total customers, the sales amount from those customers only accounted for 18% of the total sales. In order to enforce quantification of these customers, large-scale installations of wattmeter were undertaken. Such efforts allowed KEPCO to reduce distribution losses to 5.59% from 18.17%, which lasted for 10 years from 1961 to 1971.

■ Construction for Illegitimate Power Usage Prevention

Previously, since customer's lead-in wires and lead-in hole facilities were old and rough, it was fairly easy to get connected to lead-in holes and steal electricity, even with installation of service-drop facilities. Fixing the lead-in holes to fundamentally make impossible illegitimate power usage was the aim of illegitimate power usage prevention construction which had the following process.

First, by raising a lead-in wire's junction with a prop of 0.9~1.5 m and connecting wires to the wattmeter with a cap-tyre cable, illegitimate adjustment of meter became impossible.

Second, with installation of illegitimate power usage prevention box, along with sealed construction of meter, deliberately adjusting it became impossible as well.

Also, in order to make it difficult to adjust a meter and easier to inspect it, all new customers from 1977 were required to install their meters outdoors instead of indoors, and even the existing customers were required to do so.

■ Management of Illegitimate power usage Detection Team

In all cases, the most effective way to stem illegitimate power usage is investigation and detection. Most power companies tend to rely only on field service workers such as power line technicians or inspectors and money collectors. However, it is not usually effective due to the following reasons.

- Since illegitimate power usage is done secretly and intellectually, it is not easily detected by workers who are inexperienced or lack technical knowledge.

- Workers whose main duties exclude illegitimate power usage detection have a low sense of responsibility, and they are only concerned about their immediate duties.

- Many workers tend to tolerate malpracticies of customers, rather than enforcing company's rules, an attitude rising from the discontent that they are treated like slave workers with low salary.

Sometimes, these field workers ignore illegitimate power usage or they even help customers go ahead with it. Therefore, power companies needed to have a special team dedicated to theft detection, so that it may be actively promoted. Illegitimate power usage detection should be conducted systematically and aggressively, rather than relying on occasional reports from customers or workers.

Also, it should be carried out by special employees designated as illegitimate power usage prevention specialists, and they should visit every household in all supply regions to check the status of power line connections. This investigation and detection program should be implemented by the head of loss reduction department whose sole duty is illegitimate power usage detection, and the results should be reported to the director.

If it is conducted by each branch office unit, it should consist of at least two teams with at least two workers in each team. It allows protection of inspectors from possible threats from customers and flexible operations with reinforcement of personnel, combined with at least two teams for intensive investigation in particular areas.

■ Incentive System for Illegitimate power usage Detection

Since illegitimate power usage detection can be dangerous, it should encourage voluntary participation with reasonable rewards. Furthermore, illegitimate power usage detection is associated with customer's bribery, so appropriate incentives should be provided, depending on the detection, resolution and money collection efforts, which lead to perceptions that legitimate incentives are more beneficial than customer's dangerous commissions. After all, power company workers have no reason to report illegitimate power usage voluntarily without special incentives, even with reports about neighbor's theft.

The situation will get worse if customer's bribery is quite enticing. The only way to solve it is high-handed and reward policies. One of the major high-handed policies is to aggressively operate detection teams and penalize corrupt employees; as a reward policy, incentives can be provided to illegitimate power usage reporters. To enforce this policy, the collected money from illegitimate power usage should return to the power company, and it should be managed properly with systematic devices in place. Throughout the 50-year history, Korea has been able to dramatically reduce illegitimate power usage with the following incentive system.

Korea’s Incentive System for Illegitimate power usage Detection

Distinction	Outside Reporters	Power Company Employees
Illegal Use	50% of the collected money	30% of the collected money
Violation of Contract	20% of the collected money	15% of the collected money

4. Automation of Power Grid Facility Operation

4.1 Background on Automation of Facility Operation

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Expansion and Complexity of Power Grid

With the rising power demands, a large number of new substations were built and power supply facilities significantly increased. The operation and management of such complex facilities require state-of-the-art technologies. Since the existing management systems that relied on facility operator’s judgments and intercommunications had limited capabilities in terms of accident processing capacity and speed, there was a strong need to have centralized automation system that could perform comprehensive assessment and control of the entire grid quickly and accurately.

■

Increased Level of Customer Needs

With industrial development, more and more customers were producing high-precision products and they were vehemently demanding high-quality electricity (no power failure, constant voltage and frequency), and power suppliers had to be responsible for manufacturer’s losses caused by interruption of power supply. Meanwhile, with extensive supply of electronic products and the general public’s increasing dependence on electricity, the customers’ demands and interests in high-quality power were heightening, and it led to the introduction of more advanced power control system with state-of-the-art technology.

Rapid Technological Advancement

At the time, as electronic industries were rapidly growing, Korea saw a dramatic improvement of calculators and word processing application capabilities, followed by the expansion of supply, stabilized prices and the increasing demand. These phenomena led to the rising needs for more reliable, remote monitoring control system. In developed countries, computerized power facility automation, remote monitoring, and practical operation of control devices were already in place, and they were about to be introduced to Korea.

4.2 Automation of Transmission Facility Operation

A smooth power supply requires consistent monitoring of facility operation, rapid response to power demand changes, prevention of unforeseen accidents and effective emergency treatment in case of an accident. Before 1980 when computer and telecommunication technologies were developed, facility operations were dependent on substation operator's field reports with wired-communications such as telephone; but this system was inaccurate and slow in power grid management. Meanwhile, as power facilities were rapidly increasing with the industrial development, their scales were getting quite large and complex, which called for a new system of grid monitoring and facility management. In order to respond to the changing grid environments, the SCADA system that allowed automatic monitoring of facility operation status was introduced for computerized and effective facility management in 1981.

SCADA stands for "Supervisory Control and Data Acquisition", which translates into remote monitoring and control system; it refers to facilities that automatically monitor and control the remote power facilities with computerized devices installed in the central control office.

4.2.1 SCADA project

KEPCO installed its first SCADA system in Seoul Power Transmission Branch Office (current Seoul District Division) in April 1981. It was manufactured by Harris Corporation of the U.S. This system had a capacity that could accommodate approximately 50 substations, with its main units composed of dual-core devices to improve its operational reliability. After that, the same model was introduced and installed in Seoul in 1983 and in Busan in 1985.

Since then, the SCADA system was expanded nationwide, and in 1987, Daejeon Power Management Department (current Chungnam District Division) installed a system that had more advanced capabilities than the previous system with larger substation capacity; the SCADA system was introduced to Kwang-Ju in 1989 and Dae-Gu in 1990. Also, as power facilities were becoming gigantic and more sophisticated, following the industrial development, KEPCO subdivided wide-area power supply business into a hierarchical structure of tasks, and created the foundation for improvement of load-dispatching tasks and operation of unmanned substation. Then in 1991, Korea saw its first retroactive power SCADA facility developed with domestic technologies.

Meanwhile, SCADA sector came to a turning point in the 1990s in terms of system configuration and functions, following the advancement of telecommunication technologies. The first SCADA system which had been developed in the 1980s was independently designed and manufactured by individual manufacturers, and it had very limited capabilities, in terms of compatibility, scalability and accommodation ability for new technologies. On top of that, it provided limited amount of information to the operators with its load concentrated on the central processing unit in terms of system configuration. However, in the 1990's, the international standardization in the telecommunication and computer technology sectors progressed, including the SCADA system which developed open structure system with the international standard. Its system configuration was switched to a distributed processing system. Such technology trends led to the introduction of Seoul's first open distributed system in 1993.

In 1998, the retroactive SCADA system which had been entirely dependent on foreign technologies was scheduled to be localized, and finally in 1999, "KEPA-99", the first domestic production unit, was launched in Kwang-Ju after 2 years of development. The localization of SCADA was the framework for expansion of domestic power automation technologies and it saved tremendous amount of foreign currencies ($ 1,640,000 per unit). Meanwhile, the SCADA remote control device was initially installed with Harris Corporation's products, but in 1983, domestically-manufactured remote control device was first introduced and installed. In 1990, SCADA was incorporated into a scheme for unmanned substation operations, and the following year saw the first unmanned 154kV substation.

4.3 Automation of Distribution Facility Operation

Following the elimination of on-site field offices in downtown areas and provincial regions where the traffic congestion and long distances delayed repair service for blackout, the remote operation of distribution switches in rural areas minimized the sections and duration of power outages; it also improved the management of field workers with computerized remote operation of switches for the measurement of voltage and electric current conducted in the office instead of the field.

The purpose of the distribution automation system was to modernize the distribution lines and increase the quality of customer service by improving supply reliability, leading to fulfilling the social responsibilities, and improving the corporate management efficiency by optimizing the facility operations and effectively utilizing the field workers.

4.3.1 DAS Project

The 1960's was entirely in the manual-operation stage when the facility operators were dispatched to the field and handled the work. In the 1970s, the power lines were independently managed by semi-automatic machines (recloser and sectionalizer) installed on the distribution lines, and in the 1980s, the machines that exchanged loads between power lines were manually-operated.

In April 1981, the SCADA system for substation automation system-which had been first installed and operated in Seoul Power Transmission Branch Office-was restructured, developed and operated as the remote operation automation system for the underground distribution lines in the Central Seoul's Myung-Dong area. Due to the SCADA system's characteristics, its functions were quite limited, and in case of power line fault, the point of failure was traced back in a sequential manner, instead of computerized calculations.

In 1983, the "Remote Monitoring and Control Research for Distribution Automation" began, in order to develop Korea's own systems, and among foreign distribution automation systems, America's Westing-House Corporation's automation system was chosen for research and development because of its compatibility with Korea. This system was used for Kyung-Ki branch office automation system, and was installed in some areas in downtown Su-Won city. In January 1988, a trial operation was conducted for four distribution lines. For communications, PLC (Power Line Carrier) system that utilized power lines for communications was adopted. But the communication speed was slow and interruptions occurred, in case of distribution system reconfiguration.

However, the introduction of this system demonstrated the significance of distribution automation and inspired domestic engineers to engage in further research and development. Based on this experience, Korea's research and development of distribution automation system began in 1990 supported by the government. The first prototype domestic system named as KODAS (Korea Distribution Automation System) was unveiled by the end of 1993, and its practical operation was launched in 1997 for the existing distribution lines. After that, the earlier system's problems were repeatedly analyzed and fixed, and in 1988, simple, small-scale, PC-based automation system-separate from the KODAS-was first installed in the several distribution offices, and in 2000, the comprehensive distribution automation system with remote-monitoring and control capabilities performed on the geographic information screen, and optimal operation capabilities of distribution grid was being extensively installed.

In the late 2002, all the distribution offices were equipped with distribution automation system, and in 2003, the dualization of main units for comprehensive distribution automation system were actively expanding. In 2005, a pilot operation of an IT type distribution center equipped with digital dashboards of comprehensive distribution automation system that displayed the grid, instead of the existing hand-written grid map, took place in the Kang-Nam area and the Chung-Nam region, along with the nationwide expansion of distribution offices that performed grid operations by consolidating the existing two to ten offices. It became possible with the completed development of “wide-area distribution automation system”, achieved by the domestic research and development efforts in 2006, and the system was actively introduced starting in 2007. In the same year, 14 distribution centers (47 offices) were launched and with 13 additional centers (71 offices) in 2008, the wide-area distribution center project was completed in 2010 with 41 centers nationwide.

4.4 Effects of Facility Operation Automation

The effects of distribution automation are divided into quantitative effects which translate into lower costs to run the distribution system, and qualitative effects that represent improved work efficiency. The quantitative effects include lower labor costs for facility management, decreased power interference associated with reduction of power outage (unsold electricity caused by power failure), and delay of new investments in power grid with equal operation of grid load, as well as economical effects of extended operation of primary equipments. The main effects of facility automation are as follows.

4.4.1 Quantitative Effects of Facility Operation Automation

Effects of Interference Power Reduction

The existing manually-operated system took an average of 73 minutes to handle the faults, while the automated system with remote switch control took only 6 minutes; so it saved 67 minutes in handling the faults. The rise in electricity sales, corresponding to the reduced power outages, is a direct effect of distribution automation.

The following is a calculation of annual power supply interference.

$$= \frac{\text{Frequency of Interruption} \times \text{Reduced Time of Interruption} \times \text{Number of Household} \times \text{Average Annual Load per Household}}{365\text{days} \times 24\text{hours} \times 60\text{minutes}}$$

Based on the above calculation, the direct effect of interference power reduction is estimated to be nearly 640 million won every year nationwide. However, such reduction was calculated from the power company’s standpoint, and it did not include the overall damage costs of customers with power outages.

Deferral Effects on New Investment in Power Grid

When the load increases on its own power line, there are two factors that determine whether to build new power lines or supply with the current facility: First, “Does the neighboring grid have sufficient supply capacity to allow a load switch when a failure occurs?” and second, “Is it possible to shift the load’s sound section to the neighboring power line?”

The biggest determining factor for evaluating power line’s recovery capability is the accurately-estimated maximum load for each section. With knowledge of the maximum load of a particular, a load increase can be accommodated by changing the normally-open points, with the ability to shift the load against accidents without expanding the facility.

4.4.2 Qualitative Effects of Facility Operation Automation

Although quantitative aspects of automation system refer to the economical effects that translate into the cost savings compared to the investment costs, qualitative effects, including customer’s lower damage costs with reduced power outages and improved work environment, are also tremendous. Also, the additional benefits of being able to perform the field tasks such as voltage and current measurements-which had been postponed under the previous circumstances-would be significant.

Improvement of Fault Handling

Automation system can reduce the on-site field tasks of engineers, since they don’t have to go out to the field to operate a switch. In fact, power grid usually breaks down under bad weather such as rain or storm, which delays the field service with hampered road conditions and visibility range. In the past, operating the power facilities or disconnecting the power grid required the challenging on-site field services even under the bad weather or at night, but the remote operation of automation system greatly improved such tasks and facility operations.

Improved Operational Efficiency of Distribution Grid

It became possible to obtain information about the remote grid operation, and check the real-time status of grid, which allowed the optimal grid operation with improved coefficient of grid utilization, voltage loss reduction and resolution of power line imbalance.

Prevention of Customer Complaints and Improvement of Customer Service

As the power dependence escalated with rising standard of living, customers had almost zero tolerance for long power outages of the past which had a huge impact on society. In particular, in case of extended power outages, customers whose livelihoods were dependent on electricity were inflicted with huge losses, and they made strong complaints which could lead to serious social issues. The automation of facility operations reduced power outages, and greatly improved the customer services, saving tremendous amount of money. These effects would allow all power companies to achieve their ultimate goals of supplying high quality electricity with no power outages and achieving customer satisfaction.

5. Modernization of Distribution Business

5.1 Evolution of Distribution Business

Computerized distribution is widely practiced in developed countries as an essential tool for business management. In Korea, the Korea Electric Power Co. Ltd established the “Management Mechanization Committee” in October 1967 to introduce electronic calculators, and on July 1970, the Electronic Calculation Office was established under the direct control of Korea Electric Power Co. Ltd, which operated its first electronic calculation organization on July 1st, 1971 to handle simple calculation tasks.

Computerized calculations were actively promoted with adoption of the computerized management policy in 1976, and the Computerization Promotion Committee’s regulations were enacted in on April 9 in the same year, which held its first meeting on May 24th, accelerating the computerization of tasks and the introduction of additional computerized equipments. The year 1975 embraced the beginning of the online era, connecting the computerized tasks through the communications network, and improving the work efficiency with real-time data processing by installing new models of terminals from June 1978. From 1971 to 1977, it was the “Introduction Period” when the basic, everyday tasks, such as statistical management of distribution facilities and power outages, were performed with the systematic execution of computerized tasks.

Until 1981, it was the “Expansion Period” during which the development of comprehensive business and distribution system-the first comprehensive system in the business and distribution sector-was launched for systematic computerization of business and distribution tasks. During the “Integration Period” from 1982 to 1988, the internal and external environments surrounding the power industry gave incentives to use computers, which further improved the development tasks of the 1970s. In this period, more complex tasks in distribution designing and construction management were developed, and the goal was to integrate the individual systems. Therefore, the interconnection of computer systems was expanded and the comprehensive computerization for each sector was developed, which led to the completion of comprehensive business and distribution systems with batch processing of distribution, business, materials and accounting in 1986.

In the 1990's, cutting-edge information systems were developed for analysis, planning and facility management, including high-voltage facility management, hydroelectric facility management, distribution maintenance planning and facility data management. Therefore, all the tasks of the distribution sector, including the distribution facility statistics, power outage statistics, low voltage load management and computerized designing of distribution, were computerized. The major systems in each sector are shown on <Table 3-3>.

Table 3-4 | Details of Distribution Business Systems (1971~1997)

Sector	Number of Systems	Name of Systems
Distribution Planning	2	Distribution Facility Index Management, Distribution Line Maintenance Planning
Technical Calculation	2	Technical Calculation of Distribution, Technical Calculation of GIS Utilization
Distribution Designing	6	Distribution Designing, Management of Business and Distribution Figures Underground Line Designing, Lead-in Wire Designing 220V Boosting Designing, Distribution Designing with GIS Utilization
Construction Management	2	Management of Distribution Construction, Management of Construction with GIS Utilization
History of Facilities	3	Regular Report of Distribution History of Underground Facilities History of Protective Devices
Power Line Management	3	Management of Power Outages and Suspensions Management of Distribution Line Operation Status History and Inspection of Distribution Lines
Load Management	2	Management of Low-Voltage Load Management of Low-Voltage Load with GIS Utilization
Distribution Statistics	4	Facility Statistics, Statistics of Distribution Construction, Power Outage Statistics, Statistics of Facilities with GIS Utilization
Total	24	

In the late 1990s, as the environment surrounding the power industry was changing,- such as the privatization trends of state-run firms, the variation of customer needs, and the demands for high-quality electricity-the key issues on the agenda were power outage reduction; establishment of investment plans for economical and profitable distribution facilities; preventative maintenance on the massive distribution facilities; real-time control and management of power line operations with automation system; improvement of construction quality with reinforcement of construction supervision; standardization of tasks, and improvement of productivity through information-sharing. Therefore, there was a strong need to develop new distribution processing systems that could integrate and process the state-of-the-art information technologies, such as the independently-introduced GIS (Geographic Information System), DMS (Document Management System), WFM (Work Flow Management), and HHPC (Hand Held Personal Computer).

So the business sector was reorganized and developed into the New Custom Information System, and the distribution sector was transformed into the New Distribution Information System. The two newly-developed systems were combined and developed into the "Sales Management System (System Integration)," which started to expand nationwide on March 2005, processing the distribution business through the New Distribution Information System (NDIS). Also, the locations of all the underground distribution facilities were measured. These data were stored and managed in computer databases for the first time, in accordance with the government policy of digitalizing underground facility information, and improving the accuracy of NDIS DB (database), which allowed stable and efficient management of the domestic underground facilities and it significantly contributed to improving the power company's public relations through cooperation from the public sectors.

Table 3-5 | Effects of Sales SI System

Distinction	Existing System	Sales SI System
Facility Information DB	Information on transformer, low voltage, low voltage customers, and facilities	1. Integration of specifications, construction and history of major distribution facilities and cantilever equipments 2. Provides information on substations, high and low voltage grid and the customers 3. Database of NDIS drawings for GIS
Business Support System	Focuses on computerization of unit tasks for distribution planning, construction management, low-voltage load management and power outage statistics	1. Integrates the overall distribution tasks, including distribution planning, designing, construction, management and technical calculation 2. Provides information in cooperation with sales, financing, materials and construction companies

5.2 Background on Sales SI System (Integration System of Computerized Tasks)

As briefly-mentioned in the Evolution of Computerized Distribution Service, the systems that were developed before 1997 were focused on practitioners and unit tasks. With their limited capabilities, processing information took a long time, and the necessary data for computerized tasks had to be entered repeatedly, causing multiple errors for data storage and difficulties in providing a variety of customer services.

On top of that, the linkage between computer systems, and accurate and various handling of distribution business were problematic, due to the biased system management focused on written information. Since the existing systems were outdated, the software was obsolete, hard to maintain or repair, and it was tough to apply new information technologies. Furthermore, the centralized computer facility management magnified failures and caused difficulties for the terminal users to access the systems and communicate with each other.

As a countermeasure, the BPR (Business Process Reengineering) was executed in order to actively respond to the customer's various needs. At the same time, the "Sales SI System" was developed to prepare for the technological advancement of the 21st century and to develop a new system, integrating the state-of-the-art technologies.

5.3 Sales SI System Promotion Approach

The Sales SI System was on the agenda of the task force which established the blueprint for the Vision-21 in the sales sector in November 1996 and the policy discussion meeting, and was developed into the ultimate Sales SI scheme. Its purpose was to develop the latest business processing system as previously mentioned, and in accordance with the scheme, necessary systems were developed in two stages. Then, the database establishment-the most fundamental part of system management-was carried out step-by-step in the major regions, following the supply expansion schedule of Sales SI System.

5.4 Effects of Sales SI System

The primary effects of Sales SI system development and management are as follows:

First, it allowed the systematic integration of the overall distribution business and the convenient management of unit task progress and business processing. Also, it eliminated the additional tasks associated with the unit tasks, such as typing of various documents, and innovated the distribution business management by creating a distribution information system.

Second, it improved the work efficiency by linking various systems and providing a more efficient work environment: finance-related information such as the customer information, budget estimation and asset acquisition were automatically connected; the information of materials systems including invoicing, cancellations and changes of materials were linked; the information of load and power line operation such as DAS and SCADA were connected.

Third, various technical support systems such as technical calculations and grid analysis, necessary in the distribution sector, were strengthened, and systematic technical review functions were supported, improving the accuracy.

Fourth, based on the maximized efficiency of scientific facility management, utilizing the facility history and grid information, along the established information, it became possible to estimate the appropriate period of facility repair and replacement, and the infrastructure for long-range management information was secured for economical investment planning and effective maintenance work. The comparison and detailed impacts are as follows.

Table 3-6 | Effects of Unit Tasks

Distinction		Existing System	Sales SI System
Comparison of Business Processing	Distribution Planning	Various data collection and processing were handled by hand.	The optimal and economical plans were created by accurately predicting the load, based on the basic information in the database.
	Distribution Designing	The input system of distribution designing was coded and inconvenient. Calculations were done by hand with no technical support.	Conveniently done by entering the item selection. The optimal power line configuration and construction costs are estimated with various load analysis and technical calculations.
	Construction Management	Construction management-related tasks were manually handled.	Information about construction progress can be checked anytime and aggregate assets are estimated according to the construction history.
	Facility Management	Maintenance of distribution facilities were based on the supervisor's experiences.	Maintenance tasks are effectively executed with scientific statistics created with utilization of facility history.

Table 3-7 | Effects of System Linkage

Linkage with other systems	Processing Information	Effects
Cantilever Facility Management System	Unification of System Management	Accurate management of cantilever facilities and timely payment of cantilever rates
Distribution Automation system	Distribution grid information sharing and actual grid current sharing	Prevents redundant management of distribution facility information related to high voltage grid and reduces power loss by maintaining load balance
Materials System	Materials inventory and purchasing information sharing	Reduction of logistics costs with smooth adjustment of materials supply and timely measurements
New Financing System	Provides information about budget spending and asset acquisition	Proper budget allocation for each distribution power line and acquisition of accurate assets
Site Investigation System with PDA	The updated distribution facility information is automatically entered with PDA	Entering information on the field is faster and easier.
Linkage of municipal information system	Underground facility information sharing	Prevention of underground facility damage by locating the excavation of underground line

Table 3-8 | Improved Productivity Achieved by the System

Distinction	Before using the system	After using the system	Work Efficiency Rate
Low voltage construction designing	310 minutes per task	10 minutes per task	96.8%
High voltage construction designing	310 minutes per task	130 minutes per task	58.1%
Management Statistics Reporting	70 minutes per task	Automatic creation	100%
Distribution investment planning	15 days on average	One day	93.3%

6. Promotion of Smart Grid

6.1 Concept

Smart grid is the intellectual new generation grid that optimizes the energy efficiency with its two-way, real-time information sharing between the power supplier and the customers by applying telecommunication technologies to the existing grid. In other words, the power grid is intellectualized in order to produce, transport and use electricity more efficiently with real-time data acquisition in the process of transporting the generated or transmitted power by utilizing telecommunication technologies.

6.2 Background

In the 2000's, Korea's economic growth gradually slowed down, compared to the previous high-growth periods, and it changed the trends of power demand growth. Following this phenomenon, Korean government has established and promoted plans for the green growth sector, in order to find a tool for the new economic growth and particularly to increase its global competitiveness in the power sector, and to respond to the climate change caused by fossil fuel. In addition, as the customer's interests and participation in the improvement of energy and environment were escalating, the power sector developed the smart grid that could intellectualize the existing power grid with electricity and telecommunication technologies and could provide high-quality services and maximize the energy utilization factor.

6.3 Progression

The Korean government established the "Smart Grid Road Map" on January 2010, designed to improve the energy efficiency by 46% through power demand management and expand the proportion of renewable energy and nuclear power to more than 40% from the previous 17% by the year 2030. "Smart Grid Promotion Act" was legislated in August 2010 that included a development scheme of power industry structure. It was intended to systematically support the smart grid promotion, and the main plans of the government.

〈Government Scheme〉

Promotion of Smart Grid Establishment and Utilization

A. For Suppliers (Power Company)

1. Investment expansion of integrated infrastructure of power and I.T and establishment of measures for securing funding
2. Open management of power infrastructure for integration of different industries
3. Establishment of grid security measures against cyber terrors

B. For Customers (Electricity users and New businesses)

1. Promotion of energy information utilization
2. Technology development, substantiation, tax breaks and financial support
3. Supporting the integrated new technologies and the product supply for creation of domestic market
4. Creating base regions for expansion of Smart Grid

C. Establishment of Promotion System

1. Establishment and promotion of "Smart Grid Basic Plans" and "Execution Plans"
2. Management of "Smart Grid Committee"
3. Legal institutionalization of Smart Grid Committee

6.4 Key point of Roadmap

■ **Development and Standardization of Key Technologies**

The goal was to develop the key technologies such as connecting renewable energy to the power grid, storing energy and grid IT, and to create a standard guide to secure the compatibility among the different technologies.

■ **Infrastructure Development and Market Entry Support of New Products**

By the year of 2020, all households will be provided with Smart Wattmeter, the development of electric car infrastructure (filling stations) will be completed, and certification system for Smart Grid-related products will be introduced and purchase-related incentive system will be developed for market entry of the products.

Reform of Rate System

In order to promote installation of Smart Wattmeter and introduction of Smart Grid, the electricity rate system will be shifted to production cost-based fee system, and various kinds of other systems will be developed, granting customers a right to choose their own energy consumption.

Overhaul of Legal and Institutional Infrastructure

In an effort to secure a long-term investment funding for Smart Grid promotion, and create a support system such as an incentive system, the legal and institutional infrastructure will be overhauled. In addition, a new legislation will be introduced to mandate installations of electric vehicle filling stations and renewable energy related to the Smart Grid.

6.5 Potential Effects

Introduction of Smart Grid is expected to spur an integrated technology development, associated with parts and materials, hardware, software, and system technologies. It will be an essential tool for Korea's new economic growth and will contribute to export increase. The Smart Grid Project is a development of infrastructure that integrates all industries pertaining to power, communications, electronics and energy, which will play a primary role in the future industry development.

Chapter 4

Achievements and Implication

Achievements and Implication

1. Achievements of Project

It has been one hundred years since the power business began in Korea. It started with the first electric lighting of Kyung-Bok Palace, and was initiated as a power company in a small provincial region, leading to the management of three power companies throughout the end of Cho-Sun Dynasty, Japanese colonial period and liberation, and the Korean War.

After those three companies were merged in 1961, it became the Korea Electric Power Corporation. Since then, the power industry has achieved a remarkable growth by stepping up its effort to supply stable power, along with the national economic growth. In fact, Korea's power transmission, substation, and distribution facilities have grown tremendously, despite the numerous difficulties and obstacles since the power business began in 1898 with Han-Sung Electric Company. The power facilities-which were almost destroyed after the Japanese occupation and the Korean War-have experienced a robust growth. The transmission facilities expanded to approximately 30,000 km, the substation capacity reached nearly 190 GVA, and the distribution facilities increased to approximately 400,000 km by the end of 2010.

It is the history of Korea's power development, and reflects the country's modernization and industrialization process. Now Korea's transmission and distribution technologies, and the quality of electricity are among the best in the world, by successfully completing the numerous projects, such as establishing the nation-wide multiple transmission loop grid and the HVDC power grid connecting Jeju Island with main land, stepping-up of 765kV followed by 345kV, operating unmanned substations through remote control systems, building underground distribution facilities, and stepping-up and unification of 22.9kV.

Following the growth, KPECO is implementing the project of sharing its technologies and experiences overseas since the year 2000s, sharing its grid establishment technologies all over the world, including Libya, Philippine, Vietnam, Egypt and Paraguay.

1.1 Timely Expansion of Grid Facilities for Stable Power Supply

Korea's power industry has achieved a remarkable growth since 1960. The circuit length has increased from 6,232c-km in 1961 to 30,676c-km in 2010. The number of substations has increased from 291 in 1961 to 711 in 2010; the number has increased only three folds, but the proportion of large-scale substations has skyrocketed with supply capacity of 249,040 MVA.

In addition, Korea's distribution facilities have rapidly expanded, following the increase of power generation. The power line length has jumped from 9,171c-km in 1961 to 428,259c-km in 2010. In addition to the quantitative expansion, the qualitative aspects also greatly improved. The distribution and transmission loss rates, one of the indicators of power industry's efficiencies, were 29% in 1961, but have steadily improved to 7% in 1980, 6% in 1990, 5% in 2000, and a 4% range in 2008.

It shows that Korea's transmission and distribution loss rates are relatively very low, even lower than the major developed countries that are in competition; Korea's rates are lower than Japan's 5% and the U.S. and China's 7% in 2007. Meanwhile, power selling price has significantly improved with the introduction of nuclear power, and price has steadily decreased since the record-high in 1981. Although it increased slightly after the mid 2000s during the era of oil price rise, it is stabilized at a level that is far lower than the oil price increase.

1.2 Keystone to National Economic Development

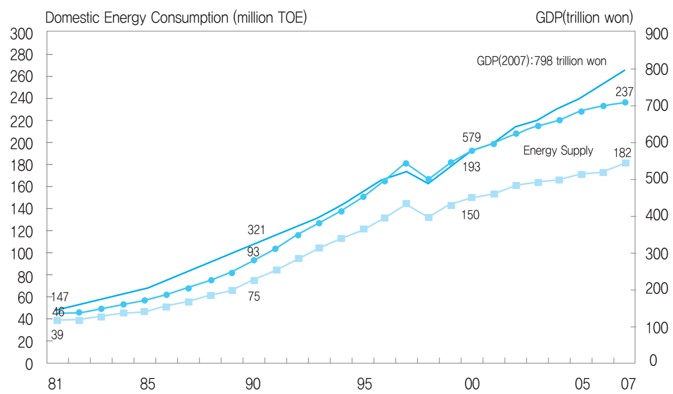
The power business faced a huge crisis after Korea's liberation from Japan, since approximately 90% of the power generation facilities were located in North Korea. The power crisis became even more severe in the aftermath of the Korean War. At that time, it was unimaginable to use lighting in most homes. In that period, there were three power companies in South Korea including Cho-Sun Power Business, but they were not able to solve the power shortages due to their chronic deficit operations.

In an effort to overcome the challenges, KEPCO was established in July 1961. It conducted the historical, unlimited power transmission in April, 1964, finally solving the power shortages that had repeatedly occurred since the liberation from Japan. KEPCO was dedicated to the Rural Electrification Project from December 1965, and achieved a power supply rate of 98% in 1979, providing electricity for almost every household.

In addition, KEPCO has provided stable electricity-the essential tool for the national economic development-and has continuously grown and progressed by incessantly innovating its business management and technologies.

Korea's economic growth is closely related to its development of electricity industry. The rapid industrialization since the 1960s had led to the skyrocketing energy demand, with transition to an industrial society from agricultural society. In order to meet the increasing demand, four 5-Year Power Resources Development Plans were implemented to expand the power generation. The following figure shows the correlation between the domestic energy consumption and GDP growth. As it illustrates, an increase in energy consumption goes hand in hand with GDP growth. It indicates that stable power supply is a pillar of economic development. High-quality power supply is an integral part of high-technology society, and economical energy supply is an important factor in raising the national competitiveness.

Figure 4-1 | Transition of Domestic Energy Consumption and GDP Growth



1.3 The World-Class Power Industry

1.3.1 Overseas Expansion of Power Grid Technologies

Korea's power industry has grown tremendously for 100 years since its first electric lighting in the country. As the keystone to Korea's economic development, KEPCO has become a world-renowned power company. It has continuously been stepping up its effort to become a comprehensive global power energy group. In fact, KEPCO's power quality is the best in the world. The average length of power outage is 18.8 minutes in 2006, much shorter than 30 minutes in Taiwan, 122 minutes in the U.S. and 51 minutes in France. The maintenance rate of standard voltage and frequency is 99.9% and 99.7% respectively-the best in the world. Its overseas expansion that started with power generation has shifted to transmission and distribution.

It was initiated with a "Feasibility Study of Transmission and Distribution Grid in Philippine" in September 2002, and KEPCO successfully executed the "Feasibility Study for Improvement of Supply Reliability and Management of Transmission and Distribution Grid in Libya" in 2003. It seized an opportunity to export Korea's power grid technologies for the first time by securing the "Libya's Transmission and Distribution Grid Improvement

Project", worth nearly $800,000 as a single technology consulting project. Based on the technology and know-how's obtained through development and operation of the national grid, Korea conducted the "Feasibility Study of Uruguay's Power Loss Reduction and Power Quality Improvement", and exported its grid automation technologies to Indonesia, Egypt and Paraguay.

1.3.2 Sharing Growth in the Power Sector

In the 2000s, Korea's domestic power equipment market was saturated, and new market expansion was needed. But small and medium-sized power equipment manufacturers had insufficient information about overseas market, as well as a lack of human network, making it difficult to directly contact the overseas power companies, and were unable to go international, due to their financial situations and low brand value recognition.

So KEPCO-striving to grow small and medium-sized companies-actively utilized its "Korea Brand" value created through its overseas projects in order to find new markets for those companies and held a promotional event for power equipment export together with Electrical Industries Association of Korea in July 2003, while conducting the "Feasibility Study of Distribution Grid Improvement in Philippine"-the starting point of overseas transmission and distribution project. Fifteen manufacturers of power equipment such as transformer, and wattmeter advertised the superiority of Korean power equipments and conducted export counseling to 150 Philippine power company officials and material suppliers, leading to a number of contracts and securing a channel to expand to Philippine.

In addition, the Korea Electric Industries Association conducted the export market promotion activities in Tripoli, Libya, in cooperation with the local KOTRA. Meanwhile, KEPCO has been actively utilizing domestic power equipments for executing overseas transmission and distribution projects, in order to help Korean equipment companies to expand to overseas market as a predecessor.

1.3.3 Statistics of Major Grid Management Comparison by Country

Power loss rate, average length of power outage, and load factor that indicate the technological level of grid management are shown in the tables below in comparison with developed countries.

Table 4-1 | Power Loss Rate

Country	U.S.A	Japan	France	U.K	Korea
Loss Rate (%)	6.8	5.2	6.8	8.0	3.9

* Overseas Power Statistics (KEPCO)

Table 4-2 | Average Power Outage

Country	U.S.A	Japan	France	U.K	Korea
Outage Time (minutes)	138	11	57	68	15

* Overseas Power Statistics (KEPCO)
* Excludes blackouts caused by natural disasters

Table 4-3 | [Load Factor] Indicates the Optimal Utilization Factor of Power Grid

Country	U.S.A	Japan	France	U.K	Korea
%	58.6	66.7	66.8	66.3	75.8

* Overseas Power Statistics (KEPCO)

2. Implication

2.1 Overview

Korea has been solving various tasks in different periods while conducting the national grid development project since 1961. Due to the insufficient power generation at the time, a blueprint for the national grid was necessary for systematic power resources development and grid construction; it was imperative to expand the grid to supply sufficient electricity for the economic development while slashing the power loss. After the 1970s, there was a need to diversify the energy resources needed for power production in the mist of oil crisis, and to establish a foundation for the domestic power industry, in order to economically supply electrical equipments that had been dependent on imports.

In addition, Korea had to strive to provide more reliable power rather than just focus on expanding power supply regions. After the 1980s, Korea beefed up its effort to efficiently to manage the power facilities that had significantly expanded, following the economic growth. In this part, we will look at the implications associated with solving the tasks in each period and the possibilities of applying them to developing countries in the future.

2.2 Implication and Application Possibilities

For power resources development and the national grid development project, a basic blueprint should be prepared on a national scale for effective economic and industrial development and a reliable power supply-it is better than multiple, small projects. Throughout the Japanese occupation and the Korean War, there were practically no industrial facilities, not to mention a funding and human resources needed for economic development, and the power industry's production and transport situation were very poor.

However, Korea did not get frustrated or give up. Based on the 5-year-Economic Development Plan created by the government in 1962, master plans were created in the various economic and industrial sectors, including the power industry that established a basic scheme for power resources development and the national grid development.

In order to create a master plan for power grid establishment, the Korean government asked the U.S.-based power sector consulting firms for assistance. The EBASCO and Burns&Roe, provided consultations, which set the direction for Korea's power grid establishment policy. The facility plans for 345kv, 154kv, and 22.9kv, the foundations of current power grid, was created at that time, and was used to establish the national power grid, including Industrial Zone power supply, Rural Electrification Project, and grid connection between power plants and the Metropolitan areas.

The funding for master plan was obtained through loans and grants from the U.S. and international organizations. Korea was in need of huge amount of construction funding for national power grid establishment, and domestic funding alone was not sufficient. So KEPCO received several loans and grants from the U.S., the U.K, and IBRD for power facility construction, and has built Kori Nuclear Power Plant, Gamcheon and Samcheonpo Thermal Power Stations, and nationwide transmission and distribution grid, laying the groundwork for economic development.

In the early stages of Korea's power grid establishment, the number and quality skilled workers were insufficient. Although solid construction and maintenance of power facilities required a large number of competent technicians, they were in short supply. So the state-owned company, KEPCO established an Employee Training Center in 1961, and has provided continuous education for employees of KEPCO and its partnership companies, producing technical personnel for the national power grid establishment project.

Also, KEPCO stepped up its efforts to develop technologies by building Power Research Institute and Gochang Demonstration Complex. A variety of new technologies were developed for transmission and distribution grid construction, and power loss reduction. As a result, KEPCO reached a level where it was independently able to execute the national power grid establishment by localizing the imported technologies, as demonstrated in the 765kV grid construction project. For power loss reduction, KEPCO made various efforts, such as transmission and distribution voltage step-up, improvement of utilization factor, replacement of obsolete facilities, 3-phasing of power line, and prevention of illegitimate power usage. It resulted in a dramatic decrease in transmission and distribution loss rate to 3.99% in 2010 from 29.3% in 1961; it greatly improved the energy efficiency and provided extra power, equivalent to the amount of several power plants.

KEPCO'S stable power supply is closely tied to Korea's economic development. High-tech industries, such as semiconductors, shipbuilding, steel, automobiles, and electronic components require stable power supply for their strategic development foundations. As Korea's economic development triggered a steady rise in power demand, a number of new power plants, substations, and transmission and distribution power grids were built. Also, some power facilities were expanded. In order to efficiently operate and manage the expanded facilities, the existing operation methods, highly dependent on plant operators' assessments and intercommunications, had to be upgraded for higher accident-processing capabilities and speed. It called for centralized automation with swift and accurate capabilities for comprehensive assessment and operation of power grid. At the time, the rapid development and expansion of electronic industry, including calculators and information-processing technologies, raised a pronounced need for reliable remote monitoring systems, and led to the importation of distribution automation system.

Such technologies slashed unnecessary generation costs by reducing power losses through effective control and management, and accurately forecasting power demand with integrated technologies of power and communications. In terms of power facilities of 2010, a 1% reduction in power losses could save approximately 200 billion Korean Won, meaning that effective management of power facilities is crucial. Also, a disruption of power supply today could lead to a collapse of national security, indicating the tremendous significance of the power industry, and importance of facility maintenance.

Since then, KEPCO has developed its own technologies through automation technology benchmarking, and established a proper system for Korea's power facility environment.

Now KEPCO is exporting its automation technologies to many countries around the world including China, Saudi Arabia, Vietnam and Egypt.

In this aspect, the implications for developing countries are that Korea has also experienced catastrophic economic difficulties in the aftermath of colonial rule and the war just like many of them, and the problems appearing in their power grids are quite similar to the issues that Korea was grappling with in the 1960s or the 1970s.

The problems inflicting the developing country's power industry are as follows: shortage of power supply; tremendous grid loss rate, dealing a severe blow to the power company's financial management; and low reliability of power supply caused by frequent power failure and long recovery time.

However, these issues or tasks can be actively addressed by securing a proper basic scheme and funding, and training workers and developing technologies, as well as executing the scheme rigorously, as Koreas has accomplished through its national power grid development project. Furthermore, it can be used as a role model with a high possibility of success.

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