Power system and technical issues in South Korea

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ABSTRACT

In South Korea, power transmission voltages are 345kV on major networks and 154kV or 66kV in local systems. Most 66kV lines are now either being removed or replaced by higher voltage lines. As of 1999, the total length of transmission lines was 25,337 Circuit-km (C-km) and the total capacity of substation facilities was expanded to 120,257MVA.

765kV facilities are now being constructed, to be operated beginning in 2002, to transmit electricity stably between large power generation plants and customer areas due to the rapid increase in power demand in metropolitan areas.

The power system on Jeju island is now connected to the mainland via a 100km-long submarine transmission system of HVDC (High Voltage Direct Current) cables.

Power transmission networks and substations are monitored and controlled by SCADA **(**Supervisory Control and Data Acquisition**)** systems. These systems feature T&D (Transmission & Distribution) facility improvements and control automation, which includes installing more indoor and unmanned substations to enhance power supply reliability.

To prevent the problematic rise in system voltage during off-peak times because of the continuous expansion of the EHV (Extra High Voltage) system and underground power lines, the power system in South Korea has installed shunt reactors. Also, static condensers have been installed at 154kV substations in order to compensate for the voltage drop of the system during heavy load periods. The regulation of a distribution line voltage has adopted automatic ULTC (Under Load Tap Changer) operation in order to maintain a constant voltage level.

Looking at the past 40 years, the domestic electric power industry, encompassing all sectors of power generation, transmission, and distribution, has been monopolized by the state-run Korea Electric Power Corporation (KEPCO). This system had been justified due to the economic benefits; the required huge investments; and the unique characteristics of electricity, such as simultaneous production and

consumption. However, with the recent development of small but high-efficiency generators and information technology, the private sector investment in the electric power industry can be facilitated, and the transaction of electricity is made possible. This has led to the worldwide trend of the introduction of competition and privatization of the electric power industry. The Korean government has decided to introduce competition into the electric power industry sector to increase efficiency and transparency, and to attract the participation of the private sector. Based on the evaluation of KEPCO's management system from 1994 to 1996 and incorporating public opinions, the basic plan for the restructuring of the electric power industry was announced in January 1999. According to the basic plan, the Korean government established the new Act on Promotion of Restructuring of the Electric Power Industry and revised the Electricity Business Law in December 2000. By December 2002, the electric power market will be operated as the cost-based generation pool. The two-way bidding pool (wholesale competition) will start in January 2003, and finally, retail competition in January 2009.

Large-scale power plants have been constructed in the southern area of Korea, and the metropolitan areas in central parts of Korea have consumed nearly of 42% of the total electricity generated. Multiple connections were established to supply the metropolitan areas, and a relatively large quantity of power flows northward. The transmission capacity was increased, so that some buses must be operated separately, and the reliability of the system has been taken into consideration in the planning stages to improve system performance. The northward power flow should be restricted for the security of the supply in a metropolitan area, and this constraint should be investigated under various operating conditions.

The transient stability of the system should be examined under severe cases such as a 3-phase fault and the simultaneous trip of a major two-transmission line. Some simulations show that a fault on a major transmission line can cause system instability.

1. Statistics and restructuring of the electric power industries

1.1. History and present status

The history of the Korean electric power industry is shown in Table 1-1. Korean power systems have been expanded and improved rapidly in quantity and quality, complying with the requests of customers to follow the improvements in the level of life styles and for the stimulation of industrial development. That is, since the development of a network of 154kV power systems around the middle of the 1970's and the first operation of the 345kV extra-high voltage transmission line for domestic use in 1976, the construction of 7,281C-km of 345kV transmission lines by the end of 2000 contributed to a revolutionary improvement in supply reliability and a reduction of power loss in spreading to a nationwide grid as well as to metropolitan areas. Also, to solve the difficulty of obtaining financing for transmission lines, a plan to increase the 765kV transmission line voltage was adopted, and a 345kV operation was initiated by completing a 765kV line between the Dangjin thermal power plant and the Shin Dangjin transmission line in 1998. In 1997, to solve the deficit of the management balance by the reduction of generation costs in the Jeju area, the business of the HVDC power system interconnection between Jeju island and the main peninsula was completed.

Table 1-1 History of the Korean electric power industry.

1887	The first electric bulb lit the royal court in Kyung Bok Palace.
1898	Electric power line laid along the street between Seo Dae Moon and Hong Neung in Seoul. At the same time, a 75kW class power plant was constructed at the present site of the Dong Dae Moon Arcade in Seoul.
1923	Construction of 66kV transmission line running for 166.9km between Seoul and Jung Dae Ri in Kang Won Do created the first high voltage line in our country.
1935	Construction of the first 154kV transmission line between Seoul and Pyong Yang.
1961	Foundation of Korea Electric Power Company.
1975	Construction of the first 345kV Sin Yoe Soo transmission line running 93km between Yoe Soo power plant and Sin Nam Won substation.
1979	Installation of Dual On Line Real Time Computers in the head offices of A.F.C (Automatic Frequency Control) and E.L.D (Economic Load Dispatch).
1981	Start up of the first SCADA system in the Seoul Power Transmission Department.
1988	Department establishment of EMS (Energy Management System).
1992	Construction of the highest pylon (195m) in Asia crossing the Han River.
1993	Construction of the first 345kV underground transmission line running between Mi Geum and Seong Dong in the eastern area of Seoul.
1997	Plant for 300MW HVDC link between Jeju Island and the mainland.
2002	The first 765kV transmission line planned to be energized.

As shown in Table 1-2, the 345kV & 154kV transmission & substation facilities and 22.9kV distribution facilities have been steadily increased and can be inferred from the transition of transmission-distribution facilities for the past 30 years, but the expansion of 66kV & 22kV transmission facilities and 6.6kV & 3.3kV distribution facilities was restricted. As a result, the rising voltage levels of the entire power system have greatly contributed to the improvement in reliability and to the reduction of power loss in the power system with high voltage and with the simplification of the existing 154kV-66kV-22kV-6.6kV (3.3kV) to a 345kV-154kV-22.9kV.

Table 1-2 Transmission, substation and distribution facilities since 1961.

Division		1961	1970	1975	1980	1985	1990	1995	2000
Trans. Facilities (C-km)	765kV								595
	345kV				2,044	3,669	4,935	5,952	7,281
	154kV	606	1,590	2,050	6,062	8,072	10,609	13,530	16,747
	66kV	1,778	2,913	3,498	4,484	4,498	3,877	3,192	1,727
	22kV	2,854	2,812	1,057	95	24	11	-	232
	Total	5,237	7,316	6,605	12,686	16,263	17,101	22,674	26,582
Substation facilities (MVA)	345kV				6,333	13,503	21,171	36,507	53,116
	154kV	373	1,803	4,013	9,789	16,451	27,632	47,059	70,820
	66kV	519	1,084	1,852	2,213	2,373	2,251	1,939	1,441
	22kV	317	537	889	773	586	631	456	257
	Total	1,209	3,424	6,754	19,108	32,913	51,685	85,961	125,634
Distrib. Facilities	Distrib. line(km)	9,171	21,002	67,365	122,919	168,043	231,263	298,000	336,694
	Trans. (MVA)	694	1,347	3,165	6,774	10,731	18,223	33,677	41,550

1.2. Power supply-demand prospects

Around the middle of the 1980's in South Korea, the maximum power demand of relatively low growth had highly increased by carrying out favorably the '86 Asian games and '88 Olympic games. This increase in maximum power demand was accelerated with the spread of air-conditioners in 1994. Records show a tremendous increase in demand of 20% in 1994, of 12% in 1995, and a continued increase by 10% every year since the beginning of 1990.

Table 1-3 Load & capacity factors (in %) and average load & peak load (in MW).

Items	1980	1995	1996	1997	1998	1999	2000
Facility Capacity	9,391	31,791	35,722	40,534	43,261	44,427	47,876
Supply Capacity	7,645	31,968	34,295	38,452	37,928	43,418	46,078
Peak Load	5,457	29,878	32,282	35,851	32,996	37,293	41,007
Avg. Load	4,239	21,080	23,394	25,622	24,578	27,320	30,328
Load Factor	77.7	70.6	72.5	71.5	74.5	73.3	74.0
Capacity factor	45.1	66.3	67.2	64.7	55.7	57.3	62.2

However, the structure of the IMF (International Monetary Fund) and the effect of low temperatures in the summer of 1997 were represented by a negative growth within a ratio of 8% for maximum power and within 3.7% for power sale quantity in 1998.

Table 1-3 shows the facility & supply capacity and peak load (in MW), load & capacity factor (in %), and average load & peak load (in MW). Table 1-4 shows the installed generating capacity (in MW).

Table 1-4 Installed generating capacity (in MW).

Items	1980	1995	1996	1997	1998	1999	2000
Hydro	1,157	3,093	3,094	3,115	3,131	3,148	3,149
Domestic Coal	750	1,020	1,020	900	1,091	1,291	1,291
Bituminous Coal	0	6,800	6,800	9,300	10,240	11,740	12,740
Oil	6,897	6,119	7,349	8,860	7,410	4,716	4,866
Gas	0	6,536	7,836	8,551	9,518	12,368	12,698
Nuclear	587	8,616	9,616	10,316	12,016	13,716	13,716
TOTAL	9,391	32,184	35,715	41,042	43,406	46,979	48,451

The potential of growing power demand in Korea was higher than that of any other country; the maximum demand by the fifth long-term power supply-demand established on January, 2001 had reached 41,007MW and will be increased to 60,718MW in 2010. The electrical load will saturate in 2020-2030 to the level of the power consumption per person of a current developed country, representing over 80,000MW. The capacity of generation plants in keeping up with the growth trend of this power demand will be increased greatly every year, and will be raised to 1.5 times the current level with a total of 74,611MW in 2010. Power capacity (in MW), reserve ratio (in %) and long-term load forecast (in MW) are shown in Fig. 1-1.

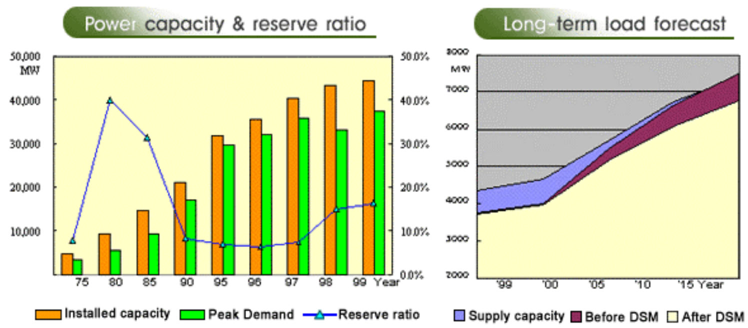

Fig. 1-1 Power capacity (in MW), reserve ratio (in %) and long-term demand forecast (in MW).

1.3. Restructuring of power industries

The electric power industry in South Korea had been recognized as a monopolistic industry due to the benefit of economy as shown in Fig 1-2. However, with the development of small but high-efficiency generators and information-communication technology, it has been asserted that the economy of scale has vanished. In this context, the worldwide restructuring and deregulation of the electric power industry is in progress to promote competition in both the supply and demand sides.

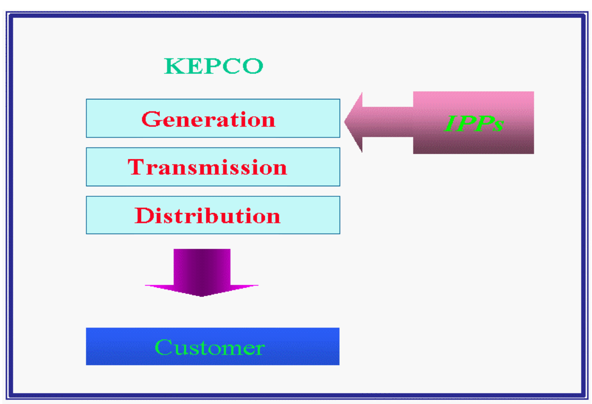

Fig. 1-2 Monopoly in the past

Also, Korea has decided to introduce competition into the electric power industry. In the past forty years KEPCO has had an integrated operating monopoly over the generation, transmission, and distribution of electricity and has kept pace with the rapidly growing demand for electricity. During the 1980's and 1990's, the average annual growth in demand exceeded 10%. KEPCO had owned 94.2% of the total domestic electricity generation capacity of 49,050MW, which is the 17^{th} largest in the world. KEPCO now faces a new milestone in its history.

After a management evaluation of KEPCO from 1994 to 1996 and the incorporation of many-sided public opinions, the basic plan for the restructuring of the electric power industry was announced in January 1999 to introduce competition to the monopolized industry thereby increasing efficiency.

The first stage of the basic plan is to prepare for the competitive market in terms of legislation, valuation, and separation of KEPCO's assets; formation of generation companies; and development of a wholesale power pool. According to the basic plan, the government established the new Act on Promotion of Restructuring of the Electric Power Industry and revised the Electricity Business Law. In accordance with the enactment of related laws, the KEC (Korea Electricity Commission) and KPX (Korea Power Exchange) were established in April 2001 to ensure fair competition. Also, the generation sector of KEPCO was divided into six separate companies, i.e. five thermal power companies and one nuclear power company. The five thermal power companies were designed to secure fair competition by ensuring equal power source composition, installed capacity, asset, profit valuation, etc. By December 2002, the electric power market will be operated as a cost-based generation pool, which is the second stage. In this second stage, the distribution sector of KEPCO will be separated and divided into several companies as shown in Fig 1-3. Then, a two-way bidding pool (wholesale competition), which is the third stage, will start in January 2003, as shown in Fig 1-4. Finally, the retail competition will start in January 2009, as shown in Fig 1-5.

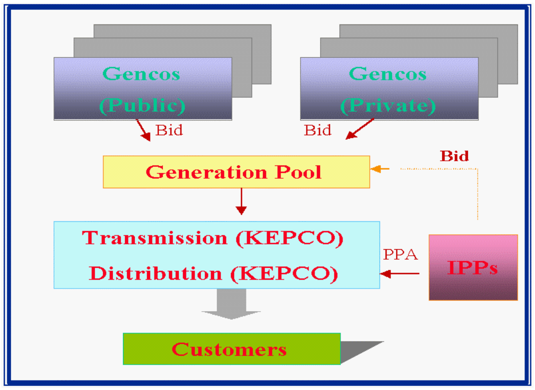

Fig. 1-3 Competition in generation by December, 2002.

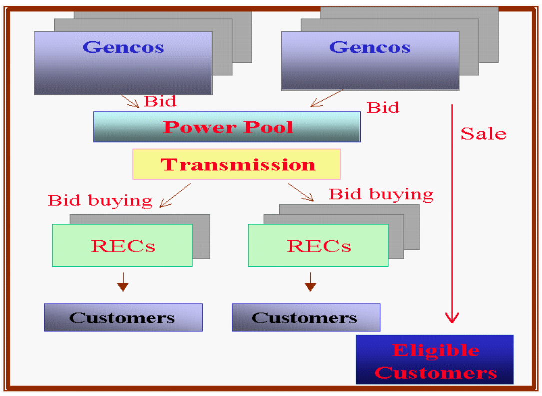

Fig. 1-4 Wholesale competition from 2003 to 2008.

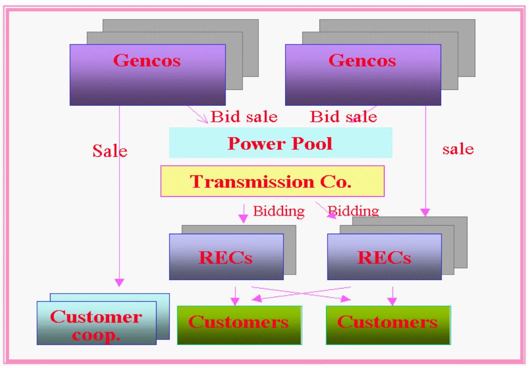

Fig. 1-5 Retail competition after 2009.

2. Transmission system

2.1. Transmission & substation systems

The power transmission system voltage levels in South Korea are 345kV, 154kV and 66kV. First, 345kV transmission lines are made to form a bulk power transmission system to transmit electric power among regions and to connect with external transmission systems around small, medium, and large cities. Second, 154kV transmission lines form a main branch system within a region, which is a power distribution line in the center of large cities. Third, 66kV transmission lines will be reduced gradually because of the improvement in transmission capacity and the simplification of the power system. The transmission & substation divisions play the role transmitting large power stably from power plants to load centers.

Table 2-1 Transmission line (in C-km).

	1980	1990	1991	1992	1993	1994	1995	1996
345kV	2,044	4,935	4,941	5,259	5,560	5,762	5,952	6,256
154kV	6,062	10,609	11,189	11,631	12,084	12,485	13,530	14,181
Under 66kV	4,579	3,888	3,721	3,579	3,551	3,370	3,192	2,705
Total	12,685	19,432	19,851	20,469	21,195	21,617	22,674	23,142

Table 2-2 Substation capacity (in MVA).

	1980	1990	1991	1992	1993	1994	1995	1996
345kV	6,334	21,171	24,172	23,339	28,339	29,173	36,507	41,675
154kV	9,789	27,632	29,767	32,982	36,834	41,239	47,059	52,059
Under 66kV	2,985	2,881	2,824	2,611	2,497	2,477	2,395	2,426
Total	19,108	51,674	56,763	61,932	67,670	71,889	85,961	96,160

Tables 2-1 and 2-2 show the trend of the transmission circuit length (in C-km) and the substation capacity (in MVA) since 1980. The Korean power system has been expanded to include T&S facilities to achieve these goals while power demand has rapidly grown since the 1960s. The total transmission line length at the end of 1996 reached 23,142C-km including 834C-km of underground transmission lines. The number of substation facilities is 400 including 195 unmanned substations with a total of transformer capacity 96,160MVA. T&S facilities have become complex and large in capacity along with increasing demand. There have been attempts to improve system reliability and operate these facilities stably, and these have met with good results, shown by the reduction of outage duration and faults, maintenance of regular voltage levels, etc. The most vulnerable power system facilities continue to be replaced. In the future, there will be introduced scientific supervision and diagnosis equipment for T&S facilities, and new techniques are being developed and installed, such as IDPCS (Integrated Digital Protection and Control System), and APRS (Automatic Power Reconfiguration System), etc.

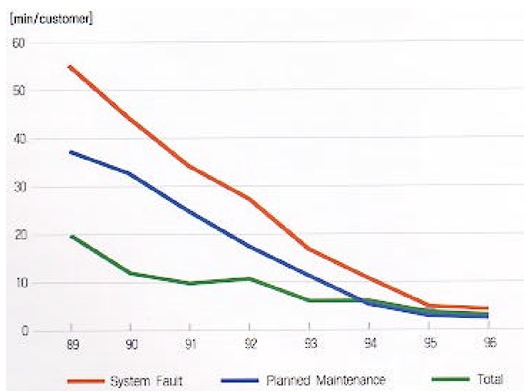

Fig. 2-1 Duration of outage (in min/customer).

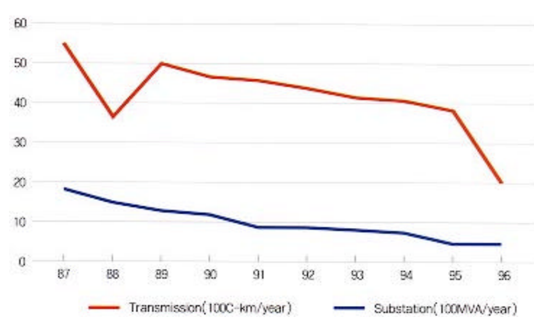

Fig. 2-2 Trend in faults of transmission and substation (in %).

Moreover, KEPCO is actively driving the TFTS (Trouble Free Transmission and Substation) movement to improve facilities and prevent human error. The duration of outages and faults is being reduced dramatically to achieve better electricity quality as shown in Fig. 2-1 and Fig. 2-2.

2.2. 765kV transmission lines

The Korean power system has reduced transmission losses by upgrading the system voltage and the control of reactive power, etc. Fig. 2-3 represents the trend of energy loss rate (in %). However, there are many potential factors which result in transmission losses because of the distance between large power plants in the southern district and customers in and around the capital area, as well as the reactive power increase due to underground line expansion.

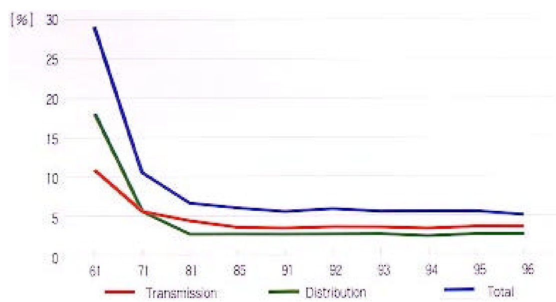

Fig. 2-3 Trend of energy loss rate (in %).

In the future, high efficiency facilities will be developed and installed, and 765kV T&S (transmission & substation) facilities, etc, will be constructed in order to reduce transmission losses. The 765kV project as shown in Table 2-3 is under way for bulk power transmission between large power plants and the demand area (T/P=thermal power plant and S/S=substation).

The purposes for upgrading the highest system voltage to 765kV are to solve poor regional distribution between large power plants and the load centers, to supply electric power stably to meet the rapidly increasing demand of the metropolitan areas, to solve difficulties in obtaining transmission routes and substation sites, to connect large capacity power plants, and to create the backbone of the transmission system in and around the metropolitan areas. KEPCO is now constructing 765kV facilities (3 transmission lines and 2 substations).

Action plans to reduce transmission losses include upgrading transmission voltage and reducing 66kV facilities, installing facilities to perform reactive power control with static capacitors and shunt reactors, effective operation of transformers, and the replacement and installation of high efficiency facilities and voltage upgrading to 220V in the distribution system.

Table 2-3 765kV construction plan.

Transmission Line		Length (km)	Completion	765kV Operating
Step	- Dangjin T/P Sin S eosan S/S	40	1998	2001
	- Sin Seosan S/S Sin Ans ung S/S	137	1999	2001
	- Sin Taebaek S/S Sin Gapyong S/S	157	1999	2004
Step	- Sin Ansung S/S Sin Gapyong S/S	75	2005	2005
	- Sin Namwon S/S Sin Jincheon S/S	200	2003	2010

2.3. HVDC link between the mainland and Jeju Island

Table 2-4 A project summary of the Jeju HVDC line.

Project main parts	Contents
- Section	- Jeju Island (the largest island in Korea) H aenam (South mainland)
- Rated voltage & capacity	- DC ±180kV, 300MW
- Main equipment	- Converter (2 sets): Jeju & Haenam converter station - Power cable: 101km 2 circuits (submarine 96km, land 5km) - Communication system (fiber optic communication cable): 101km 2 circuit

KEPCO is linking the mainland (Haenam) and Jeju Island to reduce generation costs and enhance power supply stability on the Jeju electric power system. The project summary and benefits are listed in Table 2-4. The benefits of HVDC are a stable power supply for Jeju Island, power cost deficit reduction on Jeju Island, accumulation of HVDC technology, and establishment of communication systems. Also, the HVDC system is a necessity for fault level reduction and stability improvement in the power system. The rated voltage and capacity are DC 180kV, 300MW (two poles of 150MW) and the length of the power cable is 101km, two circuits of which (96km) is submarine cable and 5km is on land. There are 101km of two circuits and a 24-core fiber optic communication cable. This system was constructed in 1997.

2.4. Underground lines in urban areas

Considering environmental sites in urban areas, 345kV underground lines are being extended to make loop systems. Civil structures that use various underground transmission cables are ducts, culverts, and tunnels. Culverts are on the increase recently due to increasing electric power demand and the need for installation of a number of cables in the same route. Especially in the downtown areas, tunnels are increasing due to local government needs to obtain roads. Since 1995, XLPE (Cross-Linked Polyethlene) cable has been used exclusively for 154kV underground transmission facilities, with some exceptions (connection to existing OF cable), because of environmental considerations and low operating costs due to the simplicity of the cable system in comparison with traditional oil filled cables. In the future, XLPE cable will be used for 345kV, and local cable makers are actively engaged in the development of the 345kV XLPE cable.

2.5. Transmission planning

Power system interconnections among regions are shown in Fig. 2-4.

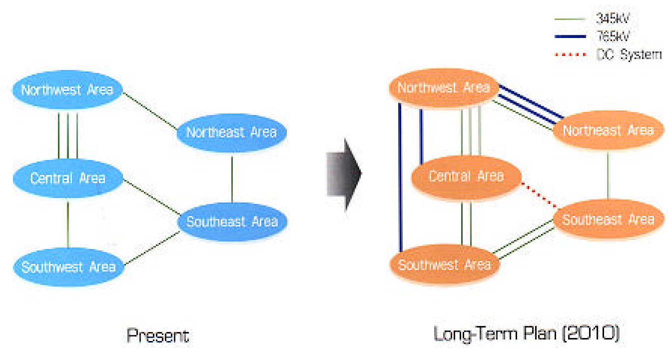

Fig. 2-4 Present & long-term plans (2010) for system connection among regions.

Transmission planning is divided into three categories: long-, mid-, and short-term. The long-term plan is the expansion of the 345kV system during the next 10 years; the mid-term plan is the expansion of system facilities of 154kV during the next 5 to 7 years; and the short-term plan is the expansion of 154kV during the next 3 to 5 years. Table 2-5 shows the expansion prospects for 345kV and 765kV facilities from 2000 to 2010.

Table 2-5 Expansion prospects for 345kV & 765kV facilities.

Year			**2000 (installed)**		**2001~2005**		**2006~2010**	
Line Voltage [kV]			765	345	765	345	765	345
Trans.	**Length** [C-km]	**Line** (sum)	595	7,188 (7,188)	179 (774)	950 (8,138)	419 (1,193)	552 (8,690)
		Under Ground Line (sum)	-	93 (93)	-	138 (231)	-	23 (254)
		Total (sum)	595	7,281 (7,281)	179 (774)	1,088 (8,369)	419 (1,193)	575 (8,944)
Subs.	**Substation Number** (sum)		-	44 (44)	4 (4)	10 (54)	2 (6)	4 (58)
	Installed Capacity [MVA] (sum)		-	55,010 (55,010)	20,000 (20,000)	18,000 (73,010)	8,000 (28,000)	7,500 (80,510)

The basic principles for stable operation in both normal and abnormal conditions and the optimization of environmental aspects of the system in the future are given as measures of improvement in reliability, such as maintaining the rated system voltage and frequency and reducing failure incidents, etc, with feasibility studies for annual investment and composition of the power system. To establish the optimal system plan, the Korean power company has been making use of computer program packages such as EMTP (Electromagnetic Transient Program) and PSS/E (PTI Power System Simulator) etc., for load flow studies, dynamic analysis, and to locate faults. Nowadays, the selection of substation sites and transmission line routes is becoming more difficult due to civil petitions and environmental problems, etc. Based on its mid- and long-term plans, KEPCO chooses the most suitable site considering economic effects, the environment, operation and maintenance conditions, the possibility of expansion in the future, and construction cost, etc.

When constructing transmission and substation facilities, KEPCO takes all possible measures to ensure preservation of the environment. After deciding upon the most suitable construction site, KEPCO requests the government (Electric Power Bureau of Ministry of Trade Industry & Energy) to approve the facility’s construction plan. KEPCO is required to submit the cadastral map, a map of the construction area, the general arrangement plan, a list of the land’s owners, and the land’s purchasing plan.

As sensitivity to civil rights increases, more arguments against electric power facilities, namely the NIMBY (Not In My Back Yard) phenomenon, are being made. Despite these numerous difficulties, KEPCO continues to purchase land for transmission and substation facilities, while establishing a feasible plan of land usage in conjunction with the land's owners. That plan of land usage broadly covers environmental issues and regional society development, as well as fundamental land usage.

Transmission lines will be continuously expanded with multi-conductors, which may be 2 or 4 bundles of ACSR (Aluminum Conductor Steel Reinforced) 480mm^2 per single phase in 345kV lines, 2 bundles of ACSR 410mm^2 per single phase in 154kV trunk lines and single or doubles of ACSR 410mm^2 or 330mm^2 per single phase in 154kV branch lines.

2.6. SCADA

According to the EMS (Energy Management System) and SCADA system plans shown in Fig. 2-5, the Korean power system has a 3 level hierarchical structure comprised of a Central Load Dispatching Office (CLDO or EMS), a Regional Control Center (RCC or SCADA) and a Local Control Center (LCC (or M-SCADA). SCADA's major functions are presented in Table 2-6. First, the responsibility of the CLDO is to give out dispatches and the operation of the 345kV power network, frequency control, economic dispatch, and control of the operation plant units except small hydro power plants. Second, the responsibility of the RCC is to manage all the 154kV power network facilities and small power plants, which are not controlled by the CLDO.

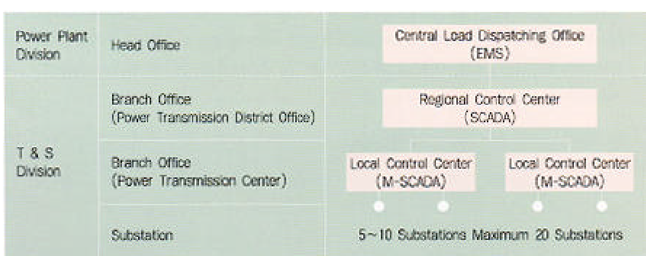

Fig. 2-5 Conceptual diagram of EMS and SCADA system plans.

Table 2-6 SCADA major functions.

Major functions	Items
- Remote supervisory for power system's operation	- Circuit breakers and disconnection switches - Protection relay's operation - Alarm occurrence
- Remote control of unmanned substations' equipment	- Circuit breakers and disconnection switches - Transformer tap changers - Static condenser - Control panel switches
- Tele-metering	- Line Voltage, Current and Bus Voltage - Watt, Var - Oil temperature and wire temperature of transformers
- Event logging	- Circuit breakers' and disconnection switches' operation - Alarm due to network faults - Alarm due to system faults - Alarm due to equipment's erroneous action
- Report generation	- Daily, monthly, and/or yearly reporting
- Dispatcher training function	- DTS (Dispatcher Training Simulator)
- Data link	- EMS-SCADA: network status, network load current - SCADA-SUB SCADA: 154kV substation status, load current

KEPCO introduced the SCADA system in the RCC in 1981 and had it installed in 9 PTDO's (Power Transmission District Offices).

Third, local control centers are installed in power transmission centers. They monitor and operate remote unmanned substations. By the end of 1996, 28 LCCs (Local Control Centers) had been established. There are ten SCADA systems. The M-7500s were KEPCO's first SCADA generation system and are now being replaced with the new system, XA-21. The M-9200 is the second-generation system and is still in operation in three sites (NamSeoul, Kwangju, and Taegu). The XA-21 is the newest system; KEPCO considers it the next generation SCADA system and the standard SCADA system model. The TADCOM-5000 and TADCOM-Xs are Korean made systems located in two small RCCs (Changwon and Jeju) and 29 SCCs (Sub Control Centers). The major supplier for KEPCO's SCADA system is the HARRIS corporation in the U.S.A. It supplied a total of 12 systems (including replacements), and the replacement XA-21 for the RCC at Jecheon will be finished in December 1998. It is the basic policy of SCADA systems that KEPCO adopts the DOAS (Distributed Open Architecture System) complying to the specifications of IEC 870.1 or ANSI/IEEE C37.1.

3. Technical issues

The technical issues of the Korean power system are fault current problems, secure system operation, voltage regulation problems in metropolitan areas, and transient stability problems.

3.1. Fault current problem

As power plants become bigger and power systems are multiply connected, the fault current exceeds the limit of circuit breaker capacity. So, the separation of buses is inevitable—which lowers system reliability. Presently (March 2001), 6 345kV substation are operated in separation and 50 154kV substation and transmission lines are in separation, but as the system load increases, we must check the limit of the present state. So, tests are performed to investigate the limit of the fault current. The circuit breaker capacities used in this test are shown in the following Table 3-1. Mid-term and long-term fault current tests have been performed under the following premises. In the 345kV system, SeoIncheon CPP (Combined Power Plant) is composed with a transposed line; Incheon TPP (Thermoelectric Power Plant) is operated in 2 bus operation; Hwasung, Hadong, Boryong, DongSeoul, Chongyang, BukBusan, ShinKimhae, ShinYangsan, Wolsung, and Wooljin are in bus separation; and ShinSiheung-Pyungtaek, SeoSeoul-Asan, Gori-ShinYangsan, and Bukbusan-ShinYangsan are in line separation.

Table 3-1 Circuit breaker capacities (in kA).

Voltage (kV)	**765**	**345**	**154**
Capacity (kA)	50	63/40	50/31.5

In the 154kV system, independent 154kV loop systems of each 345kV substation are operated. The fault current tests reveal that some buses have the risk of over current and the number of buses that exceed the circuit breaker's capacity is shown in Table 3-2. In this test, the standard capacity of a circuit breaker is 40kA in the case of a 345kV bus and 50kA in the case of a 154kV bus (some circuit breakers' capacity is 31.5kA in a 154kV substation). As a countermeasure for this situation, we have planned to install larger capacity circuit breakers (63kA for 345kV, 50kA for 154kV) and series reactors near risky buses.

Table 3-2 Number of buses whose fault current exceeds circuit breaker's capacity (in kA, site).

Year	2001	2005	2010
	No. of buses	No. of buses	No. of buses
345kV	-	6	7
154kV	8	25	27

3.2. Secure system operation

Large power plants are located far from metropolitan areas possessing massive loads (about 42% of total loads), so reactive power loss is increased due to long distance transportation. Northward power flow goes through six transmission lines: Asan, Seocheong, ShinJecheon, ShinYongin, Wooljung, and ShinDangjin-ShinYongin T/L (March 2001). In this situation the security of these areas is a severe operational problem of the Korean power system. We must prevent overload of transmission lines and maintain a voltage profile of this area. There are some criteria for this. The overload situation must not exceed 100% of the nominal value in a normal situation and 120% in an abnormal case, and the voltage can't be lower than 0.975p.u. in a normal situation and 0.925p.u. in an abnormal case. The limit of northward power flow is set up to prevent the overload of facilities and to maintain the voltage profile of the metropolitan area in both cases of normal state and simultaneous trip of 2 lines of the 345kV transmission line. The limit of northward power flow (year 2001) is investigated under the following conditions. Constant demand (generation for the metropolitan area is decreased and that for other areas is increased) is assumed, and the total load is 43,465MW (average p.f.: 91%).

3.3. Voltage regulation problem

To prevent the problem which causes the system voltage to rise during off-peak times because of the continuous expansion of the EHV system and underground power lines, the power system in South Korea has installed shunt reactors with a unit capacity of 30MVA on the tertiary side of 345kV transformers and of 100MVA or 200MVA on the 345kV bus or line to keep the system voltage within limits. The 345kV substations include 2 or 3 banks of shunt reactors. Static condensers have also been installed at 154kV substations in order to compensate for the voltage drop of the system during heavy load periods. At the end of 1996, the total capacity of the static power condensers and the shunt reactors reached 4,870MVAR and 3,270MVAR, respectively. The regulation of distribution line voltage at the T&S Division has adopted automatic ULTC operations in order to maintain a constant voltage level.

3.4. Transient stability

The most typical stability problem of power systems is transient stability. We investigate the transient stability of the Korean power system under the following premises. Faults assumed in this test are bus 3-phase shorts and simultaneous trip of two lines of the main 345kV T/L. Fault duration time is set to 6 cycles and simulation time for transient stability is 5 sec. The results of simulation for transient stability are given in Table 3-5.

Table 3-5 Simulation results for transient stability.

Tripped line	Initial flow (MW)	Angle (degree)		Stability
		Initial	Maximum	
SeoIncheon ~ Yangju T/L	1,611	74	100	Stable
SeoIncheon ~ Incheon TP T/L	808	74	85	Stable
Incheon TP ~ ShinIncheon T/L	1,171	74	86.5	Stable
Pyungtack ~ Hwaseong T/L	1,139	74		**Unstable**
ShinDangjin ~ ShinYongin T/L	1,260	74	115	Stable
Cheongwon ~ ShinYongin T/L	585	74	87	Stable
Boryong TP ~ Asan T/L	958	74	99	Stable

This shows that if some 345kV transmission lines near power plants are tripped, transient stability cannot be assured.

4. Conclusion

This paper presented the power system and technical issues in South Korea. Power transmission voltages are 345kV on major networks and 154kV or 66kV in local systems. Most 66kV lines are now either being removed or replaced by higher voltage lines. 765kV facilities are now being constructed, to be operated from 2002, to transmit large power stably between large-power generation plants and customer areas to meet the rapid increase in power demand in the metropolitan area. The power system on Jeju Island is now connected to the mainland via a 100km-long submarine transmission system of HVDC (High Voltage Direct Current) cables. Power transmission networks and substations are monitored and controlled by SCADA (Supervisory Control And Data Acquisition) systems.

To prevent the problem of the rise in system voltage during off-peak times because of the continuous expansion of the EHV (Extra High Voltage) system and underground power lines, the power system in South Korea has been equipped with shunt reactors and static condensers. For regulation of distribution line voltage, automatic ULTC (Under Load Tap Changer) operation has been adopted to maintain a constant voltage level.

The Korean government has decided to introduce competition into the electric power industry sector to increase efficiency and transparency and to attract the participation of the private sector. Using the evaluation of KEPCO's management system from 1994 to 1996 and incorporating public opinions, the basic plan for the restructuring of the electric power industry was announced in January 1999. In accordance with this basic plan, the Korean government established the new Act on Promotion of Restructuring of the Electric Power Industry and revised the Electricity Business Law in December 2000. By December 2002, the electric power market will be operated through a cost-based generation pool. The two-way bidding pool (wholesale competition) will start in January 2003, and finally retail competition will begin in January 2009.

Large-scale power plants have been constructed in the southern area of Korea. The metropolitan area in central parts of Korea has consumed nearly of 42% of the total electricity generated. Multiple routes of connection networks were established to supply the metropolitan area, and large-scale power flows relatively northward. The size of the transmission system was increased, so that some buses must be operated separately. The reliability of the system has been taken into consideration in the planning stages to improve system reliability. The northward power flow should be restricted for the security of the supply in a metropolitan area, and this constraint should be investigated under various operating conditions.

The transient stability of the system should be examined under severe cases such as 3-phase fault and the simultaneous trip of major two-transmission line. Some simulations show that a fault on a major transmission line can cause system instability.