Korea Corner

765kV Transmission Technology Development in Korea

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1. Introduction

The historic 765kV age began in Korea on May 8, 2003, when operation of 765kV double-circuit transmission lines, the highest voltage in Asia, was started for the first time in the world from Dangjin to Shinansung, 115 years after the first electrical bulb was lit in Korea Kyongbok palace in Seoul.

The opening of the era of 765kV Extra-High Voltage (EHV), which we refer to as the power transmission highway, was a significant event for the Korean power industry in that it represented a major upgrade in technology.

Due to economic development and improvement in living standards around 2003, Korea was showed an annual increase in the demand for electricity of around 8%. Just as highways need to be built for smooth traffic flow, in a small-sized and densely populated country like Korea, the construction of 765kV transmission lines to transmit power from generation plants to end users was imperative.

2. Current Status of 765kV Facilities

2.1 Worldwide 765kV Facilities

Power transmission at the 700kV level began in 1965 when Hydro-Quebec of Canada transmitted 500MW of power generated at the Churchill Falls Hydro Plant to Montreal using a nominal voltage of 735kV and a maximum voltage of 765kV. American Electric Power started transmitting power at a nominal voltage of 765kV and a maximum voltage of 800kV in 1969. Since then, 765kV transmission lines of nominal voltage have been introduced in other areas such as New York (by NYPA), Brazil, Venezuela, and South Africa. In Eastern Europe, Poland and Hungary started to operate of 750kV transmission lines of nominal voltage in the 1970s in order to receive power from the former Union. Recently, China and India also developed 765 kV and 1,000kV transmission lines.

▸**Worldwide 765kV Power Transmission**

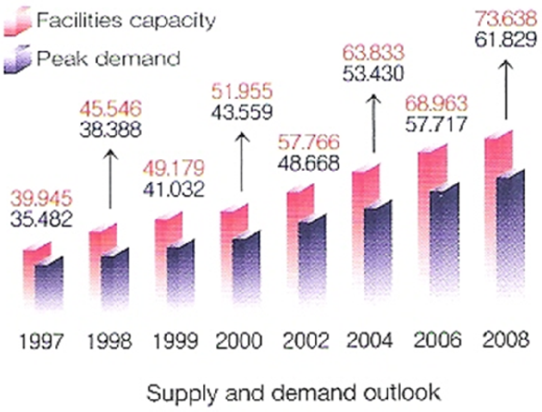
Country	Enhanced voltage (kV)	Year	Transmission Distance(km)
USA	345→765	1969	300
Russia	750→1,150	1985	2,000
Canada	315→735	1965	600
Japan	500→1,000	2000	250
Brazil	375→750	1982	900
South Africa	400→765	1988	440
India	400→765	2000	450
Venezuela	400→765	1984	650
Poland/ Hungary	400→765	1986	114
China	500→750→1,000	2009	640

2.2 Reasons for Introducing 765kV Facilities to Korea

Owing to the rapid economic development of Korea, there was a significant yearly increase in the demand for electricity of around 8%. Energy consumption per person was also rised steeply on an annual basis. In Korea, the area with the largest increase in electricity demand is concentrated in the Seoul-Gyeonggi Province region. However, it is difficult to construct a new power plant in this densely populated area. Therefore, bulk transmission lines are required to transport power from Central Korea or Kangwon Province, where large-scale power plants are located, to the Seoul-Gyeonggi area. Accordingly, Korea commenced preparations to upgrade the voltage class to 765kV in 1979, and research and development for 765kV began in 1983. In October 1997 the first 345kV line was energized with 765kV. On May 8, 2003, history was made when 765kV power transmission commenced. 765kV transmission lines in Korea are the first in the world to use vertical double circuit tower types, which have twice the transmission capacity of the horizontal one-circuit types used in other countries.

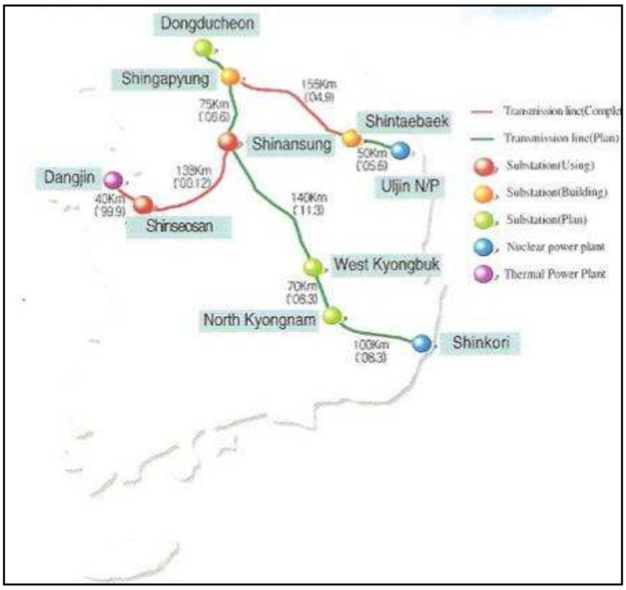
Around 2003, 765kV transmission lines extending 340km, from Dangjin Thermal Power Plant through Shinseosan to Shinansung (178km), and from Shintaeback to Shingapyung(162km), were completed; and currently, there are plants build more transmission lines,

▸**765kV Test Line in Gochang KEPCO PT Center**



▸**Power demand in Korea**

including a transmission line extending from Shinansung-West Kyongbuk-North Kyongnam-Shinkori Nuclear Plant. Also 765kV single circuit line was completed on July, 2010.



▸**Route of 765kV lines**

2.3 Effects of Upgrading the Voltage of Transmission Lines

- Solves misdistribution problems in the Seoul-Gyeonggi area
- Minimizes land required to build transmission facilities and substations
- Reduce electricity losses
  - Enhances the stability of the power network
- Improves international competitiveness by improving technology in the power industry

3. Advantage of 765kV Transmission System

3.1 Effects of Upgrading the Voltage of Transmission Lines

765kV transmission lines have 5 times the transmission capacity of 345kV lines. This is of great advantage for effectively utilizing land, as it decreases sites for transmission towers and right-of-way.

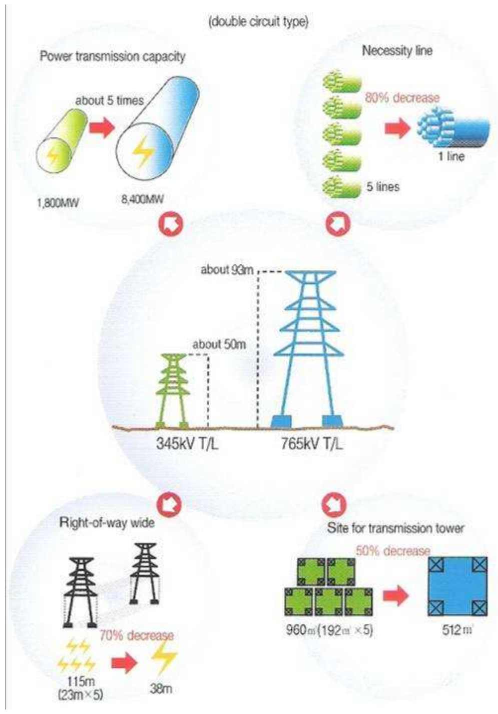
3.2 Minimizes Loss of Power during Transmission

Loss of power during transmission is inversely proportional to the square of the voltage, hence if voltage is raised from 345kV to 765kV, loss of power decrease 20%.

3.3 Saves Constructional Cost

If transmission capacity is taken into consideration, 765kV transmission lines save construction costs per KW by 74% compared to 345kV lines.

Division		154kV T/L	345kV T/L	765kV T/L	
		Double circuit	Double circuit	Double circuit	Double circuit
Transmission capacity		480 MW	1,800 MW	8,400 MW	4,200 MW
Losses		1.2%	0.26%	0.05 %	0.05 %
In terms of Capacity	Number of lines	18	5	1	2
	Site area (m^2)	2,304	960	512	760
Construction cost in terms of transmission capacity			650₩/kW	480₩/kW	



▸**Advantages of 765kV Transmission System**

3.4 Environmental Friendly Design

765kV transmission lines were designed and constructed to be environmentally friendly after extensive experiments, including assessments of audible noise from corona, radio, noise, electric field, magnetic field, and Aeolian noise, using full-size test lines. The Gmax of KEPCO 765kV transmission lines with that of 500kV and 765kV lines of other countries. Gmax functions are an important factor in environmental problems, the lower the Gmax, the less the electrical environment is affected.

4. Facilities for 765kV Transmission

4.1 Conductor

The Power line is the medium that actually transmits electric power. It must have high conductivity, great mechanical strength, low density, and durability. Bare wires are used in 765kV lines because heat is generated, and ACSR (Aluminum Cable Steel Reinforced) is the most commonly used conductor type. ACSR is made by twisting hard-drawn aluminum wires, which have relatively high conductivity (about 61%), around galvanized steel wires, which have high ultimate tensile strength ($125kg/mm^2$). Most electricity flows through the aluminum core and the cross section and resistance of the stranded wire is calculated for the aluminum part only. Compared with hard drawn copper stranded conductors with the same resistance, the outer diameter of the conductor is larger, and is more effective in preventing corona, making ACSR advantageous for high-voltage transmission lines.

After a comprehensive review of RI/TVI, corona noise, transmission capacity, and maintenance of appropriate height level, ACSR $480mm^2$ Cardinal 6 conductor bundle, which is stronger than ACSR $480mm^2$ Rail generally used in 345kV transmission lines, was chosen for the 765kV transmission lines. ACSR/AW conductor was chosen for the Dangjin Thermal Plant, which is closed to the coastline, to prevent wires from corrosion.

Kinds of Conductor	ACSR $480mm^2$ (Cardinal)	ACSR/AW $480mm^2$ (Cardinal)
Composition of conductors	Al 54/3.38 St 7/3.38	Al 54/3.38 St 7/3.38
Calculated diameter	Al 484.53 St 62.81	Al 484.53 St 62.81
Tensile load (kg)	15.300	15.300
Outer diameter (mm)	30.42	30.42
Weight(kg·km)	1.836	1.760
Modulus of elasticity	7.987	7.565
Coefficient of linear expansion($10^6/^oC$)	19.53	20.5

4.2 Insulator

Insulators are used to support insulation between power cables and towers, and it also used to insulate them electrically. An insulator is used outdoors and hence it must have good electrical and mechanical qualities under unfavorable weather conditions such as wind, rain, salt, dust, and snow. It must also have sufficient electric surface resistance while leakage current must be sufficiently low.

Corona discharge should not occur at rated voltage, and insulators must not be damaged or destroyed if arc or corona discharge occurs on the surface.

There are many different types of insulators, such as porcelain, glass and composite. The 765kV transmission lines use porcelain insulators.

4.3 Spacer Damper

765kV lines use multiple sub-conductor types, which have the characteristics of corona reduction and are better for improving line constants. 6 conductor bundle types are used in KEPCO 765kV. In such cases, spacer damper is used to prevent conflict between sub-conductor, maintain distance between sub-conductors, and prevent damage that might be caused to wires by oscillations due to wind and electromagnetic force. Spacer dampers used in 765kV transmission lines were developed in Korea and they are used on all lines.

4.4 Steel Tower

A 765kV steel tower weights over 200 tons and their height ranges from 80 to 150m. If angle type tower is applied to such huge structures, complex components must be used, which is very difficult to construct and repair. Therefore, steel pipe members, which can be applied as a single member, were used as the main member and diagonal member. Angle components were used in only tower arm parts. For the foundations, which must be constructed in rugged mountain areas, reliable deep foundations were used.

4. Researches on 765kV Transmission System

4.1 Air Insulation Test

Air insulation tests were conducted using 4MV outdoor impulse voltage generators to test full size suspension insulators. The results of the tests were used when designing the 765kV steel towers, for determining how many insulators to use and for designing air insulation clearance. They were also used when deciding the design levels of various 765kV devices, such as BIL (Basic Impulse Level) and BSL (Basic Switching Level) of the transformers; the TRV (transient recovery voltage) of HSGS (High Speed Ground Switch), circuit breakers and the rating of the lightning arresters.

4.2 Transmission Line Oscillation Test

Full size transmission line oscillation test facilities are used to test the oscillation of overhead transmission liens. They are also used in assessing the oscillation of the 6-conductor bundle type and to test methods of applying spacer dampers for overhead transmission lines.

Oscillation Test Facilities

- -3 arch type steel towers, CCTV set for oscillation observation
- -Equipment for recording and analyzing oscillation data
- -Tension measurement system and load cell
- -Meteorological observation equipment, such as anemoscopes, anemometers, and thermometers
- -Sensors for oscillation measurement

4.3 Electrical Environmental Simulation Tests using Corona Cage

A corona cage was used to conduct simulation tests for evaluation of the environmental effects of 765kV transmission lines and for choosing candidate conductor types. Many types of tests can be conducted efficiently and economically with a corona cage, because the conductor used in the test and applied voltage can be altered easily, and because the conductor surface voltage gradient can be increased with low voltage increments.

The corona cage is used for studies on phenomena such as corona noise and radio wave interference, which are the most important factors when designing the conductor for 765kV transmission lines.

4.4 Leakage Current Measurement System : LCMS

Experimental outdoor stations for long term testing of EHV (Extra High Voltage) insulators were constructed. LCMS which can measure and acquire the tendency data of leakage current of EHV insulators in real time was developed and used for research. EHV insulator experimental facilities have been utilized for long term reliability assessment of EHV insulators through leakage current tendency analysis which considered environmental factors and different characteristic of EHV insulators.

4.5 TV Wave Interference of 765kV Transmission Lines

When incoming TV waves occur in large scale transmission lines such as a 765kV 6-conductor bundle transmission line, TV waves are usually reflected or shielded by the conductors and consequently TV wave interference occurs.

TV wave interference is a problem that directly affects residents near transmission lines. Therefore TV wave reception before and after the lines were built was measured and compared to check whether the transmission lines have caused additional interference. Appropriate measures for each region are then recommended. Technical support has been offered to solve potential civil petitions under construction of transmission line.

5. Conclusion

KEPCO have been operating single circuit 765kV and Double circuit 765kV transmission Lines for the first time in the world since 2010 by more than 15 years development research. This KEPCO 765kV double circuit technology is very economic and useful for transmission utility. Therefore the KEPCO 765kV electromagnetic interference technology was selected as a standard of IEC TR CISPR 18 on June, 2010. KEPCO will continue to develop more effective and safe maintenance technology for 765kV system and also to develop +/- 500kV Class HVDC transmission technology.

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