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KEPCO

KAPES KEPCO and Grid Solutions Joint Venture

## Study Committe B4

DC System and power electronics

Paper ID_10584

# ±180 kV, 300 MW KEPCO BP1 Haenam–Jeju HVDC Scheme Refurbishment – Key Features and Execution Experiences

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## Summary

This paper presents the key features and execution experience of the ±180 kV, 300 MW Haenam–Jeju HVDC refurbishment project. The Haenam *(Figure-1)* –Jeju *(Figure-2)* HVDC system is owned and operated by Korea Electric Power Corporation (KEPCO) and originally supplied by GEC Alsthom.

*Figure-1 Mainland*

*Figure-2 Island*

## Key Features

- 101-km-long Bipole submarine cable connection between the Korean Peninsula and the island of Jeju in South Korea (BP1)
- This HVDC system has been in service since the 1990s
- BP1 intend to supply power from mainland of South Korea to island Jeju
- Heavily utilized since the BP1 went into operation
- Major components to be upgraded are converter valves and associated base electronics system
- New network studies to evaluate impact of change in AC network data due to additions of significant renewable generation, mainly wind
- Modifications of control functionalities to coordinate with additional second Bipole link (BP2)
- Updates in control & protection (C&P) to enhance reliability and availability of scheme
- Refurbishment of BP1 link while minimising outage duration for installation, pre-commissioning, and commissioning

## Introduction

- A 400 MW HVDC submarine line (BP2) was install in year 2014 to meet increased energy demand on Jeju Island due to increase in tourism
- Control system of BP1 had already exceeded its design life by 7 years so KEPCO decided to upgrade the BP1 at same time *(Table 1)*
- Thyristor valves and its auxiliaries in BP1 also approaching to its maximum design life *(Table 1)*
- For stability reasons of AC Network, replacement scope extended by KEPCO to additional devices

| Main equipment | Design life | Excess years |
|---|---|---|
| Control systems | 15 Year | 7 Year |
| Thyristors valves and its auxiliaries | 30 Year | coming in 2024 |

*Table 1 – Design life of main equipment (based on 2017)*

## Scope of Supply

Following scope of supply was included as part of this refurbishment project:

- Converter valves and associated base electronics system
- Valve cooling system
- Valve protection arresters
- DC measurement devices
- Control and Protection system for AC and DC system
- Auxiliary/back up power supply
- Additional switchgear/bus-works for metallic return operation (MR)

## HVDC System Configuration

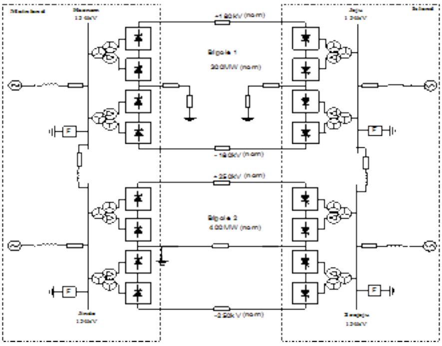

*Figure 3 - Original HVDC system configuration on Jeju Island for Bipole 1 and Bipole 2*

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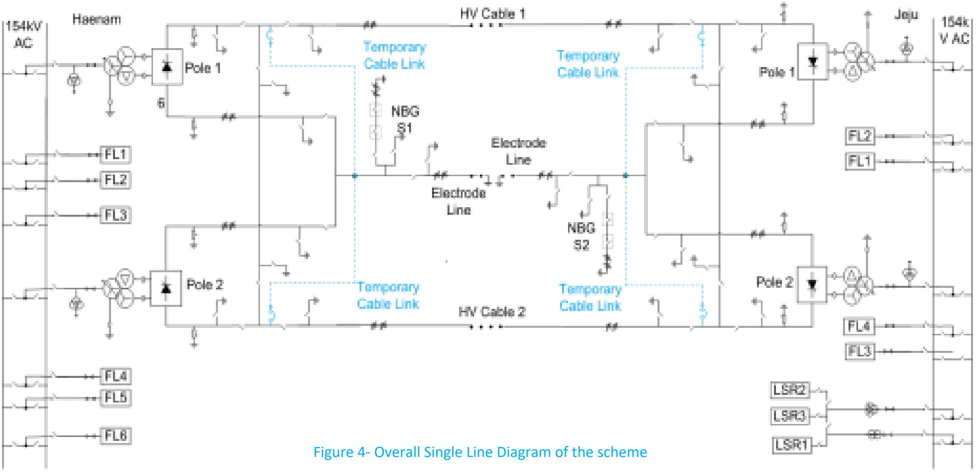


Figure 4- Overall Single Line Diagram of the scheme

## Scheme Overview

- Overall single line diagram is shown in *Figure 4.*
- Two converter stations are connected to 154 kV AC feeders at Haenam and Jeju.
- Originally designed to operate in ground return mode during monopole operation
- Upgraded to metallic return operation during a long-term outage of one pole converter
- A temporary cable link is permanently installed to enable this metallic return upgrade
- The DC connection comprises of two HVDC cables of 101 km, and electrode lines of 15.92 km and 13.39 km at Haenam and Jeju respectively.
- Transfer buses are provided *(Figure 4)* to allow one HV Cable to be acted as neutral line for either pole.
- Disconnectors on either end of electrode line for isolating it from pole to enable maintenance

## DC Circuit Configurations

The scheme can be operated in the following DC Circuit configurations:

- Bipolar (BP) Operation using sea returning via electrode
- Bipolar (BP) Operation using NBGS
- Monopole Ground Return (MGR) Operation with its own conductor (either pole)
- Monopole Metallic Return (MMR) Operation with its own conductor and returned through another pole conductor (either pole)
- Monopole Ground Return (MGR) Operation with faulty converter conductor via transfer bus (either pole)

## Main Scheme Parameters

| Parameter Description | Haenam | Jeju | Unit |
|---|---|---|---|
| Steady State AC Voltage range | 154 ± 10% | 154 ± 10% | kVrms |
| Steady State AC Frequency | 60 ± 0.2 | 60 ± 0.2 | Hz |
| Maximum Short Circuit Current for equipment rating | 50 | 50 | kArms |
| Minimum Short Circuit Level | 1500 | 1300 | MVA |
| Nominal DC Power per pole (Rectifier DC Bus) | 154 | | MW |
| Nominal DC Voltage per pole (Rectifier DC Bus) | 184 | | $kV_{dc}$ |
| Nominal DC Current per pole | 840 | | $A_{dc}$ |
| Maximum Overload for 5 second | 1.8pu of DC Current | | - |
| Minimum Steady State Rectifier Firing Angle | 15 | 15 | ° |
| Minimum Steady State Inverter Extinction Angle | 19.5 | 19.5 | ° |
| Converter Transformer Parameters: | | | |
| Vector Group (Three phase three winding)<br>Rated Power<br>Rated Valve Winding Voltage<br>Base Impedance (@ Rated)<br>Taps | YN/y0/d11<br>188.2/94.1/94.1<br>79.2<br>0.12<br>±14 | | -<br>MVA<br>$kV_{rms}$<br>pu<br>% |
| HVDC Smoothing Reactor | 60 | | mH |
| Number of thyristors per valve | 26 | 28 | |
| Installed Reactive Power | 6 x 27.5 | 4 x 27.5 | MVAr |

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## Continued

## Control Concept

- DC Voltage Control by firing angle regulation for both rectifier and inverter operation
- Tap Changer Control (maintain valve winding voltage within specified range)

Under Steady State:

- Jeju station will control the DC current to maintain constant nominal DC power at the rectifier terminals.
- Haenam station will maintain the DC voltage of the rectifier DC terminals at a target value

## Valve Design Description

- Old generation valves are replaced by a recent modernized design of valves
- In latest generation valves, valve module *(Figure 5)* has 40% less footprint than its predecessor
- Thyristor is a 100 mm, 8.5 kV electrically triggered device
- Direct liquid cooling is used which enable a single-circuit system with coolant (pure deionized water or water/glycol mix)

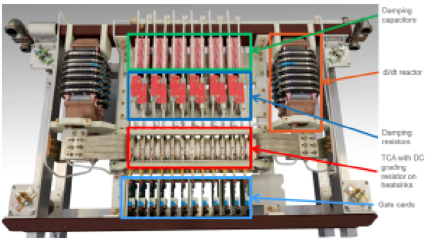


Figure 5 – Valve Module

## HVDC Control & Protection System

- Frequency control modified enabling coordination with BP2 frequency controller
- For fast constant frequency control, current control is provided at Jeju Island for bidirectional power flow
- Original frequency control was designed with synchronous condenser but new frequency controller is based on deficit power at Island and voltage measurement is at PCC bus.
- Frequency control slope ranging from 0 to 3%
- "Under frequency kicks" have been introduced to enhance the recovery of the island frequency
- Protections are updated to latest algorithms enabling faster fault detection, telecommunications capability between converters
- Cable longitudinal differential protection (CLDP) added to implement cutting edge technology at BP1

## Optimization in Erection Time

- Site survey and 3D scanning of existing construction enabled engineers to provide optimized solution
- Significant reduction in civil work by utilizing existing foundation/structure for various apparatus
- Pre-assessment and verification of roof beams to avoid any catastrophe at site during valve replacement
- Utilization of existing busbar wherever validated
- Decommissioning drawings provided at site before commencing new installation
- 3D model coordination to minimize error (Figure 6)

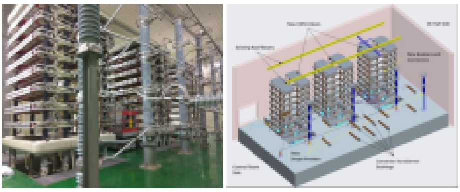

Figure 6 – Old Valve Hall Picture & 3D Model of Refurbished Valve Hall

## Challenges

- Commissioning activities were carried out in stages to maintain power flow by either pole of the Bipole
- Minimise the civil work and optimise the erection and commissioning time
- Replacement of the old non-fire-retardant cables with new fire-retardant cables
- Utilization of existing infrastructure, connection and equipment
- Laying of DC Cable which is used as MR in limited space
- Update in control functionalities to make it coordinate with control of ±250 kV, 400 MW KEPCO BP2 Jindo–Jeju and other generators at Jeju Island

## Notable Improvements

- New generation valves with smaller footprint and better dielectric distances lead to better performance
- Ground return to Metallic Return monopole operation during long outage capability added
- 3 Shunt reactors are no longer required after scheme refurbishment
- New DC measurement devices to increase accuracy and to enhanced performance of the scheme
- 'Gamma Kick' function developed to avoid commutation failure at inverter due to low SCL considering combined operation of BP1 and BP2