



World's First 5-Terminal VSC-HVDC Links

Advanced Solution to Enhance Power Security



Zhoushan group of islands, a highly critical and enormously developing area situated in the southeast coast of China, were suffering from power instability and power failure due to high load demand and weak power inter-connection system. The successful operation of VSC-HVDC links not only interconnects the whole grid, but also provides reactive power compensation and maximally stabilizes the whole grid.

Overview

Zhoushan islands include Dinhai, Daishan, Qushan, Yangshan and Sijiao five main islands. The islands are highly critical and aggressively developing archipelago, which are situated at the south-east coast of China. There were frequent power instability and power failure problems due to high load demand and weak power integration system.

For the past few years, State Grid Company of China(SGCC) is continuously searching a solution to improve the reliability of Zhoushan Grid. Considering advantages of VSC-HVDC, the multi-terminal VSC-HVDC technology was chosen as the final solution. The project was put into service in July, 2014 and is the first and only five-terminal HVDC project worldwide up to date.

Technical Data	
AC Voltage Level	220kV, 220kV, 110kV, 110kV
AC Frequency	50Hz
DC Voltage Level	±200kV
Power Rating	400MW/Dinghai station
	300MW/Daishan station
	100MW/Qushan station
	100MW/Yangshan station
	100MW/Sijiao station
Cable Length	129km submarine cable in total
Converter	5-terminal with MMC

Table 1. System Technical Data

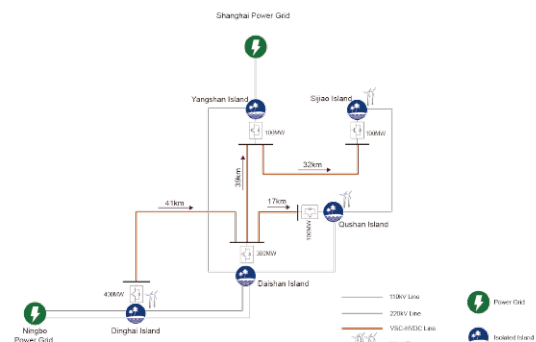


Figure 1. System Diagram of Zhoushan 5-Terminal VSC-HVDC Transmission Project

Existing problems

The total installed generating capacity and peak load demand of Zhoushan islands were 765.3 MW and 818 MW. The estimated power demands will rise to 2649 MW by 2020 and 4775 MW by 2030. Moreover, prior to installation of VSC-HVDC, there were only one 220kV double-circuit line and three 110kV transmission lines connected Zhoushan islands to the mainland. Between Dinghai and Daishan, there was only one 220 kV & one 110kV AC line, whereas only one 110 kV AC line was used for all remaining islands. Weak interconnection and lack of large power sources on the islands make Zhoushan grid a highly unstable grid, which always relied on small generations.

Compared to HVAC and LCC-HVDC transmission, VSC-HVDC possesses several unique features, such as fast control of grids, enhanced system stability, black start function, wind energy integration and reactive power compensation. In addition, VSC-HVDC also offers availability for renewable power integration for each and every island.

NR Solution

In the Zhoushan 5-terminal VSC-HVDC project, NR provided complete solution covering system design, manufacture, test and commissioning. For system design, NR collaborated with Design Institute in consultation with State Power Economic Research Institute (SPERI).



1. System Design

- Research on Zhoushan five-terminal VSC-HVDC main wiring/main circuit scheme
 - Capacity and voltage class of each converter station
 - Zhoushan five-terminal VSC-HVDC transformer type and grounding mode
 - Zhoushan five-terminal VSC-HVDC networking mode
 - Grounding mode of converter station
 - Converter valve topological structure and parameters
 - Start circuit and parameters
 - Transformer selection, tap position and other parameters
 - Power range of converter station
- Operation mode research
 - Research on AC/DC steady state operation mode
 - AC/DC steady-state PSCAD/EMTDC simulation analysis
 - AC/DC transient-state PSCAD/EMTDC simulation analysis
- Control and protection strategy research
 - Five-terminal coordination control strategy
 - Networking island switch strategy
 - Fault ride-through control strategy
 - Five-terminal start/stop strategy
 - Protection strategy: AC failure, DC failure and converter valve failure
 - Black-start control strategy
- Overvoltage and insulation coordination research
 - Operation overvoltage
 - lightning surge overvoltage
 - Lightning arrester configuration
- Transient current calculation and research
 - Converter station layout plan
 - Interface of NR equipment with other equipment

2. Manufacturing

- Design, manufacture and testing of IGBT valves and controllers for the Dinhai, Daishan and Qushan converter station;
- Design, manufacture and testing of control and protection for five terminal stations
- Design, manufacture and testing of electronic measurement instrument for all five terminal stations
- Develop and implement the overall five terminal control scheme
- Valve tower



3. Factory Acceptance Test

- Control and protection system RTDS test;
- Control and protection system function performance test;
- Control and protection system static performance test;
- Control and protection system dynamic performance test;
- IGBT valve support DC voltage test and partial discharge measuring;
- Valve support AC voltage test and partial discharge measuring;
- IGBT valve hydrostatic test;
- Communication test between VBC and modules
- Water cooling system pre-commissioning and load test;
- System start-up operation test;
- Protection tripping test;
- Duplicated equipment switching test;
- System island mode test;
- VSC-HVDC test platform





4. Installation

- Supervise installation of NR equipment including valve tower,
- control & protection cabinets, DC measurement equipment, etc.
Drawings and assistances of subsystem interfaces.



5. Commissioning and Site Acceptance Test

- Check if the performance of system are in accordance with requirements;
- Coordinate and optimize system coordination;
- Test to ensure economic and stable operation of the system;

Client Benefits

Since putting into service, the VSC-HVDC links solves power insufficient problems that it has transferred 390 million kWh to Zhoushan grid by the end of October, 2015. It also significantly improves stability and reliability of Zhoushan grid.

- It increases the amount of power supply and enhances reliability of power grid, especially for the grid systems on the northern islands.
- It improves power quality of whole grid especially on Yangshan and Sijiao inlands where the grid suffers from impact loads attributable to cargo handling at the ports.
- It provides voltage support to the existing ± 50 kV 60 MW LCC-HVDC system on Sijiao island to prevent commutation failure.
- It prevented blackout in squally weather. The VSC-HVDC system operated reliably and adequately when typhoon "Nakri" and "Canhong" swept Zhoushan island in July, 2014 and July, 2015 respectively.

