Case Study

NR's VSC-HVDC Solution

±500kV Zhangbei DC Grid for boosting large scale hybrid renewables penetration

NR Electric Co., Ltd.

Project Overview

A new era in DC grid

On the part of combating the critical issue of air contamination and global climate variations, China is keen on the implementation of a comprehensive renewable energy strategy, as a member-state of the "Paris climate accord (agreement)", China plans to accomplish a monumental milestone of 20% out of the total renewable generation before year 2030. In 2017, China invested at a record breaking level towards sustainable power generation, with the total being around (USD) 132.6 billion worth, making China the leading investor in this sector globally, which is more than twice as large as the world's second renewable market's annual investment.

Along with the ever growing size of the renewable energy sector, the need for a safer, more reliable, higher quality renewable power transmission is also at its peak. VSC-HVDC has become the primary method for renewable power transmission due to its unique advantages.

Zhangbei DC grid emerged as a response to this background, the grid is a 4 terminal VSC-MTDC grid with ±500kV DC voltage rating, each terminal rated as 3000MW/3000MW/1500MW/1500MW, see table one for details.

Table 1 : Basic Information

Rated DC voltage	±500kV
Rated power	3000MW/3000MW/1500MW/1500MW
Topology	Bipolar
Converter technology	MMC
Type of construction	Overhead transmission lines

As Fig. 1 illustrates, Zhangbei region and Kangbao region are the bases for renewable generation, while Fengning will act as a pumped storage plant, providing smooth electricity for Beijing's load centre.

Fig. 1: system schematic diagram

The Challenge

Bulk renewable's penetration in weak AC grid

By year 2020, Zhangbei region (north of zhangjiakou) will have a total renewable generation capacity of 20GW. The "Zhangbei" power grid is located near the end of the "Jibei" power grid, it currently has a relatively fragile grid structural integrity. Furthermore, most of the power generation within the Zhangbei region are renewable energy, thus, making the grid' s short circuit capacity and voltage support capability inadequate, together with a highly fluctuation voltage, when a high volume of green energy connects to the AC grid directly, can result in a very unstable grid-connection for renewable sources, this is also capable of producing more severe effects such as system disconnection and widespread blackout.

In addition, Kangbao region has many PV and wind generation units, facing similar challenges as Zhangbei.

For the purpose of solving the challenges for renewable grid connection listed above, VSC-HVDC became the best option.

- VSC-HVDC does not require AC system' s support from sending end, with its innate reactive and active power control capabilities, can sustain a safe and stable renewable grid connection.
- VSC-HVDC does not face the technical glitches relating to synchronous instability, it can integrate multiple unstable generation sources into one source, and become one stable & continuous output power source.
- VSC-HVDC grid features a highly manageable system, active power imbalances will be filtrated within the HVDC grid, therefore, eliminating the restrictions of renewable distribution, greatly decreases its negative impact on main grid, assisting a compatible grid connection.
- Establishing a HVDC grid network between Kangbao and Zhangbei, multipoint connection and distribution. Accompanied by a pumped storage facility, so minimizing renewable generation' s power frequency fluctuation.

Zhangbei DC grid utilizes overhead lines for power transfer so as to decrease the total construction cost and explore VSC-HVDC' s high voltage, large capacity and long distance power distribution application. In order to minimize its environmental impact, natural line also utilizes overhead lines.

The Solution

Breakthroughs in DC grid technology

1. Wide area hybrid AC/DC study, such as:

- DC grid modelling and simulation, including electromagnetic & electromechanical simulations
- Wide area control strategy study of wind, solar , power storage plant and DC grid
- High frequency oscillation study and restrain measures of renewable penetration through VSC-HVDC
- Stability control strategy in event of severe contingencies, like VSC-HVDC blocks

2. Main equipment design and manufacturing

This project has all equipment as common point to point VSC-HVDC link, including AC breaker & switchgear, converter transformer, starting circuit, converter valve, water cooling system, bridge arm reactor, smoothing reactor, DC switchgear, AC/DC measurement device, control and protection system and etc.

It also will install unique equipment-DC breaker because it' s a DC grid with overhead transmission lines. There are 2 main measures for DC fault clearance: half bridge topology + DC breaker and full bridge topology or topology alike with DC fault clearance capability. By comprehensive technical and economic study, the former is finalized as the final solution. This is the first time that DC breakers are installed in commercial VSC-HVDC link, it is a big milestone for VSC-HVDC development.

Now almost all of the equipment is commencing to manufacture.

Contribution of NR

Give its full support to Zhangbei DC grid

NR besides involves in wide area hybrid AC/DC study, DC grid study and design as fore mentioned, also will provide its state of art equipment & sophisticated management and technical team to Zhangbei DC grid.

1. Control and protection system

Control and protection system is the “brain” of DC grid, NR is awarded to supply protection & control system to all 4 converter stations, including coordinate control system of whole DC grid. The protection & control system is hierarchical structure and fully redundant configuration.

Coordinated control systems are located at Beijing station and Zhangbei station. Beijing station will enact as the primary control station, while Zhangbei station acts as hot standby station, there will be bilateral communication between the two stations. Kangbao station and Fengning station will communicate with the other two station for coordinate control through inter-station communication.

DC coordinate control system illustration see Fig. 2, coordinate control system 1 is in Beijing station, coordinate control system 2 is in Zhangbei station.

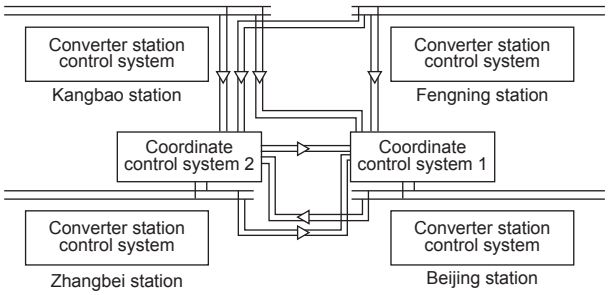
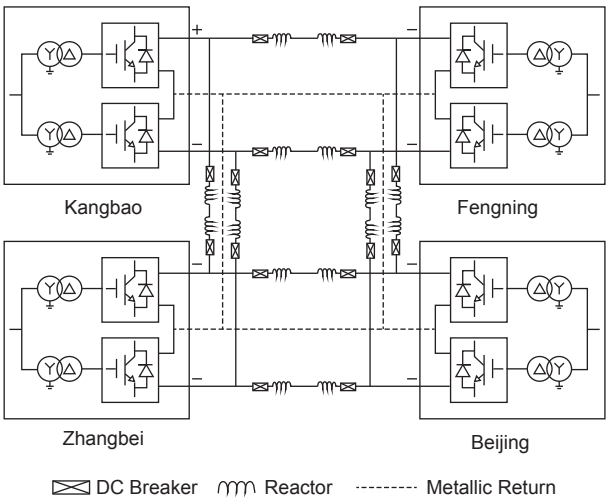


Fig. 2: DC coordinate control system illustration

The basic goal for DC system protection is to quickly disconnect the system from devices with short circuit or abnormal operation, preventing the entire system’ s operation from being interrupted or damaged by those malfunctioning devices. DC system protection is separated into zones based on its intended responsibility; converter transformer protection zone, valve end connection protection zone, converter protection zone, electrode & busbar protection zone, neutral wire protection zone, neutral busbar protection zone, DC power line protection zone and metallic return protection. Arrangements by DC protection system along with correlating devices can ensure the functionalities of DC converter devices, zones and DC related devices within the converter station with all inclusive protection.



2. Converters

Zhangbei VSC-HVDC utilizes 500kV, IGBT, indoor type, water-cooling valves. NR will provide mature and reliable valve towers and water-cooling systems, using compact structure design to minimize footprint.

NR’ s ±535kV/3000MW converter has got type tests verification by DNV GL in 2017. The type test is fully compliance with IEC 62501. All the test items were implemented in NR’ s in-house facilities, including back to back operational testing platform and high voltage testing hall whose testing capability are up to 1650kV AC, ±2400kV DC and 4800kV lightning surge test.

The specific converters for Zhangbei DC grid will also be type tested and routine tested in these testing facilities.

Fig. 3:

Converter Tower

±535kV /3000MW

Fig. 4: type tests verification by DNV GL

NR has carried out detailed design and testing to deliver a line of high performance electronic devices, including:

- Detailed seismic testing
- Redundancy design satisfy the needs of product reliability
- Valve specifications meets the demand for grid operation and future developments.
- Design capable of fault ride through.
- Submodule condition surveillance & warning.
- Rational valve design, dependable operation, easy to conduct maintenance.
- Fireproof design
- Blast-proof design
- Anti-leak design
- Noise reduction and anti-electromagnetic interference design.

3. DC breakers

Zhangbei DC grid will install 16 sets of DC breakers and 4 sets in each converter station.

NR will provide its fully tested DC breaker and water cooling system.

Fig. 4

DC Breaker

535kV

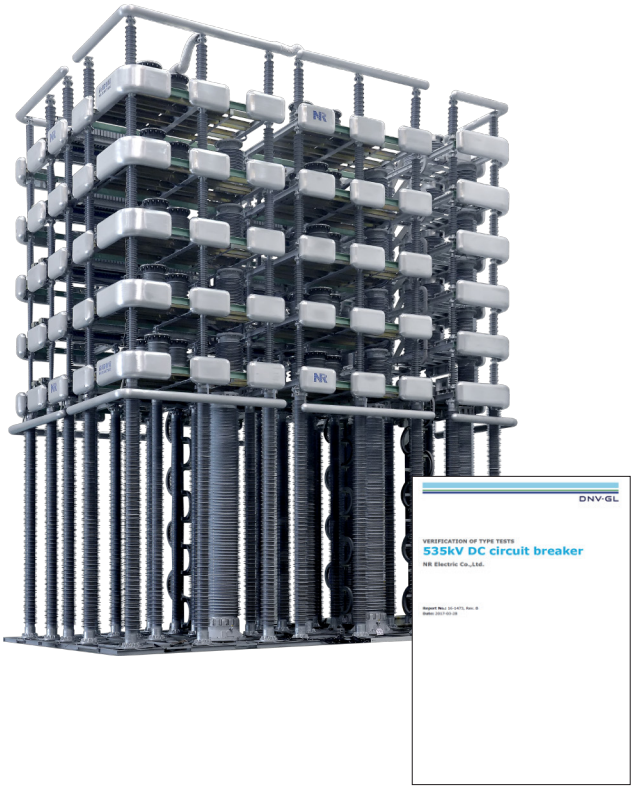


Fig. 6: Type tests verification by DNV GL

Table 2 : Parameter of DC Breaker

Items	Parameter
Rated voltage	500kV
Rated current	3kA
Breaking current	25kA
Breaking time	<3ms

NR' s 535kV DC breaker has got type tests verification by DNV GL in 2017.

NR is not only producing DC breaker, but also manufacturing its own circuit breaker product standard based on Zhangbei DC grid specification and Chinese national standard. This will help to boost the development of international DC breaker standard.
All the test items were implemented in NR's in-house facilities.

4. DC measurement device

Fast overcurrent protection is mandatory for VSC-HVDC converters on account of inadequate overcurrent withstanding capability of IGBT. This is one of the reasons for applying high speed DC measurement devices. The sampling frequency of NR's DC measurement devices is up to 100us which assists to make proper control and protection for DC grid. DC current measurement device in ±800kV Jinhua converter station shown in figure 7, the one for VSC-HVDC has similar appearance.

Fig.7 DC Current Measurement Device
±800kV Jinhua converter station

Benefits and Future Plan

Planned extension to larger DC grid

Zhangbei VSC-HVDC is planned to be operational in 2019, the grid will become a stable and efficient renewable energy distribution channel for Zhangjiakou city and realizing direct power distribution from Zhangjiakou to load centers located within the Northern China region. Effectively solving the absorption and distribution crisis caused by a high proportion of renewable generation within the region, it is estimated to reduce the economic loss generated from solar and wind curtailment for over $50 million. Zhangbei VSC-HVDC' s operation can provide 26TWh of green electricity for the nation's capital region, Beijing and its surrounding area; increase the ratio of green energy consumption in the Beijing-Tianjin-Hebei area. The project will also be providing clean electricity for the 2022 Beijing winter Olympics, achieving the goal of "Green Olympics".

For project' s ambition, Zhangbei VSC-HVDC grid will extend its connections to Chengde, Xilin Gol and other wind/PV power generation plants, furthermore increasing the size of renewable generation connection; simultaneously, there are plans to broaden the grid coverage to suit the consumption need of surrounding load centers such as Tangshan, Tianjin. Building a bigger VSC-HVDC grid network, further increase the ease for renewable utilization, pushing the rate of sustainable depletion inside the energy market to a new level.

www.nrec.com/en

NR Electric Co., Ltd.
69 Suyuan Avenue, Nanjing 211102, China
Tel +86 25 8717 8888 Fax +86 25 8717 8999
NRservices@nrec.com / NRsales@nrec.com