



VSC HVDC best suited for power transmission in Africa

by Dale Pudney, HV Power Systems, and Luo Wei, NR Electric

There are big plans to develop Africa, but those development plans are often stumped by the weak electrical infrastructure and the inability of utilities to supply the power required for the development. Voltage source converter (VSC) HVDC is one of the technologies that is well suited to strengthening the African transmission networks and act as an enabler for economic development.

Most of Africa's transmission networks, outside of South Africa, are operated at a maximum of about 220 kV. Higher voltages or alternate technologies are necessary to meet the power transmission requirements in the near future. Hence there are a number of transmission projects that are being planned with higher AC voltages (e.g. 400 kV) and DC systems.

Limited capacity of existing electrical infrastructure

Africa's transmission systems are often characterised by:

- Long distances between generation and the load centres
- Limited redundancy – radial lines, underrated infrastructure
- Limited capacity – thermal constraints, volt drop limits
- Poor power quality – low voltages, fluctuating voltages, frequent dips caused by faults

Installing reactive power compensation equipment, such as series capacitors, shunt capacitors, and dynamic compensation can maximise the transmission capacity of the existing networks, but often that is not enough for the rapidly growing demands of power hungry developments. Therefore new infrastructure projects are required in order to supply the growing needs.

For the purposes of comparison, we shall consider a case where there is a 220 kV network with a single overhead line feeding a number of load centres. Distances are long (about 700 km) and the network is already under severe stress with the existing

loads of about 200 MW. A new request was received for an additional 300 MW for a new industrial development at the end of the line. It is impossible for the existing network to meet the new demand.

Two technologies have been considered in order to supply this new load:

- 400 kV single circuit AC line linking into the existing 220 kV network at various points
- 320 kV double pole VSC HVDC system linking into the 220 kV system at the load centre

Traditional line commutated converter (LCC) technology HVDC is not considered due to the low fault levels at the load end of the line, and new AC transmission projects have limited benefits and are difficult to implement.

The 400 kV AC solution would comprise of the following components:

- Three 400/220 kV extensions to the existing substations
- Single circuit 400 kV AC overhead line (three conductors)
- Reactive power compensation
- Two to three static var compensators (SVCs) – about 300 Mvar total
- Possibly series capacitor banks

One of the challenges that might be experienced in building the AC solution is the high footprint requirement at the substations and servitude for the overhead lines.

The proposed DC solution would enable the utility to supply the additional load, but as there would still only be two circuits,

there would not be full redundancy to ensure a reliable power supply to all the anticipated loads, since the existing 220 kV system cannot supply the total load.

A VSC HVDC scheme comprising of the following would meet the demands of the growing system:

- Two bipole 320 kV 300 MW VSC converter stations
- One bipole 320 kV DC overhead line with two conductors

The main components of the VSC HVDC scheme are the connection transformer, reactors, start-up resistor, switches, disconnectors, arresters, measuring equipment (ECT/VT), converter valve and the control and protection system. Most of the converter station can be indoors and typically has a much lower footprint. VSC HVDC only requires normal transformers and not converter transformers because the AC waveform does not have high DC components that introduce high stresses as found in LCC HVDC schemes.

The VSC HVDC system offers the following main benefits:

- Strengthening weak AC systems
- Ability to supply passive networks (islands, isolated loads)
- Provide black start capability
- Independent control of active and reactive power
- Statcom function
- Smaller footprint

The proposed system introduces full redundancy, because there are effectively three transmission schemes, which can each supply around 300 MW. Any two of the three schemes can supply the full load. The VSC HVDC system comprises a multi-level converter, where the AC and DC voltages are controlled by the sub-module voltages. The more levels there are the better the sinewave on the AC side. Therefore the multi-level converter also has built in redundancy (with a bypass switch in each module), so that faulty modules can be bypassed, reducing the sine wave quality slightly but continuing to operate.

NR Electric has adopted the floor standing valve tower structure, which has a small and concise structure, with modular

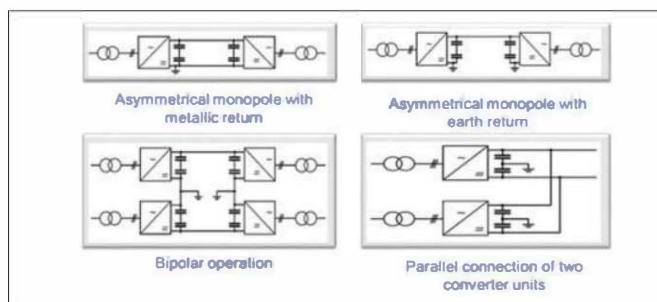


Fig. 1: VSC HVDC transmission configurations.

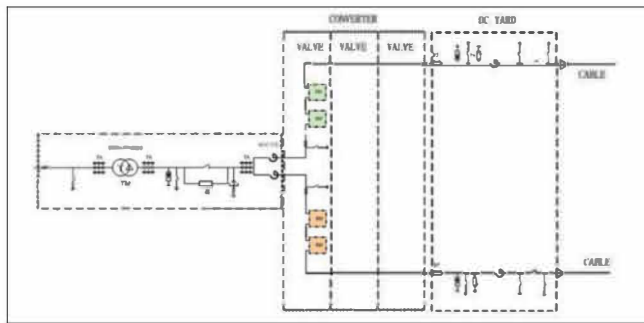


Fig. 2: VSC HVDC main components.

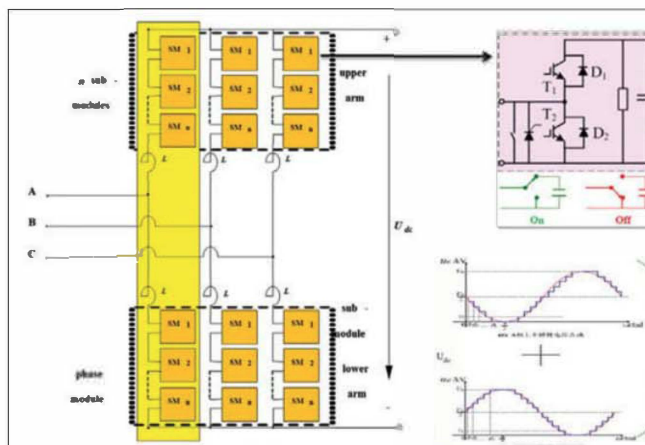


Fig. 3: Multi-level VSC topology.

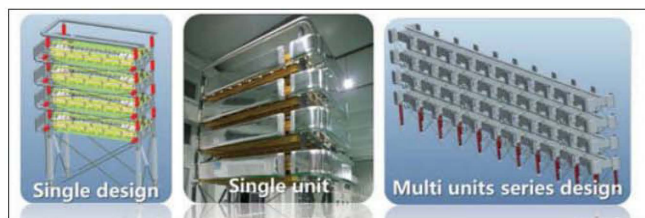


Fig. 4: Valve tower structure.

components that are easy to maintain and replace. The converter valves have been type tested to +320 kV and 1000 MW using the IEC 62501 testing standard.

The valve configuration also increases the flexibility and scalability of the VSC HVDC system with inherent redundancy. Because the system comprises standard components, it is easier to maintain. With many levels, there is a very low generation of harmonics.

Cost benefits of VSC HVDC

There are a number of factors that give VSC HVDC systems a cost advantage over AC systems and LCC HVDC. These include:

- Two sets of conductors on the tower can provide a total 600 MW (or higher) redundant system – this significantly reduces the equipment and footprint costs of the overhead line
- Standard equipment (e.g. transformers)

in the converter station are similar in cost to the step-up transformers required in the AC solution

- Smaller footprint of the converter station and building
- No need for the reactive power compensation (the system provides its own compensation with the statcom function)

The VSC HVDC option therefore tends to be cheaper than the AC alternative and offers more benefits.

Multi-terminal operation

VSC HVDC is well suited to multi-terminal operation, which is one of the main draw-backs of LCC HVDC, where multi-terminal operation is difficult. Multi-terminal operation brings DC transmission closer to the related benefits of AC – enabling city or regional distribution systems using DC technology.

	Su Cheng	Jin Niu	Qing Ao	Ta Yu
Capacity (MW)	200	150	50	50
AC Voltage (kV)	110	110	110	110
DC Voltage (kV)	±160	±160	±160	±160

Table 1: Nanao Island four terminal VSC HVDC scheme.

Converter station	DC voltage (kV)	Capacity (MW)
Dinghai	±200	400
Daishan	±200	300
Qushan	±200	100
Yangshan	±200	100
Sijiao	±200	100

Table 2: Zhou Shan five-terminal VSC HVDC project.

NR Electric has two multi-terminal VSC HVDC reference projects (under construction). The first multi-terminal project connects Nanao Island to the mainland in Guang Dong Province, China and there are four terminals, with an off-shore wind farm on the island.

Table 1 shows the capacity and voltages at each terminal.

The multi-terminal VSC HVDC systems can operate with any of the terminals out of service.

A second multi-terminal project (under construction) is the Zhou Shan multi-terminal VSC HVDC project and it interconnects five islands in the Zhe Jiang Province. Table 2 shows the voltages and capacity at each terminal.

The objective of the project is to:

- Increase the power transmission capacity to the islands
- Improve the power quality and reliability on the islands
- Connect the wind farms on the islands to the network

Conclusion

VSC HVDC technology has matured rapidly over recent years and offers significant benefits over comparative AC power transmission solutions and is also able to be cost competitive. The technology offers an optimum solution to strengthen Africa's weak AC networks for higher power transfer capability, better power quality and better reliability, while augmenting system redundancy. This strengthening of the power system will enable African nations to supply the power demands of economic development.

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