ROLF GRUNBAUM, SIMON VOGELSANGER, ANDERS GUSTAFSSON, JANISSA AREVALO – In recent years, high-voltage transmission networks have been presented with unprecedented challenges. These stem largely from deregulation, a rapid increase in inter-utility power transfers and impediments to building new transmission systems due to economic and environmental constraints. Added to this is the difficulty of controlling the flow of power and maintaining stability, especially when integrating very large amounts of renewable energy (RE) – from remote, offshore wind farms, for example – into the grid. Periods of strong wind or high solar radiation and low load can exacerbate problems. These challenges can be addressed by products such as ABB’s FACTS (flexible alternating current transmission systems) and HVDC (high-voltage direct current) technologies, which allow more power to be transferred in a very flexible, controllable and stable way.
Series compensation requires control, protection and supervision to enable it to perform as an integrated part of a power system. Also, since the series capacitor is working at the same voltage level as the rest of the system, it needs to be fully insulated from ground potential.

The main protective device in the series capacitor is a varistor – usually of the zinc oxide (ZnO) type – that limits the voltage across the capacitor to safe values and protects against any short-circuit currents. A fast protective device is often used to bypass the series capacitor when the varistor cannot absorb excess fault current.

Fingrid, the Finnish transmission system operator, enlisted ABB to install two such series capacitors (301 and 369 MVAr) to help meet internal transmission demands, improve grid stability and boost the export corridor to Sweden by 200 MW → 1.

SVC Light
SVC Light is a STATCOM (static compensator) device based on a chain-link modular multilevel voltage source converter (VSC) concept that is adapted for power system applications. It can deliver...
reactive power to the grid with a highly dynamic response. SVC Light can, for instance, support weak grids, improve large wind farm availability under varying grid conditions and relieve grids in hot countries that are loaded by a large number of air conditioners.

IGBTs (insulated-gate bipolar transistors) are key components of SVC Light. The multilevel chain-link solution is built up by linking H-bridge modules in series to form one phase leg of the VSC branch ➔ 2.

PCS 6000 STATCOM and offshore power transmission
Because the wind out at sea is strong – particularly in the afternoon, when electricity consumption is high – wind farms are increasingly being built offshore.

An offshore wind turbine delivers its power via a platform-based transformer and AC cable to shore, where the voltage is stepped up and the power fed into the grid. The remoteness of the wind generator from the main part of the grid can raise stability and reliability issues, which is why transmission system operators are strengthening grid code requirements – specifically those related to reactive power, voltage control and fault ride-through capability.

FACTS can provide the fast, dynamic voltage control required by these grid codes, whereas conventional, mechanically switched reactive power components such as capacitor and reactor banks cannot.

On top of the usual grid reactance, wind farm transformers and cables add reactance that varies with active power output. These additional, variable sources of reactive power also need to be compensated for. This can be done by using ABB’s PCS 6000 STATCOM.

An SVC can rapidly regulate line voltage and bring it to the required set point.

SVC Light is available for system voltages up to 69 kV and converter ratings up to ± 360 MVAR ➔ 3. For higher voltages, a step-down transformer is used to connect SVC Light to the grid.

To increase the dynamic stability and capacity of their network, Transelec S.A. – Chile’s main transmission owner and operator – decided to install SVC Light. The device is rated at 65 MVAR inductive to 140 MVAR capacitive at 220 kV and is located in the heavily loaded Cerro Navia 220 kV substation in Santiago de Chile. As well as increasing the capacity, SVC Light regulates and controls the 220 kV grid voltage under steady-state and contingency conditions, and provides dynamic, fast-response reactive power following system events.

Series compensation requires control, protection and supervision to enable it to perform as an integrated part of a power system.
The PCS 6000 ensures full grid compliance and dynamic power compensation for any wind farm, and is designed as a compact, modular system for applications up to 38 MVAr per unit.

HVDC Light (VSC technology)

Typically, HVDC is a more cost-efficient technology for transmission of large amounts of power over distances exceeding 600 km by overhead lines and about 50 to 100 km in the case of underground or subsea cables. However, many other factors make HVDC technology (particularly VSC-based HVDC such as ABB’s HVDC Light) the ideal complement for evolving AC grids. For example, HVDC Light systems enable neutral electromagnetic fields, oil-free cables and compact converter stations. Further, they help manage the increasing challenges of renewable energy integration with rapid control of active and reactive power (independently), the provision of voltage support and improvement in power quality. Other advantages – such as black-start capability and the ability to connect to weak AC grids – make HVDC Light especially attractive for grid interconnections and power provision to isolated systems or crowded metropolitan areas. Strong transmission connections contribute to reduced variability and increased forecast accuracy of renewable generation due to the geographical smoothing effect over large areas.

HVDC Light – highest voltage and longest cable

Recently, ABB set an HVDC Light voltage world record with the 500 kV Skagerrak link between Norway and Denmark. ABB has delivered all four of the Skagerrak system’s links: Skagerrak 1 and 2 in the 1970s, Skagerrak 3 in 1993 and now Skagerrak 4. The system spans 240 km and provides 1,700 MW of transmission capacity to enable hydrogeneration and reservoir storage in Norway to be used to balance wind generation in Denmark.

Skagerrak 4 comprises two 700 MW VSC stations. The new link operates in bipolar mode with the Skagerrak 3 link, which uses classic line-commutated converter HVDC technology. This is the first time the two technologies have been connected in such a bipole arrangement. ABB’s advanced MACH control system was used to master the different ways power reversal is handled between the two technologies.

ABB will also deliver the world’s longest extruded HVDC cable – NordBalt, between Sweden and Lithuania. NordBalt (300 V/700 MW) comprises a pair of cables with a total length of 53 km over land and 400 km under the Baltic Sea. The cable route has to pass through formerly mined areas and explosives dumping grounds, as well as pass through a Natura 2000 nature protection area on
HVDC is a more cost-efficient technology for transmission of large amounts of power over long distances.

The 525 kV extruded DC cable system can transmit 50 percent more power over extreme distances than previous solutions (eg, the 320 kV extruded DC system). The technology enables the lowest cable weight per installed megawatt of transmission capacity and the higher voltages provide reliable transmission and low energy losses.

Compared with the 320 kV level, the transferred power given as MW/kgm (power per kilogram of one meter cable) is about double that of a land cable circuit and 50 percent more than a submarine circuit ➔ 6a.

When compared with “classic” HVDC cables with their insulation comprising paper impregnated with a highly viscous oil (also called mass-impregnated or MI cables), the extruded DC cable system has an advantage in terms of MW per kg and meter cable ➔ 6b. Also, jointing time is significantly shorter for an extruded cable system compared with the MI cable.

The trend toward more and larger renewable energy plants is very clear and very strong. FACTS and HVDC technologies will help support interconnected, flexible and reliable grids. Many innovative and sophisticated products are already available to help overcome the challenges involved with RE integration and enhance the power system flexibility and efficiency required to satisfy the ever-growing need for energy around the world. New possibilities will be opened up by new technologies and products, such as ABB’s 500 kV VSC converter stations or the new extruded 525 kV HVDC cable. Advances such as these reflect ABB’s commitment to remain leaders in the development and use of power transmission technologies.

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