AC/DC grids

Concepts and design for mixed AC/DC grids

At a glance

In the last 20 years, the importance of HVDC, long-distance interconnections and back-to-back couplings has increased significantly all over the world. Classic, thyristor-based HVDC systems have been built up to ± 800 kV DC voltage. A new HVDC technology based on voltage source converters (VSC) allows the infeed of active and reactive power, acting like a controlled generator in forward and backward directions.

The increasing installation of large wind power plants, especially off-shore wind parks far away from the shores, requires transporting large amounts of power over long distances where AC solutions are no longer possible or too expensive, and DC solutions are required. Due to reliability issues, in the future the existing point-to-point HVDC connections can be interconnected to form a DC network, integrating several wind farms and AC networks into one system.

Also increasing trading and changes in the electrical power generation structure causes the need to strengthen today's transmission systems. One solution is to build an overlay network using a state-of-the-art, HVDC transmission system forming a meshed DC grid.

Siemens Power Technologies International (Siemens PTI) is a competent partner to develop solutions for new system concepts for such mixed AC/DC grids.

The challenge

Booming mega-cities lead to extremely high load densities in such areas and increase the demand for controlled infeed points. However, such infeed points should not add to the stressed short circuit levels that are often close to the limits already. In addition, VSC-based DC systems can be used to restore a system after blackout from healthy system parts. In case of a severe system fault, HVDC links acting as "system couplers" avoid disturbances from spreading to other system areas by splitting the system and isolating the fault-affected areas.

In many systems, the building of new AC lines is not possible. New ideas to use certain existing AC routes with DC backbones can increase transmission capacity. For example, such a DC overlay grid is discussed in Europe to interconnect off-shore wind parks and to transport the energy to the on-shore load centers.

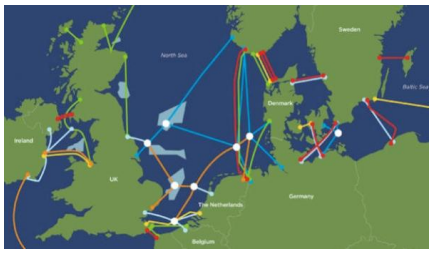

Figure 1: Vision of a European North Sea grid

The future trend will be a combination of AC and DC systems. These hybrid structures need more elaborate control concepts because in these systems point-to-point power transfers are changed into flexible multi-terminal operation with different sending and receiving sources. These sources depend on the actual situation of the system and the generation forecast for PV and wind plants. New control concepts are under development.

Our solution

Siemens PTI is a key partner in the development of new HVDC technologies and applications.

Our services include defining the control concepts of hybrid AC/DC systems and adapting the control behavior to the specific requirements of interconnecting new generation centers to load centers and of interconnecting to the grid, as well as verifying compliance to the relevant grid codes. In brief, ensuring that the overall hybrid AC/DC systems of the future are operating safely and reliably.

Due to our long-term experience with the modeling and analysis of power electronic devices and Siemens' skilled HDVS engineering groups, we have a thorough understanding of the individual components and can help to design complex DC network concepts and hybrid AC/DC system to ensure appropriate and stable behavior.

Based on the innovative Siemens HVDC Plus technology, it is possible to provide solutions for the new demand of DC back-bones, DC/AC infeeding stations and multi-terminal DC systems to collect off-shore wind power and send it to the load centers.

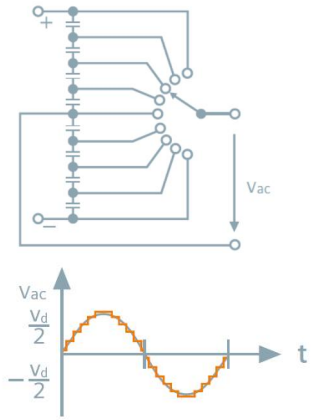

Figure 2: Basic HVDC Plus concept

Siemens PTI is involved in several studies and R&D projects concerning various topics of DC networks, including:

- creating accurate dynamic and transient models
- developing suitable load-flow control methods for the DC network
- calculation of DC short-circuit behavior and stress on the components

Siemens PTI is also involved in working groups of DKE and CENELEC for standardizing the different solutions to provide a thorough basis for DC network development.

Application examples

One major project where Siemens PTI is deeply involved is the German DENA studies. These studies are driven by the German government to analyze the future needs of the transmission system due to increasing share of renewable generation, especially wind farms in the North and Baltic Sea, and the consequences on the German transmission network. Together with the four German Transmission System Operators (TSOs), technologies and concepts have been investigated to achieve an optimal solution for strengthening the network.

One solution under discussion is to build a DC overlay network for long-distance power transmission. The result was a proposal of a DC network completely covering Germany. Additionally, new control concepts have been developed for a safe and stable operation.

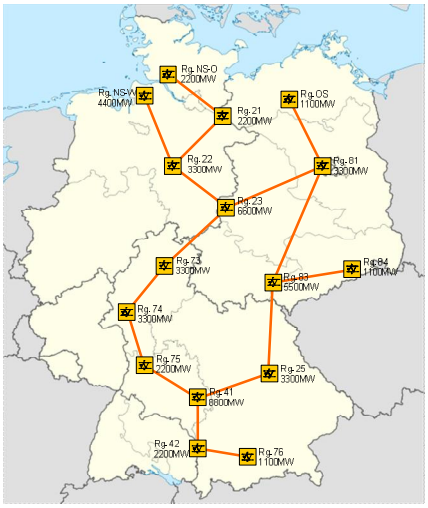

Figure 3: Exemplary DC network for a German overlay network from the study DENA II

In R&D projects and also to support standardization work within the DKE and CENELEC groups, concepts for the supervisory DC network control as well as for the individual converter control have been developed and analyzed.

The primary objective of a DC grid is to transmit power between its converter stations. Depending on the transmission task, some converter stations import power into the DC circuit, others export power. Maintaining the DC voltage within certain operational limits means export and import of power in the DC network need to be balanced at all times by the converter stations, requiring proper control concepts and settings.

The control functions can be differentiated with respect to their dynamics into converter station controls and supervisory DC network controls.

Another aspect is the calculations of short-circuit currents for DC grids. This is relatively well-known for today's point-to-point HVDC connections, but is a very new topic when it comes to more complex grid structures.

Siemens PTI performs transient, short-circuit calculations in the electromagnetic transient simulation toolbox of its simulation software PSS®NETOMAC for a number of complex topologies and as such has a pioneering role within the standardization process that is performed within the CENELEC framework.

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