



# AC/DC grids

## Concepts and designs 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 was increasing significantly all over the world. Classic, thyristor based HVDC systems have been built up to  $\pm 800$  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 direction.

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 not 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 of strengthening today's transmission systems. One solution can be to build an overlay network using state-of-the-art HVDC transmission system forming a meshed DC grid.

Siemens Power Technologies International (Siemens PTI), your provider of network consulting, network planning software and trainings on the Siemens T&D portfolio, is your 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 to spread to other system areas by splitting the system and isolating the fault-affected areas.

In many systems the erection of new AC lines is hardly 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.

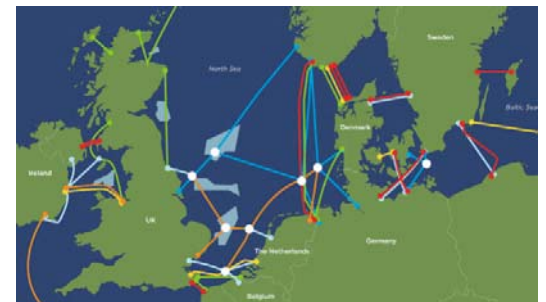


Figure 1: Vision of a European north sea grid

The future trend will be a combination of AC and DC systems. These hybrid structures need more and elaborated control concepts because in these systems point-to-point power transfers will be changed into flexible multi-terminal operation with different sending and receiving sources depending 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, e.g. for defining the control concepts and for adapting these systems to interconnect the new generation centers to the load centers considering the necessary control behavior, the interconnection to the grid and the different grid code rules to erect ultra high reliable hybrid systems for the future.

Siemens PTI – Network Consulting

Answers for infrastructure.

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Due to our long-term experience with the modeling and analysis of power electronic devices and the close cooperation with the engineering groups in the HVDC business unit within Siemens, 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.

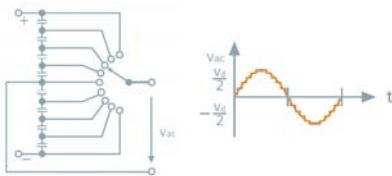


Figure 2: Basic HVDC Plus concept

Siemens PTI is involved in several studies and R&D projects concerning various topics of DC network 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

Also Siemens PTI is 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 has been deeply involved has been the German DENA studies, 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 covering complete Germany. Additionally new control concepts have been developed for a safe and stable operation.

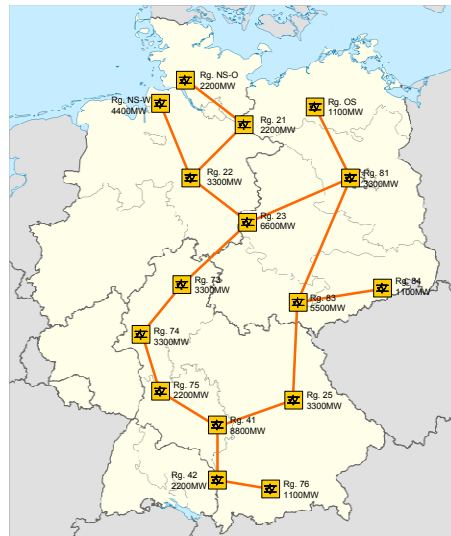


Figure 3: Exemplary DC network for a German overlay network from the study DENA II

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.

The short-circuit current consists on one side of a contribution from the cable or overhead line discharge (see Figure 4 for an example) and on the other side of the contribution of all converters in the grid. The resulting fault current depends very much on the boundary conditions, such as grid topology, neutral grounding and screen earthing and the length of the connections between the converters.

Siemens PTI performs transient short-circuit calculations in the electromagnetic transient simulation toolbox of its simulation software PSS<sup>®</sup>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.

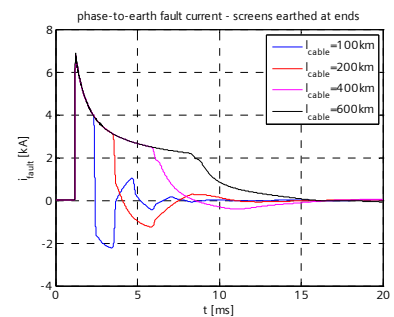


Figure 4: Short-circuit contribution from DC cable discharge for different cable lengths