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HVDC/FACTS - Highlights

Power Markets in Transition – New HVDC Solutions for the Power Grids of the Future

All over the world, the tasks of the existing power grids as well as the demands placed on them are undergoing significant changes. Decentralized power generation is gaining in importance making networks more complex. The existing linear energy chain is evolving into a power matrix, i.e. a multi-layered system with a large number of distributed renewable energy sources at all voltage levels. The power grid of the future must be environmentally compatible, cost-efficient and secure at the same time. With HVDC (High-Voltage Direct Current Transmission) systems in its portfolio, Siemens as a leading supplier offers innovative power electronic solutions that are able to cope with these challenges.

HVDC systems provide the necessary features to avoid technical problems in heavily loaded AC systems; they increase transmission capacity and system stability of the grid very efficiently and assist in preventing cascading disturbances. That's why the strategy for developing grids is clearly aimed at hybrid systems with integrated AC/DC grid connections, including "bulk power energy highways" and AC/DC overlay grid. The options for fast and selective fault clearance on transmission paths are an extremely important planning factor for HVDC connections.



HVDC/FACTS Highlights presents an interview with Jörg Dorn (figure, right), *Head of the R&D department* within Power Transmission Solutions and Dietmar Retzmann (figure, left), *Director Technical Marketing and Innovations* HVDC/FACTS talking about HVDC solution strategies for fast and reliable clearance of DC line/cable faults.

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- **What line/cable faults can occur when operating an HVDC?**

R: We differentiate between two types of disturbance: mainly flashovers on the overhead lines that are usually caused by lightning strikes, or mechanical faults caused by broken branches or bushes, for example. They can normally be cleared in no time by using special protection strategies minimizing the gap in power transmission. Cable faults are quite different: they must be located in order to undergo thorough repair, which takes time, i.e. no "quick process" is possible.



Dietmar Retzmann, Prof. Dr.-Ing.
Siemens TOP Innovator

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Dietmar Retzmann has been with Siemens since Dec. 1982. His area of expertise covers project development, simulation, testing and commissioning of HVDC/FACTS, system protection and custom power; system studies, innovations and R&D. Dr. Retzmann is active in IEEE, Cigré, ZVEI, ETG and VDE. He is author and co-author of over 250 technical publications in international journals, books and at conferences and he cooperates with universities in Europe, in the Americas and in Asia.

- **What strategies have been used to clear DC line faults so far?**

R: For overhead line faults, up to three restart attempts are made after fast short-time polarity reversal of the converter voltage. In doing so, current extinction and electric arc deionization are followed by a short voltage break; the whole procedure can be repeated up to three times. The voltage break time and the rate-of-rise of the DC voltage during recovery can be variably adapted to the degree of pollution of both the environment and the overhead line. Using this "adaptive" strategy, system availability can be significantly improved. However, these repeated restart attempts with high-voltage circuit-breakers are not possible in AC grids; HVDC is of particular advantage here. If the third restart attempt also fails, a permanent line fault is assumed, so the overhead line

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must be disconnected, and the fault must be found (for example, by helicopter) and eliminated. The fault location on the overhead line is detected by the HVDC measurement and protection systems with the accuracy of some hundreds of meters making the repair duration shorter.

If the fault affects a combined overhead line/cable transmission, the response is selective due to the HVDC protection measurement; cable faults must be disconnected and repaired – just like with an AC cable. Overhead line faults must be handled with high-speed reclosure as described above.

Jörg Dorn, Dipl.-Ing.
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Jörg Dorn started his career as application engineer at euepec GmbH. In 2002 he joined Siemens Automation and Drives as a development engineer for HVDC valves and medium voltage drives. From 2005 to 2008 he had been head of the development of the modular multilevel converter technology for HVDC before he was delegated as a managing director to the joint venture Infineon Technologies Bipolar GmbH & Co. KG. Since March 2012 he has been head of the R&D department within E T TS.



- **Given that the type of DC link plays a part in fault clearance, are there additional influencing factors?**

D: For HVDC, the topology of the converter also determines whether multiple restart attempts are possible. In the case of classic HVDC technology with thyristors, this is standard for overhead lines, even in combination with cables (for example, the Basslink project in Australia).

For cable connections like those of the Trans Bay (USA), INELFE (France/Spain), and offshore projects in Germany the VSC-based (**V**oltage-**S**ourced **C**onverter) half bridge topology is used for converters. This technology is highly efficient, but direct fault clearance through the converter is not possible. It is performed instead by the AC circuit breaker. This is somewhat slower than with the full bridge, but this isn't a problem since the cable has to be repaired anyway.



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- **What options are available for interrupting fault current on overhead lines in VSC technology when using HVDC PLUS or for attempting restarts?**

D: There are two possible technical applications to eliminate overhead line faults in conjunction with VSC technology - implementing a converter as a full bridge or using a DC circuit breaker. We prefer the full bridge solution. As with classic HVDC, the converter temporarily reverses the polarity of the line voltage to extinguish the current and deionize the arc.

- **Why did Siemens decide to go with the full bridge solution?**

R: One important reason is that the technology has already been proven numerous times. Worldwide, Siemens has been successfully using the full bridge circuit for traction frequency converters Sitras[®] as well as for FACTS and industrial installations with the SVC PLUS[®] since 2009 and can already point to 74 reference converters with full bridge.

D: In addition, the modules of Siemens' Multilevel PLUS technology can be flexibly used depending on the customer's system requirements, whether in a half bridge or full bridge circuit. The full bridge variant has advantages when operating DC connections with overhead lines.

- **What additional system benefits does a full bridge circuit offer?**

R: Under adverse weather conditions and high degree of pollution in the area of the transmission route, the HVDC can be flexibly operated at a reduced voltage as a precautionary measure. With the half bridge variant, this is only possible to a limited extent.

D: Plus the flexibly controllable DC voltage permits a slow ramp-up along the arc's dielectric recovery characteristic when the HVDC is connected, resulting in extremely short recovery times.

- **One of the solutions mentioned was the DC circuit breaker. Is this also a future option for Siemens?**

R: In our opinion, the DC circuit breaker is necessary only in highly meshed DC grids. This is not the case yet, nowadays the worldwide maximum is a three-terminal interconnection (three projects so far) with the "classic" line-commutated technology, i.e. without the DC circuit breaker. In line with the ENTSO-E plans, a DC grid can be expected in Europe in the distant future only (*Working Group Supergrid 2050*). Other continents have similar long-term plans regarding this kind of DC super grids.

With the exception of China which is already building a hybrid AC/DC grid with up to 40 large line-commutated HVDCs – and there is no need for a DC circuit-breaker. These HVDCs acting as point-to-point power highways

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are integrated into the surrounding 500 kV AC network; additionally, a 1,000 kV AC grid is being planned, three prototype stations for which are already being operated for test purpose.

A corresponding grid code is extremely important for building meshed DC grids. A CENELEC working group that includes Siemens and other manufacturers is already working on this. The group will define the basic operating conditions (voltage and power ratings), standardize control and protection strategies, and use them to further develop DC converters, circuit-breaker technologies and test methods. It must be taken into consideration that, in addition to the DC circuit-breakers, suitable protection concepts are required in order to locate the DC fault extremely fast and to make sure that only the line segment affected is selectively disconnected by means of the corresponding circuit-breaker. Here, the requirements are far higher than in the existing AC grid, i.e. in the middle and long term there is definitely a lot of potential for innovative solutions.