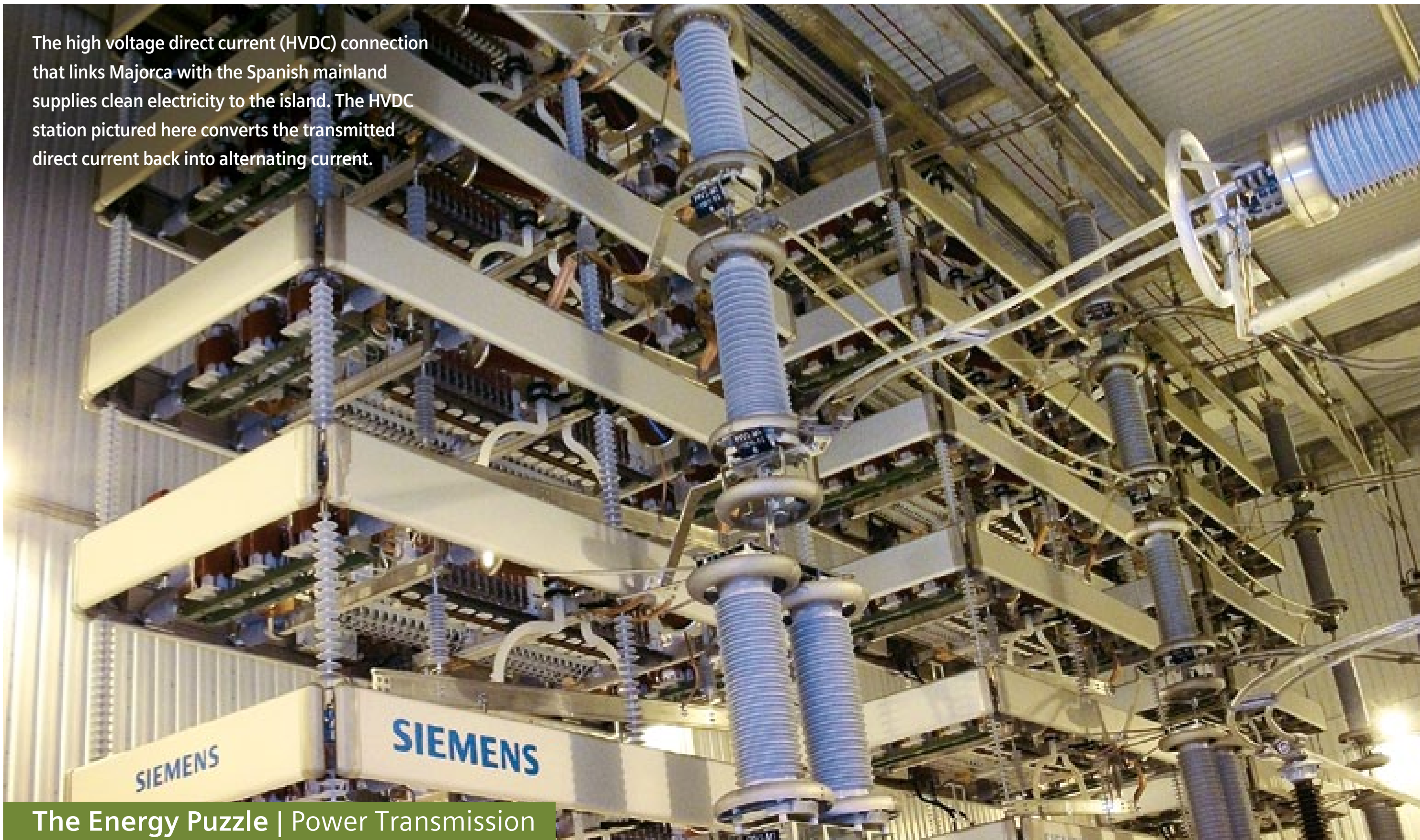
siemens.com/energy

Electricity Superhighways

The Energy Puzzle | Power Transmission

Reprint from
Pictures of the Future
Fall 2012

Answers for energy.



The high voltage direct current (HVDC) connection that links Majorca with the Spanish mainland supplies clean electricity to the island. The HVDC station pictured here converts the transmitted direct current back into alternating current.

Electricity Superhighways

The creation of a sustainable energy system requires the expansion of long-distance power transmission networks. The problem is that transporting high voltages over long distances with conventional alternating current causes prohibitively high losses. What's more, new lines often meet with considerable public resistance. *Pictures of the Future* examines some surprisingly efficient alternatives.

Renewable energy sources should be used wherever they are abundantly available — from wind power on the high seas to solar energy in sunny regions. Germany, for instance, plans to build wind farms with up to 30 gigawatts of capacity in the northern part of the country between now and 2020. But most of its energy consumption is in the south. So the real question for Germany is how to get its renewably-generated electricity from the north to the south. Existing power lines can't do the job; already, clean electricity from the north often has to be redirected through Germany's eastern and western neighbors in order to get to the south. A huge expansion of the grid therefore appears to be unavoidable. In response to this challenge, Germany's federal government and the country's four power transmission companies presented a grid development plan in May 2012. The plan calls for the construction of 3,800 kilometers of new transmission lines over the next ten years. After it's completed, this colossal project could serve as a model for sustainable energy supply systems in other countries, especially if, as is the case in Germany, a large share of renewable energy sources is situated far from major energy consumption centers.

Can the German grid be expanded as quickly as planners would like? "Losses over just a few hundred kilometers would be too high with the alternating current technology that's generally been used to date," says Professor Dirk Westermann, Director of the Electrical Energy Supply Department at Ilmenau University of Technology (east of Frankfurt, Germany) and a member of the Advisory Council for the "Future-Oriented Grids" platform at Germany's Ministry of Economics and Technology. "The most efficient approach would be to expand the system using high-voltage direct current (HVDC) transmission technology," he says. HVDC makes it possible to transport electricity over a distance of more than a thousand kilometers with low losses. "Direct current lines reduce transmission losses by 30 to 50 percent as compared to alternating current lines," says Jörg Dorn, Director of HVDC Systems Development at Siemens Energy.

Siemens has been demonstrating the effectiveness of the technology since 2010 in China, where an HVDC connection now supplies megacities in Guangdong province with clean electricity from a hydroelectric plant located

1,400 kilometers away (see *Pictures of the Future,* Fall 2009, p. 24). Other reference projects in New Zealand, New York City, and Spain also highlight the advantages the technology offers. The island of Majorca, for example, now receives electricity from renewable sources on the Spanish mainland via an HVDC connection. The system is designed to provide extra capacity during peak loads during the vacation season and spare the island the burden associated with construction of new power stations. Siemens, one of the leading suppliers of HVDC systems, currently has a world market share of around 40 percent.

Transmitting More Power. An HVDC connection is similar to a pipeline that links two locations. At one end, a converter station transforms alternating current into direct current at a very high voltage – for example, 400,000 or 800,000 volts. A second converter at the receiving point then transforms the DC into AC current that can be supplied to consumers. "The converters are very expensive, but the lower transmission costs begin making up for that after a distance of 600 kilometers," Westermann explains.

Another benefit offered by HVDC is that it can transport two to three times more power than an AC transmission line with the same route width. Existing lines can also be converted into high-capacity electricity superhighways. The idea becomes exciting when one considers that virtually all the conducting cables in Germany are supported by masts with two cross-arms. These run an independent three-phase alternating current connection on each side (left and right), which makes the system redundant. "That's why, instead of building completely new lines, we're thinking of equipping existing masts with a common line, with one connection each for AC and DC current," says Dorn. In addition to this upgrade, all that would be needed would be to add HVDC converters at the beginning and end of each line. Such a solution would also meet with greater public acceptance because, rather than building new masts, we would only need to upgrade existing ones," says Dorn. "These modifications could be carried out much faster than it would take to build a new transmission route. However, there are major technical challenges involved; these have to be studied and potential solutions have to be tested."

and the network will soon reach a point where it can no longer function as a long-range synchronous grid. That's because the alternating current networks in these regions are not directly compatible with the inner-European grid in a technical sense. HVDC converter stations could offer a solution here, because HVDC transmission systems make it possible to link different AC grids over long distances. In addition, the converter stations act as a firewall by blocking the cascade-like expansion of system disruptions – thereby reducing the chances of blackouts. HVDC can also help to end blackouts quickly. As Dorn explains, "We've refined HVDC technology to enable it to rapidly get a failed grid back on line."

In the future, it will even be possible to add a spur to an HVDC link, which would allow metropolitan areas located at the periphery of a planned line, such as Germany's Ruhr district, to benefit from the technology as well. Such "multi-terminal" HVDC systems will also be needed if a European Super Grid is to be built in the future.

Involving the Public. Once technical challenges have been addressed, nothing more will

Amprion, a grid operating company, would like to complete a roughly 430-kilometer parallel AC/DC connection from Germany's Rhineland region to the state of Baden-Württemberg before 2019; only 10 percent of the route would require new construction. Parallel transmission of AC and DC has not been sufficiently tested in practice, but research in this area has produced promising results. Siemens is working closely with various colleges and universities in order to determine whether and how the AC and DC systems might affect one another, for example.

HVDC lines could also improve networking between different energy systems in Europe. The coming expansion of the European power grid is focused on the east and south – all the way to Russia, the Middle East, and Africa –

stand in the way of grid expansion. Still, technical feasibility isn't everything, since the expansion of the energy system will also require widespread public support for the construction of new overhead lines (see *Pictures of the Future,* Fall 2009, p. 14). Success here will hinge on providing accurate information, getting the public involved in the planning process as early as possible, simplifying approval procedures, and ensuring a high level of transparency.

It's also important to remember that some locations are not suitable for high-voltage masts – for example, major cities and the areas surrounding airports. In such areas, gas-insulated transmission lines (GILs) can provide a practical alternative. GILs are equipped with a mixture of nitrogen and sulfur hexafluoride (SF_6) as insulators, rather than the paper or plastic-based

Gas-insulated transmission lines can carry high voltages in environments where masts are impractical.

materials used in underground cables. The conductor is a tube around 18 centimeters thick surrounded by a protective second tube with a thickness of 50 centimeters. Transporting high voltages is not a problem here – all you have to do is to increase the diameter of the tubes as needed. A direct ground line today can move around 3,200 amperes, while an airborne line can transmit up to 5,000 amperes – at 550,000 volts.

A further advantage of GILs is that virtually no electric or magnetic fields can be detected in their immediate vicinity, which means that they do not disrupt telecommunication networks or air traffic control systems. GIL technology also complies with even the most stringent European guidelines, which explains why there have never been any problems regarding people standing or walking above GIL tunnels. Thus it's clear that underground lines now offer a good alternative to masts – although they're still approximately four times more expensive than their free-standing counterparts. That's why they will mainly be used when high voltages need to be transmitted in places where space is limited or where local environmental regulations must be adhered to.

Experts are now thinking about linking electricity and data lines in order to reduce the high costs that grid operators will incur as a result of network expansion. The idea here would be to bury both types of grids side by side in accessible tunnels next to highways, canals, and rail lines. ■ *Bernd Schöne*

This article appeared in:
Pictures of the Future
Fall 2012
Pages 24–26

This reprint is published by:
Siemens AG
Energy Sector
Power Transmission Division
Transmission Solutions
Freyeslebenstrasse 1
91058 Erlangen, Germany

For more information, please contact
our Customer Support Center.
Phone: +49 180 524 70 00
Fax: +49 180 524 24 71
(Charges depending on provider)

E-mail: support.energy@siemens.com

Power Transmission Division
Order No. E50001-G620-A155-X-4A00 | Printed in Germany |
Dispo 30003 | c4bs No. 7803 |
TH 250-130101 | WÜ | SD | 02131.0