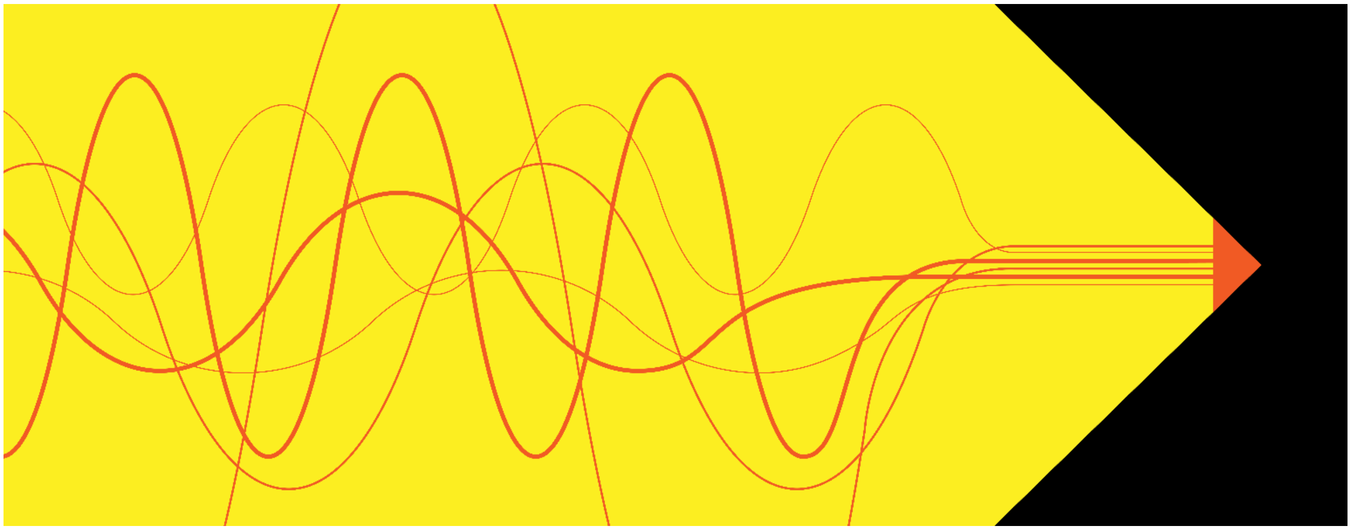
# Feature—HVDC on the Rise



*EPRI Helps Industry Navigate New Opportunities with High-Voltage Direct Current Transmission*

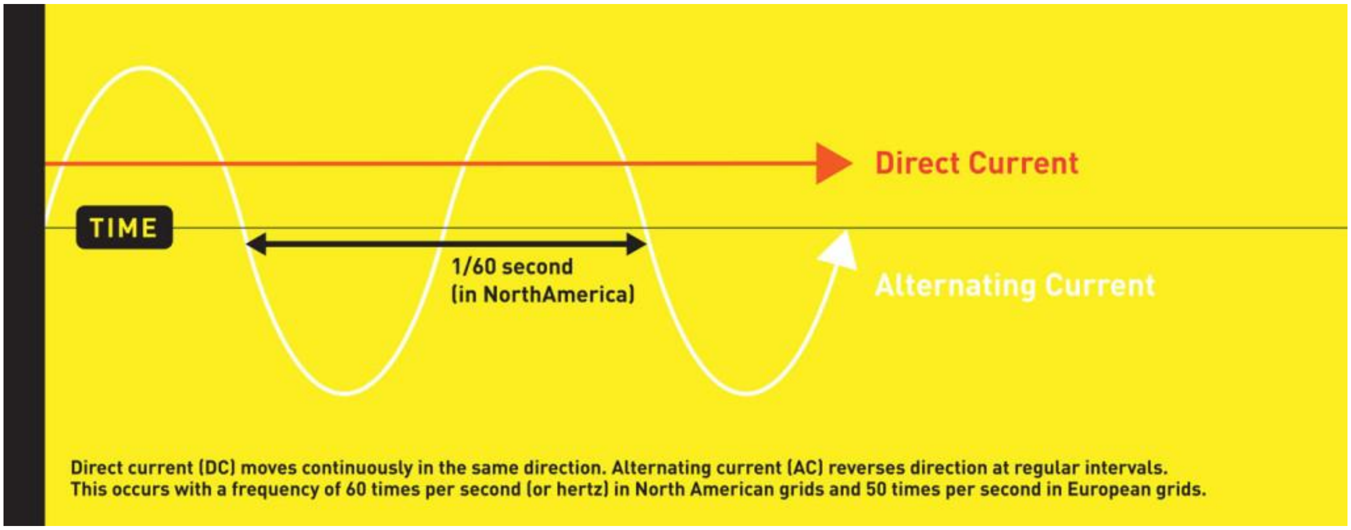
***By Matthew Hirsch***

Since the construction of the Bipole I high-voltage, direct current (HVDC) transmission line in the 1970s, Winnipeg, Canada, has relied more than most cities on HVDC technology. This reliance grew in the 1980s with the construction of Bipole II and is poised to increase again with the construction of Bipole III for Winnipeg's power supplier, Manitoba Hydro.

The two HVDC lines share a transmission corridor connecting the city with the Nelson River hydropower projects in the far north. When built, they offered a more economical option than the more familiar high-voltage alternating current (HVAC) lines because of the long distance to the hydro generation, decreased power losses, and a smaller right of way.

Unlike HVAC transmission technology, HVDC travels through the entire cross section of a conductor and needs fewer wires, enabling it to move energy over greater distances with less power loss. HVDC also provides controlled power flows, contributing to grid stability. As costs come down for DC transmission, the business case improves for even shorter distances. HVDC links can connect two power networks operating at different frequencies.

HVDC also has many challenges. For example, managing the loss of an HVDC link, which may constitute an extremely large power import into an area, can be difficult. The converters are costly and can generate harmonics, and multi-terminal HVDC systems require expensive communication systems. Many utilities have a lack of familiarity with HVDC maintenance practices. Historically, HVDC power electronics and controllers have had shorter lifetimes than HVAC assets. Each situation requires thorough technical and economic analyses to determine whether HVDC or HVAC makes the most sense.




Globally, demand for HVDC transmission is growing, and power companies are seeking EPRI's guidance as they consider new lines or attempt to derive more value from existing assets. EPRI's High-Voltage Laboratory in Lenox, Massachusetts, provides one of a few labs in North America equipped to test HVDC power, and its global partnerships enable EPRI and its member utilities to conduct research at facilities such as one under development in the United Kingdom, where HVDC vendors can plug in their products and test interoperability with other solutions (see box at end of article).

## Driving HVDC: Renewables

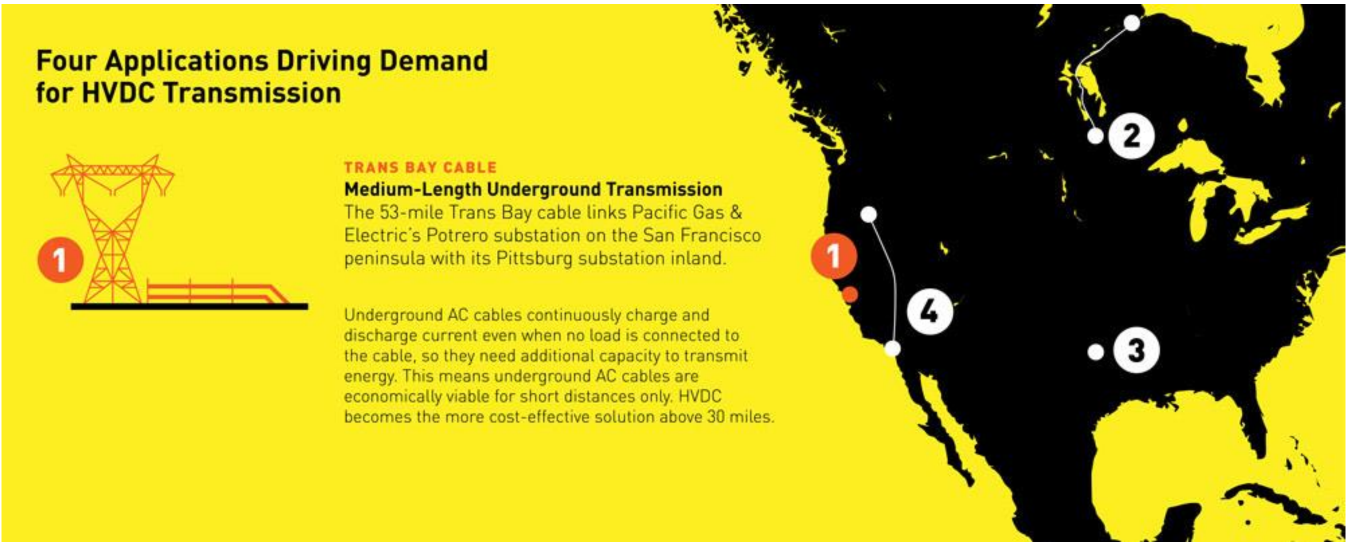
What will drive growth in HVDC technology? For one, the integration of large-scale solar and wind generation is well suited for HVDC. Such generation is typically far from load centers, and increasingly many proposed wind plants are at remote offshore sites. An example is the Atlantic Wind Connection, a proposed undersea transmission cable running from New Jersey to Virginia that would deliver up to 6,000 megawatts of offshore wind energy. Its first phase is estimated to come into service in 2020–21, but the project is already exchanging technical information with the HVDC Cable Interest Group convened by EPRI.

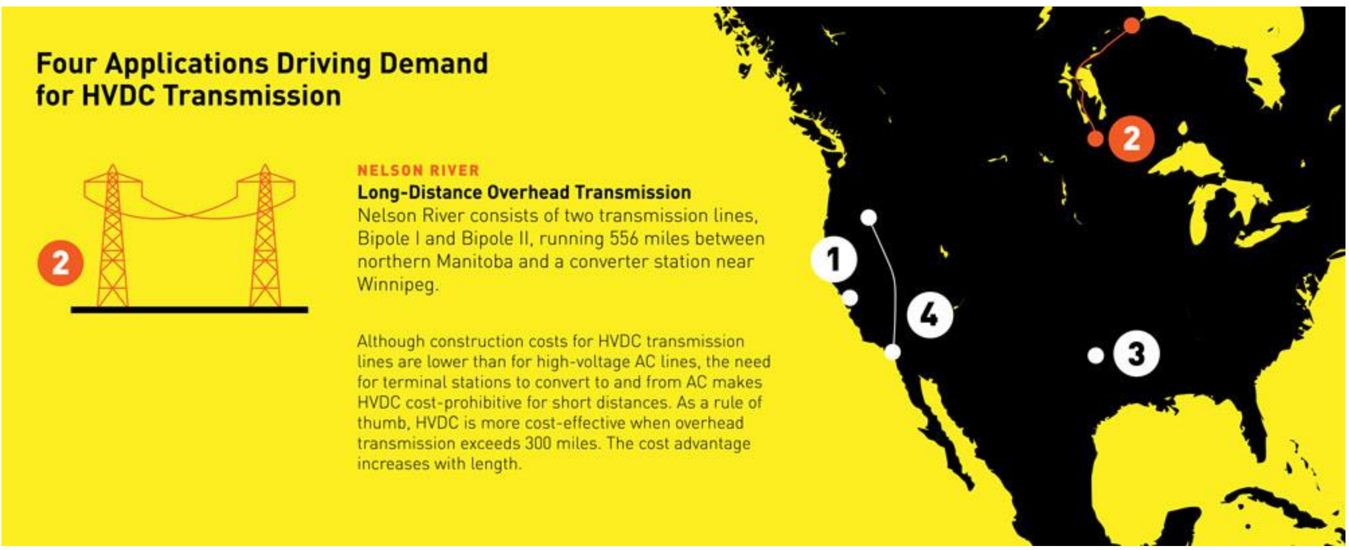
"As utilities face the challenges of integrating renewable resources into the existing power grid, our research has been instrumental in identifying the scenarios where HVDC is a cost-effective solution," said Ram Adapa, an EPRI technical executive in HVDC and power electronics.

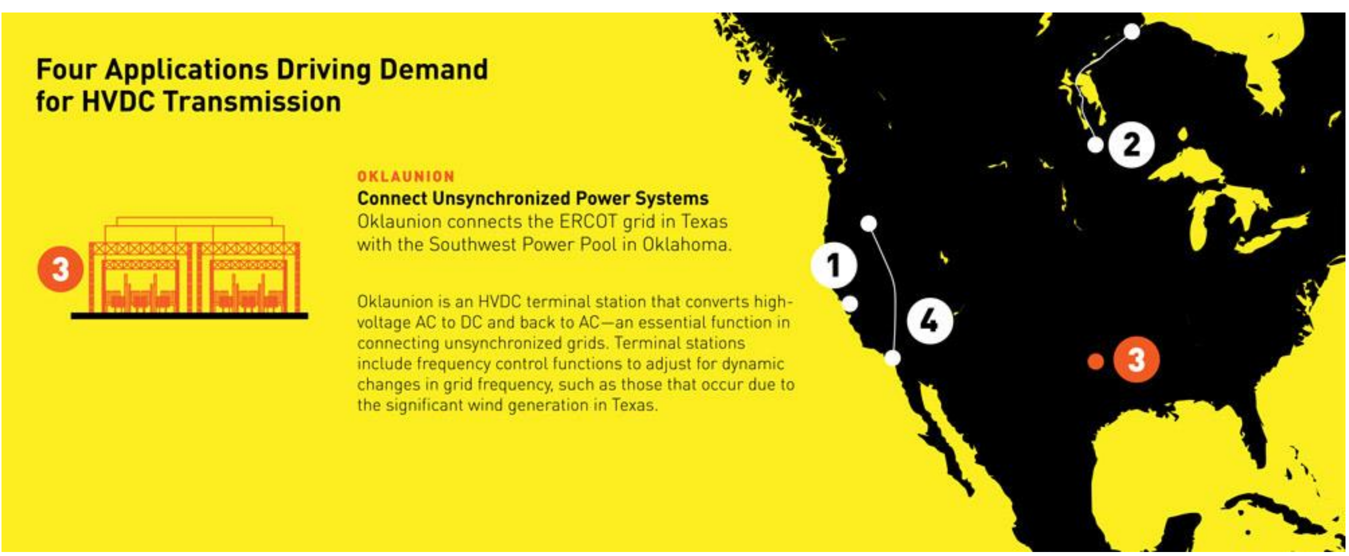
## Driving HVDC: Reliability

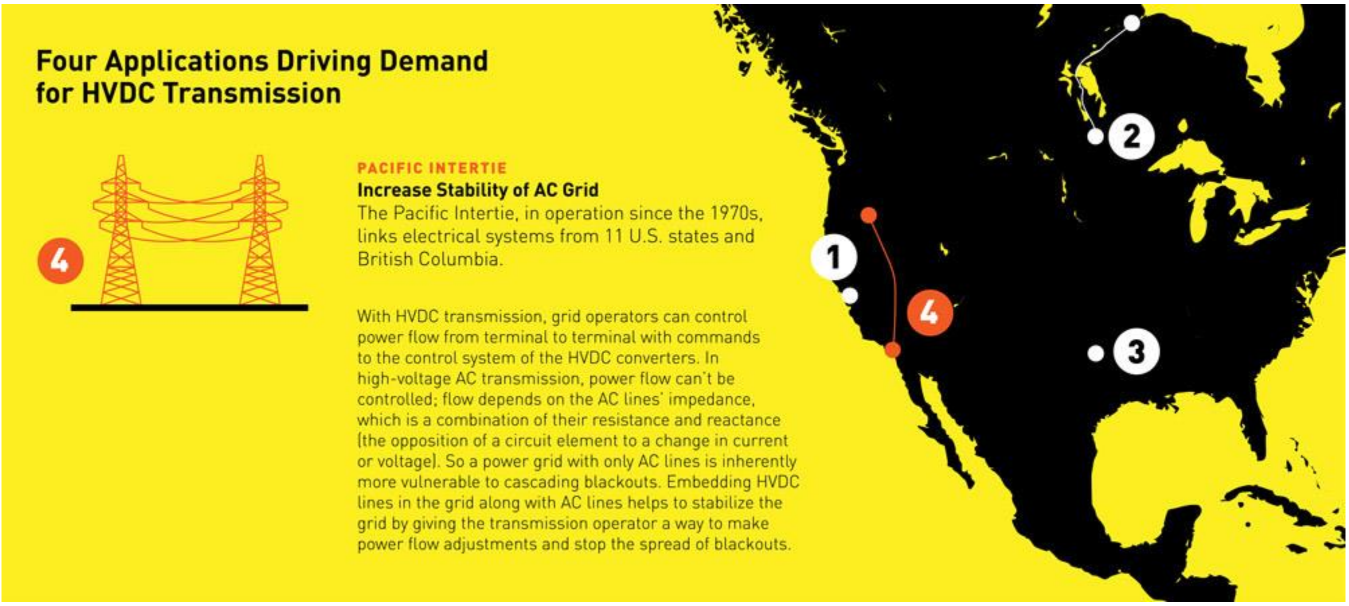
Electricity customers around the world—including those in North America, Europe, and Asia—are experiencing more blackouts and brownouts. The most recent major U.S. blackout in 2003 affected 50 million people in eight states and Canada. HVDC can help reduce the spread of such large-scale disturbances by providing a buffer between regions. EPRI research is helping to improve inspections and maintenance on energized HVDC lines, providing a scientific basis for using proper tools and setting minimum approach distances.

These graphics depict four HVDC transmission applications in North America.






## Driving HVDC: Crowded Landscapes, Capacity Constraints

Building new transmission lines becomes more difficult and expensive with rising land costs, lawsuits, and other barriers in permitting. The need to build can be offset by using HVDC to increase capacity on existing transmission lines. EPRI research shows that converting AC lines to DC operation can increase capacity as much as constructing one or more AC lines. EPRI is discussing with several utilities field demonstrations of AC-to-DC line conversion.

## EPRI Guidance on Changing Technology

In the mid-1980s, when Manitoba Hydro completed Bipole II, only one converter technology was commercially available: line-commutated converters (LCC). The core of LCC technology is a semiconductor with a controllable switching-on action. The device switches off automatically in response to changing AC voltage characteristics. In 1997, the industry deployed a new technology: a voltage-sourced converter (VSC), which uses power electronics to control both switching-on and switching-off actions. This gives the system flexibility to switch on and off at any time, instead of relying on an outside AC voltage source to turn off the device.

For Bipole III, Manitoba Hydro, which participates in EPRI's HVDC R&D, evaluated the two technologies. Both options had advantages. LCC is an established technology for transporting bulk power through overhead lines. Some LCC projects carry as much as 8,000 megawatts. While it's technically feasible for VSC to carry 2,000 megawatts through overhead lines—the capacity specified for Bipole III—this hasn't been accomplished yet. VSC generally requires less infrastructure and offers greater potential to connect with multiple HVDC transmission lines, such as in a DC grid. In the end, all three bidders proposed LCC projects.

Even though Manitoba Hydro selected the tried-and-true technology, technical information from EPRI task force meetings and on-site workshops has provided the utility with important insights for planning future transmission projects—an important advantage, given the pace of change in HVDC. Already, Manitoba Hydro is preparing to replace converter equipment on Bipole II, and Bipole I will need equipment upgrades about 10 years from now. "To be diligent, we need to assess and consider the possible savings VSC technology may offer on future projects," said Scott Powell, manager of public affairs for Manitoba Hydro.

## Improving Transmission Line Reliability

In South Africa, HVDC transmission provides residences and businesses with essential energy needs, and vultures present unique challenges to reliability. These large birds are drawn to areas along the Cahora Bassa HVDC line known as “vulture restaurants” where farmers dump animal carcasses. After eating their fill in the daytime, vultures roost for the night on the HVDC tower. It is believed that during roosting or as the vultures are about to take off into flight, they release a stream of excrement that may lead to an electrical arc on the line known as a *flashover*.

Since 2012, Eskom and EPRI have simulated the Cahora Bassa line configuration at EPRI’s Lenox lab to determine if bird streamers are the cause of flashovers and under what conditions they occur. After three rounds of testing, simulations demonstrated the possibility of flashovers occurring when bird streamers bridged the air gap between the power line and the tower. The findings will inform Eskom’s consideration of the application of bird guards to keep vultures away from electrical insulators on the lines.

As HVDC technology matures and costs come down, EPRI R&D will continue to help power companies operate existing lines while evaluating and implementing new HVDC transmission. “EPRI’s collaborative and unbiased HVDC research provides utilities globally with unique and valuable scientific information,” Adapa said.

### Building an HVDC Supergrid

Since the first HVDC project launched in Sweden in 1954, most HVDC transmission has been built as a single line connecting one terminal with another. Linking projects with multiple terminals could increase the supply of energy across networks and the ability to control voltage and frequency fluctuations. Two main technical challenges remain: enabling HVDC technology to handle multiple terminals and making devices from different vendors interoperable.

Voltage-sourced converters—a technology developed in the 1990s that uses power electronics to control the converter’s switching-on and switching-off actions—have created a simple process to reverse any terminal’s power flow. Using this technology, researchers around the world are testing how multiple HVDC systems interact in real time.

With guidance from EPRI, United Kingdom utility SSE is setting up a facility in Cumbernauld, Scotland, to help HVDC system planners, asset owners, and operators learn how an HVDC network could connect with networks from neighboring countries and offshore renewable generation. The project is procuring simulation equipment, and commissioning and testing are expected in 2017.

About a dozen initiatives around the world are attempting to link HVDC transmission across large territories. Examples include the Atlantic Wind Connection in the eastern United States, the Desertec project in North Africa and the Mediterranean, and a supergrid in China.

In a recent article in *IEEE Spectrum*, EPRI Fellow Clark Gellings discusses the construction of a worldwide HVDC supergrid to improve grid stability; tap the world’s best solar, wind, and eventually ocean energy resources; and deliver the energy to population centers.

## Key EPRI Technical Experts

Ram Adapa, John Chan