

The Case for HVDC

The U.S. needs to consider more HVDC use to improve controllability, increase underlying AC grid throughput and enhance grid resilience.

By **Terry Boston**, PJM Interconnection

While the rest of the world is moving ahead with extensive transmission builds employing high-voltage direct-current (HVDC) technology, the U.S. lags in using this technology to strengthen the electric grid. This is especially true of the Eastern Interconnection, where HVDC transmission is still uncommon.

The benefits of HVDC are widely recognized, foremost among them is that it provides controllability that increases the throughput of the underlying alternating-current (AC) grid. Thus, it can help to resolve some of the issues grid operators and transmission owners face in keeping pace with the demands being placed on transmission infrastructure.

The expansion of HVDC in the U.S. is essential to take full advantage of the growing use of intelligent devices on the grid. Building HVDC transmission will speed the creation of a truly smart grid that enhances reliability and resilience in the face of natural and man-made threats.

Needed Capabilities

For moving power long distances with low losses, HVDC is a cost-effective solution, one ideally matched with moving the energy output of remotely located renewables to distant load

centers. HVDC may well get a boost from the growth of wind energy, which results from carbon-reduction policies.

Through computerized controls, HVDC transmission offers grid operators the ability to manage the electric system in real time with higher levels of controllability than currently possible, a significant benefit for reliability and electricity markets. Because both the amount and direction of power flows can be controlled, operators can address issues such as thermal overloads and voltage control to help maintain the stability of the AC system.

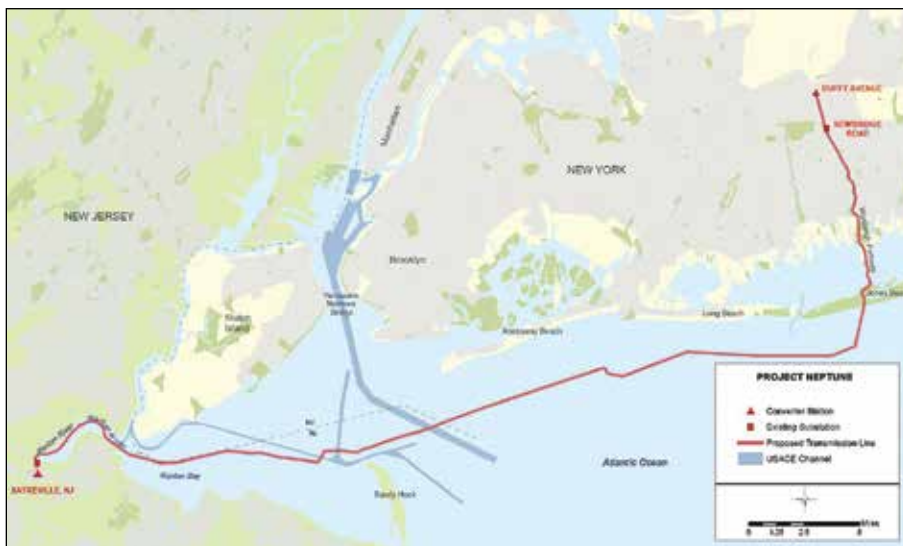
HVDC also enables the interconnection and exchange of power between grids operating asynchronously, using a back-to-back terminal. Likewise, the technology facilitates long-distance lines — such as the one between Hydro-Québec in Canada and the northeast U.S. — so a utility can take advantage of remote hydro storage to respond to the variability of wind and solar.

Benefits of HVDC

In many ways, there are echoes in the discussions of HVDC today of the AC versus DC battles of George Westinghouse and Thomas Edison. Back then, AC was the winner in the struggle to define the technology platform for the U.S. electric system's infrastructure. In today's environment, a strong argument can be made that Edison was correct. More HVDC technology is needed on the grid.

For all these reasons, HVDC transmission can enhance the flexibility, reliability and resilience of the grid:

- It provides higher transmission capacity than AC over the same distance.
- It lowers losses over long distances compared with high-voltage AC (HVAC) transmission. As voltage increases, losses decrease, so more electricity can be transmitted.
- It also can be used underwater and underground, although at a much higher cost.



The Neptune Regional Transmission System is a 660-MW, 500-kV HVDC line connecting supply resources in the PJM system to consumers on Long Island, New York.

- It requires smaller rights-of-way and smaller towers when used in overhead applications.

- It has the unique capability to connect asynchronous grids and can help to control the AC voltage and frequency.

- It provides fast response times and the ability to control power flows accurately while preventing the transfer of faults between connected AC grids.

Since its first commercial application in 1954, HVDC transmission has matured. Continuing technology innovations have made HVDC both more efficient and cost-effective. Those advances have also served to expand the range of applications in which HVDC is an appropriate option.

International Growth

Internationally, HVDC's use is expanding dramatically, particularly in applications where HVDC has special strengths. These include moving large amounts of energy across long distances while controlling the power flows and even the voltage of the AC terminal, which can be done with the HVDC terminal equipment much like a static synchronous compensator (STATCOM).

One recent estimate put the HVDC capacity in service at



The switchyard at the Neptune Regional Transmission System converter station on Long Island receives direct-current power from the PJM network in New Jersey before converting it to alternating current for use by PSE&G's Long Island customers.

about 100 GW, with another 250 GW to be added this decade. Another study found 110 new lines being planned or under construction for service by 2020, representing more than 300 GW. It is estimated more than 120 HVDC systems are in operation around the world.



Thyristors convert up to 660 MW of energy from direct current to alternating current inside the valve hall at Neptune Regional Transmission System's Duffy Avenue converter station. Since commercial operation began in 2007, Neptune has provided approximately 20% of the electric power used on Long Island.

HVDC use is substantial and still growing in Europe, China, India and Brazil. Because of their high-demand growth, these locales are leading the way in HVDC construction. Two of these countries, Brazil and China, claim four of the world's five longest transmission lines, with the other in Congo. These lines range from 1,044 miles to 1,482 miles (1,680 km to 2,385 km). For these countries, HVDC is efficient and cost-effective given the distances covered and higher capacities required to bring remotely located hydropower and wind energy to population centers far away.

In China, 14 projects are in operation, with 11 more planned, including two employing ultra-HVDC (more than 1,000 kV) capable of moving up to 8,000 MW of electricity per line. In July 2014, China's State Grid Corp. commissioned the 800-kV Xiluodu-Zhejiang project. The line, the largest HVDC project in the world at the time, carries power from the Xiluodu hydropower station in southwestern China to the east. The line is expected to transmit 40 million MWh a year.

This flurry of activity is not just a reflection of development needs in rapidly growing economies, it also reflects, as in Europe, the recognition that HVDC is the right tool for the job in numerous applications.

U.S. Status

Lagging HVDC development in the U.S. represents a problem when much more HVDC transmission is needed to create a hybrid AC-DC system to enhance controllability and resilience for the grid of the future. Adding HVDC backbone elements will increase the throughput of the underlying AC network, benefiting both reliability and the economics of new bulk transmission.

There are more than 20 HVDC projects currently in the U.S. They include submarine projects that connect PJM Interconnection to the New York Independent System Operator; several other projects are in PJM's queues, including a pro-

posal for an HVDC submarine line crossing Lake Erie. State siting and cost allocation appear to be the major obstacles to the expansion of HVDC in the U.S. This is especially true in the case of multi-state projects needed to move electricity from remote areas to load centers.

State siting can be problematic because of the distances involved and the point-to-point nature of the long-distance lines, often with no off-ramps for local interconnections. This can lead to the belief there are no local benefits to be gained from the HVDC project, when the benefits derived are to the system as a whole, in terms of added stability, improved reliability and additional supply of low-cost energy to the market. Some multi-terminal lines are being proposed to help with state siting approval.

HVDC also can be disadvantaged in terms of cost-allocation rules, in which benefits to the system as a whole may conflict with a beneficiary-pays methodology. Projects that support regional public

policy requirements, such as renewable portfolio standards, should be considered for wide-area cost allocation. These issues must be addressed to provide HVDC with better opportunities to compete in transmission planning decision making in the U.S.

PJM Study

Given the state renewable portfolio standards requirements, PJM has been examining the integration of renewables as part of its planning studies. One study compared two parallel 500-mile (805-km), 600-kV HVDC lines with two parallel 500-mile, 765-kV HVAC lines. At transfer levels of 3,000 MW and 1,000 MW, the simulation demonstrated slightly lower losses occurring with the HVAC lines, while N-1 and N-1-1 voltage analyses showed no significant differences in performance between the DC and AC options.

A stability study evaluating the transfer of 3,000 MW of wind generation to the PJM system found, for most of the tested contingencies, the HVDC option performed comparably to the HVAC option from a transient stability perspective, with no sustained angle oscillation. In terms of fault recovery (a single-line-to-ground fault with a delayed clearing contingency as a result of a stuck breaker), the simulation showed the HVDC option provided better performance in power transfer level recovery after the fault was cleared while the HVAC option produced faster recovery of power transfer but at a reduced transfer level.

To assess impacts on the wholesale electricity market, PJM conducted market simulation studies to estimate the impact of a 3,000-MW HVDC line interconnection to deliver renewable resources from a remote location in 2019. The simulation resulted in average production cost savings of US\$405 million in 2019. In addition, assuming the transmission system enhancements to handle the 3,000 MW were made, payments by load would be reduced by \$181 million. The simulation found these

HVDC Project Connects PJM's Resources with New York Demand

The Neptune Regional Transmission System (Neptune RTS) is a 660-MW, 500-kV HVDC submarine cable transmission system that connects power generation resources in the PJM system to electricity consumers on Long Island, New York, U.S. The Neptune cable extends from the FirstEnergy substation in Sayreville, New Jersey, to the Public Service Enterprise Group Newbridge Road substation in Levittown, Long Island, with converter stations located at Sayreville and near Hicksville on Long Island. The majority of the 65-mile (105-km) cable route — more than 50 miles (81 km) — is underwater in the New York Harbor and the Atlantic Ocean, and 14 miles (22.5 km) are buried in the existing right-of-way of Long Island's Wantagh State Parkway.

In May 2004, the Long Island Power Authority chose Neptune RTS as the centerpiece of its long-range plan to provide approximately 1,000 MW of new, urgently needed power sources to Long Island by 2010. Because Neptune is a transmission connection to the PJM system, it increases the capacity and energy available to Long Island in a more flexible and reliable manner than simply connecting to generators. Moreover, it saves Long Island ratepayers money, adds capacity and makes available more (and diverse sources of) energy without adding local impacts associated with new power generation.

Neptune was completed in the summer of 2007, ahead of schedule and within budget. It provides enough power for 600,000 homes and supplies more than 20% of Long Island's typical electric demand. Operationally, Neptune RTS has fulfilled its promise of being highly controllable in response to market conditions, capable of serving either as a base load resource or as one that can provide very rapid load changing.

financial benefits also would be accompanied by a significant reduction in carbon-dioxide emissions.

The study concluded the HVDC system overall was “very comparable with the HVAC system in terms of the system security and reliability in the static state and dynamics (transient stability and system oscillations.)” It added that, while HVDC can regulate the 3,000-MW transfer flow through HVDC lines into the PJM system, the HVAC system would need an addi-

tional phase-angle regulator to control the flow to achieve the 3,000-MW transfer.

A Vital Role

Technology development trends in the HVDC realm are leading to better controllability, higher transfer capabilities and lower losses. These attributes can benefit the nation's electric grid now and pave the way for a hybrid AC-DC grid of the future, as the industry moves to integrate more digital intelligence into the transmission infrastructure and address the growing role of renewables in the energy mix.

HVDC use is increasing worldwide and needs to receive more serious consideration in transmission planning in the U.S. With actions to address siting concerns and cost-allocation impediments, it can play a vital role in the modernization of the North American grid as foreseen in the U.S. Department of Energy's Quadrennial Energy Review. **TDW**

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Mentioned in this article:

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