A Cool Possibility For The Power Grid

Superconducting cables to the rescue?

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Late next year, the Long Island Power Authority plans to break ground on a cable project in East Garden City that should help show whether superconducting materials, long a laboratory curiosity, are ready for widespread use in the electric power grid.

The 2,000-foot underground cable, with a capacity of 138 kilovolts, will be capable of carrying enough power to serve 300,000 homes, according to LIPA. It will be placed underground in an existing right-of-way and incorporated into the utility's grid. Full operation is set for the end of 2005.

The Long Island project is part of an accelerated effort in the United States and abroad to exploit superconductivity to improve the efficiency of the power grid and make it less vulnerable to the widespread blackouts that affected the United States, Canada and Italy this summer.

While superconducting cables, using wiring formed from ceramic powders, might someday help form the backbone of a more capable national transmission system, experts say, there are niche uses opening up, as well as roles for superconductivity in transformers and voltage-control devices that can help upgrade the aging power grid.

"Transmission companies are going to look real hard at what happened in the Northeast blackout," said Dale Bradshaw, senior manager for power delivery systems at the Tennessee Valley Authority. One issue during the blackout was the loss of so-called reactive power, voltage produced by power plants to keep the electricity flowing, like the water pressure in a pipeline. TVA, the nation's largest public utility, will soon begin tests of a superconducting device capable of generating or absorbing reactive power as needed.

Such superconducting technology relies on a phenomenon first identified in 1911 but not widely exploited until the discovery in 1986 of a new class of superconducting materials offering more potential for real- world use. When chilled sufficiently by a recirculating coolant, a superconducting material loses virtually all resistance to the flow of direct current and nearly all resistance to the flow of the alternating current used in the commercial power grid.

In the power cable design for the Long Island project, two layers of woven superconducting wire in the cable's core are bathed by a surrounding flow of liquid nitrogen coolant. The outer layers of the cable act like a Thermos bottle to keep the coolant in and heat out. Copper wire at the cable's center will not transmit power but is designed to absorb any short-circuit currents.

Once chilled, a superconducting cable will tend to remain cold for hours after a coolant leak, according to Gregory Yurek, president of American Superconductor of Westborough, Mass., a leading maker of superconducting wire.

That would give grid managers time to switch power to other pathways or isolate the leak.

Yurek, whose company will supply the superconductive wire for the Long Island cable, said existing superconducting cables can transmit 140 times more power than conventional cables of comparable diameter. The superconducting cables are costly, four to eight times as expensive as conventional copper wires, but Yurek said the price should continue to drop in the next several years. "We expect our costs to continue to come down," he said recently. "They've been coming down about 20 to 30 percent a year."

The price is pegged to the kiloamp meter, the cost of one meter of wire capable of transmitting 1,000 amperes of electrical current. According to Yurek, his company's superconducting wire now costs about $100 to $200 per kiloamp meter, compared to about $25 per kiloamp meter for copper. He said he expects the cost of his wire to drop to about $50 per kiloamp meter "within the next couple years." Further price reductions are anticipated when a next-generation superconducting wire now under development becomes available, Yurek said.

"The price is still considered fairly high at $50," said Robert Hawsey, a specialist on superconducting technology at Oak Ridge National Laboratory in Tennessee. But he said even that price would be sufficient to spur certain applications, including replacing sections of transmission cable in densely populated areas where much more power could be transmitted through existing conduits, eliminating the battle for new rights-of-way.

"The cables on Long Island won't use that much of our wire, but they will increase the power flow through the same right of way by five times," Yurek said.

"We see some real benefits with the superconducting technology," said Bruce Germano, LIPA vice president for retail services. "For us, it was the ability to put more [power] through the system" that was attractive, he said. "I think a lot of utilities are watching what we are doing to see if it makes sense." The Department of Energy will pay half the cost of the $30-million Long Island project; LIPA pays $2 million, the cable manufacturers pay the rest.

Hawsey said that superconducting cables with low impedance, a measure of the hindrance to flow of electric current, can be used to offload overloaded or stressed transmission lines. "They will help relieve congestion in the event of a hot summer afternoon," he said. Low-impedance cables become more controllable, Yurek said, letting operators dial the power up or down, or reverse the flow as needed. Such cables, if placed in the right locations, can "take the heat off conventional lines and upgrade the entire flow" of the system, he said.

A computer simulation by RAND, a nonprofit research organization, predicted that replacement of 20 strategic segments of transmission cable in downtown Chicago with superconducting cable could "relieve stress on a heavily overloaded network, resulting in increased reliability and increased power transfer capacity."

"The ability to improve the reliability of the system is to me a real benefit of superconducting cable technology," Hawsey said. "It's one reason utilities like LIPA are very interested."

Improving the reliability of transmission systems has emerged as a key issue on the heels of the Aug. 14 blackout, both in better management of the grid by overseers and in upgrading the infrastructure.

Superconducting cables are designed for underground use, a more costly proposition than stringing conventional overhead wires. In many cases, particularly in urban areas, transmission and distribution lines already have been placed underground.

There are, of course, some tradeoffs, Germano said. Underground cables, whether conventional or superconducting, are less susceptible to damage during storms. But doing maintenance and repair is more expensive for the underground cables, and one goal of the LIPA project is to demonstrate that the test cable and its associated cooling system can be reliably maintained.

"Once we prove the technology, we'll look to expand this," Germano said, by connecting to one of LIPA's other substations south of the East Garden City location. Yurek said it is possible superconducting cable eventually could be laid along the backbone of Long Island.

Germano said LIPA is not at the stage yet of assessing the long-term possibilities. But he said he does not envision such cables being extended into residential neighborhoods. Interest in possible uses of superconducting technology in the electric grid has a history on Long Island. During the 1970s and early '80s, a team at Brookhaven National Laboratory showed the feasibility of using superconducting material made of niobium and tin in two 430-foot-long transmission cables. The niobium-tin material is a low-temperature superconductor that, to be effective, had to be chilled to about 440 degrees below zero degrees Fahrenheit with liquid helium. While the cable could carry huge amounts of power, utilities did not consider it technically mature enough for use commercially.

In 1986, researchers discovered the first of a class of materials able to superconduct at relatively warmer temperatures than before, more like 265 degrees below zero. Such materials could be chilled with liquid nitrogen, cheaper and more abundant than liquid helium, and the findings prompted a new flurry of interest in practical applications of superconductivity such as transmission cables, electric motors, energy storage devices and powerful magnets that could levitate high-speed trains.

While some of the initial enthusiasm was premature, there has been steady progress in developing so-called high-temperature superconductors. The first- generation wiring is made of thin filaments of a compound of bismuth, strontium, calcium, copper and oxygen. A second-generation high-temperature wire is under development by American Superconductor and others. It is based on a compound of yttrium, barium, copper and oxygen.

LIPA is not alone in its interest in superconductivity. In Copenhagen, a company called nkt cables installed the world's first working superconducting cable in a public utility grid in 2001. During the test, the 100-foot segment served some 50,000 homes and businesses.

In Carrollton, Ga., Southwire Co. - a manufacturer of conventional wires and superconducting cable - has installed three 100-foot-long superconducting cables to provide three-phase AC power to two of the company's manufacturing plants and its machinery division. The cables have been operating since February 2000.

For a more ambitious project, Southwire and nkt cables have formed a joint company called ULTERA to design and produce a 1,000-foot superconducting cable to be installed in Columbus, Ohio, by late 2005. The utility involved is American Electric Power. As with the Long Island cable project, the Department of Energy will pick up half of the cost.

In another project, SuperPower Inc. of Schenectady, N.Y., is partnering with Sumitomo Electric Industries of Japan to build a 1,150-foot superconducting cable along the Hudson River and under Interstate 90 in Albany. The cable, expected to be operating in 2005, will be installed between two Niagara Mohawk substations.

In addition to the cable projects, utilities also are exploring use of superconducting materials in associated equipment for the grid. One of the problems in shipping alternating current over long distances is maintaining the voltage, or pressure to keep the power flowing.

The TVA has bought a device called a dynamic synchronous condenser from American Superconductor that produces reactive power to supplement the flow of electricity through a transmission cable, much like a water pump that helps keep water flowing through a pipe for a long distance.

The condenser, which incorporates some superconducting materials, uses only half the power of a conventional device and has several other advantages, according to TVA's Bradshaw. It is small enough to fit in a 20-foot trailer, so it can be moved as circumstances require. It is inherently stable and has a high overload capacity.

"We can get to 100 percent overload and keep it that way for two minutes," Bradshaw said. That gives the grid operator valuable time to respond to a nearby fault in the distribution system that may threaten to cascade into a major blackout.

TVA will dedicate its new dynamic synchronous condenser Nov. 12 and expects to begin a 12-month test period for the device in January or February. If the first is successful, Bradshaw said, the utility wants to be first in line to purchase at least five more. "Our perception is that demand for these could be quite high," he said.

Superconductivity also has promise for transformers that are used to convert electricity from one voltage to another. The Department of Energy is sharing the cost of developing a prototype, utility-sized superconducting transformer to convert electricity from 24.9 kilovolts to 4.2 kilovolts at the end of a power distribution line. The transformer is being built by Waukesha Electric Systems in Waukesha, Wis., and will be used to step down the voltage of power arriving at the company's plant.

Hawsey said a superconducting transformer can tolerate a doubling of its designed load for 48 hours or more, providing much more margin during an emergency. He noted that the superconducting design also is essentially fireproof, without the thousands of gallons of oil and flammable insulation used in conventional transformers. In 1997, a smoky transformer fire at an electrical substation in New Jersey forced the closing of the Goethals Bridge between Elizabeth, N.J., and Staten Island during morning rush hour.

Ed Pleva, manager of the transformer project for Waukesha, said the superconducting device is set for tests in December and, if all goes well, installation at the company's electric substation early next year. He said the company plans to operate the transformer for three to six months to demonstrate its performance but has no plans to commercially produce such devices until the second generation of high-temperature superconducting materials is ready.