

The HTS termination vessel at the National Grid service center is the injection point for liquid nitrogen into the cable system.

# Superconducting Cable Connects the Grid

## National Grid examines a cure for grid congestion.

By **Jon M. Moscovic**, *National Grid*

**UTILITIES NATIONWIDE ARE FACING A DILEMMA: AS THE DEMAND FOR POWER INCREASES**, so does public resistance to the installation of new power lines. In upstate New York, companies are taking steps to find possible solutions to these concerns. In fact, several companies have partnered to work on a promising new technology that may help meet increasing demand for power without the need for new lines.

High-temperature superconducting (HTS) cable can carry three to five times more current than conventional power lines of the same diameter. Four major companies — Super-

Power Inc. (Schenectady, New York, U.S.), Sumitomo Electric Industries Ltd. (Osaka, Japan), National Grid (Westborough, Massachusetts, U.S.) and The BOC Group (Surrey, England) of The Linde Group — have collaborated on a project using HTS in an effort to determine whether this type of cable could become a viable option in the not-so-distant future to help meet the increasing need for electricity while reducing the need for new power lines.

With congestion on electrical grids becoming a major problem, HTS cable technology enables the transmission and distribution of power through much smaller cables than

comparably rated conventional cables. And, HTS technology is more environmentally friendly. All of this is especially important in congested urban areas.

#### THE CABLE

HTS cable is composed of a ceramic-based superconducting wire that, when cooled to a very low temperature ( $-200^{\circ}\text{C}$  [ $-328^{\circ}\text{F}$ ]), has very little impedance. There are two types of HTS cable: warm dielectric and cold dielectric. This project utilizes the cold dielectric HTS cable, which offers advantages over warm dielectric, conventional and high-pressure, fluid-filled cables including:

- Higher current-carrying capacity and lower inductance
- Virtually no  $I^2R$  losses
- No electromagnetic fields outside the cable.

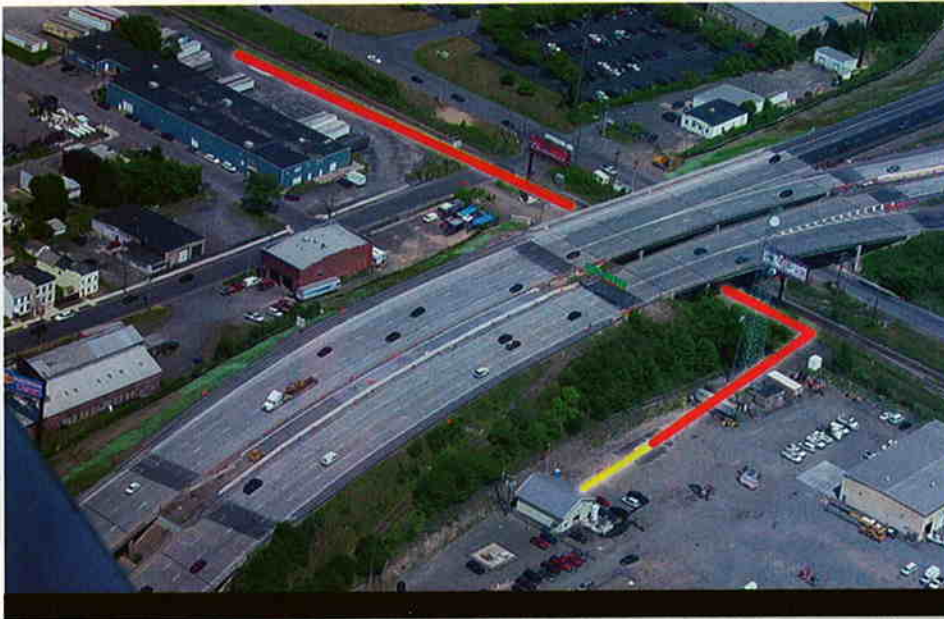
The 350-m (1150 ft), 34.5-kV HTS cable was fully integrated and energized on a portion of the National Grid electric transmission system in Albany, New York, in July 2006. The commissioning of this cable marks the world's first demonstration of an underground HTS cable system in a live utility grid as opposed to a lab, industrial or substation setting. This is also the first demonstration of an underground HTS cable-to-cable joint, which is critical for ensuring that long lengths of cable will be able to be installed in the future.

The cable will be operated over the next year as part of



This is the HTS cable-to-cable joint during construction. Future improvements are expected to reduce space requirements for these splices.

the National Grid system, which serves close to 4 million customers across Massachusetts, New Hampshire, New York and Rhode Island. Real-world utility concerns about implementing a new technology, including maintenance, reliability and compatibility with the existing grid, will be evaluated. During this period, the team will be working on phase two



The cable parallels Erie Boulevard in Albany, New York, and goes under Interstate 90 with one terminal at the service center south of I-90. The yellow-red transition marks the cable-to-cable joint, with the yellow portion indicating where the second-generation HTS cable will be installed.



Cut away view of a three-in-one cold dielectric HTS cable.

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of the project, with the goal of retrofitting a 30-m (98-ft) section of the existing HTS cable with an identical length of cable containing a newer generation of HTS wire called 2G HTS. The team expects to install the cable in the second half of 2007 and then test its performance in the grid.

#### THE START

This undertaking began in 2000 when two MBA students from Rensselaer Polytechnic

Institute (Troy, New York) conceived a plan in which their two companies, National Grid and Intermagnetics General Corp., the parent company of SuperPower Inc., could collaborate to demonstrate a new type of underground electric cable. SuperPower took the idea and submitted a proposal to the New York State Energy Research and Development Authority (NYSERDA) and the United States Department of Energy (DOE). NYSERDA has contributed US\$6 million and the DOE has contributed \$13.5 million toward this project.

One of the students, Terry O'Brien of National Grid, helped to facilitate the company's participation as the host utility for this project because of its extensive experience and expertise in energy transmission and its proximity to SuperPower, located approximately 15 miles (24 km) west in Schenectady.

#### HTS INSTALLATION

Seven locations were considered for the HTS cable installation. Most had land rights issues or the low-line current flows. National Grid's service center in North Albany, New York, was selected because of favorable logistical considerations and adequate line current flows to support the necessary research.

When digging and drilling to install the HTS cable, crews encountered several obstacles ranging from billboard and cell-tower footings to old building walls and water lines. Horizontal directional drilling (HDD) enabled the teams to overcome and avoid some obstacles. HDD uses a drilling head that can be guided remotely to tunnel underneath obstacles and

sensitive areas. HDD was used in the more critical spots such as billboard and cell-tower footings where deeper drilling was required.

Open-trench digging was required at a 90-degree turn of the cable and at the manhole where two sections of HTS cable were spliced together. Other items that were encountered during the digging, such as abandoned water pipes, sewer lines and old building remnants, were pulled out of the ground or cleared out of the way to enable the project to continue. These types of obstacles are typical of conventional underground cable installations.

#### HTS VERSUS CONVENTIONAL

A comparison of HTS cable and conventional underground cross-linked polyethylene (XLPE) cable and overhead wire yields several important benefits, including the fact that HTS cable has an impedance that is 300 times less than conventional XLPE cable and 800 times less than overhead wire. The inductance of the cold dielectric HTS cable is 6 times less than conventional cable and 21 times less than overhead wire. The capacitance of the HTS is slightly less than conventional underground cable, and the HTS cable has the ability to carry three to five times the capacity of a conventional cable with the same overall diameter. Challenges that remain to be solved before the widespread use of underground HTS cable can be an effective alternative for power delivery include cost and additional experience with cryogenic processes.

Observations from this HTS cable demonstration project illustrate the many potential advantages of the cable:

- *Higher current-carrying capacity.* This will be extremely useful in areas with a great deal of underground congestion. A conduit that contains a traditional cable carrying 200 A would be able to carry up to 1000 A with HTS. This will provide relief to overstressed parts of a network system without having

to dig and build a new duct bank. Alternatively, this ability to carry high current can reduce the number of conductors on that portion of the network, freeing up the ductwork for other uses. In highly congested areas of underground utilities this could be the only viable method available.

- *Low impedance.* HTS cables can be strategically placed in a conventional network so that current flow will be transferred from heavily loaded conventional cables onto the HTS cable. Thus, the overall system reliability would be improved by reducing the stresses in the surrounding equipment.

- *Rights-of-way.* Using duct banks that are already in place will result in a reduction of costs and time for permitting and construction. This could also reduce the level of effort to deal with various environmental concerns.

- *Very low EMF.* Inherent in HTS cable benefits to the utility are lower eddy currents that could be induced on nearby metallic objects; this also eliminates possible interference with telecommunications.

- *Less cost for the system.* Because of very small resistive losses with HTS cable, there will be long-term cost savings from the use of such cable.

Of course, since this is a new, relatively complex technology, there are challenges that must be overcome before widespread use can become a reality. Some of these include:

- *High initial cost.* The initial cost of integrating HTS cable will significantly exceed what an electric utility would typically spend on a conventional underground cable installation. This



Overall view of the cable termination vessel installation and the Cryogenic Refrigeration System building.

will be a challenge for the widespread application of HTS cable. As with any other emerging technology, the costs should drop considerably when the use increases and economies of scale can be realized.

- *Standard cable length.* This is a challenge in that HTS cables are currently manufactured to a customized length specific to each project. Because HTS is a new technology, manufacturing is limited at this time. Once the development of HTS cable progresses and its application becomes more commonplace, this challenge could likely be overcome.

- *Cryogenic Refrigeration System (CRS).* In this demonstration

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project, CRS is necessary to keep the cable at its super-cooled temperature. It is housed in a small building to allow easy access to the equipment and provide public visibility for the project. The freestanding liquid-nitrogen tank at the site also increases the space requirements for the system and adds a security concern. However, with the additional engineering that would be done for routine installations, the size needs of the CRS could be reduced to a system that could be installed in an existing manhole, also eliminating the security concerns.

- *Splicing of the HTS cable.* As is typical in the first-of-its-kind endeavor, splicing of the HTS cable takes up a considerable amount of space and time. With engineering improvements, the size of the splice should decrease along with the time it takes to complete the splice.

### RESULTS TO DATE

At the time of this writing, the HTS cable system has been running uninterrupted for more than six months carrying a nominal amount of power. There have been no major issues with the cable to report. Data are being collected and testing is ongoing.

The successful completion of this demonstration project is a significant step toward determining whether HTS technology can provide important improvements for the power grid.

There are numerous benefits to using HTS cable technology, and when costs begin to come down, HTS cable installations should increase. The DOE has estimated that the market for this technology could total \$30 billion by 2020. But today, the application of HTS cable is limited to underground utility applications. With further development in the areas noted, HTS cable could become a viable product for widespread use in the future, including some overhead applications. TDW

**Jon Moscovic** joined National Grid (formerly Niagara Mohawk Power Corp.) in June 2001 as a regional and assistant customer facilities engineer in the company's Albany, New York, location. He has a BSEE degree from Union College and an MSEE degree from the State University of New York — Buffalo. In 2003, Moscovic assumed the duties of underground engineer, laying the groundwork for his future work with the HTS project. He then moved up to senior regional and

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