EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Strategic Intelligence Update

Superconductivity for Power Delivery Applications

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First Issue of the Superconductivity Strategic Intelligence Update

Welcome to the inaugural issue of the EPRI *Strategic Intelligence Update: Superconductivity for Power Delivery Applications.* EPRI is producing this newsletter as part of its commitment to keep its members informed on the latest industry news and intelligence. Superconductivity is a rapidly evolving field, and this newsletter—along with EPRI's annual *Technology Watch* reports—will closely follow developments in key technologies, R&D programs, demonstrations, deployments, and other superconductivity activities. The next issue is currently scheduled for August 2013. Contact information for EPRI staff is provided on the back page, and we welcome your questions and feedback.

High-Temperature Superconductors Benefit the Grid

As worldwide demand for electricity grows and transmission constraints increase, the value of high-capacity, high-temperature superconductor (HTS) cables and superconducting fault current limiting (SFCL) substation devices becomes clear. According to the Coalition for the Commercial Application of Superconductors (CCAS) (see sidebar, Page 2), an industry advocacy organization, U.S. electricity demand is expected to increase 50% by 2030. The capacity, reliability and efficiency of the conventional electric grid must be improved to ensure a secure and sustainable energy supply. Superconducting equipment can help meet that need, but designing, fabricating and installing it presents many challenges.

The modern era of HTS began in 1987, when new materials were discovered that conduct electrical current with zero resistance at much higher temperatures than were previously thought possible. Although the United States led the development and demonstration of HTS materials and equipment in the 1990s and 2000s, in recent years DOE funding for superconducting research and development (R&D) has been cut to zero. Many R&D programs at national laboratories, universities, and industry were downsized or terminated. However, the worldwide growth of a superconducting wire market continues to stir both interest and investment in the superconducting wire manufacturing sector, and companies are positioning themselves to aggressively innovate and compete. Growing demand will continue to benefit such companies.

The U.S. power grid is expected to require upgrades costing more than $100 billion over the next decade to achieve and maintain acceptable electrical service. Three important superconductor characteristics promise benefits to electric power transmission and distribution (T&D) systems. First, the extremely high current density available in superconducting materials allows devices to be smaller and lighter than conventional equivalents. Second, zero resistivity lowers electrical losses in most devices to make them much more efficient than conventional systems. Third, superconductors undergo an abrupt phase change from superconducting to the normal state, which can be used to produce dramatic changes in impedance in a fraction of a second. These characteristics continue to attract attention from government and industry research initiatives, manufacturers, and

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utilities. The current focus on HTS cable and fault current limiters reflects lower technological barriers to commercialization in these applications.

CCAS points out that one-third of U.S. electric power consumption is concentrated in just 22 geographically compact metropolitan regions. Urban areas face a combination of issues that offer attractive opportunities for retrofitting existing underground ac transmission cables with superconducting ac cables. The confluence of urban load growth through increased electrification, the high cost of urban real estate and lack of space for high-voltage substations, and the growing need to harden the grid against manmade or natural power interruptions for critical loads present challenges to electricity distribution planners. Superconducting cables can help by bringing power into urban centers at lower voltages, eliminating the need for high-voltage substations. Combined with fault current limiters, they can also interconnect urban substations on the distribution side of transformers, leading to a more robust power system.

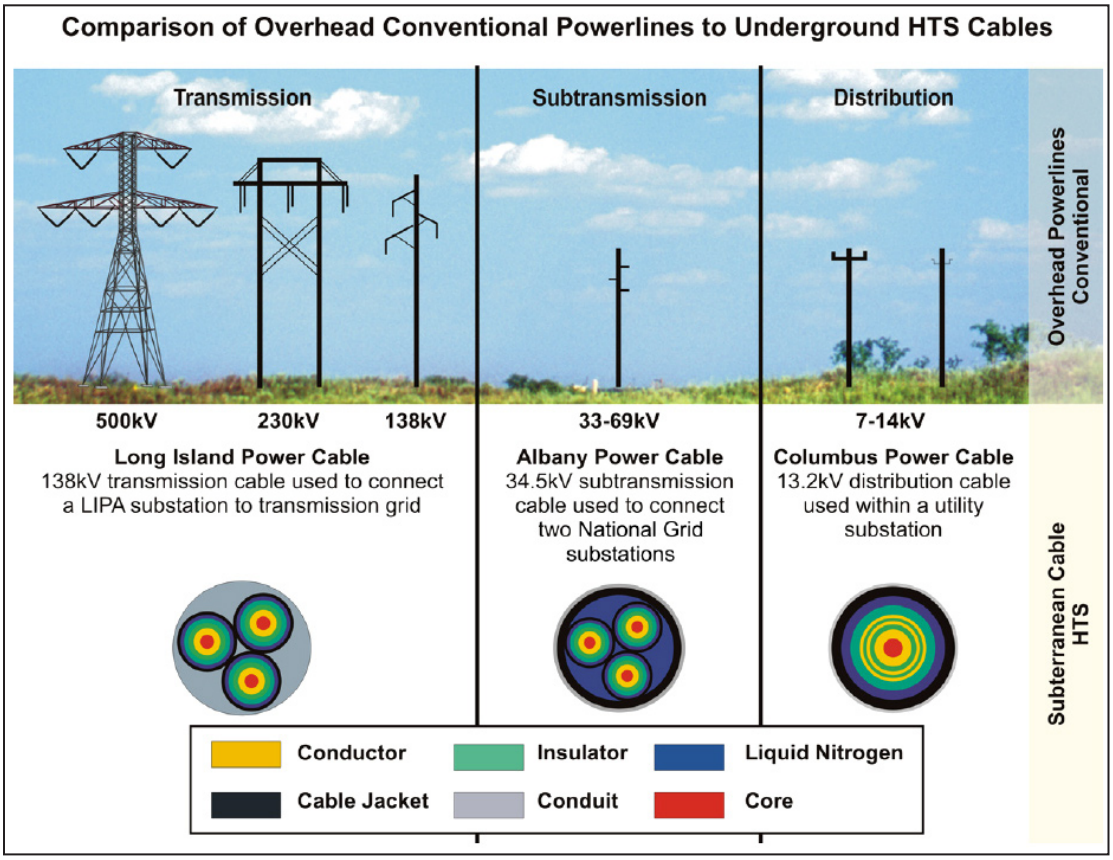
In addition, the demand to transport large quantities of renewable energy from wind, solar, or hydro projects in remote locations to population load centers is increasing worldwide, drawing attention to the greater efficiency and power capacity of HTS cables. Interest in dc superconducting cables for long-distance transfer of bulk renewable power or for special applications such as power flow control continues to grow internationally, with ongoing activity in the United States (see article on "Tres Amigas," Page 3) Germany, Russia, China, Japan, and South Korea.

CCAS Speaks for Superconductivity Stakeholders

The Coalition for the Commercial Application of Superconductors (CCAS) is a non-profit organization founded in 1987 to represent superconductivity stakeholders in the United States. Its members believe that broad commercialization of superconductors will translate into significant benefits for the U.S. economy across a range of applications.

"The mission is to communicate the varied applications and benefits of superconductivity, and to represent the superconductor industry by speaking with a united voice on public policy," reads the organization's mission statement. "CCAS enables members to communicate and collaborate, nationally and internationally, to collectively develop and demonstrate multi-disciplinary technology, to educate policy makers, and to advocate priorities for adequate government funding for superconductor-based programs from research to pre-commercial demonstrations." The coalition is also a founding member of the International Superconductivity Industry Summit (ISIS).

For more information, including access to several CCAS industry position papers, visit www.ccas-web.org.



DOE illustration of the infrastructure and land-use savings possible through the use of underground HTS cables. The references to "Albany" and "Columbus" pertain to two DOE HTS demonstration projects in New York and Ohio, respectively. (Source: DOE)

The need for advanced fault current limiters is also increasing, both for utility companies faced with unanticipated load growth in some parts of the grid and for independent power producers who want to interconnect with the grid at locations that cannot support increased contributions to fault current. Progress on developing SFCLs continues on several fronts.

EPRI's Superconductivity Project, which is part of the EPRI Underground Transmission Program, aims to address the industry's research needs in the following areas:

• Reporting on and assessment of the results of hardware demonstrations to validate equipment performance and cost

• Stakeholder dialog to increase understanding and define equipment design and testing requirements

• Guidelines for business case development to help early adopters justify investment

• Education of utility personnel via regular, timely and informative technology status information on superconducting power system research, development, and demonstration (RD&D).

For more information on EPRI's superconducting technology activities, see http://portfolio.epri.com/ProgramTab.aspx?sId=PDU&rId=233&pId=7320.

Tres Amigas Seeks $1.65 Billion in Bond Funding

The Tres Amigas SuperStation in eastern New Mexico was conceived in 2010 as a project to link the three major U.S. electrical grids (the Western Interconnect, the Eastern Interconnect, and the Electric Reliability Council of Texas (ERCOT)) using ac-to-dc converting stations and high-voltage direct current (HVDC) superconducting power lines to transfer up to 5 GW of electricity among them. The separation of the grids, which operate asynchronously, is a major barrier to the transport of electricity—particularly renewable energy—to load centers with high demand.

In late 2012, Tres Amigas LLC applied for $1.65 billion in taxable industrial revenue bonds (IRBs) from the City of Clovis to help fund the project. IRBs would allow Clovis to forgive the property taxes and other taxes the project would otherwise be obligated to pay and present no risk to the city, which is interested in employment opportunities the project would bring to the area. Tres Amigas LLC will pay the debt service on the IRBs by leasing the power station. The Clovis City Commission approved the agreement in principle in October 2012 and was scheduled to have its first resolution reading of the bond issue in late April 2013, beginning the process of public comment and deliberation.

According to Tres Amigas Chief Operating Officer and Senior VP David Stidham, $1.65 billlion "is the total projected cost of the 5-GW build-out. It is important to note that the City of Clovis is not providing financing of $1.65 billion, but only tax relief for this amount."

Tres Amigas will be built in three phases costing $485 million, $433 million, and $793 million. Groundbreaking is scheduled for summer 2013, with commercial operation date (COD) 36 months after start of construction, said Stidham.

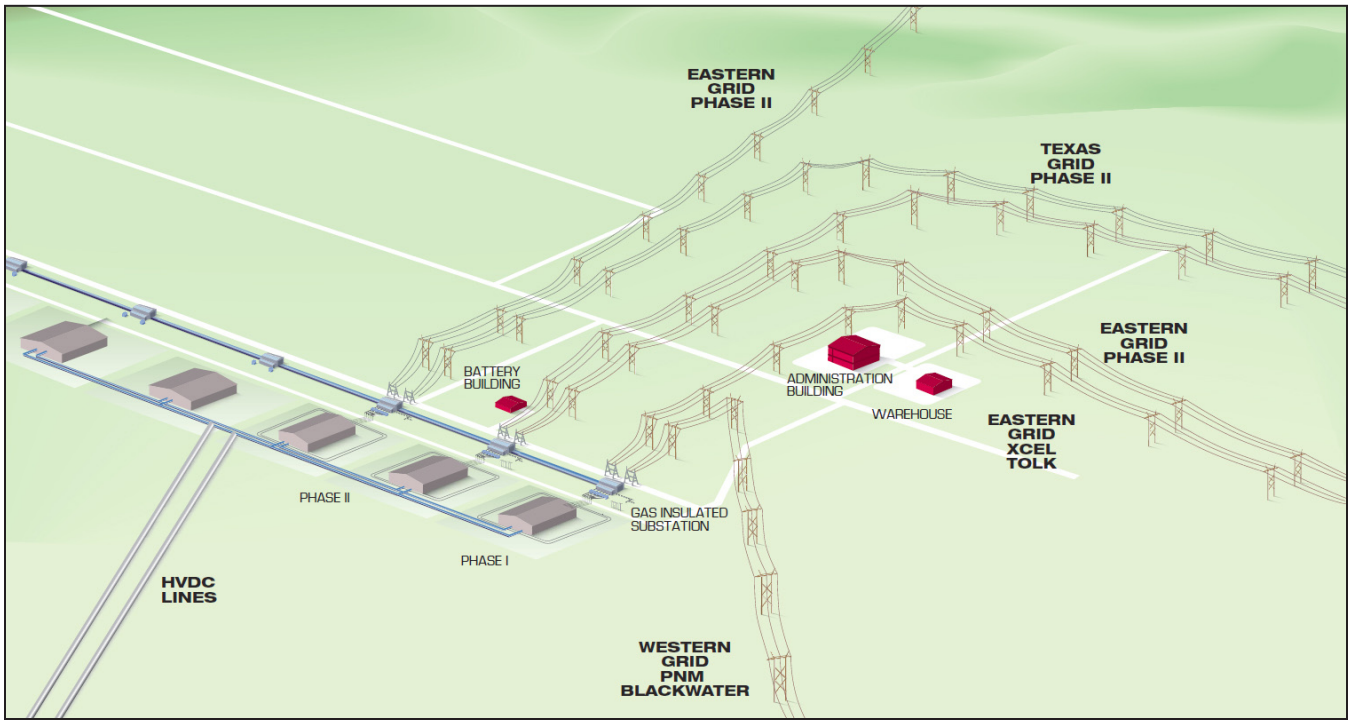


Illustration of the Tres Amigas SuperStation, to be located near Clovis, New Mexico (Source: Tres Amigas LLC)

DOE Grants Grid Logic $3.8 Million

Grid Logic, which formed in 2010 to manufacture and market technology for grid-connected superconducting and cryogenic applications, recently received a $3.8 million cost-shared grant from the DOE Advanced Research Projects Agency–Energy (ARPA-E) to support is HTS wire research and development.

Grid Logic was one of 66 companies sharing in $130 million from ARPA-E's "OPEN 2012" program to encourage promising transformational technologies. Utility NextEnergy will help Grid Logic pay its share of the award via its Michigan Accelerating Technology (MATch) Energy Grant program, which is funded through the Michigan Economic Development Corp. In 2010, Michigan's Clean Energy Advanced Manufacturing (CEAM) program awarded Grid Logic $5 million to develop a SFCL.

Grid Logic is working on new superconducting materials that could address many of the problems limiting the commercialization of HTS systems. The company will use a proprietary technique to manufacture the wire, which Grid Logic claims could reduce the cost and increase the strength of HTS cables by a factor of 10.

"The technology uses HTS particles embedded in a metal matrix to create superconducting nanocomposites rather than using the deposition systems required by rolling-assisted biaxially-textured substrates (RABiTS) or ion-beam-assisted deposition," Grid Logic VP of Operations Tim Westman explained to *Superconductor Week* (Vol. 26, No. 23). "It shows potential for applications where high current is required in demanding operating environments and relatively low magnetic fields." Materials Grid Logic uses in creating its nanocomposites include yttrium barium copper oxide (YBCO) and bismuth strontium calcium copper oxide (BSCCO-2212). For more information, visit www.grid-logic.com.

Update: SFCL Commercial Offerings

American Superconductor (AMSC) and its partner Nexans have introduced a new medium-voltage superconducting fault current limiter to commercial markets in North America. The companies are offering SFCLs with ratings up to 36 kV, which could be used on most utility electric distribution systems. The SFCL is passive, sitting idle and invisible to the grid, but can sense and suppress fault currents when they occur.

AMSC and Nexans describe their SFCL as a "cost effective, fast (response time of less than 2 milliseconds), and self-acting system" that limits potentially destructive fault currents, which are typically caused by short circuits in the grid, to safe and manageable levels. Reducing peak currents during faults can greatly reduce system equipment costs, defer or eliminate equipment replacement, increase equipment life, improve grid performance and operation, simplify renewables integration, and improve operator safety.

"We are pleased to be expanding our product line and our relationship with Nexans with the launch of the SFCL," said AMSC President and CEO Daniel P. McGahn. "Having successfully teamed to install superconductor power cables and develop and demonstrate SFCL systems, both AMSC and Nexans believe the time is now to begin capitalizing on the tremendous potential that exists for these offerings in the utility market."

Nexans installed SFCL systems at a coal plant in Germany and a substation in the United Kingdom in 2009, and plans to install additional systems in Europe.

Bruker Abandons SFCL R&D

Meanwhile, one prominent superconductivity company, Bruker, has halted all SFCL research and development in its Bruker Energy & Supercon Technologies (BEST) division. Company officials said that although they remain committed to selling superconducting materials and systems, and will retain the intellectual property needed to restart SFCL R&D, a combination of protracted technical problems and an uncertain commercialization timeline has effectively stopped the program for the time being.

"We decided not to pursue (the SFCL program) going forward in 2013 because the commercialization opportunities were just too far out," said Bruker President and CEO Frank Laukien, speaking at a JPMorgan event in January 2013. "We are going to cut back on our R&D and business development in that area."

SuperPower Project Achieving Milestones

A team led by SuperPower Inc., a subsidiary of Furakawa Electric Co. of Japan, reported "excellent progress" on its efforts to develop a new generation of HTS wire, SFCLs, and related components at the April 2013 Hannover Messe Trade Fair in Germany.

Partners on the project include ABB, SPX-Transformer Solutions, TECO-Westinghouse, and the University of Houston. Partly funded by DOE through the American Recovery and Reinvestment Act (ARRA), they are working to design, develop, manufacture and test a smart-grid-compatible 28-MVA three-phase SFCL medium-power utility transformer with Southern California Edison.

SPX Technical Advisor Shirish Mehta told fair participants that

they have made "significant progress in meeting the originally scheduled goals for key milestones" on the project.

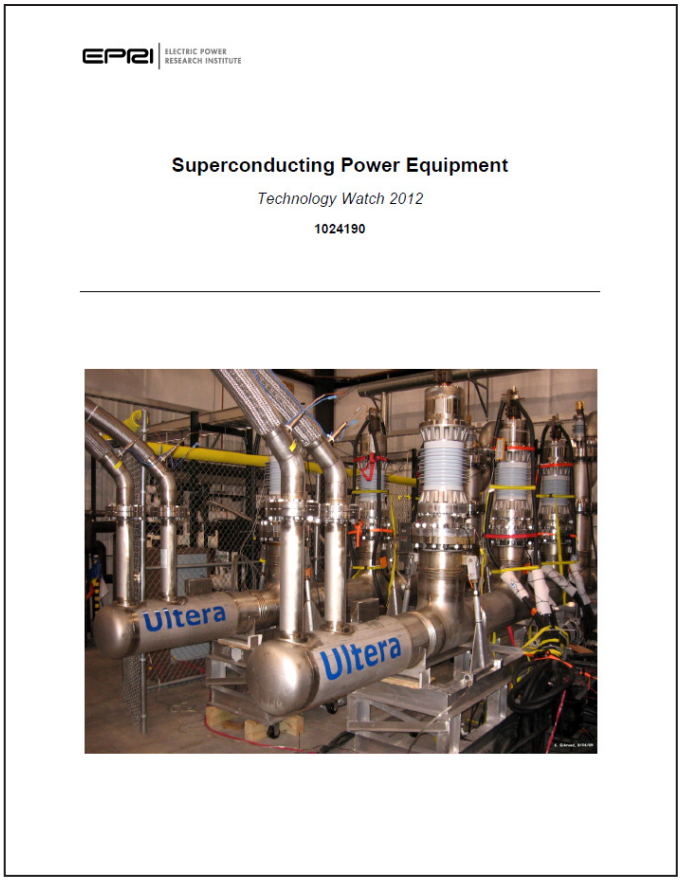
"We are excited about recent results of tests on the conductor performance with respect to ac losses in perpendicular fields for the conductor arrangement we have developed for the FCL HTS transformer windings," Mehta continued. "We will perform many other tests with transport current and different magnitude and direction of fields in order to validate these initial results. This validation should provide a pathway toward a very low-loss transformer with a simpler cooling system design that is expected to result in improved performance and reduced costs. It is our expectation that these improvements should accelerate the introduction of this new technology in the power delivery industry."

EPRI *Tech Watch* Reports on HTS

For several years, EPRI's Superconducting Technology Project has released annual *Technology Watch* Technical Updates that cover superconductivity activities in the past year, with an emphasis on particularly dynamic areas of the industry and detailed appendices summarizing projects around the world. The most recent report, *Superconducting Power Equipment: Technology Watch 2012* (1024190), which was published in December 2012, focuses on HTS cables and SFCLs.

Following an Introduction, Chapter 2 of the report describes superconducting power cable activities in the Americas, Asia and Europe. Chapter 3 discusses SFCL activities in the Americas, Asia and Europe, and Chapter 4 offers conclusions. More than 40 pages of references include detailed technical specifications on the projects described in the report as well as many others.

Technology Watch 2012 and other selected EPRI reports on superconducting technologies are available free to the public, including the *Technology Watch* updates for 2011 (1021890), 2010 (1019995) and 2009 (1017792). Although older, these reports still contain useful information because their technology emphasis varies and is not entirely duplicated in subsequent reports. For example, the 2011 *Technology Watch* provides a broad survey of all superconducting power equipment, including cables, FCLs, transformers, energy storage and substations. All are available for download at www.epri.com.



News Briefs

AMSC has been chosen to supply its HTS Amperium® wire to **Nexans** for use in an SFCL as part of **AmpaCity** in Essen, Germany. Begun in September 2011, the €13.5 million ($17.6 million) AmpaCity project will be the first combination of HTS cable plus SFCL in the European grid. A primary objective of the project is to replace an aging high/medium-voltage (110-kV/10-kV) transmission/distribution infrastructure with lower-voltage (10 kV) HTS cables, which would reduce the number of urban high-voltage transmission lines and substations with large oil-filled transformers. Project partners include local utility RWE Deutschland and the Karlsruhe Institute of Technology. EPRI's *Superconducting Power Equipment: Technology Watch 2012* (1024190) has much more detail on AmpaCity (see pages 2-20 and 3-16).

The third annual **New York State Superconductivity Technology Summit** will be held May 6–7, 2013, in Albany, New York. Agenda topics include panels on Energy & Power, Electronics & Computers, and the New York State Superconductivity Industry, as well as tours of local companies. The event will be held at the University of Albany's College of Nanoscale Science and Engineering, and is supported by the New York State Energy Research and Development Authority (NYSERDA). For details, visit www.mtechlabs.com/sc_summit/index.html.

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