2019 High Temperature Superconductivity Summer News Update

Produced by

the International Energy Agency's (IEA) Technology Collaborative Program (TCP) on HTS[1]

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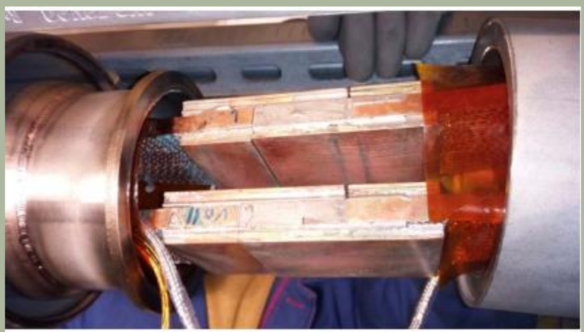
HTS Application Projects

HTS applications like these are creating unique opportunities for commercial components that can enable the needed evolution of the energy system

High-Current Superconducting DC Busbar

A German research team has developed a superconducting high current DC-busbar. The demonstration project has a length of 25 m and a nominal current of 20 kA in a real-life industrial application: a chlorine electrolysis plant. The busbar is a modular system with rigid superconducting elements that were easily transported and installed at the industrial site. To manufacture such elements, several issues had to be addressed. The arrangement of the superconducting tapes was optimized with respect to the minimization of the magnetic self-field effects. The thermal contraction of the busbar had to be balanced, and the low-resistance joints between the superconducting elements had to be developed. The system operates at 70 K with liquid nitrogen using D-Nano and Theva superconducting wires with an energy efficient pulse-tube cryocooler and cryopump.

In general, the increase in efficiency in comparison to conventional systems depends on the current and system length. The biggest component a superconducting system's losses occur at the current leads, and consequently, optimized designs are mandatory. Superconducting systems can be more energy efficient at currents above 10 kA and lengths beyond 20 m. As an example, with a current of 60 kA and a length of 60 m approximately a 50% higher efficiency can be achieved in a 2-pole system.



The figure shows the busbar inside the cryostat and the exposed area being soldered

Wind Power Projects

A countryside windfarm

In July 2019, the U.S. Department of Energy (DOE) selected three projects totaling up to $8 million to develop next-generation wind turbine drivetrain technologies that will facilitate the continued growth of wind turbines for both land-based and offshore applications. These projects will develop more efficient, smaller, and lighter-weight generators that have the potential to lower costs.

Each of the selected projects will receive up to $500,000 to design a wind turbine generator that can be scaled up to at least 10 megawatts to capitalize on the trend of larger, more powerful wind turbines, especially for offshore applications.

One project is developing a "direct drive" permanent magnet generator design that is smaller, lighter, less expensive, more reliable, more efficient, and uses less rare earth content than conventional gearbox designs.

Two projects will develop superconducting generators, which make a much stronger magnetic field using superconducting windings. This results in a significant size and mass reduction over conventional generators and significantly reduces the need for rare earth materials. AMSC will develop a high-efficiency lightweight wind turbine generator that incorporates HTS materials to replace permanent magnets in the generator rotor, potentially reducing size and weight by 50%. General Electric will develop a high-efficiency ultra-light low temperature superconducting (LTS) generator, leveraging innovations from GE's magnetic resonance imaging (MRI) business. The generator will be tailored for offshore wind and scalable beyond 12 MW.

These research projects have the potential to develop machines up to 50% smaller and lighter while reducing the cost of wind generation by 10–25%. After these projects complete a design and analysis phase, DOE will select one project to receive up to $6.5 million to build and test a scaled prototype of their generator on a wind turbine.

Chicago Cable Project

An HTS cable will increase downtown Chicago's resilience

A Superconductor Cable Development Project is being constructed as part of the Resilient Electric Grid Program of the United States Department of Homeland Security (DHS) in the Commonwealth Edison's (ComEd) service territory in Chicago, Illinois. The purpose of the project is to increase grid resilience in the downtown Chicago business district by increasing the redundancy of three existing substations from two contingency capability (N-2) to three contingency capability (N-3) and to provide voltage support and relieve thermal overloads under severe contingencies. The project will use an HTS cable to connect three existing substations in a looped transmission system and will allow for a demonstration of the technology as the first permanent installation on the U.S. electric grid to provide new looped transmission pathways.[2]

Phase I of the project will be an installation of an HTS cable located entirely within the perimeter of a substation a few miles north of the Chicago business district. The cable will connect two terminals of the substation, thereby increasing the design contingency of that substation to N-2. The purpose of Phase 1 is to learn and test the new technology, but it will also yield the contingency benefits.

For Phase 2, the main phase of the Project, ComEd proposes to install two underground 12 kV high-temperature superconducting cables to loop together the three substations in order to provide N-3 capability to the substations. ComEd explains that the HTS cable will include circuit breaker equipment that ensures that power flows will "sectionalize" as needed to share service from the other substations if there is an outage impacting the delivery to any of the substations.

The HTS system will function as transmission because it "(i) provides bi-directional flows between multiple substations in the Chicago Central Business District during emergency conditions in the same manner as high voltage transmission; (ii) increases reliability and resilience of the transmission grid; (iii) provides voltage support and relief from thermal overloads for the transmission grid; and (iv) displaces the need for transmission upgrades."[3]

ComEd anticipates placing Phase 1 of the Project in service in the first quarter of 2021. Construction of Phase 2 in downtown Chicago would not begin until after a full year of operation of the Phase 1 installation, in order to evaluate any changes or considerations that should be factored into Phase 2. ComEd estimates that Phase 2 would come on line in the fourth quarter of 2026.

DHS and AMSC will assume approximately 53 percent of the project costs, and ComEd will assume the remaining 47 percent, which it estimates to be $67 million ($11.9 million for Phase 1 and $55 million for Phase 2).

HTS for Fusion

A picture of Commonwealth Fusion Systems

Commonwealth Fusion Systems (CFS), a spinoff from MIT Plasma Science and Fusion Center, was established in 2018 to build, test, and ultimately commercialize a compact fusion reactor using high field magnets with ReBCO conductors. A commercial 200-MWe reactor would be available around 2033 according to the company. The goal

[2] United States Federal Energy Regulatory Commission, Docket No. ER19-1478-000, May 28, 2019

[3] United States Federal Energy Regulatory Commission, Docket No. ER19-1478-000, May 28, 2019

is to go from project startup to an electricity-producing tokamak fusion reactor in less than half the time planned for ITER and at a fraction of its cost. CFS is one of half a dozen or so small startups pursuing alternate approaches to fusion.

An "affordable, robust, and compact" (ARC) fusion reactor is CFS' ultimate commercial goal. The intellectual forerunner to ARC and the basis for much of its technology is MIT's Alcator C-Mod. C-Mod was a high toroidal magnetic field tokamak which operated at MIT's Plasma Science and Fusion Center (PCFC) from 1993 to 2016. CFS will start with a demonstration reactor dubbed SPARC (for "smallest possible ARC"). Unlike C-Mod, however, SPARC (and ARC) will use HTS magnets to produce up to 3 times higher field than achieved with C-Mod.

The magnets will be first-of-a-kind, high-field (20 T peak), large-bore HTS superconducting magnets. The magnets will operate at 20K, probably using gaseous He, though the coolant has not been disclosed. Design and construction of a first magnet has begun and is slated for completion by the end of 2021. Magnet conductors use ReBCO tapes in a "variant" of a twisted stacked-tape cable (TSTC) developed by MIT researchers and others. Such cables have been tested at fields up to 17 T at 4.2K. SPARC requires 10,000 km of wire; ARC doubles that. CFS solicited wire suppliers world-wide for the necessary conductor and has made about four awards to date for a total of about 500 kilometers of wire. Ultimately, CFS plans to build its own wire manufacturing facility. SPARC would produce net-energy (Q>1) like ITER, but not electricity. The estimated cost is $400 million. About $115 million has been raised in venture capital funding. The US DOE, which has sponsored MIT fusion research recently announced support for the CFS program.

Global Superconductor Market Reports

Global Superconducting Cables Market Growth 2019-2024 Report

How successfully are these HTS applications entering the energy marketplace? Two new reports shed light on the health of the marketplace.

It presents a comprehensive overview, market shares, and growth opportunities of the superconducting cables market by product type, application, key manufacturers and key regions and countries. The report is only available for purchase (for several thousand USDs!), but if you think the TCP could benefit from purchasing one copy for ExCo membership, please express your interest so the Presidium can discuss the value of using this analysis in subsequent talks and publications. Some highlights include:

- "The global installation production of superconducting cables increased from 5624 meter in 2013 to 8295 meter in 2017, at a CAGR of 10.2%. In 2017, the global superconducting cables market is led by USA. Europe is the second-largest region-wise market."
- "Over the next five years the Superconducting Cables market will register a 12.2% CAGR in terms of revenue, the global market size will reach US$ 420 million by 2024, from US$ 210 million in 2019."

Click here to request the report

Global Superconducting Magnetic Energy Storage Market (SMES) Report

The Global Superconducting Magnetic Energy Storage Market report includes market valuation, market size, revenue forecasts, geographical spectrum and SWOT Analysis of the industry. In addition, the report depicts key challenges and growth opportunities faced by the industry bigwigs, in consort with their product offerings and business strategies. The market characteristics, size and growth, segmentation, regional breakdowns, competitive landscape, market shares, trends and strategies for this market. Global Superconducting Magnetic Energy Storage Market report provides strategists, marketers and senior management with the critical information they need to assess the global Superconducting Magnetic Energy Storage sector. It provides the industry overview with growth analysis and historical & futuristic cost, revenue, demand and supply data (as applicable). The research analysts provide an elaborate description of the value chain and its distributor analysis.

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