Organization: Oak Ridge National Laboratory

Project Title: High-Temperature Superconducting Power Cable

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FY 2001 Funding: $1.4 million (DOE to ORNL)

Project Purpose: For this Superconductivity Partnership Initiative project, Southwire and ORNL have jointly developed, installed and are presently operating a 30-m (100-ft) long high-temperature superconducting (HTS) power cable to demonstrate the feasibility of this promising electric utility application. The cable has been installed in the electric network, as a section of a distribution circuit, delivering power from a utility substation to an industrial customer. The cable is rated at 12.4-kV, 1,250-A, 3-phase, 60-Hz, and 27-MVA. The industrial customer is the wire-manufacturing complex located at the Southwire Company Headquarters in Carrollton, Georgia. The cable was placed into full service in April 2000 for an extended testing period under real-use situations, highlighting Southwire's expertise in HTS cables and field testing this viable technology for the electric utility industry.

FY 2001 Objective: ORNL will work with Southwire to improve the overall design and capabilities of the HTS cable system. Specific activities include: 1) evaluation of 30-m cable operation and performance, 2) research and development and testing of cable splices, 3) continue development of the pressurized termination, 4) continued research on cryogenic dielectric materials, and 5) research improving cryogenic systems for HTS electric applications.

FY 2001 Performance and FY 2002 Plans: During FY 2001, the overall project goal has been accomplished with the successful operation of the superconducting cable system as shown in the adjacent picture. All ORNL FY 2001 project objectives will be completed. In addition, a new task investigating the characteristics of a tri-axial conductor has been initiated. In FY 2002, ORNL will work with Southwire to improve the overall design and capabilities of the HTS cable system. Specific activities include 1) a bend testing of a 5-m HTS cable with flexible cryostat, 2) design, construction, testing and analysis of 5-m tri-axial HTS cable including 3-phase terminations, 3) continued development of the pressurized termination, 4) continued development of cryogenic dielectric materials, and 5) continued research improving cryogenic system performance with industry and NASA. ORNL will begin the design and testing of cable subsystems for a long-length cable installation in partnership with Southwire and American Electric Power.

FY 2001 Results: Significant progress has been made towards the project objectives during the year and a new task investigating the characteristics of a tri-axial conductor has been initiated.

30-m HTS Cable. In April 2000, the cable was placed into extended service and has logged over 7500 hours of flawless operation in the 14 months ending May 2001. The cryogenic system has been in continuous operation since November 1999. The cable has not been the cause of any power outages to the average 20 MW industrial load served by the cable and has been exposed to short-circuit currents caused by load-side faults. The performance of the superconductor was tested in April 2001 and there has been no measurable change in the critical current of the superconductor providing further credence to the viability of this promising technology. The successful completion of the project goal represents a breakthrough in making the difficult transition from laboratory testing to a practical field application.

Splice Cable and Improved Terminations. A cable splice has been designed to allow two sections of superconducting cable to be joined into a longer cable. A 5-m long superconducting splice cable has been constructed and successfully tested at the ORNL/Southwire Cable Test Facility located at ORNL. At the same time, an improved pressurized termination (T2) design with a lower heat loss and higher impulse breakdown strength was tested. The critical current, ac losses, and ac withstand capability of the splice cable were measured. Heat loads and pressure drops as a function of LN flow was measured for the improved T2 configuration. The cable and terminations were subjected to fault current and impulse lightning tests.

Cryogenic Dielectric Aging Tests. Experiments to assess the expected life of the cable dielectric system are in progress. When a high-voltage stress, V, is applied to a cable, the time-to-breakdown, t, is generally related to the stress by the power law relation, $t \times V^n$ = constant, where n depends on the thickness and type of dielectric. A determination of n from aging experiments conducted at different voltage stresses is being used to determine the expected life of a cable at its operating stress. Partial discharge (PD), considered to be the aging mechanism of cryogenic cable dielectrics, is being studied using a state-of-the art partial discharge detection system which provides phase and amplitude resolved PD data.

Tri-axial Cable. A tri-axial cable design that compacts all three phases into one concentrically wound cable offers efficient use of superconducting wire and cable cross-sectional area. A 1.5-m long tri-axial conductor has been designed and constructed using BSCCO superconducting tape. The critical current of the tri-axial cable has been measured and the ac losses have been measured in a variety of configurations (e.g., all combinations of phases using a single-phase and a three-phase current source).

Technology Integration: During the course of the project, the project team has used the expertise of numerous individuals from Southwire and ORNL. In addition, private consultants, cryogenic equipment manufacturing firms, and superconducting materials suppliers have been sought out for expertise and advice during the project. Many major components of the 5-m and 30-m cable systems were procured via competitive subcontracts. The design, assembly, and operation of the cable test facility at ORNL and 30-m demonstration cable at Southwire have been totally integrated efforts drawing upon scientists, engineers, and technicians from Southwire, ORNL, and private industry. A program is in place with NASA to improve the thermal insulation performance of flexible cryostats for HTS cables.

Four technical papers (including one invited paper) were presented at the *Applied Superconductivity Conference* in September 2000. A technical paper was presented at the IEEE Winter Power Meeting in February 2001. Two presentations in the general session on “Next Generation of Conductor Technology” were given at the Edison Electric Institute, “Transmission, Distribution & Metering Spring 2001 Conference,” held in Seattle, Washington on May 6-9, 2001. Six technical papers are being prepared for presentation at the *2001 Cryogenic Engineering Conference* to be held in July 2001.