Project Title:	**High-Temperature Superconducting Power Cable**
Organization:	**Oak Ridge National Laboratory**
Presenters:	**David Knoll, (Southwire Co./Ultera), Jonathan Demko (ORNL), Isidor Sauers (ORNL)**
FY 2010 Funding:	$725 K

Overall Project Purpose and Objectives:
Ultera (a joint venture between Southwire Company and *nkt* cables) and ORNL have developed, built and demonstrated a series of cold-dielectric, high-temperature superconducting (HTS) power cables for a Superconductivity Partnership with Industry (SPI) and Superconducting Power Equipment (SPE) projects. In FY 2010, ORNL has worked with Southwire Company to research and improve the overall design and capabilities of HTS cable systems including:

- Monitoring the operation of the 200-m long, tri-axial, 3-phase, 3,000 A_{rms} cable that is installed at the AEP Bixby Substation in Columbus, Ohio.
- Conducting HTS cable thermal hydraulic analysis and benchmarking of test data for different scenarios such as heating from faults and calculating recovery time to return to operation.
- Continued R&D of cryogenic dielectric (CD) materials for end terminations and cables.
- Fabrication and testing of 3 meter prototype cables to qualify 1G and 2G tape for long-length HTS Triax^{TM} Cables.

2010 Approach and Results:
Significant progress has been made towards the project objectives during the fiscal year. Generic research applicable to long-length HTS cable development has continued.

HTS Cable Thermal-Hydraulics. Initial tests were conducted on the simulated HTS cable thermal-hydraulic test loop. Some instrumentation modifications were found to be required on the apparatus and are being implemented.

AEP Tri-axial Cable. The HTS Triax^{TM} Cable was energized in August 2006 and has been carrying power in the Bixby Substation since that time. Peak loading on the cable system has been in excess of 2,700 A phase current.

Cryogenic Dielectrics. A dc cable was fabricated at ORNL using HTS tapes for the conductor and cryoflex layers for electrical insulation. Last year this cable successfully passed a 60 kV negative dc withstand test for 15 minutes. The voltage however was limited since this was the maximum voltage available from the power supply at the time. Since then a new power supply was obtained which could go to higher voltages. This FY the same cable was retested using a new Glassman dc power supply capable of 125 kV dc positive or negative at 2 mA current. The voltage was stepped up to 125 kVdc neg and held with no breakdown.

1G and 2G Model Cables. In preparation of future long-length cable projects using 2G tapes, prototype cables were fabricated with different conductor architectures. Results will be presented on round-robin ac loss testing and current distribution characterization that was done in collaboration with Los Alamos National Laboratory with prototype cables that were made with American Superconductor tapes. In support of dc cable development, initial ripple studies have been carried out on prototype 1G cables and additional high voltage testing was carried out on a prototype 2G cable. Finally prototype 2G cables have been fabricated to examine the influence of current distribution on ac loss.

2011 Plans and Expectations:

Plans for FY 2011:

1. Test model cables and terminations to higher ac voltages (up to 69 kV); investigate ac breakdown strength and partial discharge inception and examine scaling to higher BIL levels; and continue development and testing of improved dielectric tapes and other materials for use at higher voltages. Perform a systematic study of failure mechanisms of electrical insulation for HTS cables to improve future design and reliability. Characterize the relative importance of known defects on breakdown strength and partial discharge inception of model cables with ac, dc, VLF, and impulse in LN2 under pressure. Partial discharge signatures will be associated with each type of defect as a potential diagnostic aid. Implications for performing factory room temperature acceptance tests will be assessed.
2. Provide technical support to Southwire Co. and monitor AEP HTS cable operation.
3. Develop and refine approach to thermal management and design of long-length HTS cable systems to include fluid transients (water hammer, thermal control, and long length diagnostic measurements). Continue conducting experiments on the small scale thermal-hydraulic test loops and compare with analysis.
4. Continue development of advanced thermal insulation systems for cables to include non-vacuum thermal insulation for increased reliability.
5. Conduct research and development on instrumentation to monitor thermal condition of long length cables and refine ac loss measurement techniques to reduce uncertainty for prototype, demonstration, or commercial systems.
6. Continued testing on 3 meter prototype cables to optimize cable design for long-length HTS cables. Plan to measure the ac losses resulting from ripple currents on a dc cable.
7. Provide technical support and testing to Concurrent Technologies Corporation for cryostat thermal insulation research and development.

Technology Transfer, Collaboration, Partnerships:

The design, assembly, and operation of the cable test facilities at ORNL, the 30-m demonstration cable at Southwire Company, the 200-m demonstration cable at AEP, and most recently the 25-m Project Hydra fault current limiting cable tests have been totally integrated efforts drawing upon scientists, engineers, and technicians from Southwire, *nkt* cables, ORNL, AMSC, and private industry. Private consultants, cryogenic equipment manufacturing firms, and superconducting materials suppliers have been used as required.

Four technical papers relating to HTS cable thermal management, HTS conductor engineering and cryogenic dielectrics were published in *Advances in Cryogenic Engineering*, Proceedings of the Cryogenic Engineering Conference held in July 2009. Three papers will be presented at the Applied Superconductivity Conference in August 2010. Several ORNL personnel attended the EPRI Workshop on Superconducting Direct Current Electricity Transmission held in January 2010 at Houston, Texas. Jonathan Demko was the facilitator for the Cryogenics, Vacuum, and Thermal Insulation session and lead author for that chapter of the workshop proceedings.

ORNL is a key participant on Project Hydra sponsored by the Department of Homeland Security (DHS) to design, fabricate, install, a new 4 kA_{rms}, 15 kV fault-current-limiting HTS cable.