Organization:	American Superconductor/Nexans/Air Liquide/LIPA
Project Title:	Demonstration of a Pre-Commercial Long-Length HTS Cable System Operation in the Power Transmission Network
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FY 2005 Funding:	$8.0 million (DOE to team)

Project Purpose and FY 2005 Objectives: American Superconductor, Nexans, Air Liquide and the Long Island Power Authority (LIPA) have joined together to collaboratively develop and produce a long-length, transmission level voltage, high temperature superconductor (HTS) cable system to be installed and tested in the LIPA grid on Long Island, New York. The cable is expected to be designed to operate at 138 kV, carry 2,400 amps for a power flow of approximately 574 MVA. In addition, the cable is being designed to survive fault current of 69,000 amps for 12 line cycles without damage to itself and to operate through many low-level system faults while still being able to survive a full-level fault. The purpose of the project is to develop the cable system, integrate it into the LIPA grid and to operate it for a period of 1 year. The objectives for the project during FY 2005 are as follows:

- Design, fabricate and test two (2) 161 kV cryogenic terminations.
- Develop the manufacturing processes necessary to produce the final cable.
- Identify and begin designing the installation site.
- Develop the methods and tools to protect the cable system against both full and partial level faults.
- Design and evaluate the cryogenic envelope necessary for the cable system.
- Develop the plan necessary to upgrade the previous SPI refrigeration system.
- Develop a suitable HTS wire product for use in the cable manufacturing process.

FY 2005 Performance: During FY 2005 Nexans developed and produced the necessary two terminations along with a 30 meter section of trial cable that was not fully populated with HTS wire. This system was assembled, connected to a refrigeration system and tested. In addition several manufacturing prototypes were produced and tested to develop and verify that the cable manufacturing process would not harm the superconductor tapes and that the cable could be bent around reasonable diameters without any damage. Samples from the manufacturing prototypes were tested for dielectric performance to verify the dielectric design under industrial manufacturing conditions. Sections of the cryostat for the cable have also been produced and tested to verify the design heat-loads and other operating parameters. Finally, a refrigeration system which was developed on a previous project and transferred to this project has been tested to verify the current performance, disassembled and shipped to a LIPA facility in NY. Plans have been made and are underway to add some additional capacity to allow the system to produce adequate refrigeration for the current project. The effect of fault currents on the cable have been modeled and used in the cable design process to ensure that the cable can safely survive a full-level fault. In addition, lower level faults have been studied and a method to protect the cable system against multiple low-level faults has been identified.

FY 2005 Results: Significant progress has been made towards the project objectives during the year:

Subscale Qualification Tasks

Cable Dielectric System The cable system involves cold dielectric high voltage insulation. After successful material testing in a plane electrode configuration, the most suitable material was selected and used in the manufacturing prototypes. The insulation system that was installed in industrial conditions utilizing existing lapping machines was then evaluated with regard to its mechanical properties with particular attention to dry bending. High voltage testing of full-scale samples was done in a specific setup under cable operating conditions confirming the design and manufacturing process selected.

Termination Bushing The superconductor cable termination involves several components that were developed and tested before prototype manufacturing. A main component, the termination bushing, was designed and analyzed. Bushing prototypes were manufactured and tested with regard to mechanical and dielectric behavior under cryogenic conditions showing good results. Various other components were tested successfully to confirm the termination design and its assembly procedure.

Cryostat A 10 meter section of cryostat was manufactured and shipped to Air Liquide for independent verification of the heat losses in the cryostat system. The cryostat was tested by flowing cold helium gas and monitoring the temperature rise as a function of distance along the cryostat. The testing verified the heat losses used in sizing of the upgrade for the refrigeration system.

HTS Wire/Cabling Several sections of cable core were produced this year to evaluate the performance of the HTS wire after the cable manufacturing process and bending of the completed cable on the shipping drum. This information was returned to the HTS wire manufacturing group to optimize the configuration of the HTS wire for this particular cable design.

Subsystem Testing/Development

30 meter Cable System Demonstration Nexans produced two terminations and associated cryostats and in February 2004 they were connected to a 30 meter section of trial cable which was not fully populated with HTS tape. The trial cable was cooled on a 5KW refrigeration system to operating conditions and several tests were performed to determine the electrical, thermal and hydraulic performance of the system so it could be compared to the expected results. The electrical measurements included voltage withstand of the insulation system, partial discharge measurements on both the cable and terminations, and AC losses. The thermal measurements included the thermal losses of the cryostat system and termination cryostats, and hydraulic measurements to measure the pressure drop of the 30 meter cryostat at various flow conditions.

Refrigeration System The refrigeration system originally produced for the Detroit Edison demonstration project will be used on this project. In order to ensure the condition of the system, Air Liquide operated the system in the Frisbee substation and measured the refrigeration power of the system. The system operated properly and Air Liquide was able to determine the values of some specific operating parameters that were used to produce the upgrade plan which is now underway

Fault Current Response A model has been developed which predicts the energy and temperature rise in the various parts of the cable as a function of the fault current level and duration. The cable system has been designed using the results from this model to safely survive a full-level fault of 69,000 amps for 12 cycles. In addition, this model has been used to study the effects of multiple low-level faults on the cable and a method of protecting the cable should the number of low-level faults be above a thermal limit.

Research Integration The project is organized in such a manner that all necessary research is driven by the organization which requires the results. American Superconductor is responsible for the HTS wire and any research necessary to produce a wire that is suitable for the cable design. Nexans and Air Liquide operate in a similar manner, Nexans has responsibility for the HTS cable and terminations and Air Liquide for the cryogenic refrigeration system.

FY 2006 Plans:

1. Complete electrical testing including high voltage qualification of the 30 meter prototype cable at Nexans, Hannover, Germany.
2. Manufacture the final cable and terminations for installation in the LIPA grid.
3. Modify, install and test the refrigeration system.
4. Complete the shipment of the HTS wire for the production cable.
5. Prepare the site for the installation and install the cable