Demonstration of a Pre-Commercial Long-Length HTS Cable System Operation in the Power Transmission Network

DOE Peer Review Update
August 2-4, 2005
Washington, DC
LIPA Project Overview

- Long Island Power Authority – Holbrook Substation
- Electrical Characteristics
  - Design Voltage/Current – 138kV/2400A ~ 574MVA
  - Design Fault Current – 69,000A @ 12 line cycles (200ms)
- Physical Characteristics
  - Length ~ 610m
  - HTS Conductor Length ~155km
  - Cold Dielectric Design
- Hardware Deliverables
  - Three ~610 m Long Phase Conductors
  - Six 161kV Outdoor Terminations
  - One 161kV Splice (Laboratory Test)
    - No splices for grid installation required
  - One Refrigeration System + Laboratory Pulse Tube System
- Installation/Commissioning – Fall 2006
LIPA HTS Cable System
LIPA HTS Cable Concept

- Outer Cable Sheath
- Outer Cryostat Wall
- Inner Cryostat Wall
- LN$_2$ Coolant
- Protection Layer
- Copper Shield Stabilization
- HTS-Shield
- High Voltage Dielectric
- HTS Tape
- Former

LIPA
American Superconductor
Long Island Power Authority
AIR LIQUIDE
Nexans
Project Status: System Design

- Pre-operation Cool Down Modeling Complete
- Normal Operation
  - Steady State Operation
    - With Main Refrigerator: Modeling Complete
    - With Back Up Refrigerator: Modeling Complete
  - System Fault Tolerance
    - Thermal Margin Verified With Major & Through Fault
  - Contingency Operation
    - Loss of cable cryostat Vacuum Modeling Complete
    - Loss of main and standby coolant Pumps Modeling Complete
    - Loss of main and standby Refrigerators Modeling Complete
- Post-operation Warm-up Modeling Complete
**Project Status: Cable Subsystem, Nexans**

- **Cable**
  - Design Complete
  - Fabrication Process Verified
  - AC Losses Verified
  - Dielectric Material Selected and Verified
  - Component High Voltage Test Completed

- **Cryostat**
  - Design Complete
  - ASME Code Applied
  - Fabrication Process Verified
  - Hydraulic Characteristics Verified
  - Thermal Losses Verified
Project Status: Cable Subsystem, Nexans

- Termination
  - Design Complete
  - Prototype Fabricated
  - Bushing High Voltage Test Completed
  - Bushing Seal Verified

- 30m System Test
  - Test Facility Complete
  - Prototype Installed
  - Ic Retention Verified
  - Hydraulic Parameter Verified
  - Cryostat Performance Verified
  - Partial Discharge Observed At Lower Than Expected Voltage Level
    - Investigation/Re-design in Progress
Project Status: Refrigerator Subsystem, Air Liquide

- Re-use of Detroit refrigerator from previous Pirelli SPI Cable Program
- Upgrades to system are necessary to adapt it to LIPA project and will include:
  - Upgraded cooling capacity (+38%) for primary and back up systems
  - New system for the cable cool down
  - New buffer for fault reaction and recovery
  - Telemetry to allow remote monitoring and control
  - New 9 000 Gal tank for LN2 supply
- Will be operated 6 months prior to cable commissioning
Project Status: Refrigerator Subsystem, Air Liquide

- Refrigerator
  - Optimization of the new process (primary and back up) complete
  - Detailed definition of the new process lines complete
  - Preliminary lay out drawing complete
  - Definition of the new components in progress
  - Equipment specifications in progress
  - Final lay out in progress
**Project Status: HTS Wire, AMSC**

Bismuth based, multi-filamentary high temperature superconductor wire encased in a silver matrix and laminated with brass to increase mechanical strength and provide a hermetic seal.

**Brass Lamination**

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**Specifications:**

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Average thickness:</td>
<td>0.36-0.44 mm</td>
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<td>Minimum width:</td>
<td>4.0 mm</td>
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<td>Maximum width:</td>
<td>4.45 mm</td>
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<td>Min. double bend diameter (RT):</td>
<td>70 mm³</td>
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<td>Max. Rated tensile stress (RT):</td>
<td>175 MPa</td>
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<td>Max. Rated wire tension (RT):</td>
<td>20 kg</td>
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<td>Max. Rated tensile stress (77K):</td>
<td>200 MPa</td>
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<td>Max. Rated tensile strain (77K):</td>
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| Hermeticity            | 30 atm LN2 for 16 hours

**Customer Options:**

<table>
<thead>
<tr>
<th>Minimum amperage (Ic)</th>
<th>Average engineering current density (Jc)</th>
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<tbody>
<tr>
<td>115 A</td>
<td>6,700 A/cm² ii</td>
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<td>125 A</td>
<td>7,300 A/cm² ii</td>
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<tr>
<td>135 A</td>
<td>7,900 A/cm² ii</td>
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<tr>
<td>145 A</td>
<td>8,500 A/cm² ii</td>
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Continuous piece length: Up to 800 m
Insulation options: PTFE or Kapton wrap
Splice options: Spliced wire is available in longer lengths

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1 Greater than 95% Ic retention
2 77K, self-field, 1μV/cm
3 Jc is a calculated value based upon average thickness and width
4 Thickness inspection after pressurized LN2 test

**Designed for use in applications where the wire is exposed to pressurized liquid cryogens**
Project Status: HTS Wire, AMSC

• Length Requirements:
  - 105 pieces x 680 meters each = 71,400 meters
  - 120 pieces x 700 meters each = 84,000 meters
  - Total production wire volume = 155,400 meters

• Status as of July 31, 2005
  - HTS insert wire manufacturing is 100% complete
  - Lamination and testing is in progress (~25% complete)
  - Finished wires will ship in September and October 2005

AMSC commercial HTS wire manufacturing meets large volume cable requirements
Plans for GFY ‘06

• System Analysis
  - Update fault and contingency studies

• Cable and Terminations
  - Complete qualification of termination for 161kV
  - Complete 30 meter cable system electrical qualification testing
  - Fabricate 610 meter cable
  - Fabricate 6 Terminations

• Refrigerator
  - Complete upgrade
  - Install at Holbrook site
  - Operate and qualify 3-6 months prior to cable install

• System
  - Install cable and terminations
  - Install data and control system and interconnects to SCADA
  - Prepare for energization
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Factory/Site Tested</th>
<th>Sample Tested</th>
<th>Full Scale Type Test</th>
<th>Subscale Test</th>
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