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

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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

World's First Installation of a Transmission Voltage HTS Cable

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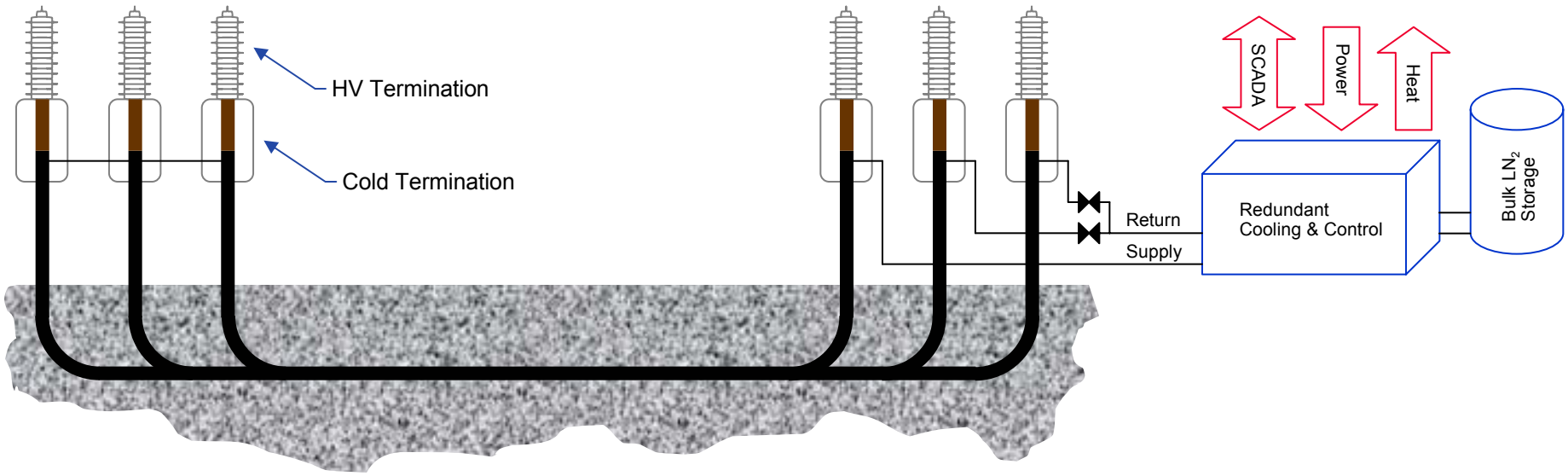
LIPA HTS Cable System



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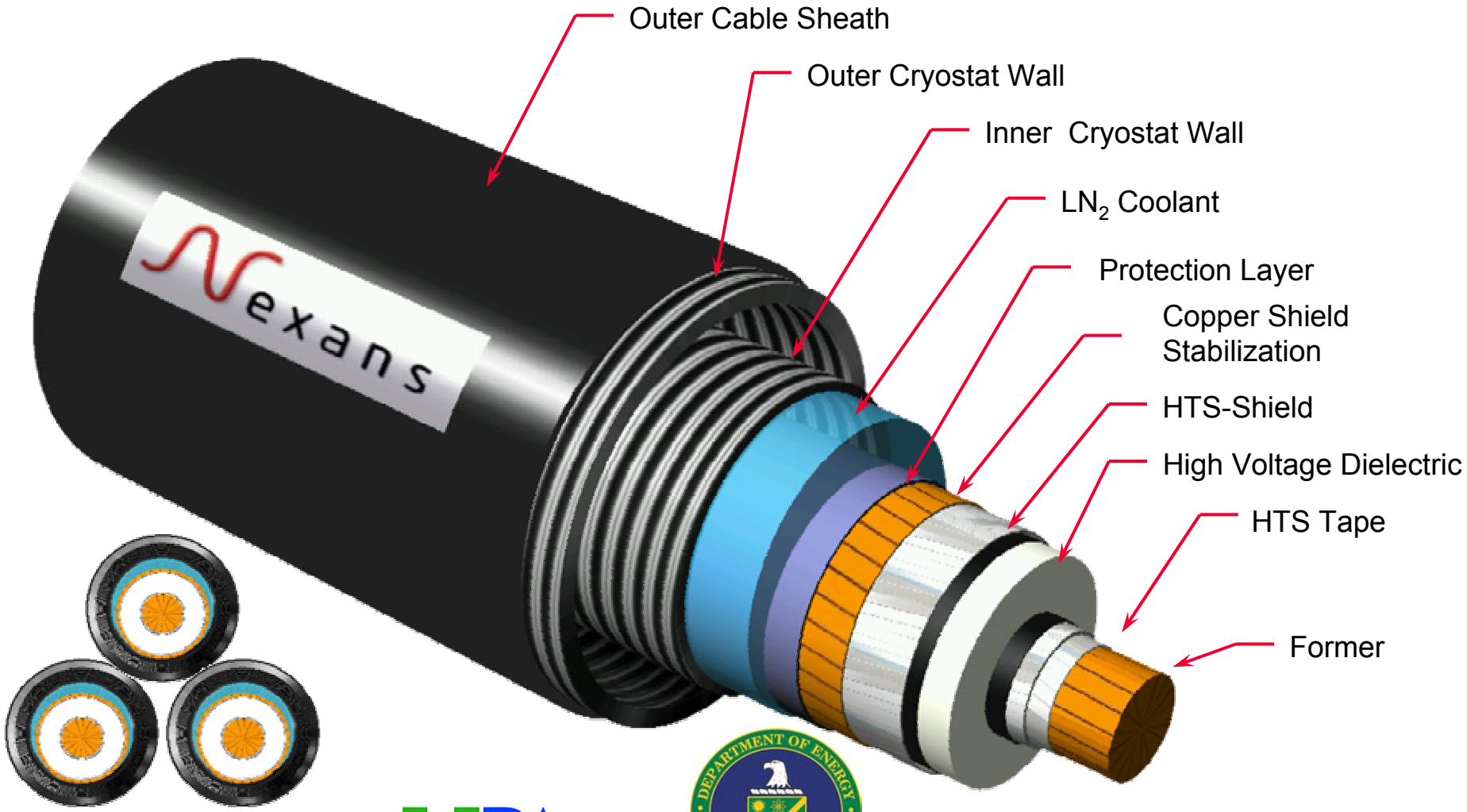
LIPA HTS Cable Concept



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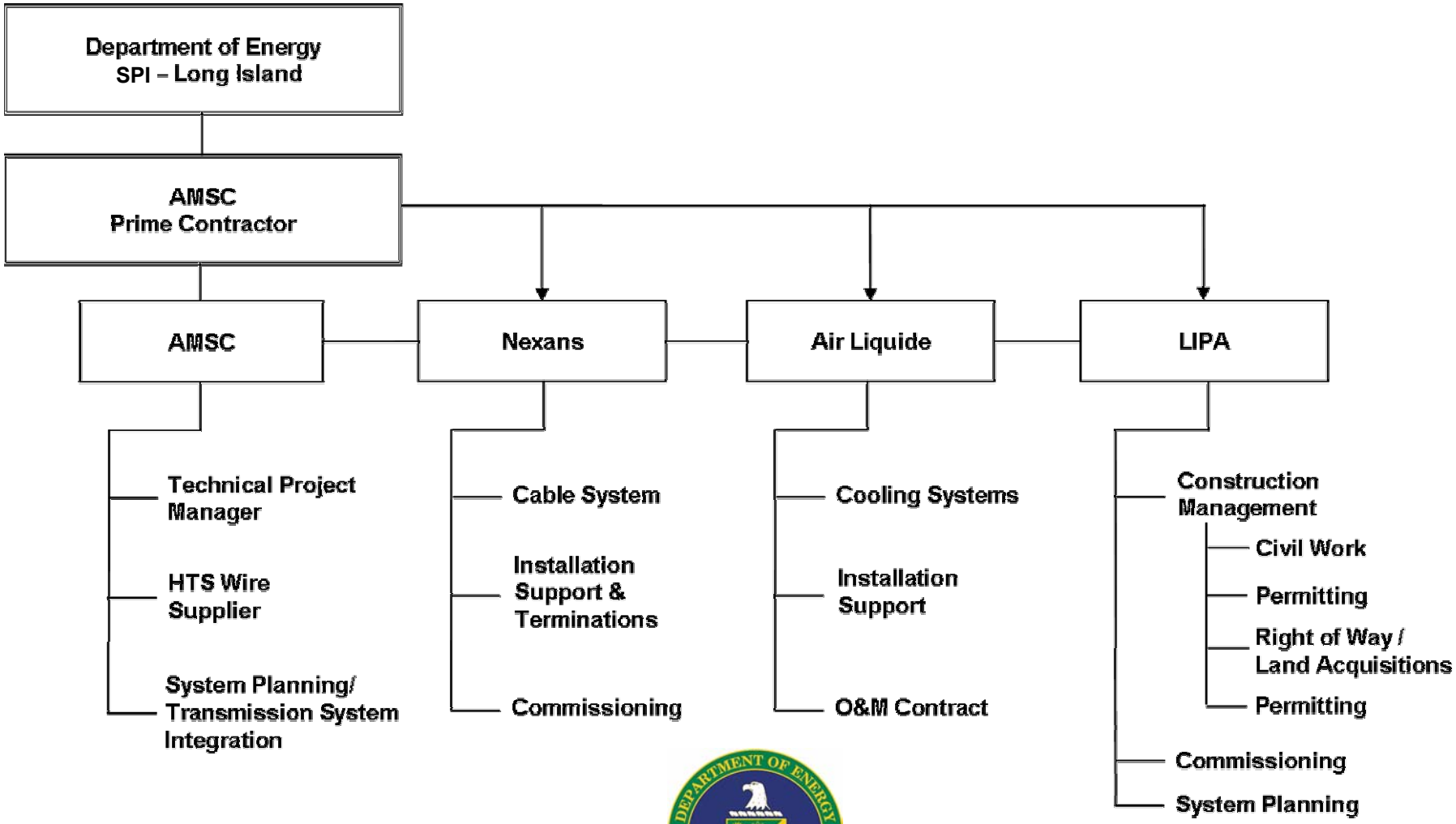
LIPA Cable Project and Project Team



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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

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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

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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

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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

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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

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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

HTS Insert

Specifications:	
Average thickness:	0.36-0.44 mm
Minimum width:	4.0 mm
Maximum width:	4.45 mm
Min. double bend diameter (RT):	70 mm[i]
Max. Rated tensile stress (RT):	175 MPa[i]
Max. Rated wire tension (RT):	20 kg[i]
Max. Rated tensile stress (77K):	200 MPa[i, ii]
Max. Rated tensile strain (77K):	0.30%[i, ii]
Hermeticity	30 atm LN2 for 16 hours[iv]

Customer Options:	
Minimum amperage (Ic)	Average engineering current density (Je)[iii]
115 A[ii]	6,700 A/cm^2 [ii]
125 A[ii]	7,300 A/cm^2 [ii]
135 A[ii]	7,900 A/cm^2 [ii]
145 A[ii]	8,500 A/cm^2 [ii]
Continuous piece length	Up to 800 m
Insulation options	PTFE or Kapton wrap
Splice options	Spliced wire is available in longer lengths

[i] Greater than 95% Ic retention
[ii] 77K, self-field, 1μV/cm
[iii] Je is a calculated value based upon average thickness and width
[iv] Thickness inspection after pressurized LN2 test

Designed for use in applications where the wire is exposed to pressurized liquid cryogens

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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

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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

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Project Confidence Matrix

	Production Item				
	Factory/Site Tested	Sample Tested	Full Scale Type Test	Subscale Test	Analysis
Parameter					
Voltage Withstand					
Termination					
Operating					
Lightning Impulse					
Cable					
Operating					
Lightning Impulse					
Current Carrying Capacity					
Termination					
Cable					
Heat Loads					
Cable					
AC Losses					
Dielectric Losses					
Cryostat Losses					
Termination					
AC Losses					
Cryostat Losses					
Refrigerator					
Capacity					
Flow capacity/pressure					
Wire					
Critical Current					
Hermeticity					
splice resistance					
splice hermeticity					
splice integrity					
Pressure Drop					
Faults					
Major Fault response					
Thru-fault response					
Material Properties used in model					n/a
Installation Methods					
Cable					
Termination					

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