SuperPower Inc.

Operating Results of the Albany (NY) High Temperature Superconducting Cable System

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Providing HTS Solutions for a New Dimension in Power – TODAY!

Program Overview

- 350m long - 34.5kV - 800A_{rms} - 48MVA
- Cold dielectric, 3 phases-in-1 cryostat, stranded copper core design

SuperPower Inc.	**Project Manager; Site Infrastructure, Manufacture of 2nd generation HTS conductor**
nationalgrid	**Host utility, conventional cable & system protection, system impact studies**
SUMITOMO ELECTRIC	**Design, build, install, and test the HTS cable, terminations, & joint**
BOC	**Design, construct and operate the Cryogenic Refrigeration System, and provide overall cable remote monitoring and utility interface**
NYSERDA · DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA	**Supported by Federal (DOE) and NY State (NYSERDA) Funds**

Major Milestones

Conceptual Design Readiness Review Mtg.	December 03 √
Detailed Design Readiness Review Mtg.	November 04 √
Subsystem Testing of CRS	September 04 √
Site Infrastructure	November 04 √
CRS Installation & Functional Testing	June 05 √
BSSCO Cable Installation & Commissioning	July 06√
YBCO Wire Delivery	Fall 06 √
YBCO Cable Installation & Commissioning	Summer 07

Site Location

HTS vs. Conventional Cables

Cable Type	Resistance	Inductance	Capacitance
HTS Cold Dielectric	.0001 ohms/km	.06 mH/km	1.08 MVAR/km
XLPE Cable	.03 ohms/km	.36 mH/km	1.4 MVAR/km
Overhead Conductor	.08 ohms/km	1.26 mH/km	.05 MVAR/km

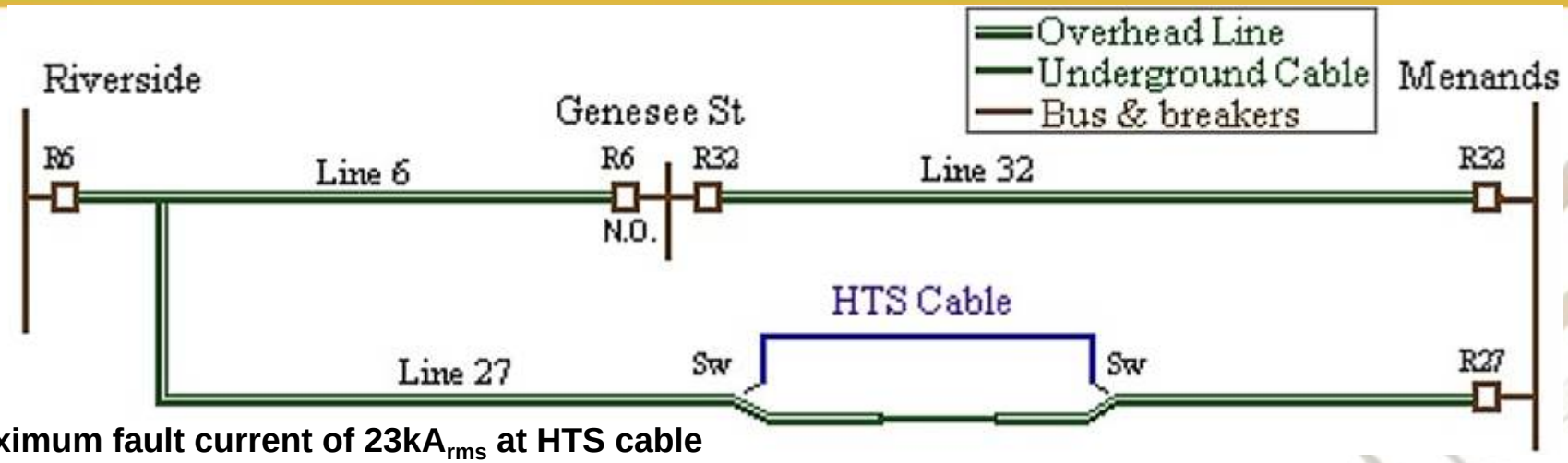
- **Resistance** - HTS cable ~ 300 times less than XLPE cable & ~ 800 times less than overhead wire
- **Inductance** - HTS cable ~ 6 times less than XLPE cable & ~ 21 times less than overhead wire
- **Capacitance** - HTS is slightly less than conventional underground cable

Cable Testing Criteria

Test	Value	Notes
Short Circuit	28.3 kA	8 cycles primary protection 38 cycles secondary protection
Impulse Test (BIL)	200 kV	10 times
AC Withstand Test	69 kV	5 minutes
Bending Test	180° both directions	12 times cable diameter
DC Withstand Test	100 kV	5 minutes – after installation

Other testing to include: critical current, AC loss testing, Dielectric power loss & capacitance, cryostat heat loss & vacuum integrity.

System Protection Philosophy



Maximum fault current of 23kA$_{rms}$ at HTS cable

Multiple levels of relay & breaker protection

- Primary Line Protection - RFL-9300 charge comparison relays (87L) - Total clearing time ~ 8 cycles
- Secondary Line Protection - SEL-311B relay packages – Total clearing time – 8-38 cycles
- Cable designed to withstand 2nd contingency fault conditions of 23kArms for 38 cycles

Breaker failure protection

- Will initiate fault clearing by tripping breakers on associated Menands or Riverside 34.5kV bus
- Cleared in 20 to 50 cycles (0.33 to 0.83 sec)

No automatic re-closing

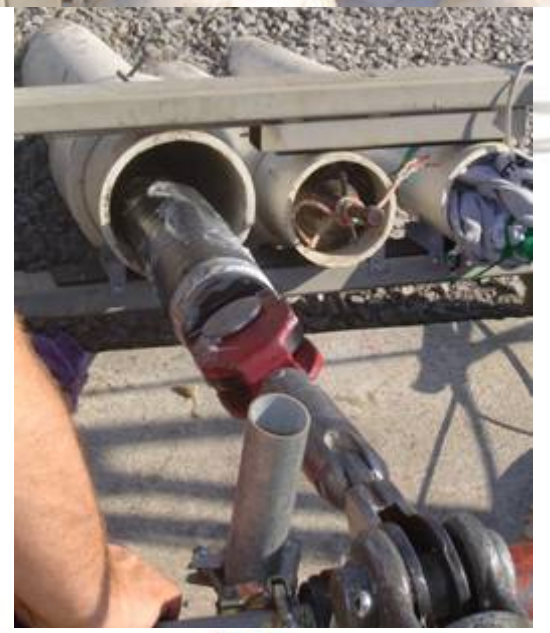
- Normally open when HTS cable is energized
- Switching between conventional and HTS cables with manually operated switch

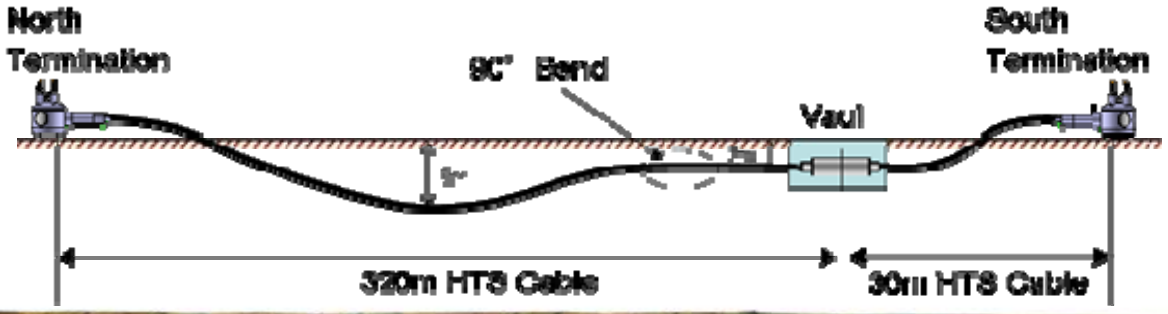
System monitoring @

- BOC Remote Operating Center AND NM Eastern Regional Control Center

HTS Cables & Return Pipe Installation

- **Push-Pull Method Utilized**
- **Maximum Tension ~ 2.5 tons**
- **No vacuum leakage after installation**
- **No degradation of Ic**





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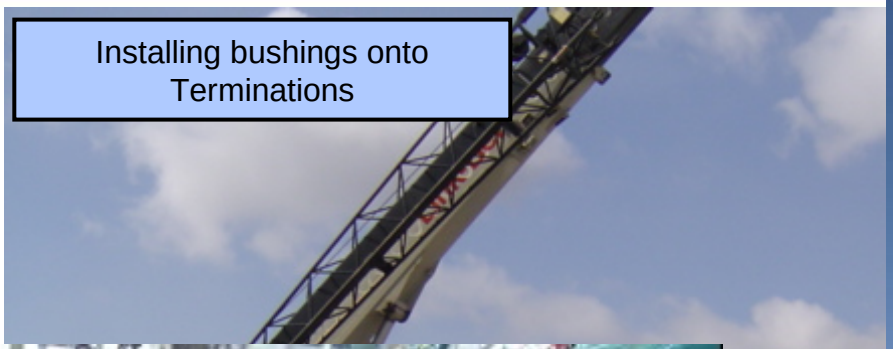
3-in-One Joint Construction

3 Cable cores before connecting

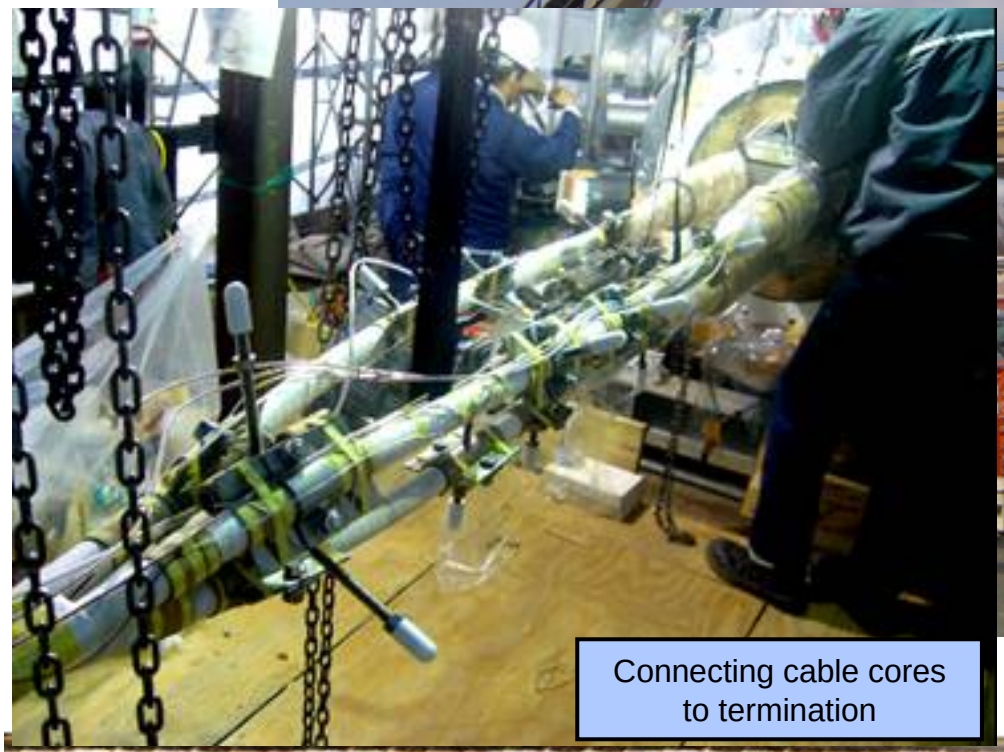
3 Cable cores after connecting

Joint box with vacuum vessel
(before covering with water-tight tapes)

Termination Installation



Installing bushings onto Terminations



Connecting cable cores to termination

Termination After Installation

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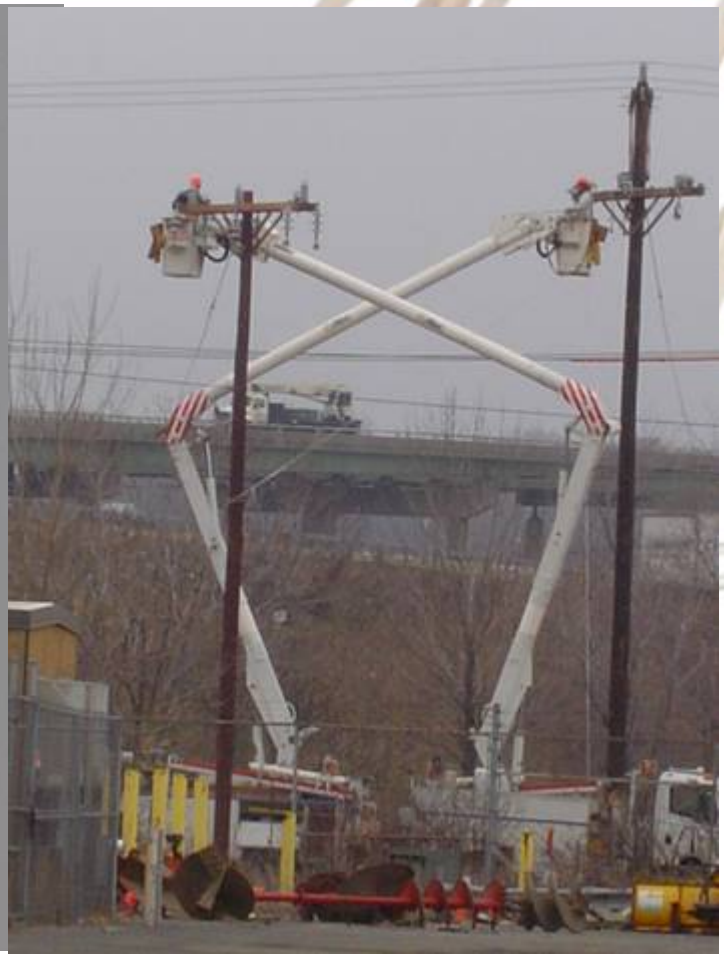
Connection to National Grid's Network

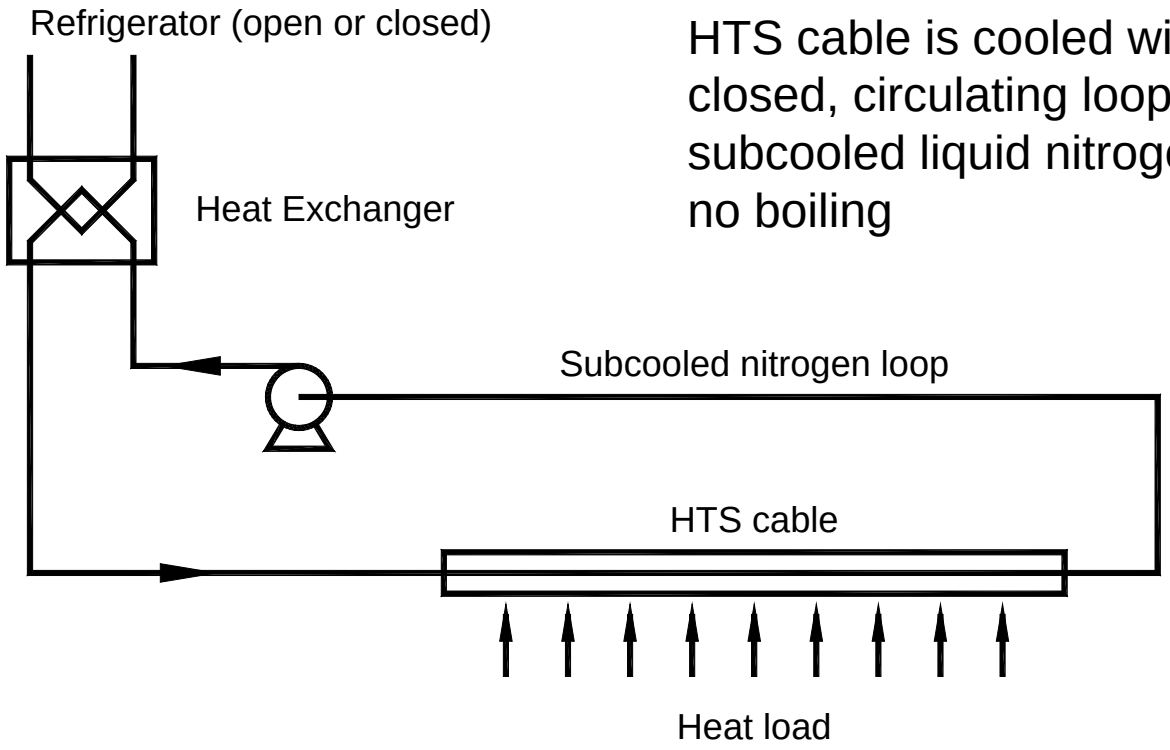
Take-Off Structure Installation

Installation of Disconnect Switches



Tie-in to Line 27 and Pulling Overhead Conductor

Generic HTS Cable Cooling

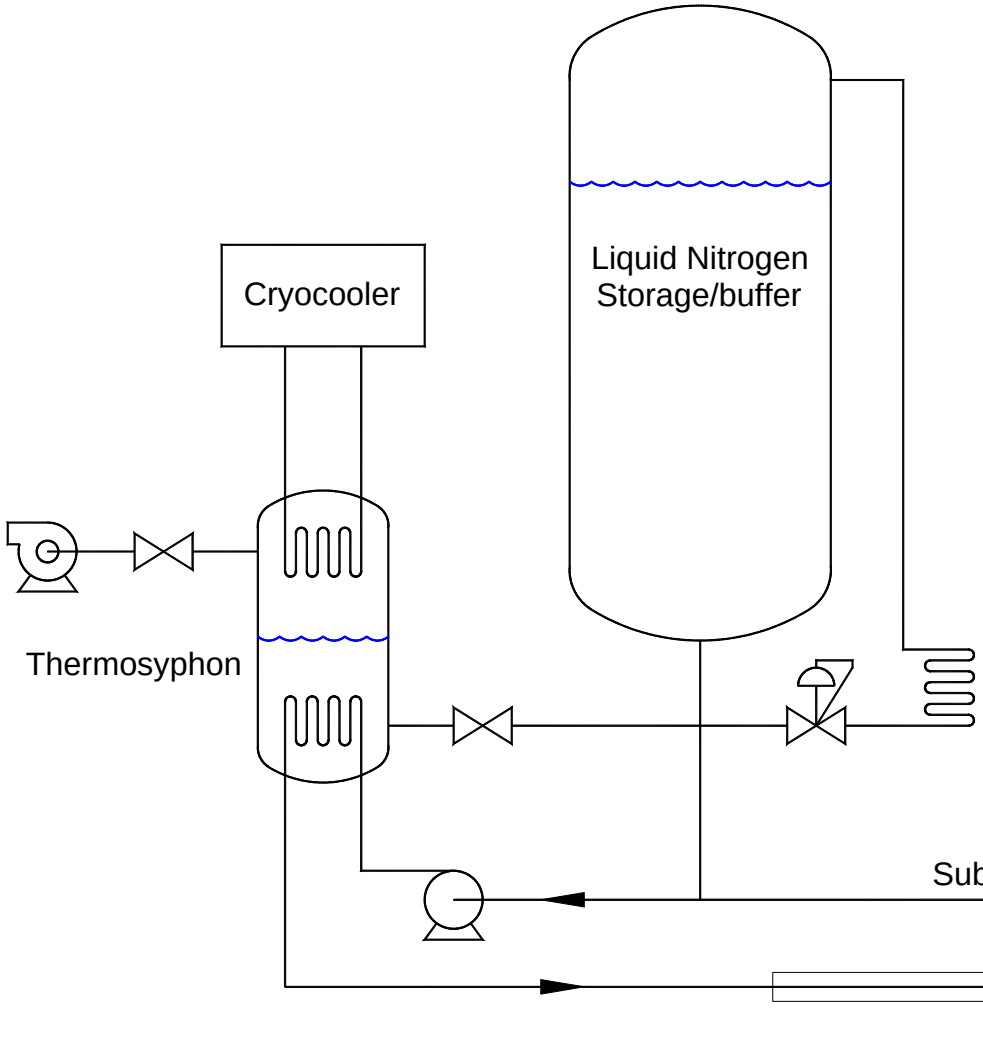


HTS cable is cooled with a closed, circulating loop of subcooled liquid nitrogen -- no boiling

Open refrigeration: bulk liquid nitrogen vaporized in a low pressure subcooler

Closed refrigeration: onsite mechanical refrigerators (cryocooler)

Cryogenic Refrigeration System: Approach



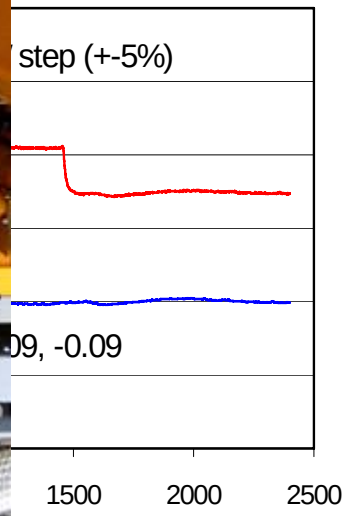
Hybrid arrangement permits transparent use of bulk liquid nitrogen for back-up

Thermosyphon provides common heat exchange interface between cable and open or closed refrigeration sources

Minimum Refrigeration System Requirements

Item	Specification
Coolant supply temperature	67 to 77 K
Temperature stability	+-0.1 K - normal operation
	+-1.0 K - backup operation
Refrigeration capacity	5 kW at 77 K
	3.7 kW at 70 K (excluding CRS)
Minimum coolant pressure	1 to 5 barg +-0.2
Maximum coolant flow rate	50 liter/min +-1

Cold Box and Skid Arrangement



rmosyphon

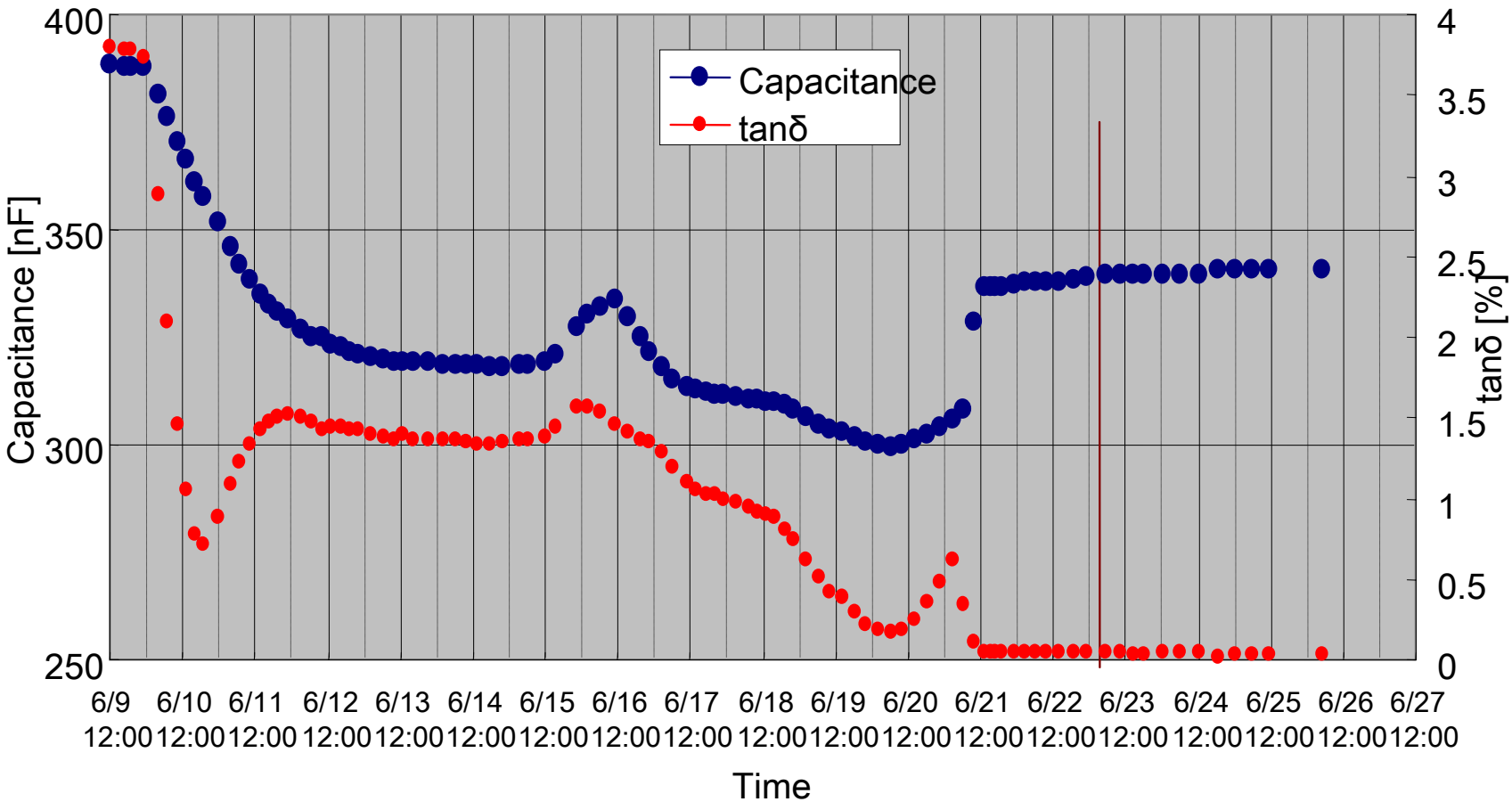
BOC Remote Operations Center

Overall cable system is continuously supported using existing remote operation facilities

- Around the clock remote monitoring and control of HTS system
- Formal interface with National Grid, Eastern Regional Control Center
- Intervene remotely, or dispatch trained local BOC personnel (Selkirk, NY)

BOC's Remote Operations Center in Bethlehem, PA

Capacitance and Tan-delta During Cool-down



Cable Critical Current Measurement

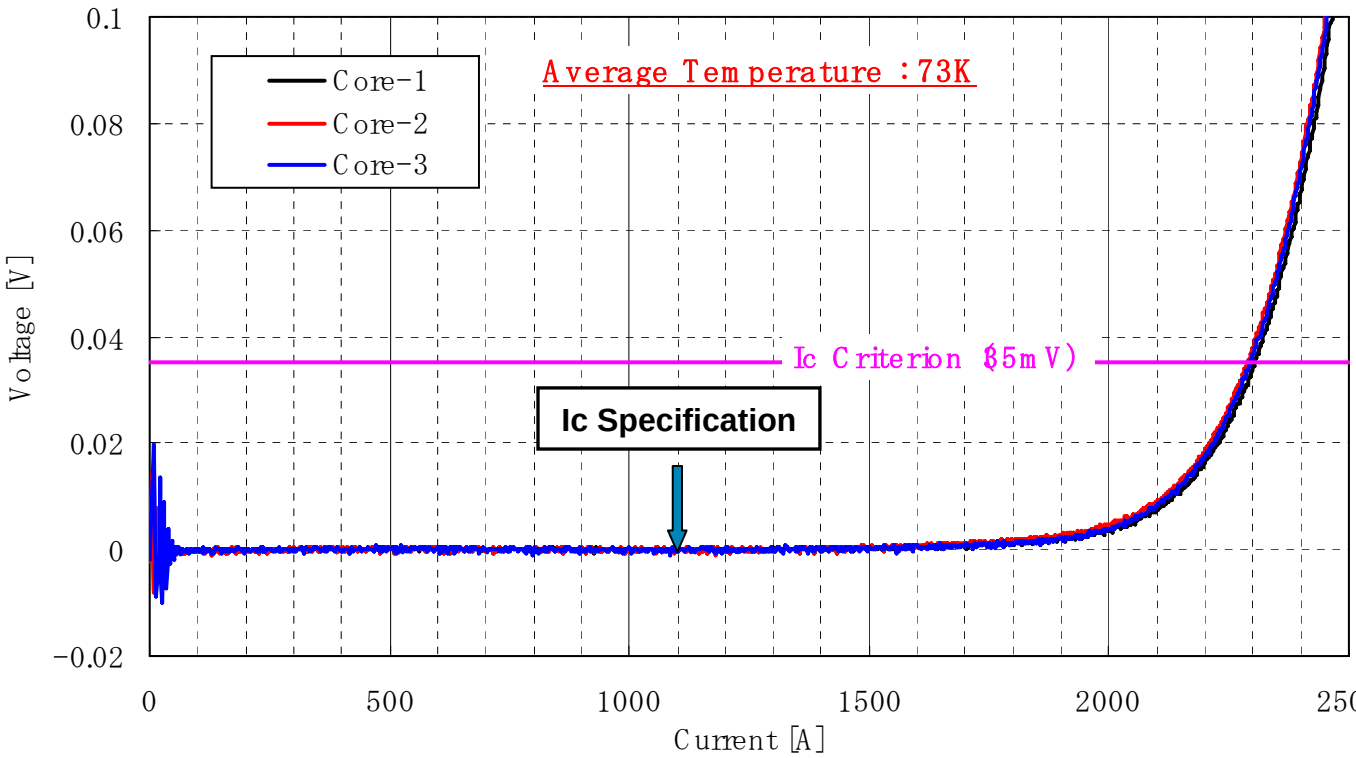
Table 1 Testing conditions

Items	Parameter
Average temperature	73 K
Pressure at LN2 tank	3.5 barG
LN2 flow rate	40 L/min

Table 2 Critical current (Ic)

Phase	Parameter
Core 1	2300
Core 2	2290
Core 3	2290

Definition of Ic : 1 micro V/cm



DC Withstanding Voltage Test

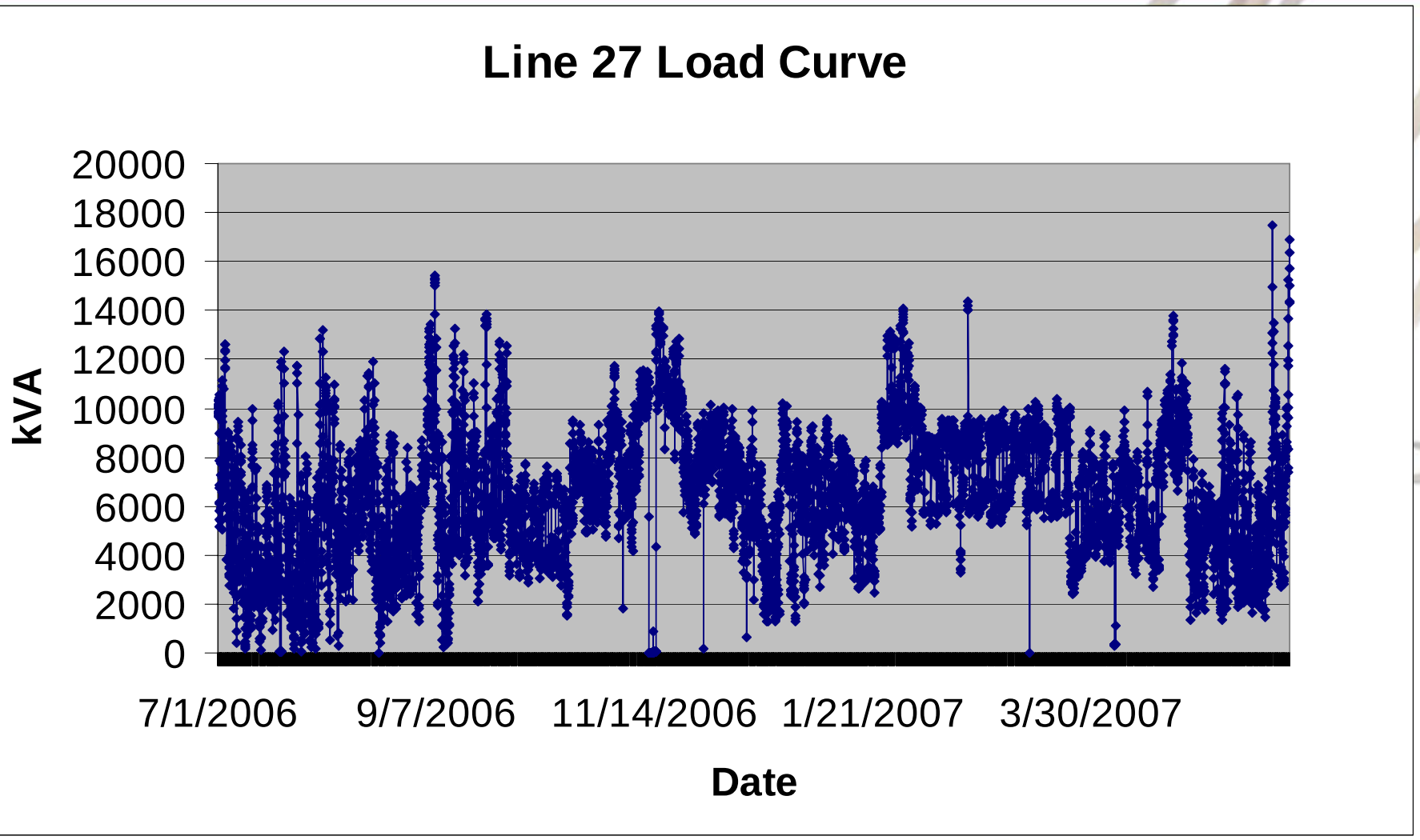
DC 100kV* was applied to each phase for 5 minutes, successfully.

***AEIC (Association of Edison Illuminating companies) code, C55-94**

On-Grid Operations Began July 20

- **3-Hour Voltage Soak** –
  - Phase Check conducted
- **Connect to the Grid at ~ 21:00**
  - Confirm stability of T and P
  - Shield/Conductor >95%
- **Commissioning Ceremony Held on August 2nd**
  - NYS set Peak Load record at 1:00pm (33,939 MW)

Phase I - Operational Data



Albany HTS Cable Project
Status Report: June 14, 2007

Project Phase I – 350 m 1G HTS Cable system in 2 sections (320 m and 30 m)

Operated without incident or interruption from July 20 thru November 11, 2006

- 114 days or >2,700 hours of continuous operation

Experienced 1st Fault Current Event on November 12, 2006 @ 9:32AM

- Breaker in nearby substation had an external flashover
- ~ 7.3 kA peak current on HTS cable
- Cable survived without damage
- Back online on Thursday (11/16) @ 12:30pm

System de-energized and began cool-down: May 1, 2007

- Total accumulated run time: > 280 days (>6,720 hours)
- Maintenance work performed on cryocooler, chillers, other equipment without interruption to cable operations

Project Phase II – 320 m 1G HTS Cable joined to 30 m 2G HTS Cable

- 2G cable delivered to Albany site, Phase I cable being prepped for removal
- Installation of new cable planned Summer 2007
- System will be energized October 2007

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Why Switch to 2G (YBCO) HTS Wire?

Superior Attributes of SuperPower's 2G HTS Wire

Our 2G wire is half as thick as 1G & 2G wire made by other companies

- Total wire thickness is only 0.095 mm; *twice the engineering current density*

Our 2G wire uses patented surround copper stabilizer

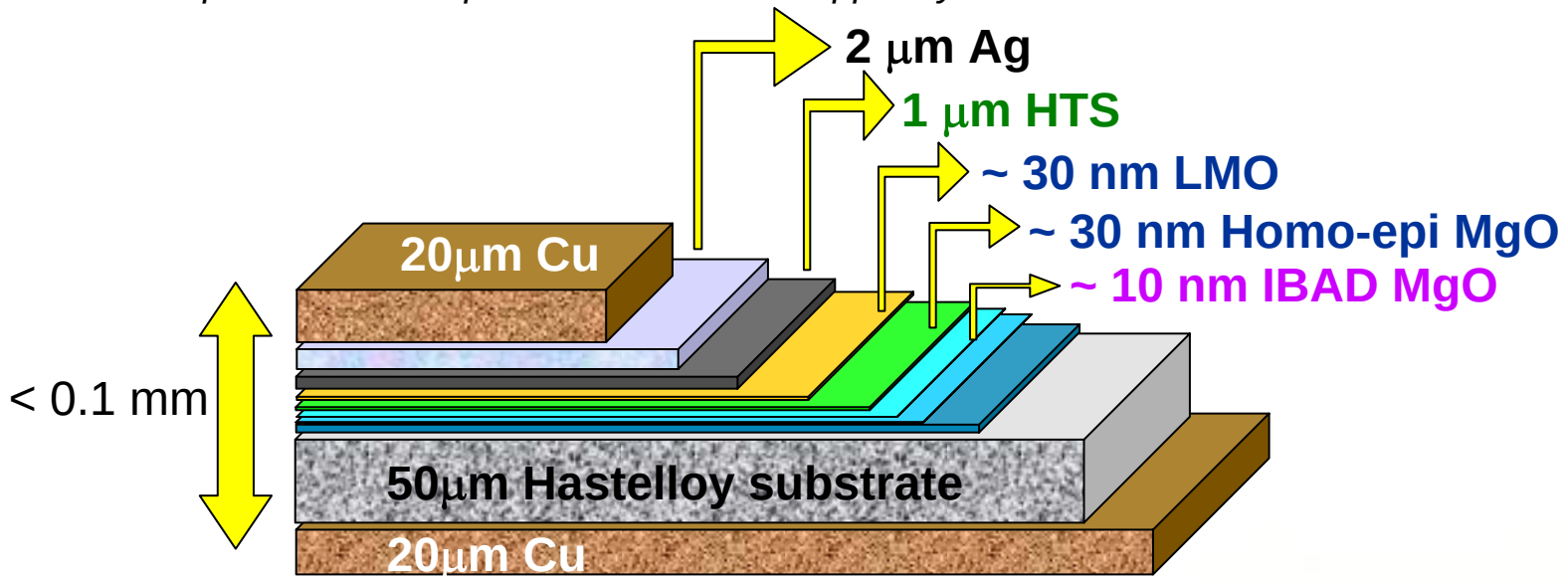
- No sharp corners – *valuable for high voltage applications*

Our 2G wire uses high-strength, non-magnetic, highly-resistive Hastelloy substrate

- *Better mechanical properties & lower ac losses*

High throughput, low cost manufacturing processes

- *Cost per kA/meter expected to be below Copper by the end of the decade*



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Thank You For Your Attention!

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