Long Island Power Authority

Holbrook Superconductor

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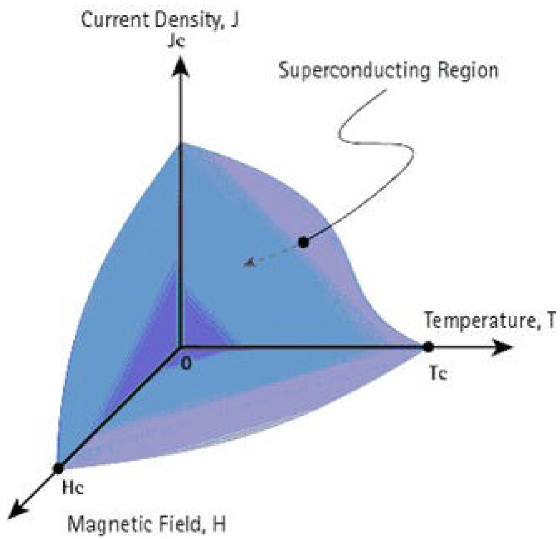
Background

What is Superconductivity?

- Superconductivity is a phenomenon occurring in certain materials at very low temperatures, characterized by zero electrical resistance.



- The electrical resistivity of a metallic conductor decreases gradually as the temperature is lowered. However, the resistance of a superconductor drops abruptly to zero when the material is cooled below its "critical temperature" (T_c).
- Because these materials have no electrical resistance, meaning electrons can travel through them freely, they can carry large amounts of electrical current for long periods of time without losing energy as heat.

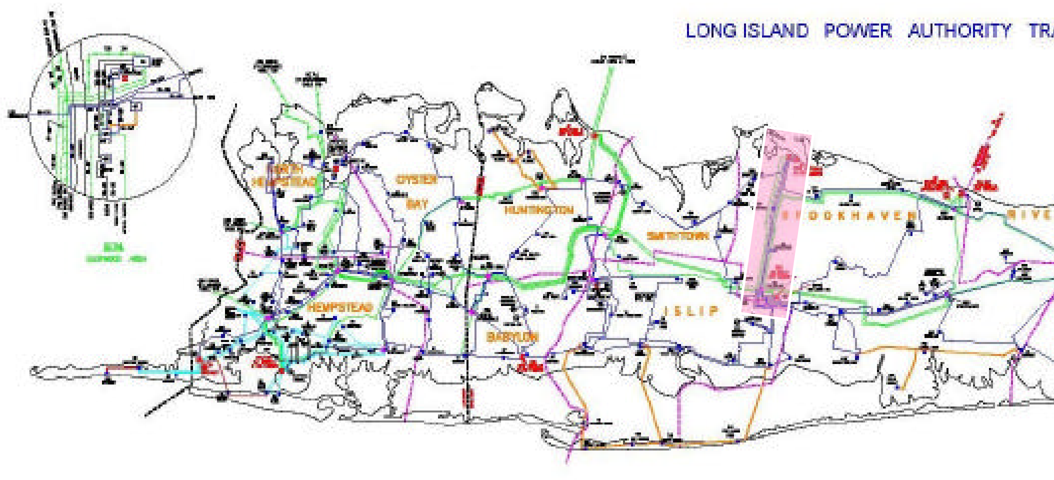
- The material must be cooled below a characteristic temperature, known as its superconducting transition or critical temperature (Tc).
  - For most superconducting materials, the critical temperature is below about 30K (30°C above absolute zero), which requires a high cost refrigeration system. But some materials, called high-temperature superconductors, make the phase transition to superconductivity at much higher critical temperatures, typically about 70K.
- The current passing through a given cross-section of the material must be below a characteristic level known as the critical current density (Jc).
- The magnetic field to which the material is exposed must be below a characteristic value known as the critical magnetic field (Hc).
- These conditions are interdependent, and define the environmental operating conditions for the superconductor.

LIPA

- LIPA is a NYS Authority established in 1998 as the primary electric service provider
- 1207 sq. mi. *(roughly 100 miles by 12 miles)*
  - Nassau, Suffolk and the Rockaway Peninsula
- Population of about 3 million
  - 1.1 million residential customers
  - 100,000 commercial customers
  - Since 1998, 5.7% population growth *(172,000 more people)*
- $2.0 billion invested in system upgrades and improvements
- LIPA owns the assets
  - All T&D operations and most IS systems are outsourced

- Generation
  - On island – 4,940 MW
  - Tie Lines – 2,362 MW
- Transmission
  - Primarily 69 kV and 138 kV
  - 345 kV, 33 kV, 23 kV (54 miles)
  - 177 substations
  - 986 miles overhead
  - 277 miles underground
- Distribution
  - 770 13.2 kV circuits
  - 124 4 kV circuits
  - 142 substations
  - 8,904 Overhead miles
  - 4,228 Underground miles
  - Primarily an open-looped radial system
  - 535,000 utility poles
- Load
  - Peak of 5,267 MW (August 5, 2005)

LIPA Transmission System



Why is LIPA Interested?

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- LIPA Long Term Needs
  - Must meet increasing power demands in existing ROWs
  - Load continues to increase
    - LIPA expects 1200 MW of new load by 2020 - Major transmission reinforcements will be required
- Project Provides Potential Tool to Meet LIPA's Long Term Needs
  - ROW Congestion - HTS Cables provide increased power transfer capability within existing ROWs (2 - 5 times the capacity in the same space)
  - Overhead Permitting Problems
  - Potential cost savings compared to upgrading to 345 kV transmission system
- Site Specific
  - East / West transfer capability increase required by Caithness 1 & 2 and other potential power insertions
  - New area development (Calverton) requiring up to 9 distribution feeders from remote substation could be feed using 2 or 3 superconductor feeders

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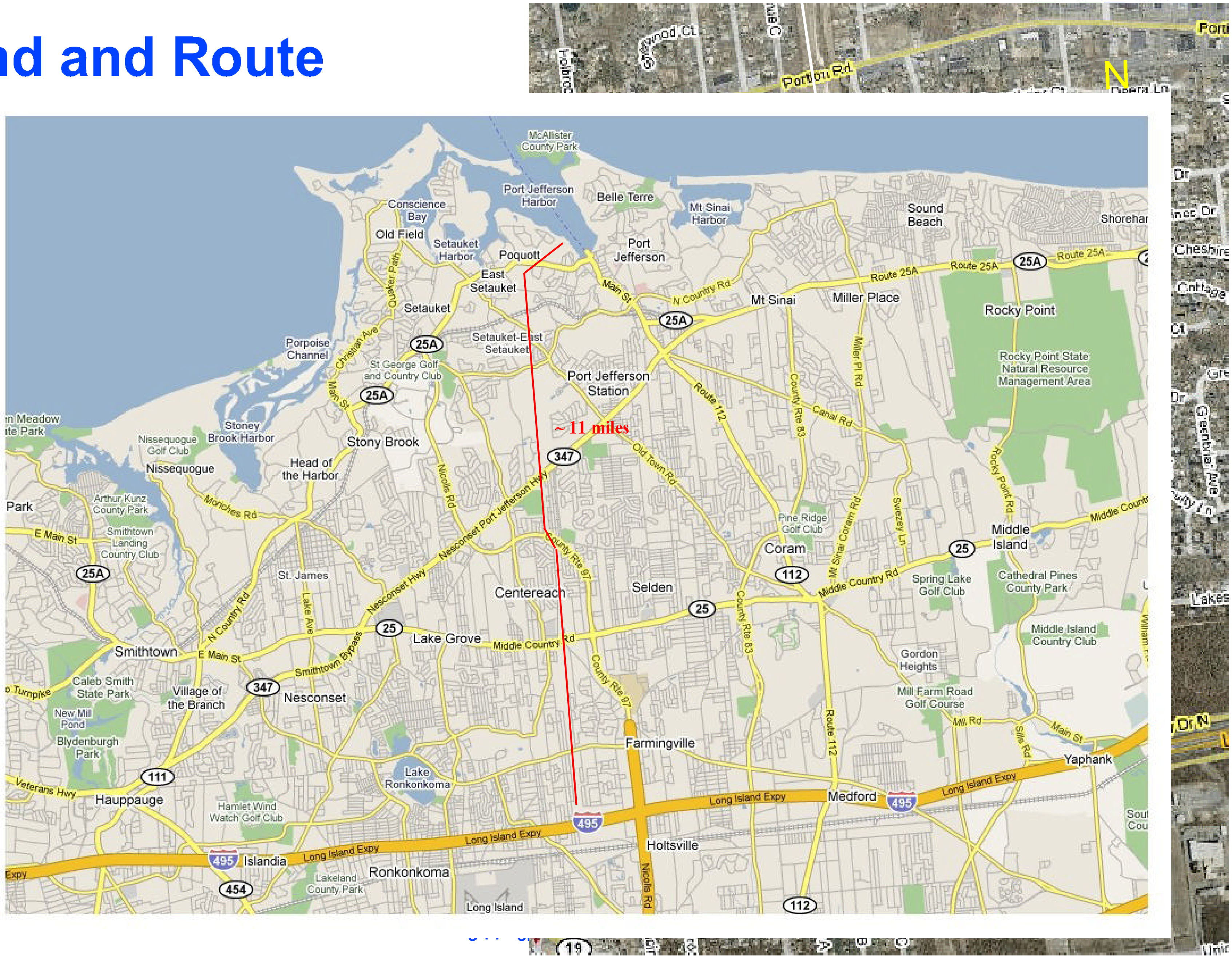
Current Facility

Land and Route



General System Design

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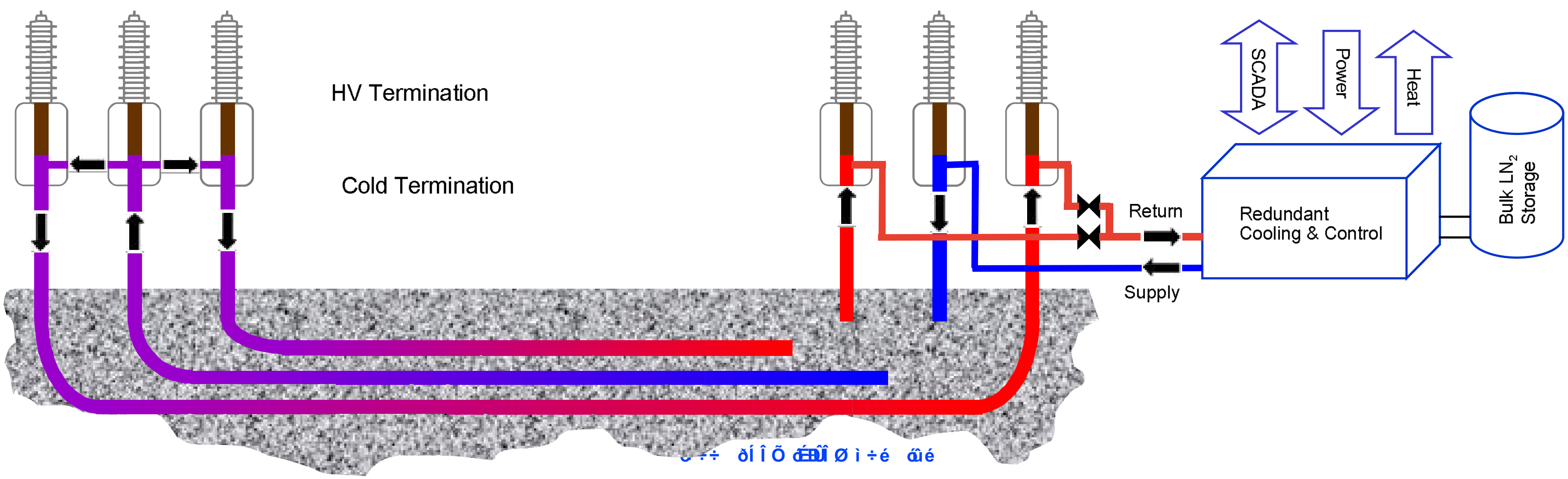
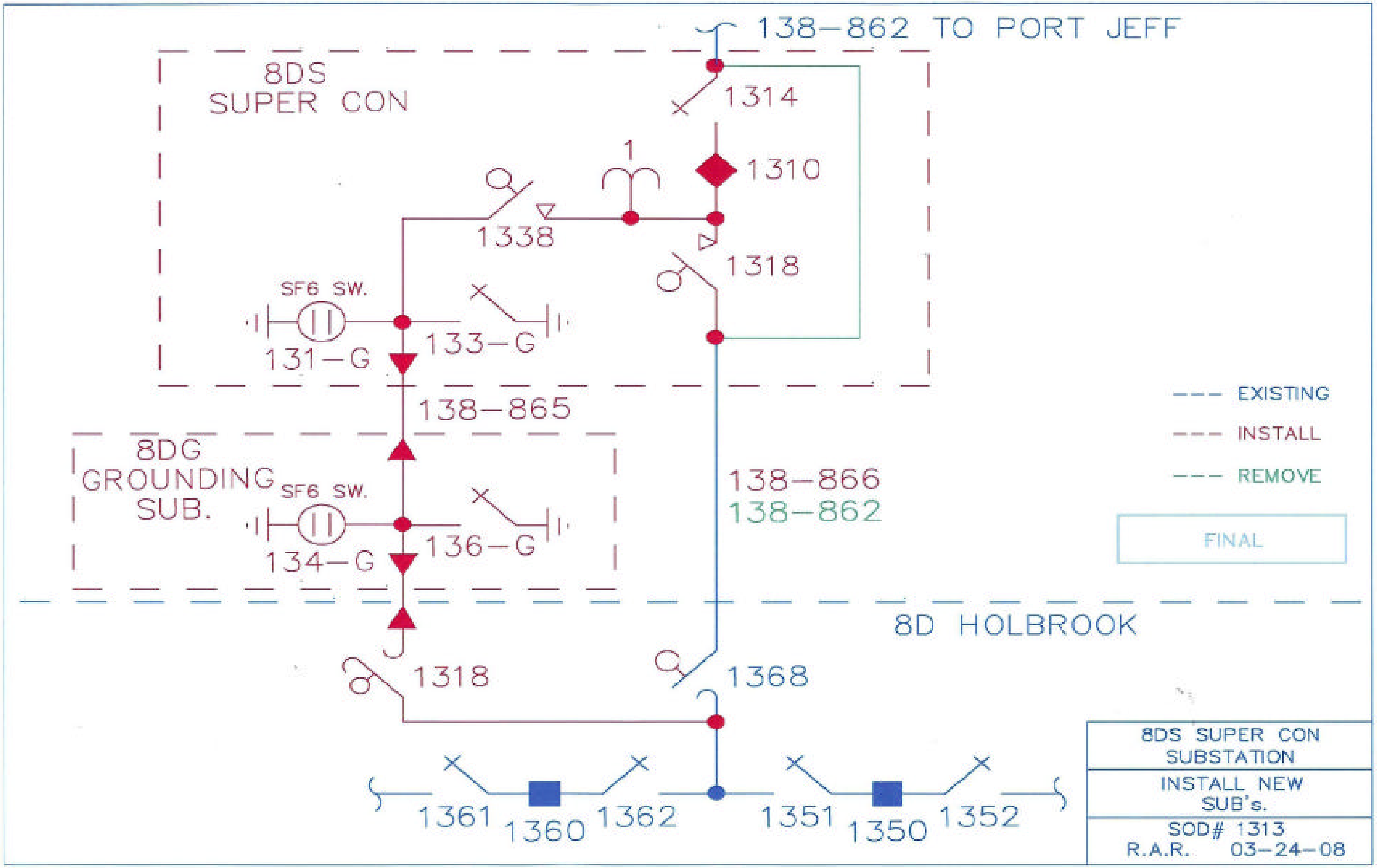
- Electrical Characteristics
  - Design Voltage/Current – 138kV/2400A ~ 574MVA
  - Design Fault Current – 51,000A @ 12 line cycles (200ms)
- Physical Characteristics
  - Length ~ 600m
  - HTS Conductor Length ~155km
  - Cold Dielectric Design
- Hardware Deliverables
  - Three ~600 m Long Phase Conductors
  - Six 138kV Outdoor Terminations
  - 5.65 kW Refrigeration System w/ 6.77 kW backup
- Energization – April 22, 2008
  - De-energized August 24 for modifications / repairs to the refrigeration system
- Re-Energized March 5, 2009



One Line



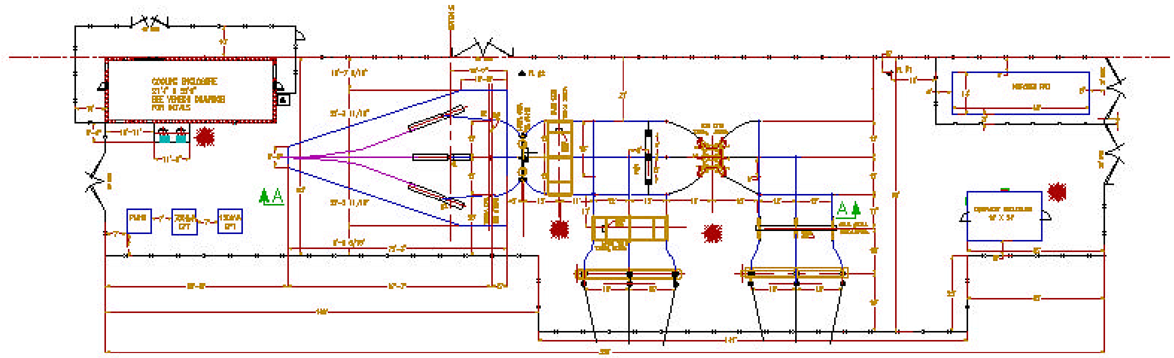
138-862 TO PORT JEFF
8DS
SUPER CON
1314
1310
1
1338
1318
SF6 SW.
131-G
133-G
138-865
8DG
GROUNDING
SUB.
SF6 SW.
134-G
136-G
138-866
138-862
EXISTING
INSTALL
REMOVE
FINAL
8D HOLBROOK
1318
1368
1361
1360
1362
1351
1350
1352
8DS SUPER CON
SUBSTATION
INSTALL NEW
SUB's.
SOD# 1313
R.A.R. 03-24-08

Major System Components

- Substation Equipment
- Refrigeration System
- Terminations
- Cable

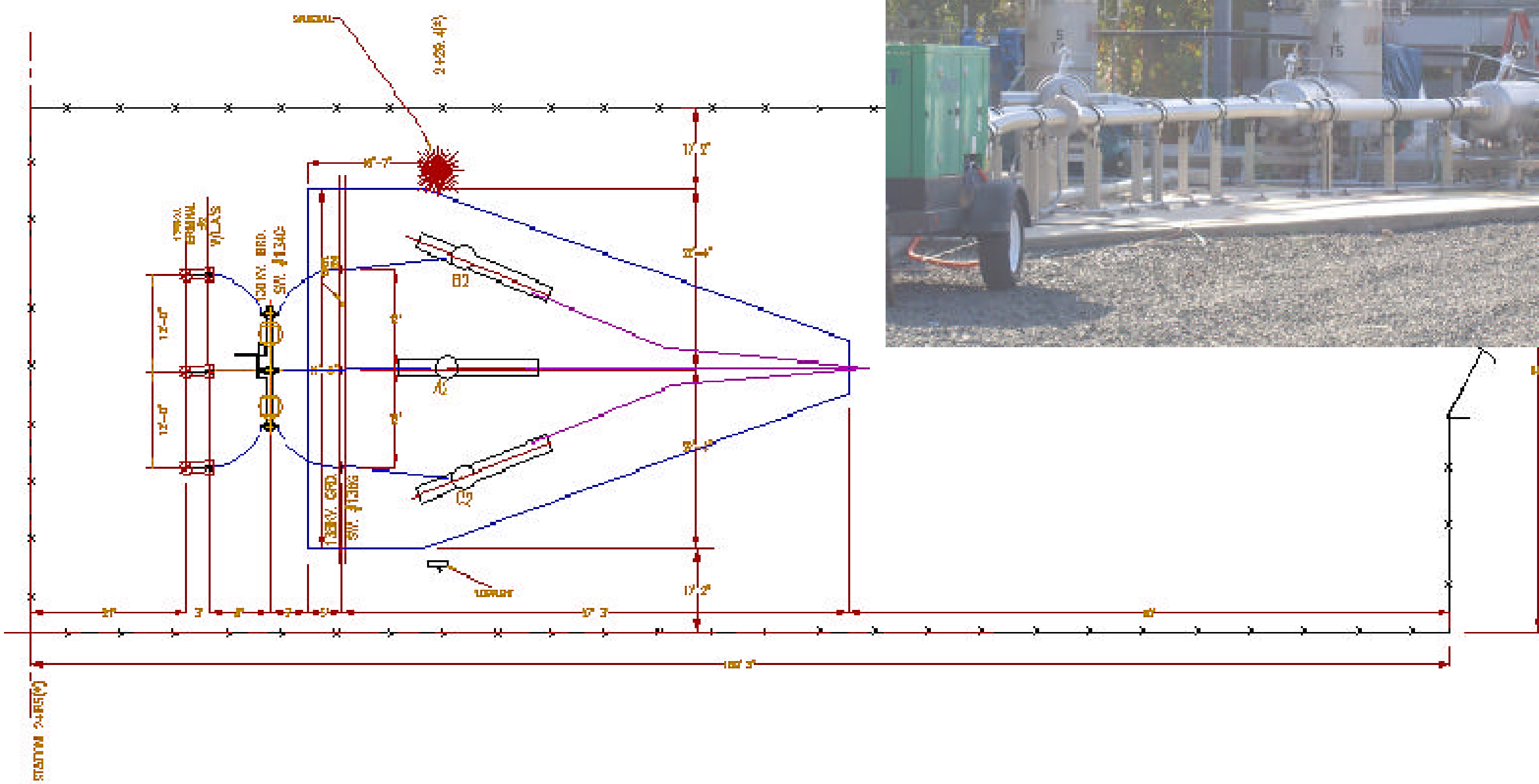
Primary (North) substation

- Refrigeration Building
- 150 kV / 750 kV Transformers
- 3 – single phase terminations (thermal / electrical)
- Manual and Automatic Ground Switches
- Motor operated Line Switch
- Current Transformers
- Circuit Breaker
- Manual Line Switch



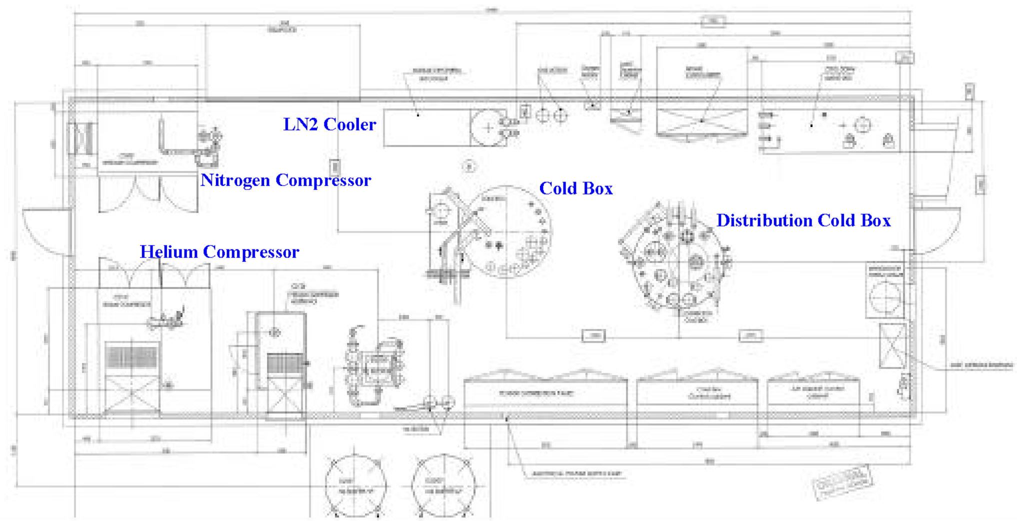
Grounding (South) Substation

- 3 – Single Phase Terminations (thermal / electrical)
- Manual and Automatic Ground Switches
- Solid Dielectric Termination (electric)
- Motor Operated Line Switch (on Holbrook Ring Bus)

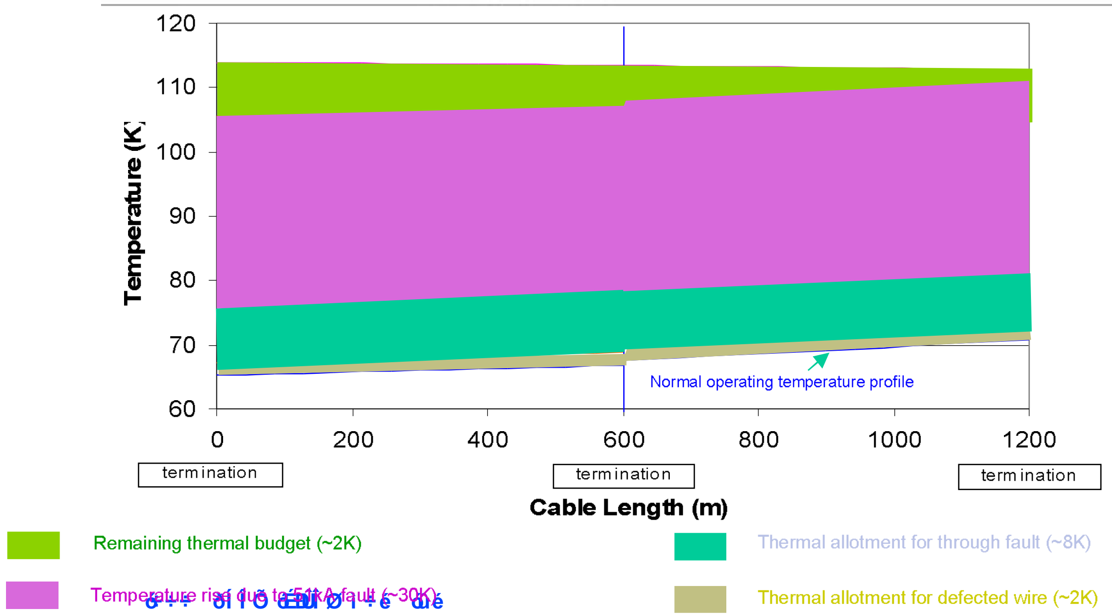


Refrigeration System

- Primary System Refrigeration: 5.65 kW @ 65K – 72K, 375 g/s LN2, 78 g/s GHe
  - 5.066 kW cable cryostat/termination loss
  - 333 W refrigeration system loss
  - 251 W extra capacity (5% Margin)
- Backup System Refrigeration: 6.77 kW (20% Margin)
  - Existing Backup System: 4.27 kW
  - New Added LN2 Module: 2.5 kW



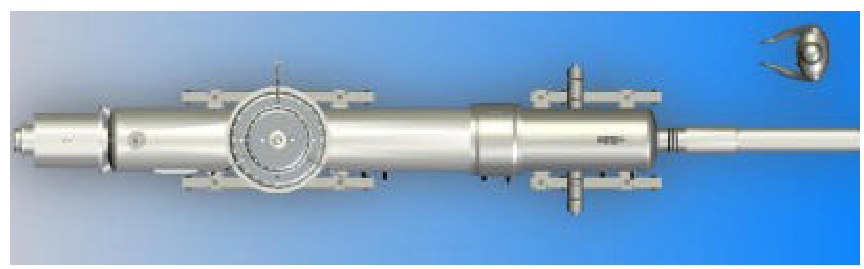
- LN2 Consumption
  - Existing Backup System: 30 g/s (135 L/hr)
  - New LN2 Module: 13.4 g/s (60 L/hr)
  - A 13,000 gal Tank to Provide at minimum 3 Day Supply (4000 gal heel)



Terminations

- Vertical part:
  - Thermal gradient management (from 65 to 300 K)
  - Connection to grid

- Horizontal part:
  - Connection to HTS cable
  - Management of cable thermal shrinkage



Cryostat (double walled insulated pipe) Description

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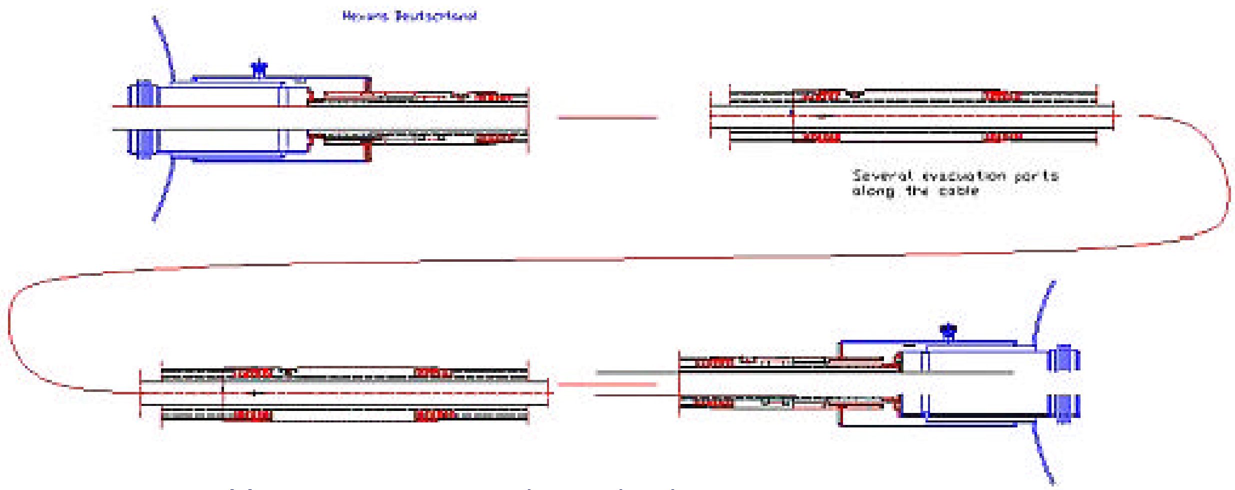
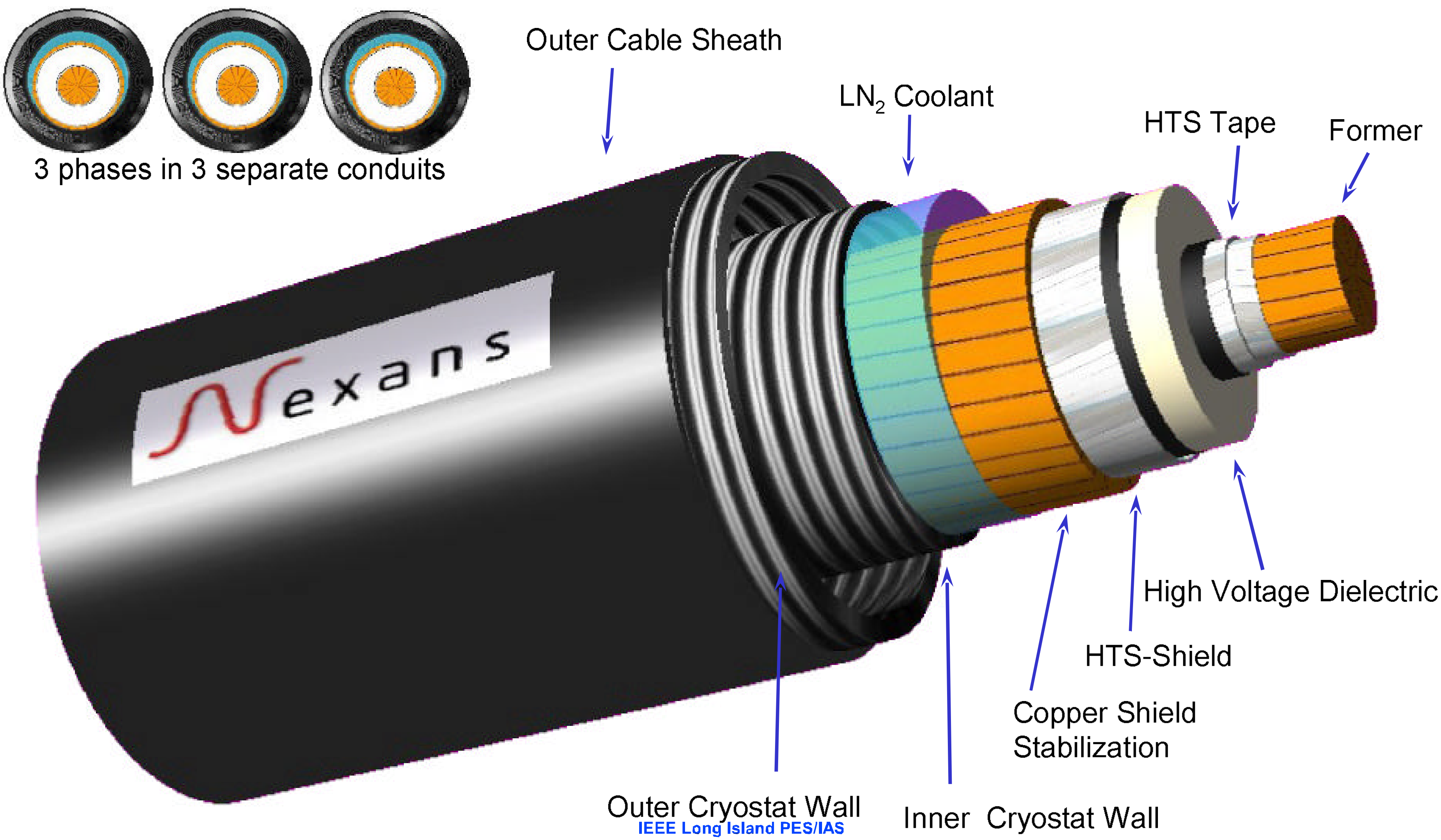


1. Corrugated Inner Pipe
2. Spacer
3. Vacuum Space
4. Multi Layer Super Insulation
5. Corrugated outer pipe
6. PE jacketing

- Vacuum ports at each termination
- For long term vacuum installation several evacuation ports along the cable are required.
  - (5 additional vacuum ports ~ every 100 meters)
- Cable cryostat is equipped with pressure relief devices and vacuum monitoring ports

LIPA HTS Cable Design



Operating Issues

- **<u>Load</u>**
  - The system has three, distinct operating conditions *(shows summer conditions)*
    - Superconductor energized, overhead de-energized
      - 922 A / 220 MVA;   STE 922 A / 220 MVA
    - Superconductor and overhead both energized
      - 1260 A / 330 MVA;   STE 1382 A / 330 MVA
    - Superconductor de-energized and overhead energized
      - 1260 A / 300 MVA;   STE 1851 A / 441 MVA

- **<u>Relay and Protection</u>**
  - Must operate within pre-defined thermal limits
    - SEL 421 monitor thermal condition
  - Must be grounded while de-energized, due to system fault conditions
    - Grounds automatically upon tripping for any reason
    - Cross trip both ends

Sound Issues

- Several questions regarding noise at the site (during operation)
- Conducted sound study
  - 35 db at ambient
  - Source: refrigerator building
  - 50 db with refrigerator running
- Acoustical Louvers
  - Lowered sound signature during operation to 38 db (modeled)

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On-going Project

Holbrook II

- General
  - Demonstrates 2G cable at transmission voltage
    - Replace one phase of existing 1G cable with 2G cable
    - Modify terminations to accommodate new cable design
  - Introduce maintainable cable system
    - Demonstrate field repairable cryostat
    - Demonstrate field cable splice
  - Develops commercially viable refrigeration system
    - High efficiency, Turbo-Brayton cycle
    - Optimize design for 20 KW module
    - Manufacture / test key components

  - Organization Meeting on October 26, 2007
  - DOE Kick-Off Meeting on February 28, 2008
  - Cable Installation Summer 2010