Nexans

SUPERCONDUCTING CABLES

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NEXANS

CIRED

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Contents

- Introduction to High Temperature Superconducting (HTS) materials
- HTS cable overview
- Main demonstration projects
- Applications
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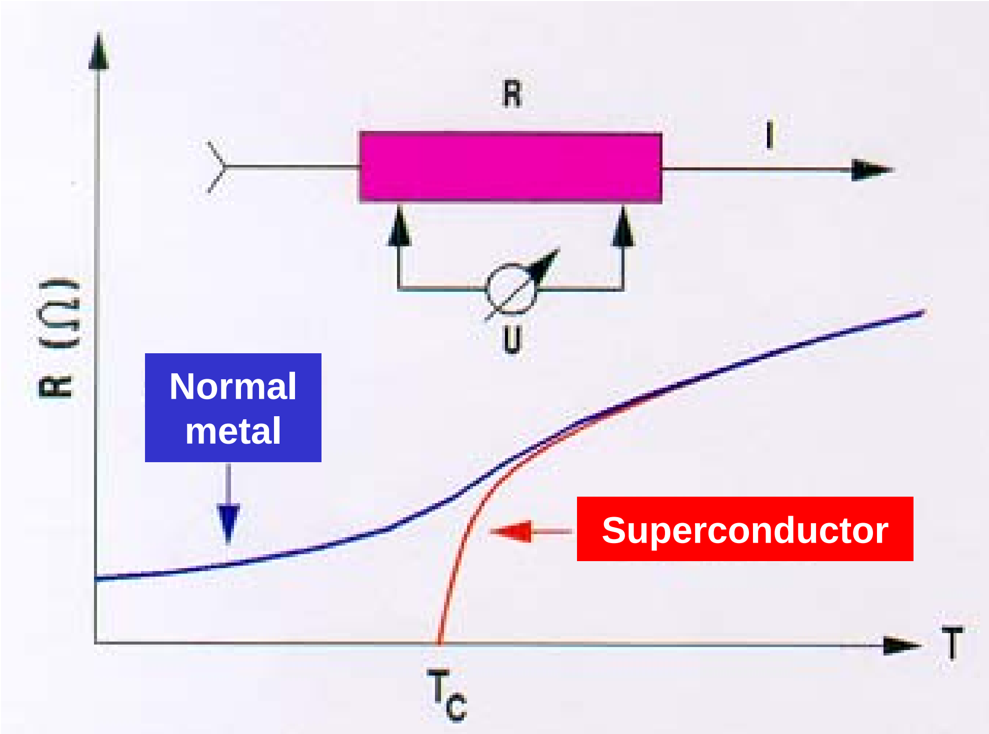
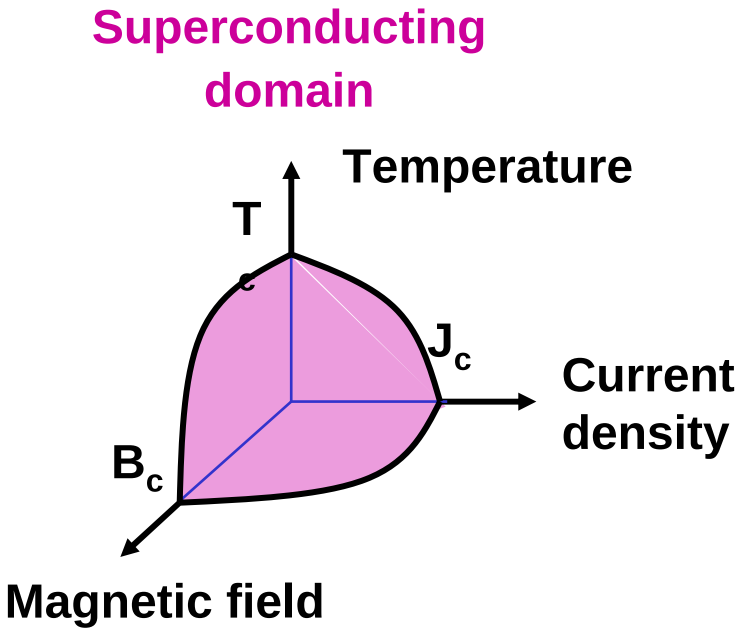
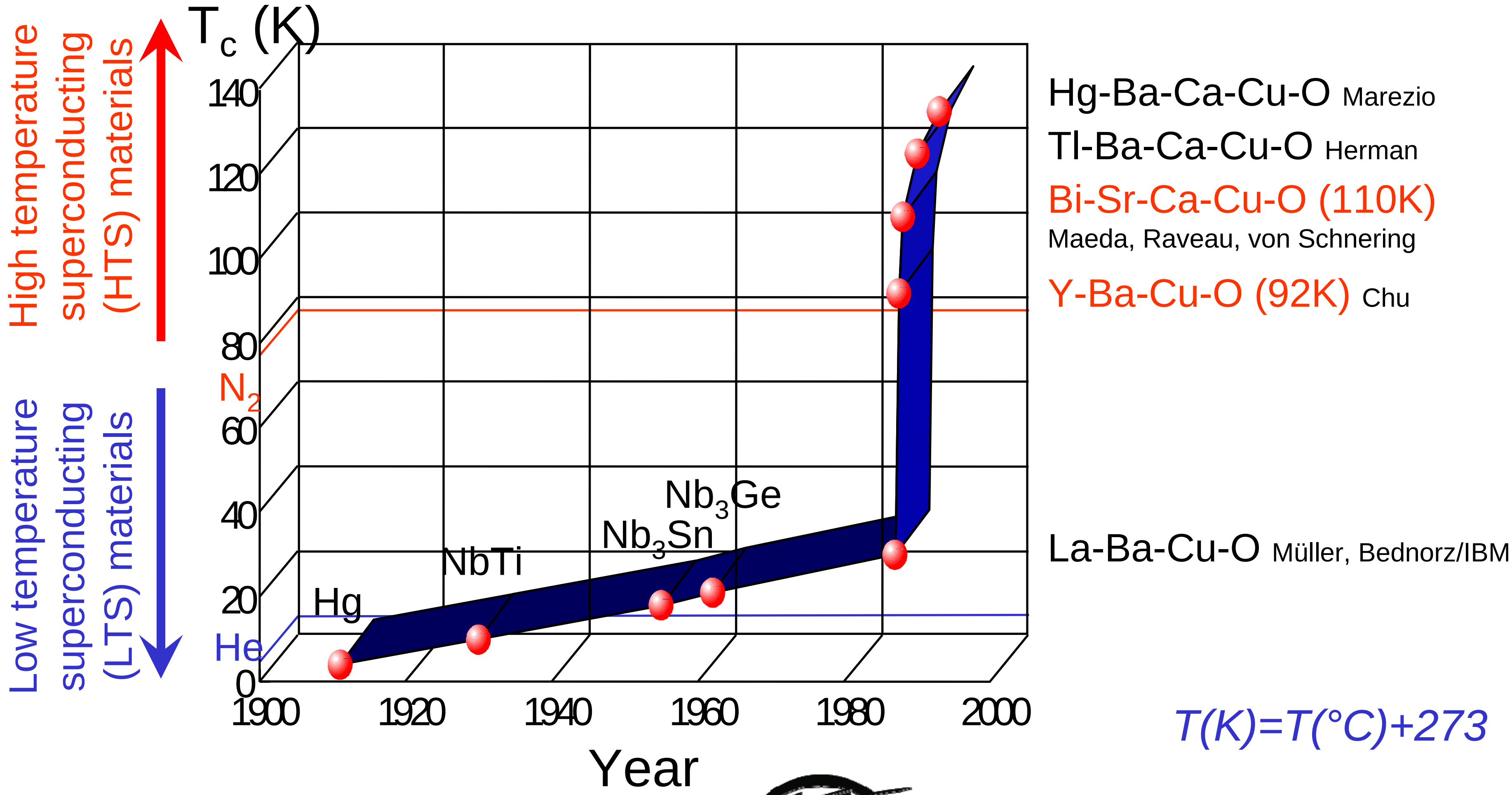
Superconductors are materials which are near-perfect conductors of electricity: virtually no electrical resistance !





HTS materials are superconducting at –200°C in liquid nitrogen

Gradual increase of critical temperature T_c



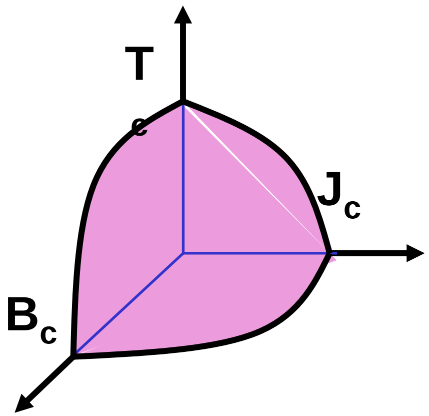
T(K)=T(°C)+273

- Huge current transport capacity: **150** times larger than the one of copper !

  ➔ HTS cables, with ampacities larger than the ones of conventional cables, provide a new way to solve power transmission issues by increasing the current (up to **5** kA or more) rather than the voltage

- Superconductors become resistive when the current exceeds a critical value

  ➔ HTS fault current limiters prevent the propagation of fault currents



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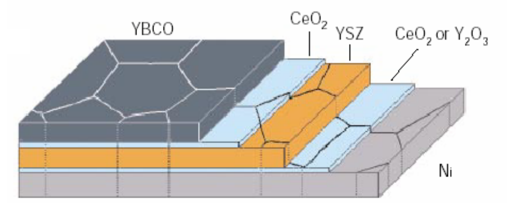
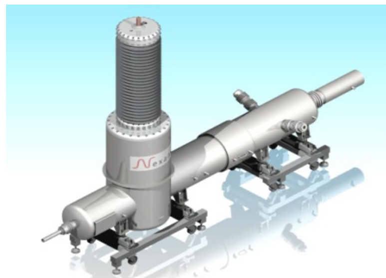
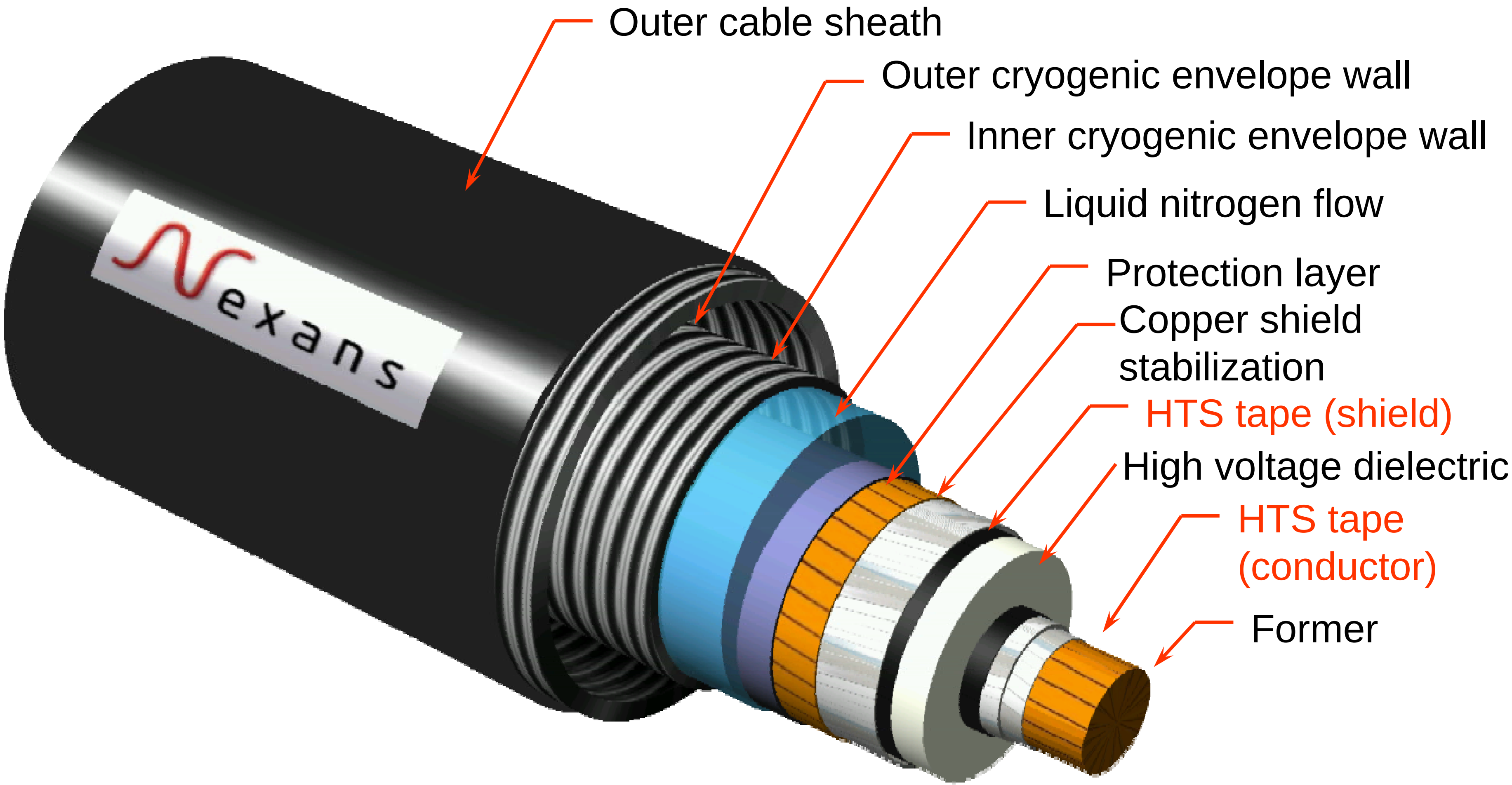
HTS cables overview
Specific components

- HTS tape: *Current carrying element*
  - First generation (1G):
    Bi-2223 multi-filament tape
  - Second generation (2G):
    YBCO,... coated conductors (CC)
- Dielectric compatible with liquid nitrogen:
  Electrical insulation
- Cryogenic envelope: *Thermal insulation*
- Accessories: *Connections*
  - Terminations
  - Joints



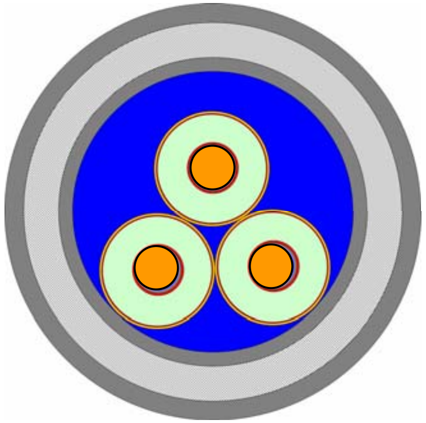


HTS cables overview
Cold dielectric concept



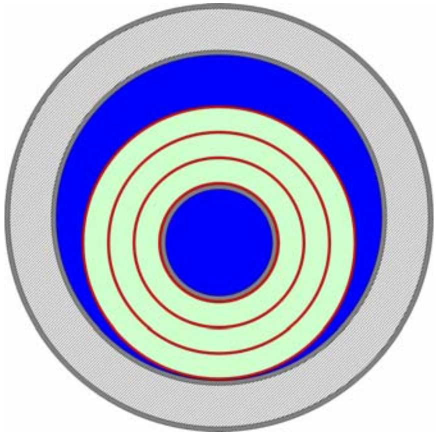
Fully shielded design (no EMF) with no thermal impact !

3 phases in one cryogenic envelope



3 separate phases

Concentric phases (triaxial design)



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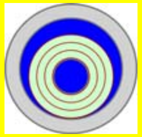
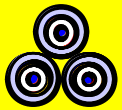
HTS cables
Main demonstration projects

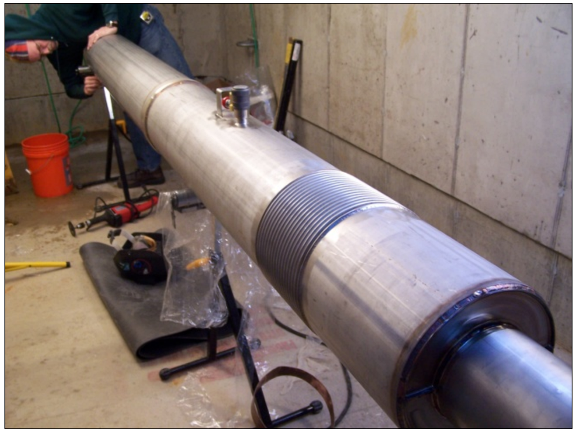
The three main cable projects were carried out in the USA, all with 1 G HTS tapes as current carrying elements

Cable design	Cable maker	Location	Utility	Cable characteristics	Cable in operation
	Southwire (Ultera)	Columbus (OH)	AEP	200 m / 13.2 kV / 3 kA / 69 MVA	August 2006
	Sumitomo	Albany (NY)	Niagara Mohawk	350 m / 34.5 kV / 0.8 kA / 48 MVA	July 2006
	Nexans	Long Island (NY)	LIPA	600 m / 138 kV / 2.4 kA / 574 MVA	April 2008

Southwire-NKT cable project in Columbus

AEP Project:

- Bixby station, American Electric Power, Columbus, OH
- 13.2 kV, 3000 A continuous service = 69 MVA
- 200 m, underground, splice, multiple 90 deg bends
- In service August 2006
- Peak Load = 2715 Amps
- Max FC experienced = 16,800 Amps



SuperPower/Sumitomo cable project in Albany

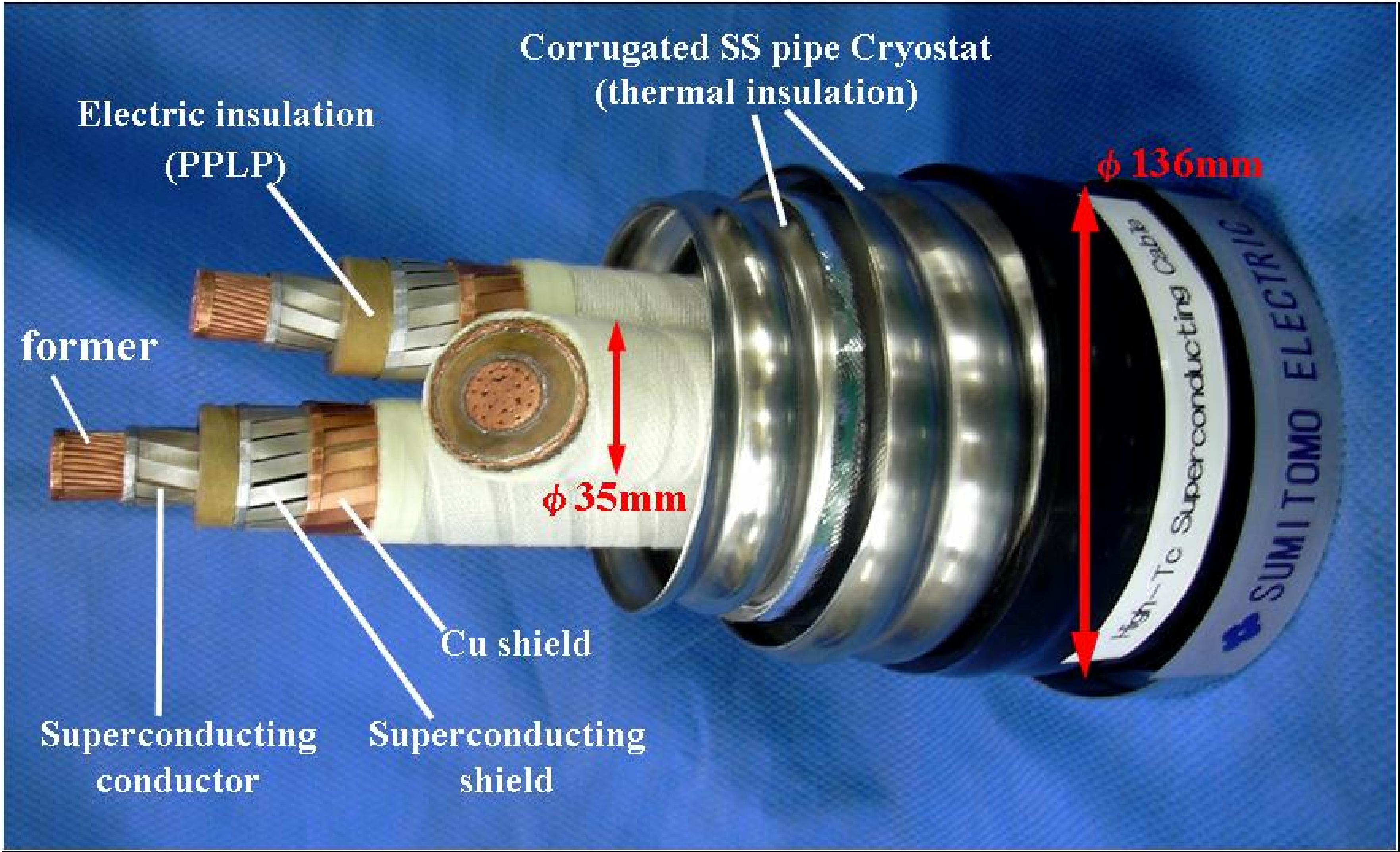


Photo: Courtesy of Sumitomo Electric Industries

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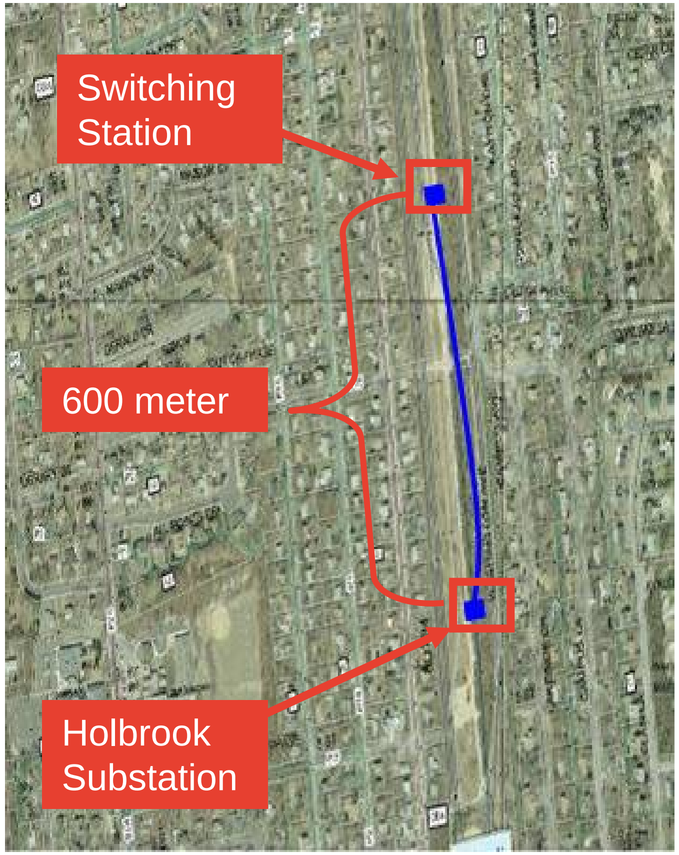
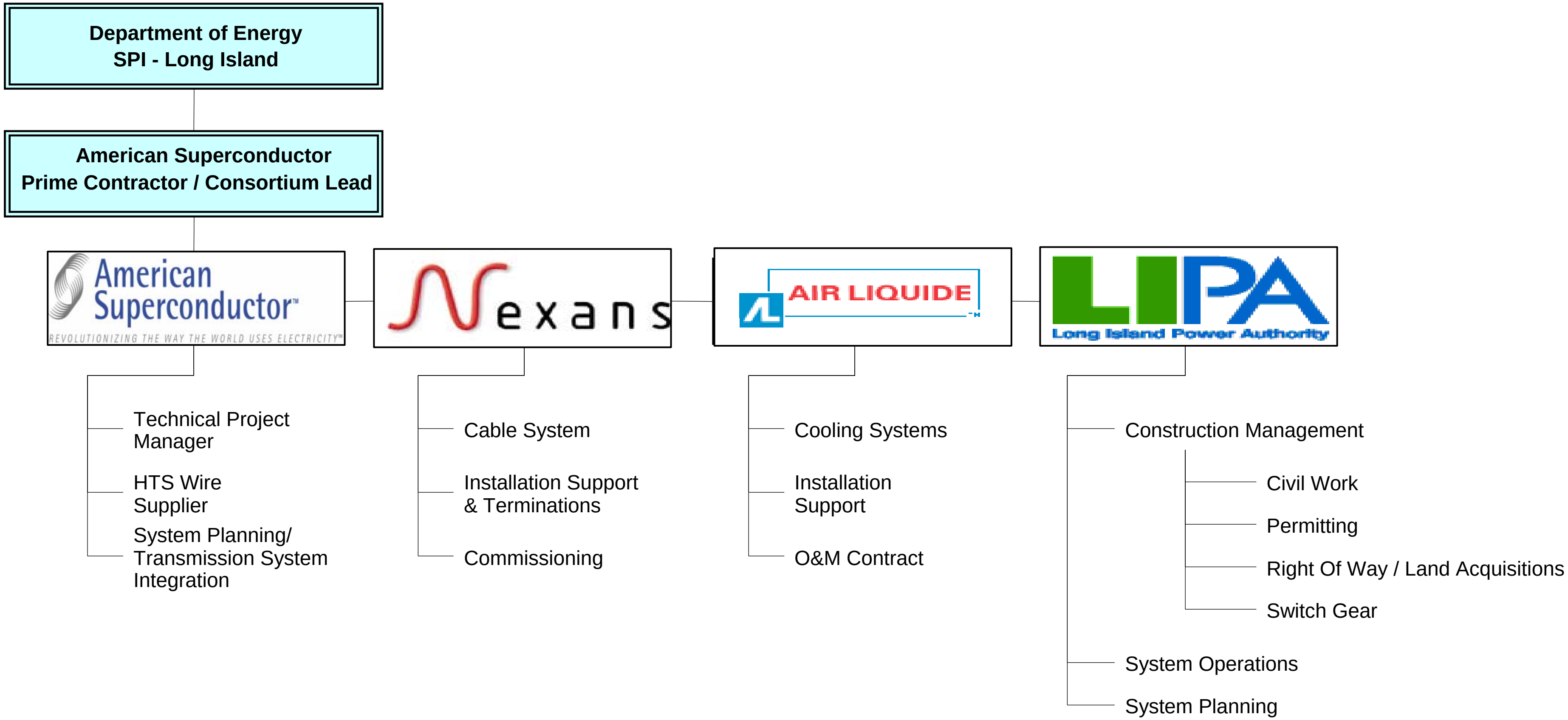
LIPA1 project Overview

World's first installation of a transmission voltage HTS cable

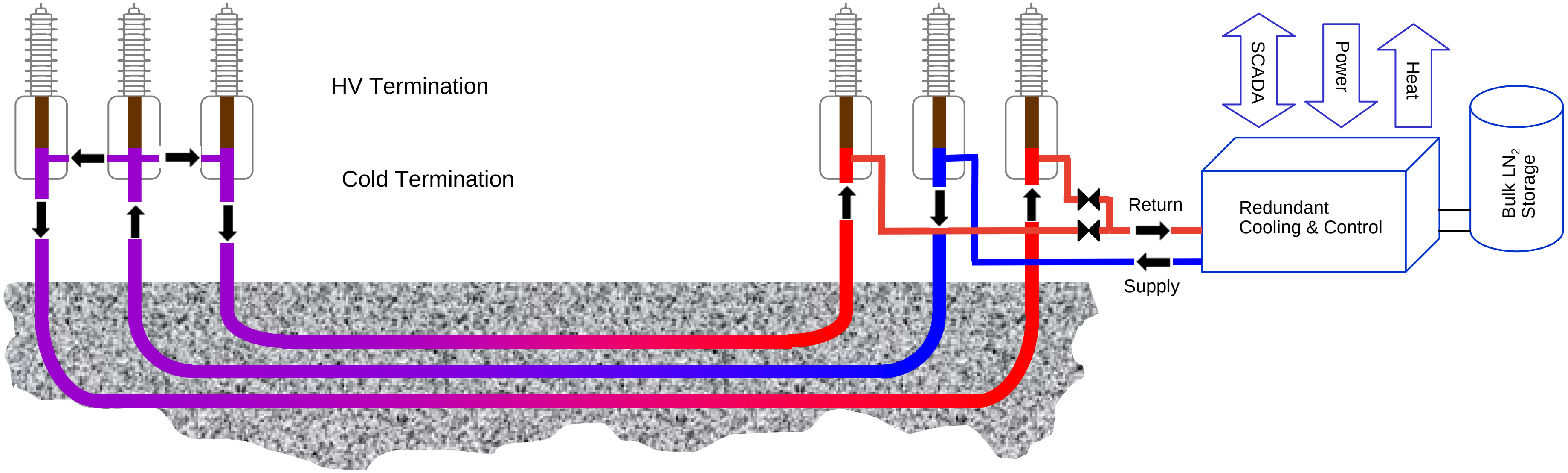
- Long Island Power Authority – Holbrook Substation
- 600 m long cold dielectric cable system 138kV/2400A ~ 574MVA
- 1G HTS tapes
- Design fault current: 51 kA @ 12 line cycles (200ms)
- 600 meter cable pulled in underground HDPE conduit



LIPA1 project Team



LIPA1 project
Cable cooling flow



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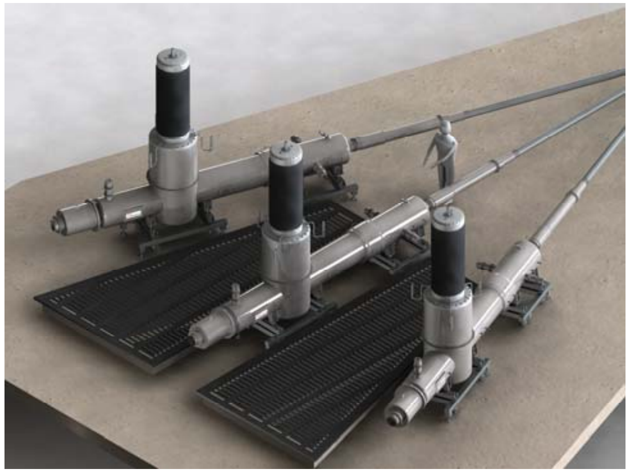
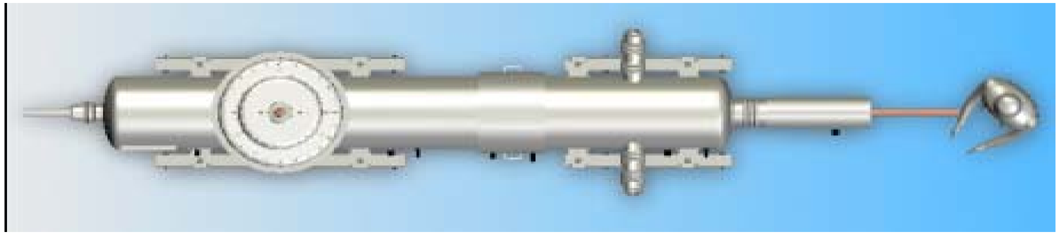
LIPA1 project
Termination concept

- Vertical part:
  - Thermal gradient management (from 77 to 300 K)
  - Connection to grid



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



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LIPA1 project Installation

Cable successfully energized on April 22, 2008

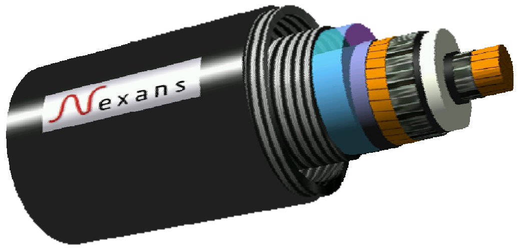
Three 30-meter AC cable projects completed

Cable design	Cable maker	Location	Utility	Phases	Cable characteristics	Project completed
	Sumitomo	USA (Albany, NY)	Niagara Mohawk	3	30 m / 34.5 kV / 0.8 kA	Early 2008
	Nexans	Germany		1	30 m / 138 kV / 1.8 kA	May 2007
	Nexans	EU	E.ON	1	30 m / 10 kV / 1 kA	Nov. 2008

European project Super3C Overview

- **Main objective:**
  Establish feasibility of low-loss HTS cable using 2G tapes as current carrying elements

- **Main deliverable:**
  Functional cable model with terminations



Super3C cable design

- **Cable model characteristics:**
  Cold dielectric design, one-phase, 30-meter, 20 kV, 0.5 kA

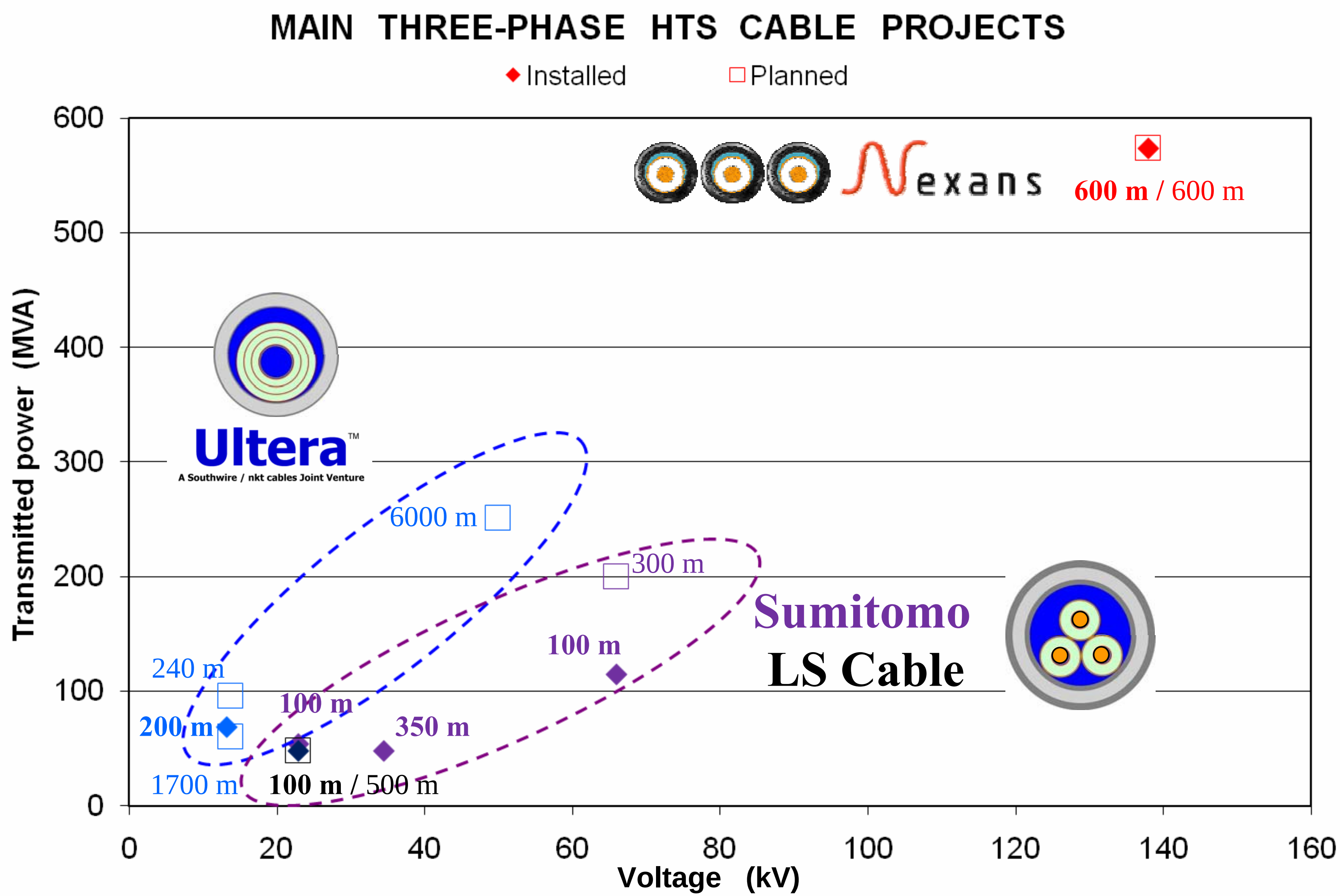
- **Timeframe:** June 2004 – November 2008

- **Partners:** Nexans, Bruker HTS, ICMAB, Labein, E.ON, Air Liquide, Tampere Univ., Bratislava IEE, Göttingen ZFW

Super3C termination

- **Funding:** EU (FP6)

HTS cable projects Overview



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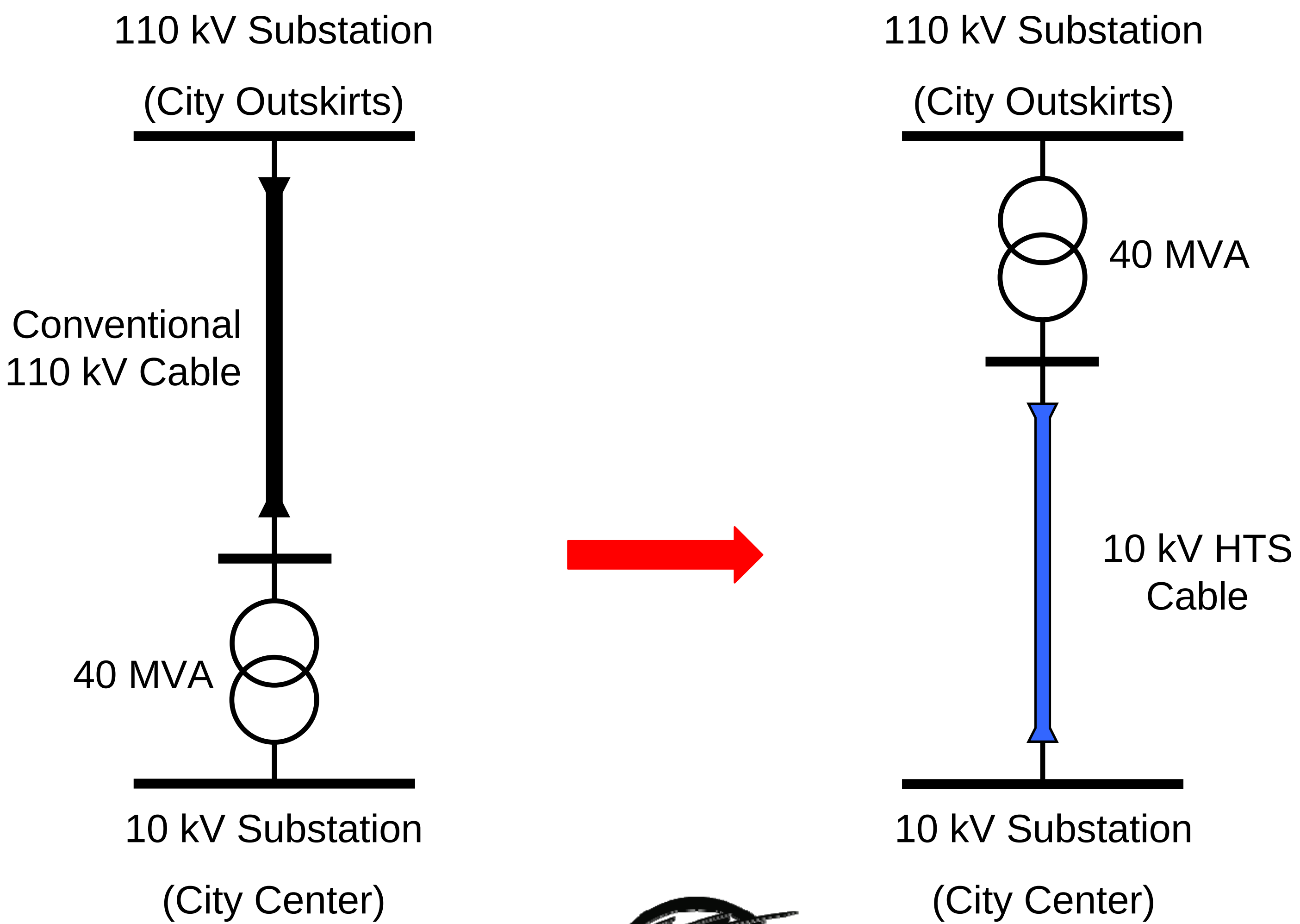
HTS cable applications
Benefits

- Allow transmission capacity upgrades with lower voltage systems
- No thermal or electromagnetic impact on the environment
- Enable use of existing right-of-way (for gas, water, highways, railways,…)
- Very low impedance (power flow controllability, better voltage stability)
- New ways to manage fault currents
  - Fault current limiting cables
- ”Soft cost” benefits:
  - Faster timing (permitting), lower construction impacts, improved community relations, protect property values, expanded generator siting options

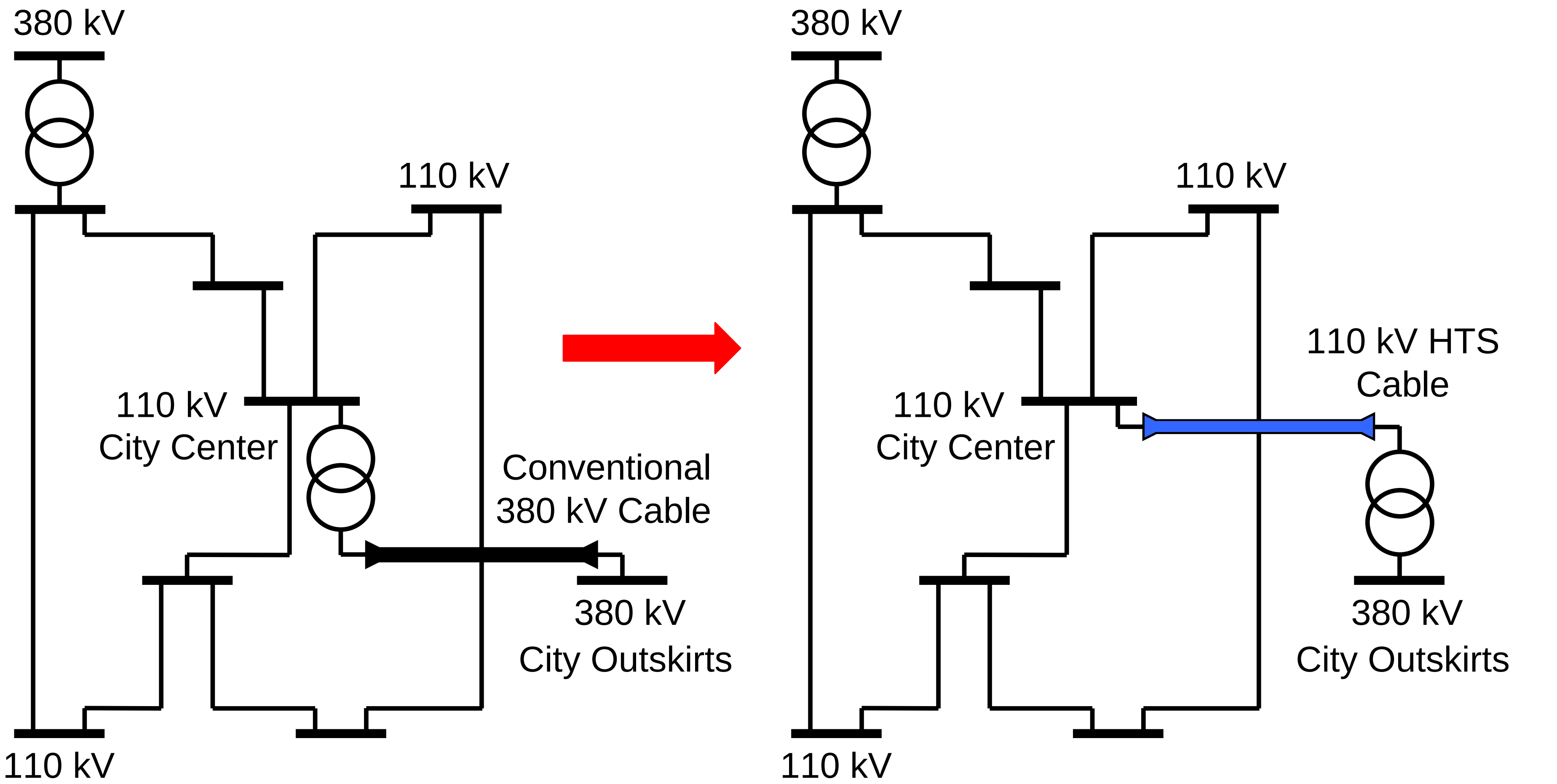
HTS cable applications
Cases envisioned for AC HTS cables

- Power transfer at lower voltage: *Takes advantage of high ampacity*
  - Transmitted power of 345 kV line achievable with 138 kV HTS cable
- Retrofit: *Takes advantage of high ampacity and elimination of EMF*
  - Use of existing RoW's or ducts
- Alternative to conventional DC cable: *Takes advantage of controllability*
  - Possibility to interconnect with AC networks without going DC
- Use of infrastructure: *Takes advantage of environmental friendliness*
  - Installation on bridges or in service tunnels
- New cable path: *Takes advantage of elimination of thermal impact*
  - HTS cables can be installed in cities below existing networks
- Network meshing: *Takes advantage of fault current limitation*

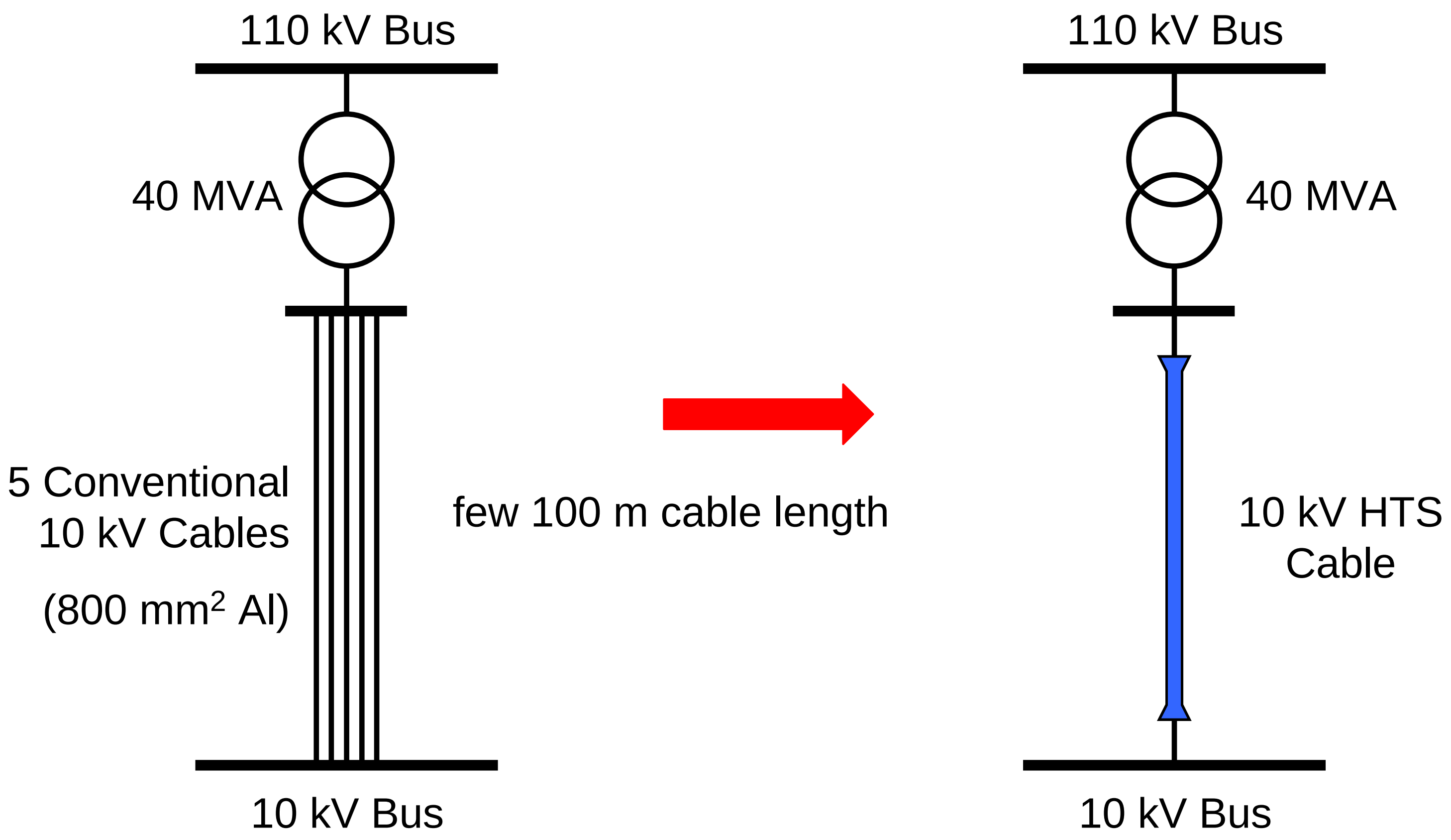
Application examples
Energy transport to medium city center



Application examples
Energy transport to large city center



Application examples
Energy transport within a substation



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Conclusion

- HTS cable systems constitute a new energy-efficient solution to improve congestion management in both distribution and transmission power grids
- The HTS cable technology has been demonstrated at both medium and high voltage (up to 138 kV) and is now moving towards:
  - Longer lengths (up to 6000 m)
  - Greater ampacities (5 kA prototype project recently announced in Japan)
  - Higher voltages (prototype projects at 154 kV in Korea and at 275 kV in Japan)
- 2G HTS wires are expected to significantly reduce costs in the coming years
- HTS cables and HTS FCL, and the combination of both through fault current limiting HTS cables, are expected to play a significant role in the deployment of future Smart Grids

Thank you for your attention !