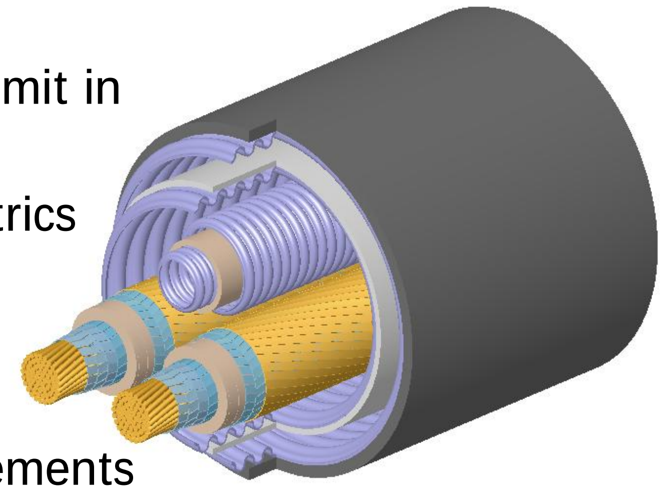
High Current Direct Current (HCDC) Superconductor Cable

Why High Current DC (HCDC) Cables

- DC is the preferred transmission method for transferring large amounts of power over long distances -
- Overhead HVDC lines are extremely difficult to permit in the US
- Underground HVDC cables are limited to oil dielectrics above ~300MW power transfer capability
- DC allows power transfers between asynchronous control areas
- Converter station reliability is increased – more elements in parallel for given power transfer capability
- Converter station size can be reduced



HCDC Cables provide smaller overall footprint and high power transfer capability

The Value of HCDC

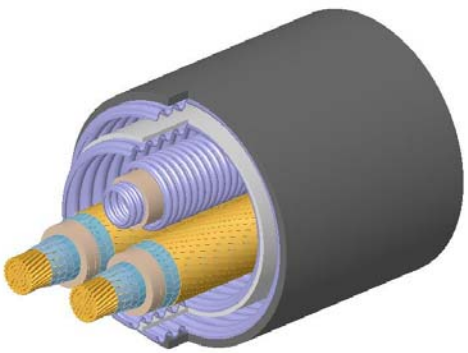
- HTS HCDC power cables increase power transfer of rights-of-way by 8-10X at the same voltage
- LV/MV ROWs are much more pervasive than HV/EHV ROWs
- LV/MV circuits have reduced permitting constraints
- Commercial Value – A 400/600MW link has less probability of destroying pricing differentials between market areas than a large 2/3GW link
- Islands & Bridges – Quick isolation enables reduced large scale system issues at the cost of more small scale system issues
- The first step towards the development of the SuperGrid concept

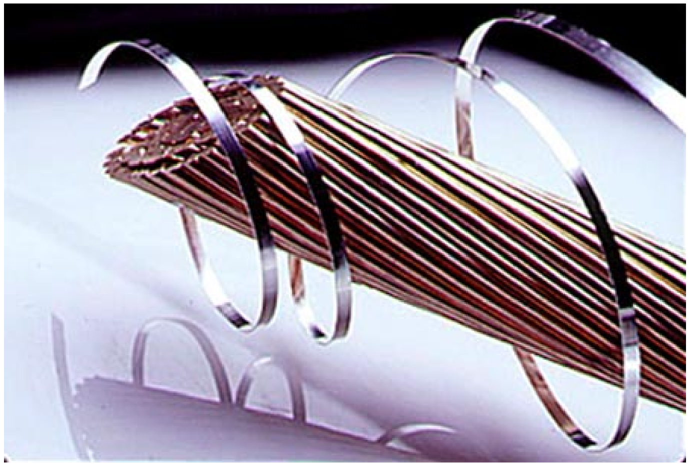
Onshore DC Transmission Technology

- Available Conventional HVDC
  - OH > +/- 600kVDC 6300 MW (Itaipu, Brazil)
  - UG Oil Filled > +/- 500kV 2000MW (Empire Project)
  - UG XLPE > +/- 141kVDC 600 MW (HVDC Light / ABB)
- HCDC Power Transfer Potential
  - UG MV > +/- 30kV 600MW
    - Seam Patch Application
  - UG MV > +/- 60kV 1200MW
    - Bulk Transfer
  - UG HV > +/-150kV 4000 MW
    - Bulk Transfer

Underground HCDC Cables provide power transfer capabilities comparable to OH

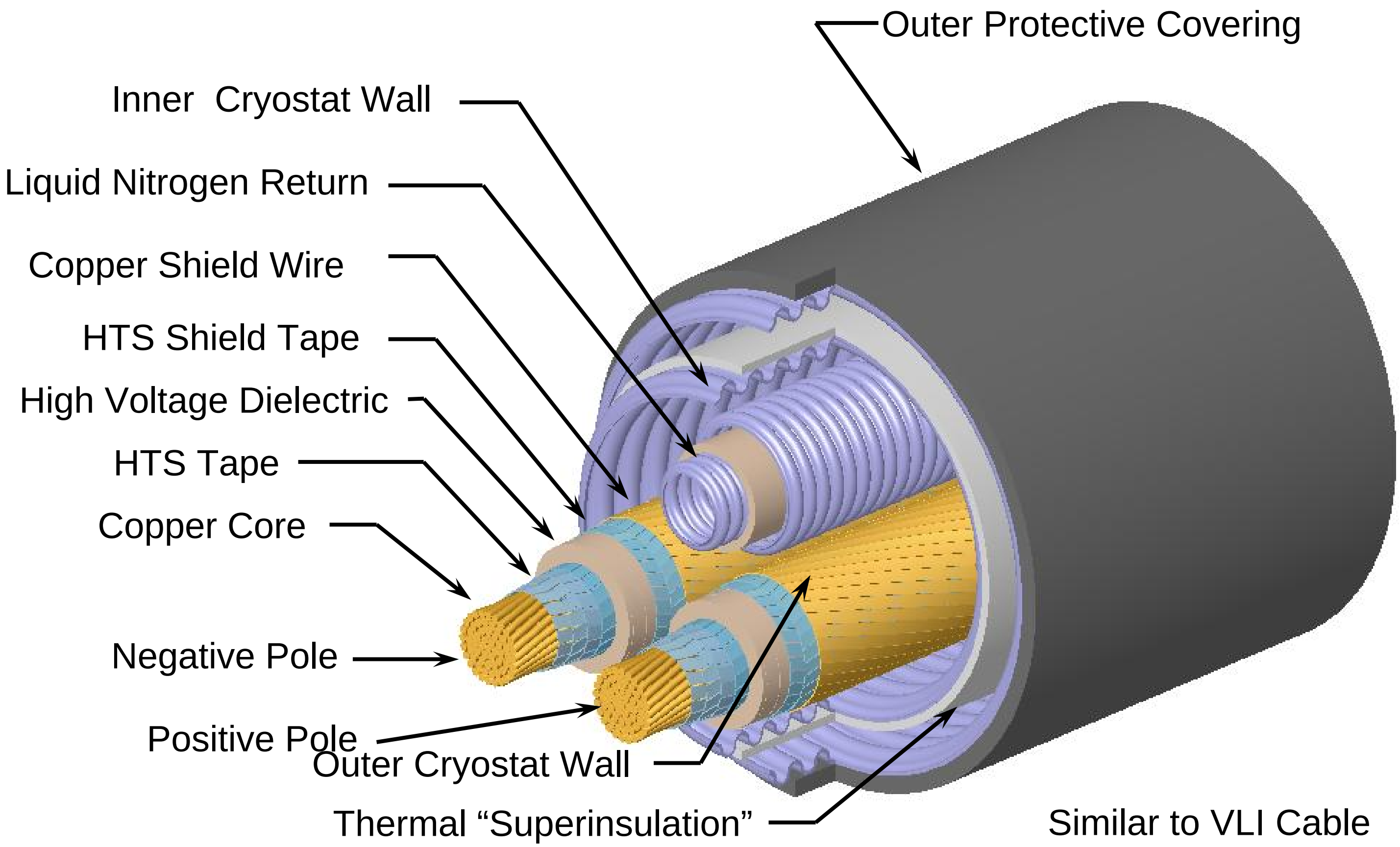
HCDC Cables – An Explanation





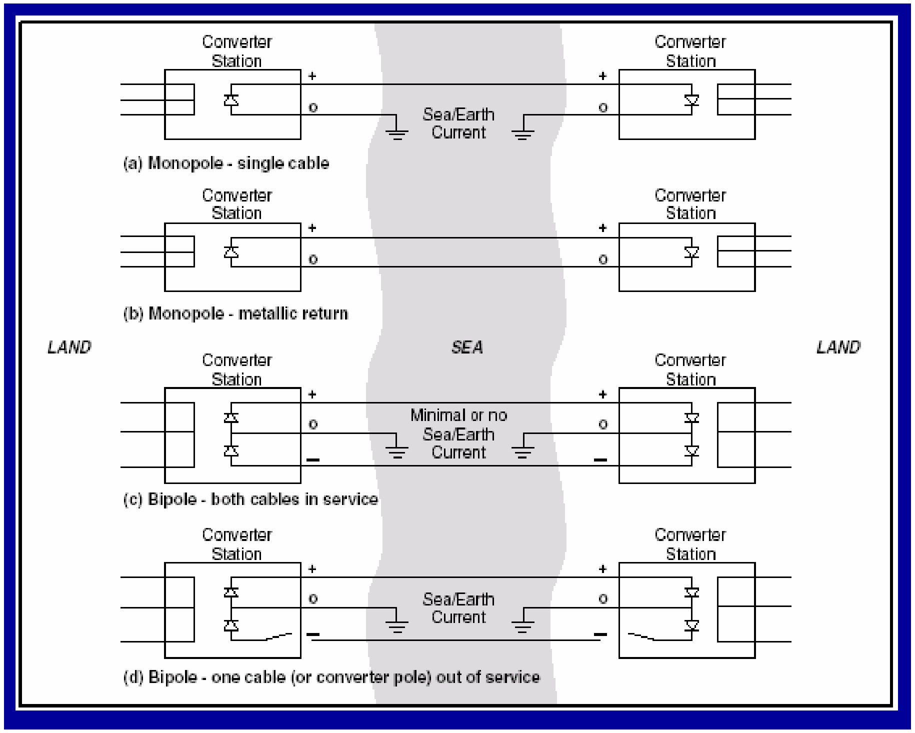
- Power Carrying Capabilities 8x to 20x Greater than Copper Cables
- HTS Wire Enables a Core Geometry that Provides
  - Low Conductor Resistance
  - Low Inductance
- Environmental Compatibility
  - Underground Placement
  - No Electromagnetic Field
  - Thermally Independent of Environment
  - Nitrogen Cooling Fluid (Inert) – No Oil

Typical DC Cable (Ground Return) Cross Section



HTS HVDC Paradigm Shifts

- Conductor size and heat removal no longer drive system design
- High current operation improves reliability due to more parallel (less serial) elements in converter stations
- Losses are function of length (thermal) – not a square function of current
- Bi-pole with Electrode Return
- HV link - voltage control vs. current control



Basic HVDC design criteria change significantly when using HTS cable

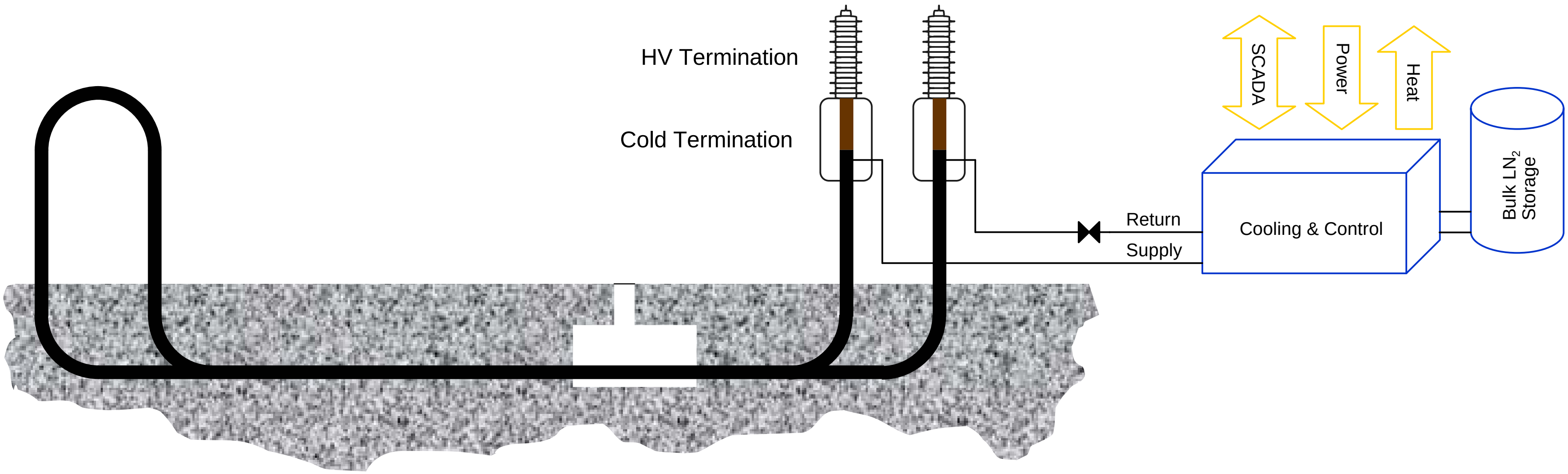
HCDC Technical Development

- System Level Items
  - Converter Architecture Trade-offs (Constant current topology)
  - Over voltage issues caused by L di/dt issues
  - AC losses due to ripple on the DC link
- Cable Related Items
  - Single/multiple cryostat design tradeoff
  - Fault capability on the DC Link
  - DC Dielectric behavior at 77K
  - Aging characteristics of DC insulation systems
  - Cable design/production time requirements
  - Accessory design/production time requirements

Project Components

- Develop and demonstrate the feasibility of a High Current Medium Voltage DC cable system
- Identify System Topologies for Initial and Future HCDC Systems
- Establish MV Converter Station Economics
- Identify and Validate Applications and Markets for HCDC Systems
- Develop Pathway to Multi-GW Class HCDC Systems

HTS HVDC Cable System Diagram



DC Cables allow direct solutions for solving transmission system problems