HTS Cable Applications for Datacenters

Microsoft

February, 2024

smarter, cleaner
... better energy

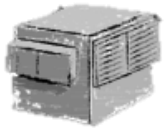
AMSC Corporate Facts

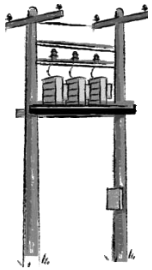
- Headquartered in MA, USA
- Founded in 1987; IPO in 1991
- Sales & Service staff in N. America, Europe, Asia, and Australia
- Wind Energy and T&D Solutions Provider

AMSC Product portfolio

smarter, cleaner
...better energy

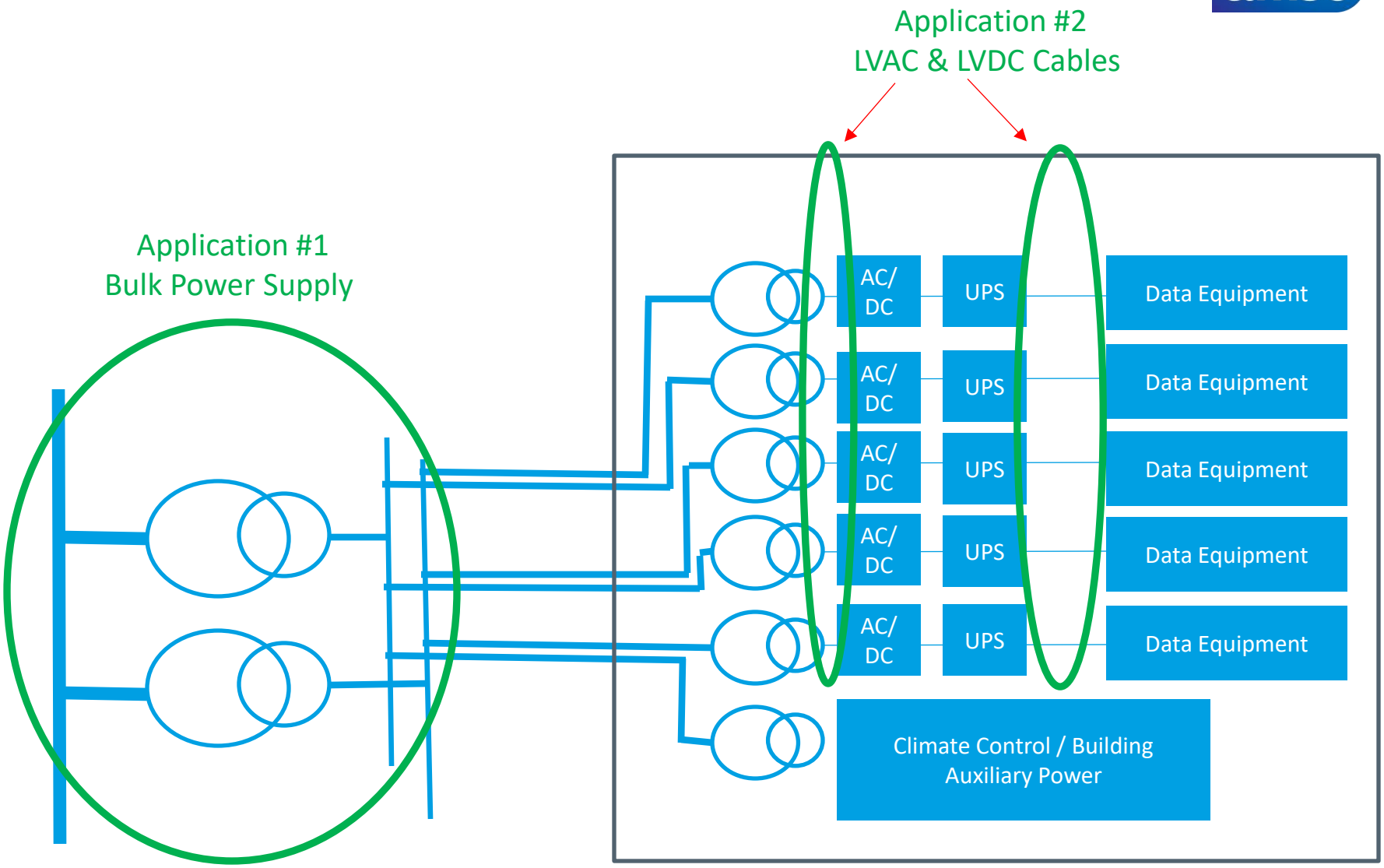
amsc



	Electrical Control System for wind turbines (wtECS™)	Transmission Voltage Management (D-VAR®)	Resilient Electric Grid (REG) systems	Distribution Voltage Optimization (D-VAR® VVO)	NEPSI and NEELTRAN	Ship Protection Systems (SPS)
What it is	Components and controls that act as the "brain" and "nerves" of turbines	Voltage regulation solution, driven by power electronics components	System that increases electric grid resiliency, reliability, and load serving capacity	Direct connect 15Kv class power quality system for distribution network	Rectifiers and transformers for industrial equipment. Capacitor banks and harmonic filters for medium-voltage power quality applications.	Advanced HTS-based systems that enhance operational safety
What is does	Maximizes power generation, ROI of wind power installations	Connects renewable energy to grid; provides reactive power compensation	Increases reliability of urban grids and provides cost-effective, simplified solution for urban load growth	Optimally controls voltage, allowing utilities to build distribution networks using distributed generation (DG)	DC power to the load. Line side mitigates common power quality issues in the areas of power-factor correction, harmonic distortion	Degaussing is a magnetic system that interferes with a mine's ability to detect and damage a ship
Target markets	Wind turbine OEMs using AMSC wind turbine designs	Electric utilities, renewable plants, industrial facilities	Urban electric utilities	Electric distribution grids incorporating DG	Industrials including Hydrogen	Navy Surface fleet

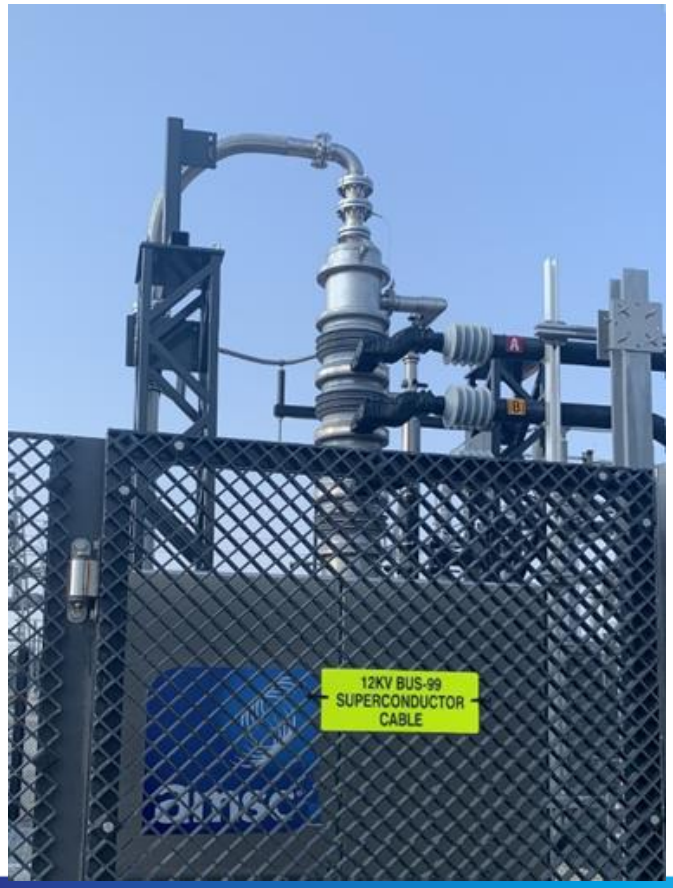
Applications of HTS: Datacenters



Resilient Electric Grid (REG) Technology

Dramatic Improvements in Resiliency

(Capacity + Reliability)



Environmentally Friendly

No oil, No SF6 gas

Compact

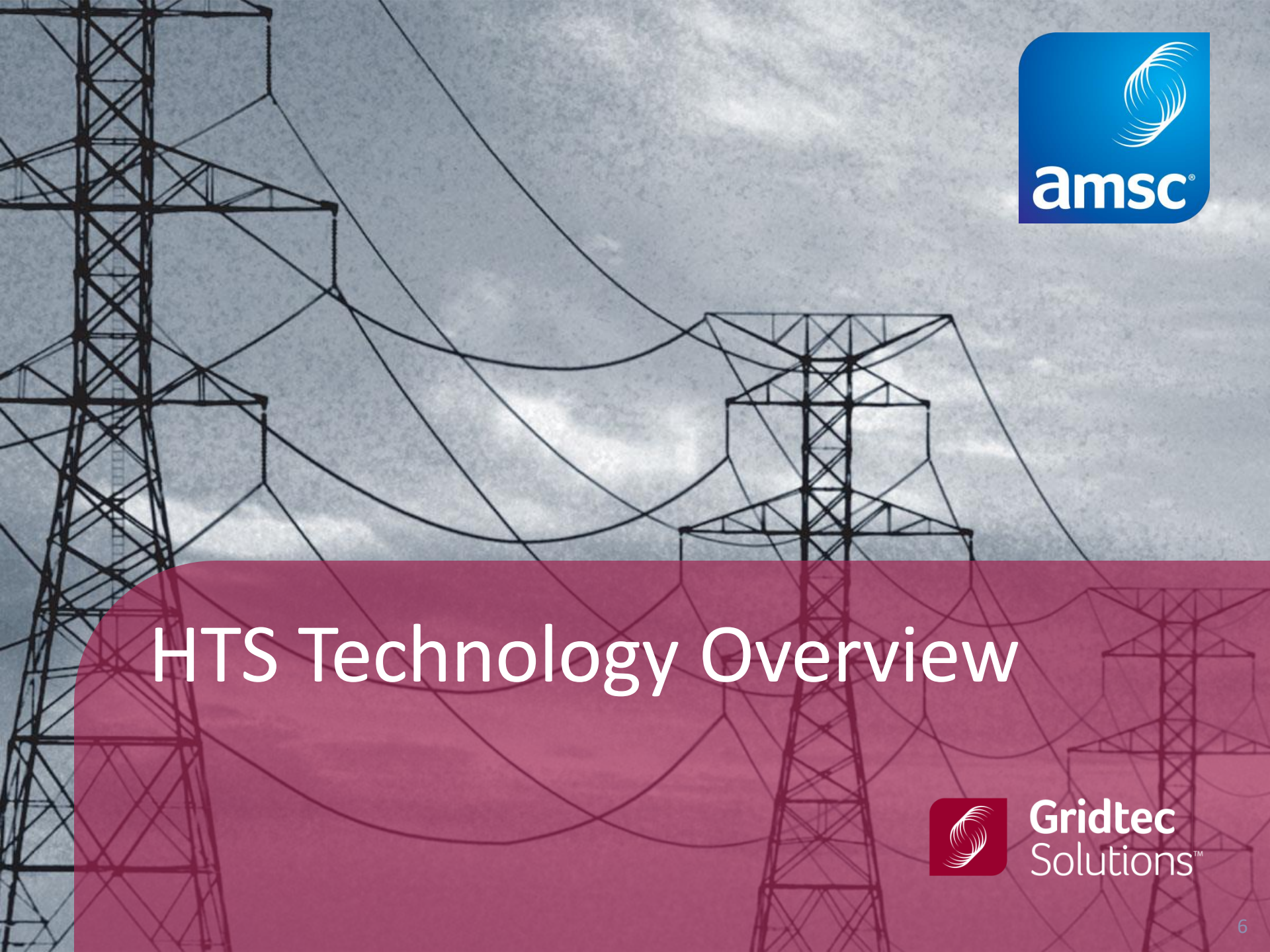
Far less New or Expanded Substations, small ROWs

Healthy and Safe

No EMF, much lower voltage levels

Minimally Disruptive

Easier to permit, site and install

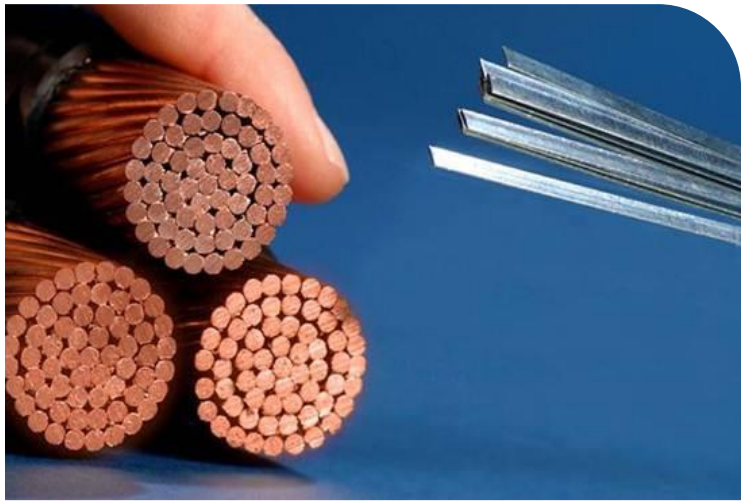


HTS Technology Overview

Gridtec Solutions™

What is a Superconductor?

- **Superconductors are materials that exhibit unique electrical characteristics:**
  - *Zero resistance (low losses)*
  - *High current density (high power)*
  - *High electro-magnetic shielding (low EMF)*



- **These characteristics require:**
  - *Cooling system that typical uses Liquid Nitrogen*
  - *Operates at around -205˚C*
  - *Liquid Nitrogen is Environmentally Safe, 78% of Atmosphere*
- **Ceramic high temperature superconductor (HTS) material discovered in 1986**
  - *Operates at higher temperature than older, Low Temperature Superconductors*
  - *Allows for Large Scale Commercial Projects, not just small machines like MRIs*
  - *Many applications outside of electric power including transportation, medical scanning, scientific machines (particle colliders), nuclear fusion, and many others*

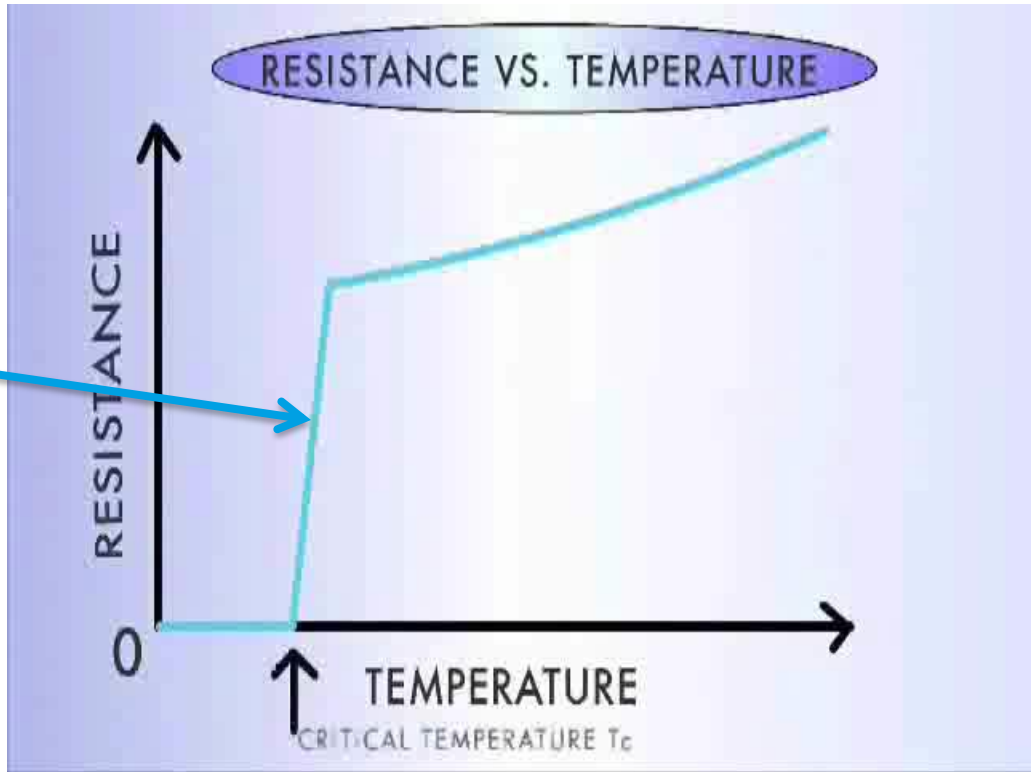
Development of HTS has enabled utility commercial applications

The Superconducting State

Superconductivity is a phase state of matter

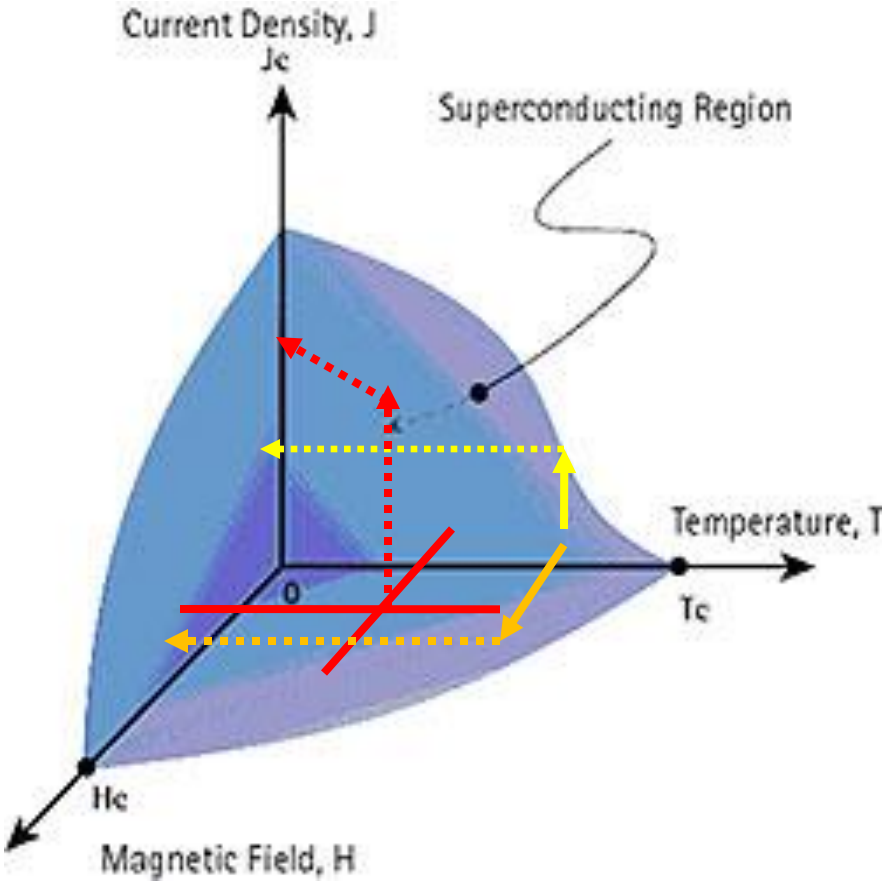
- The transition to the superconducting state involves a phase change in the material

Dramatic and sudden drop in electrical resistance: the physics governing how electrons move has changed significantly



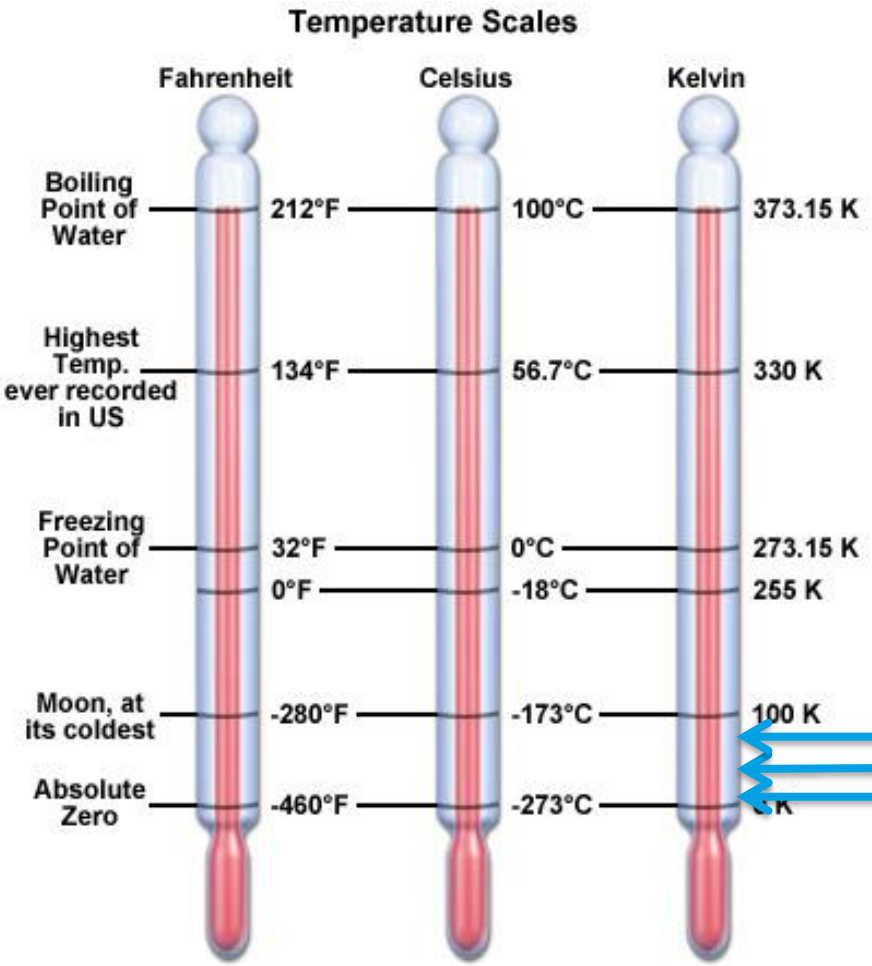
J-T-H "Phase" Diagram For Superconductors

- The superconducting state depends on three critical parameters:
  - Electrical current density (J)
  - Temperature (T)
  - External magnetic field (H)
- Fixing one of these parameters also fixes the maximum values of the other two



How Cold is Cold

“High” Temperature Superconductor – Relative term



Highest T_C materials: >130 K

Lowest T_C materials: <1 K

Liquid Nitrogen: 77K

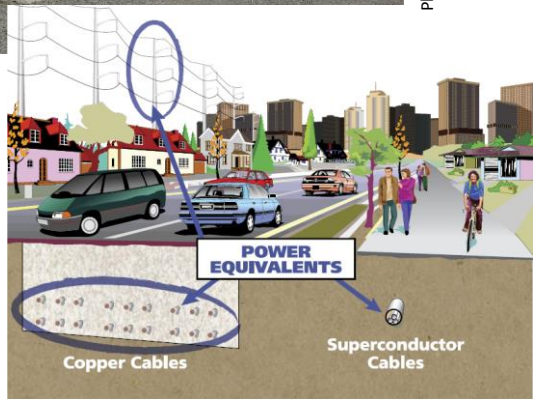
Liquid Neon: 27 K

Liquid Helium: 4.2 K

Superconductor AC Power Cables
Unique Electrical Characteristics

- Very high power transfer capability compared to conventional cables solves many siting problems
- Thermal isolation eliminates de-rating, simplifies placement concerns, and minimizes right-of-way
- Optional fault current management capabilities eliminate need to upgrade existing equipment
- Minimal magnetic field

Photo courtesy Long Island Power Authority



Superconductor cables offer unique capabilities

Key HTS Cable PHYSICAL Characteristics

Unique Electrical Characteristics

- Very high power transfer capability
- Zero resistance (low overall impedance)
- Minimal magnetic field (near zero EMF)
- No thermal constraints for placement
- Fault current management

Familiar Physical Characteristics

- Looks like conventional cable
- May be spliced
- May be placed in ducts or direct buried
- Similar bending radius and pulling strengths
- Liquid nitrogen cooling similar to conventional oil cooled cable systems

HTS Cables offer unique capabilities in a familiar package

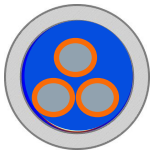
HTS Cable System Designs

Naval / Industrial Applications

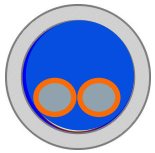
Electric Utility Applications

Low Voltage AC/DC/Degaussing

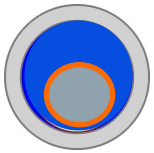
3 phase AC



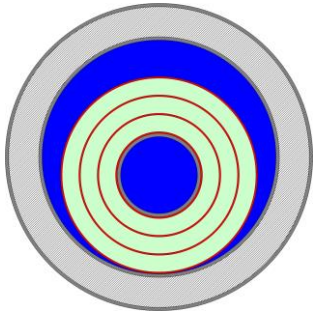
2 pole DC



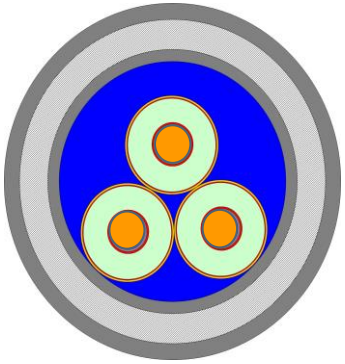
1 pole DC



3 Phase AC, Concentric phases



3 Phase AC, All phases in one cryogenic envelope



HVDC or 3 Phase AC, Separate Phases/Poles

LV → HV

Rated Voltage

HTS Concentric Phase Distribution Cable

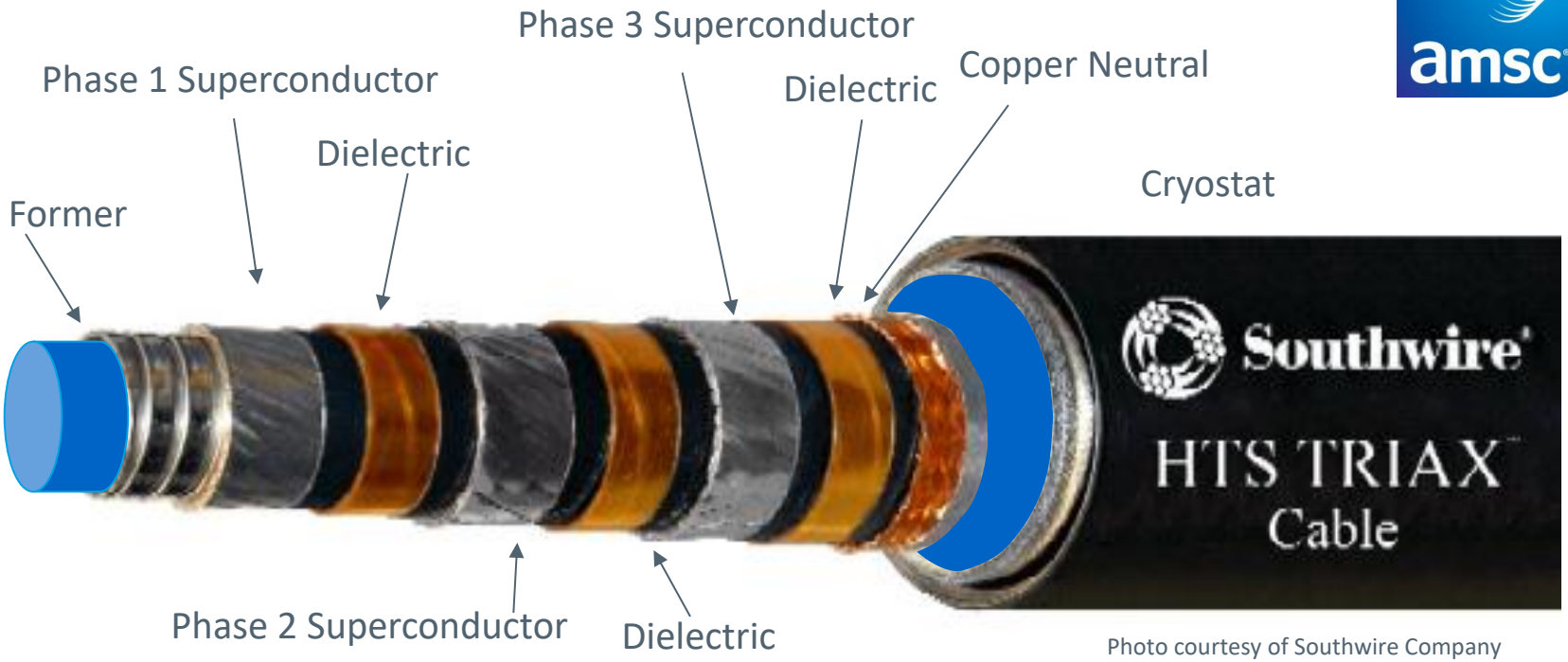


Photo courtesy of Southwire Company

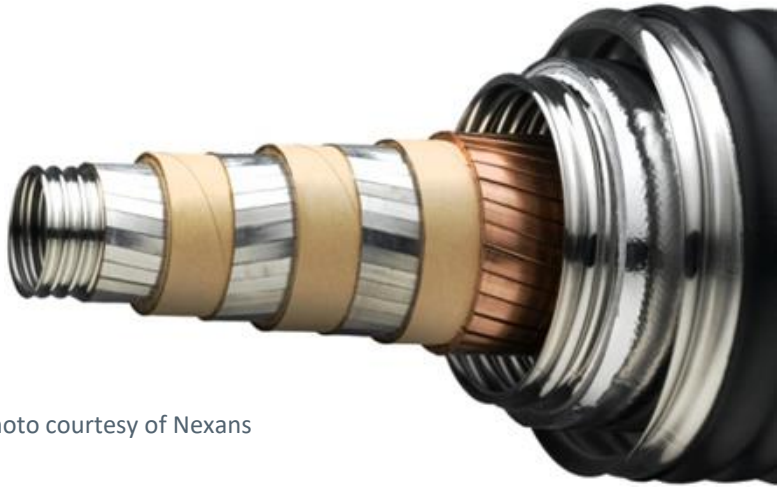
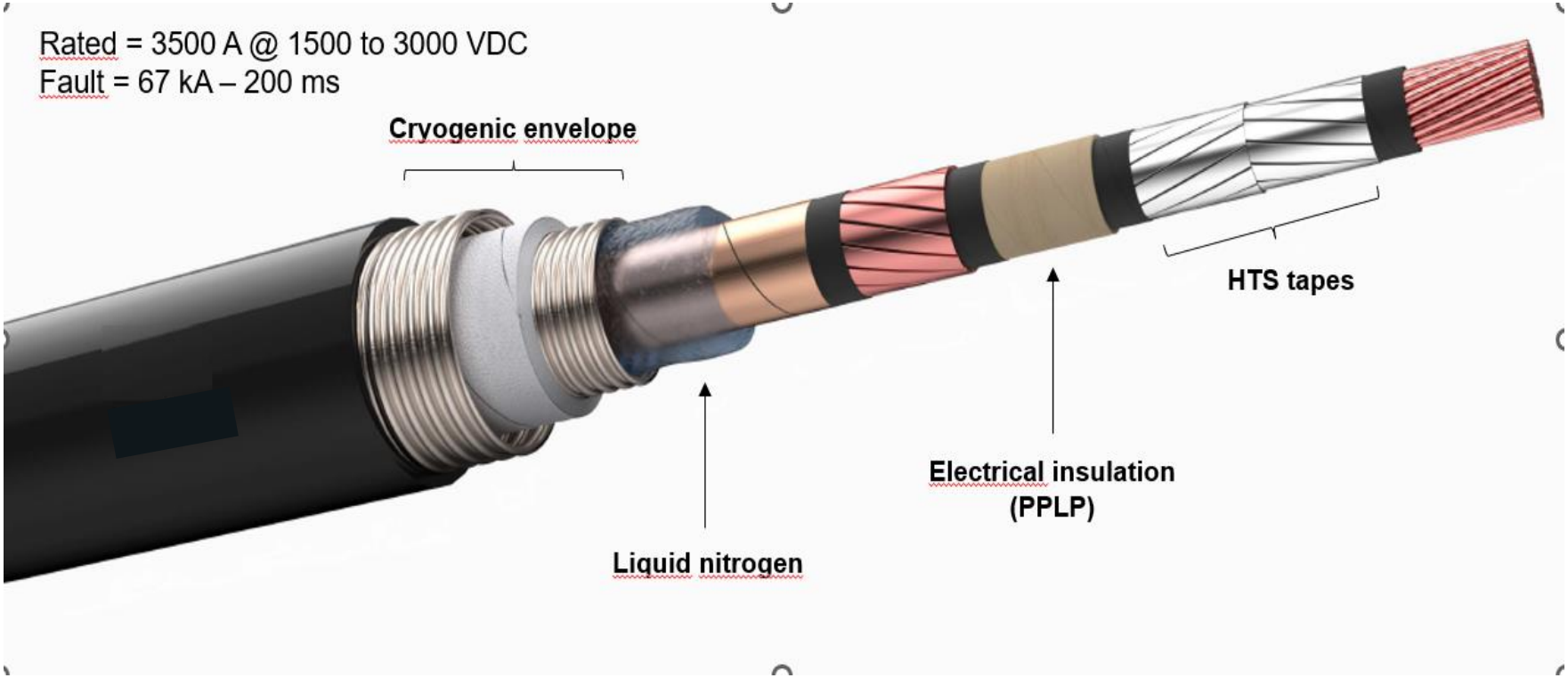


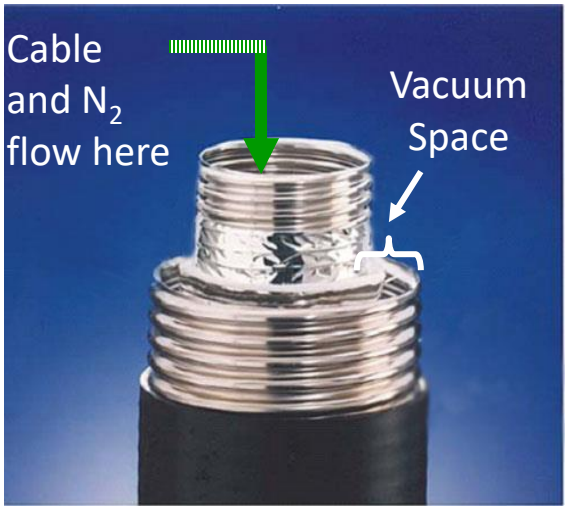
Photo courtesy of Nexans

HTS MVDC Cable (Single Pole)



Superconductor Cable Cryostat

- **Cryostat**
  - Double-walled stainless steel jacket
  - Vacuum between inner and outer walls provides thermal insulation
  - N_2 flows within the cryostat
  - Cryostats are widely used in commercial industrial, scientific, and medical applications.

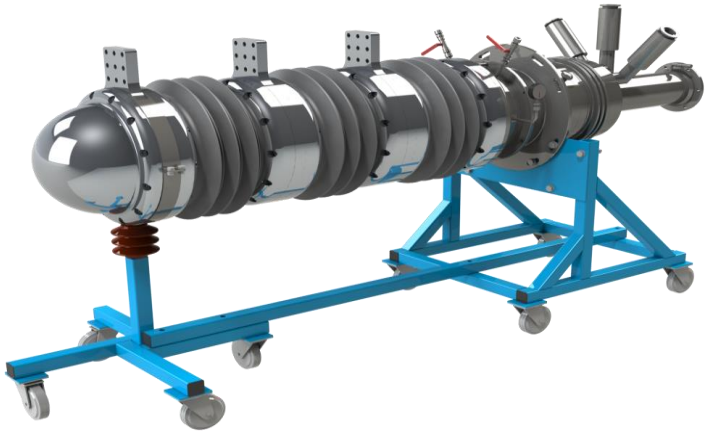


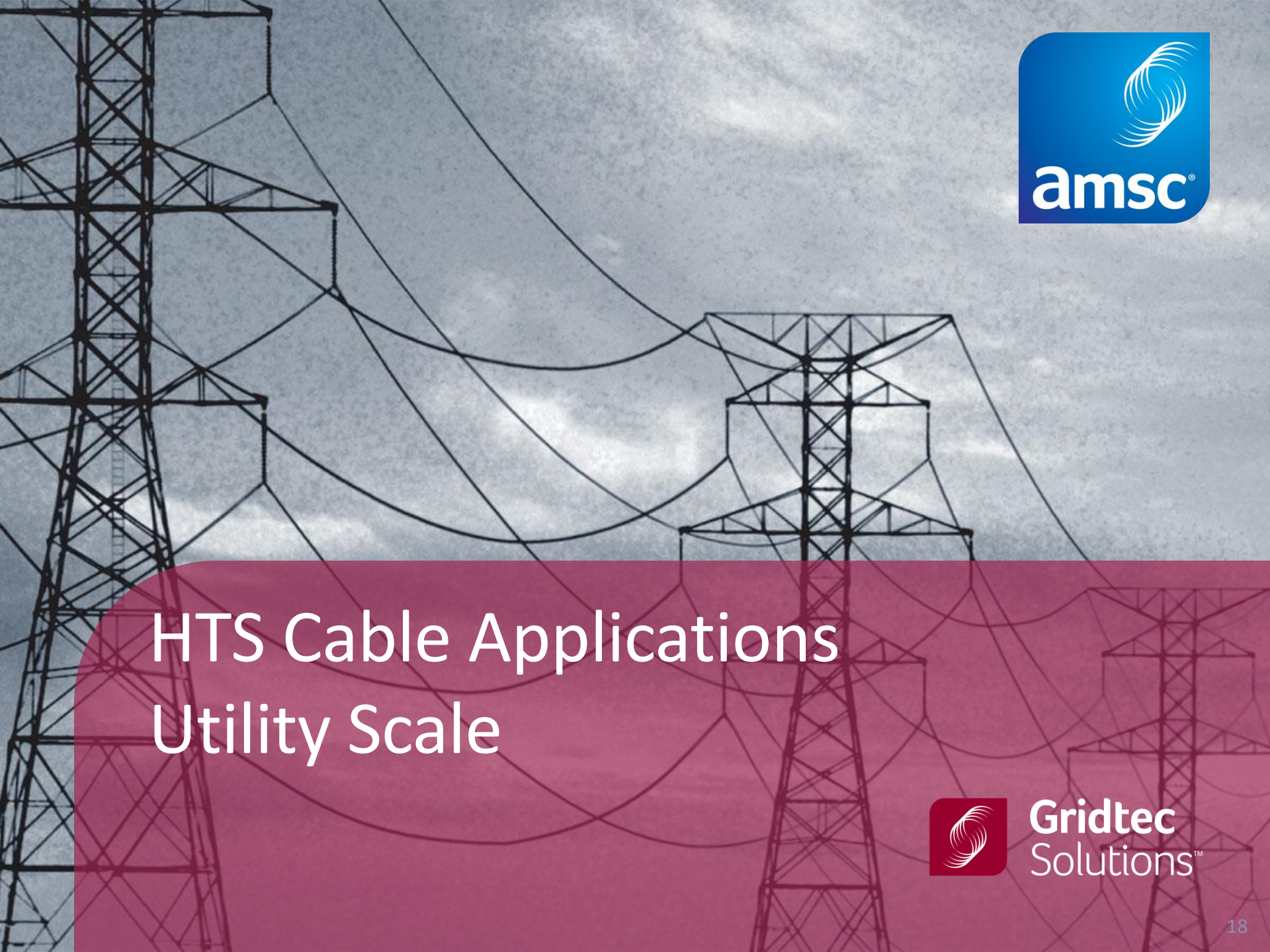
- **Cryostat/LN2 cooling benefits**
  - Extremely safe – both stainless steel walls are grounded, very low risk of electrocution even if cable is heavily damaged.
  - LN2 is environmentally benign and already widely used within industry
  - Extremely durable, cryostat has 10x the withstand to crushing relative to conventional copper or aluminum cables.
  - Light-weight , cable and cryostat can be easily maneuvered by hand

Cable Terminations

Cable terminations transition HTS cable to ambient temperature

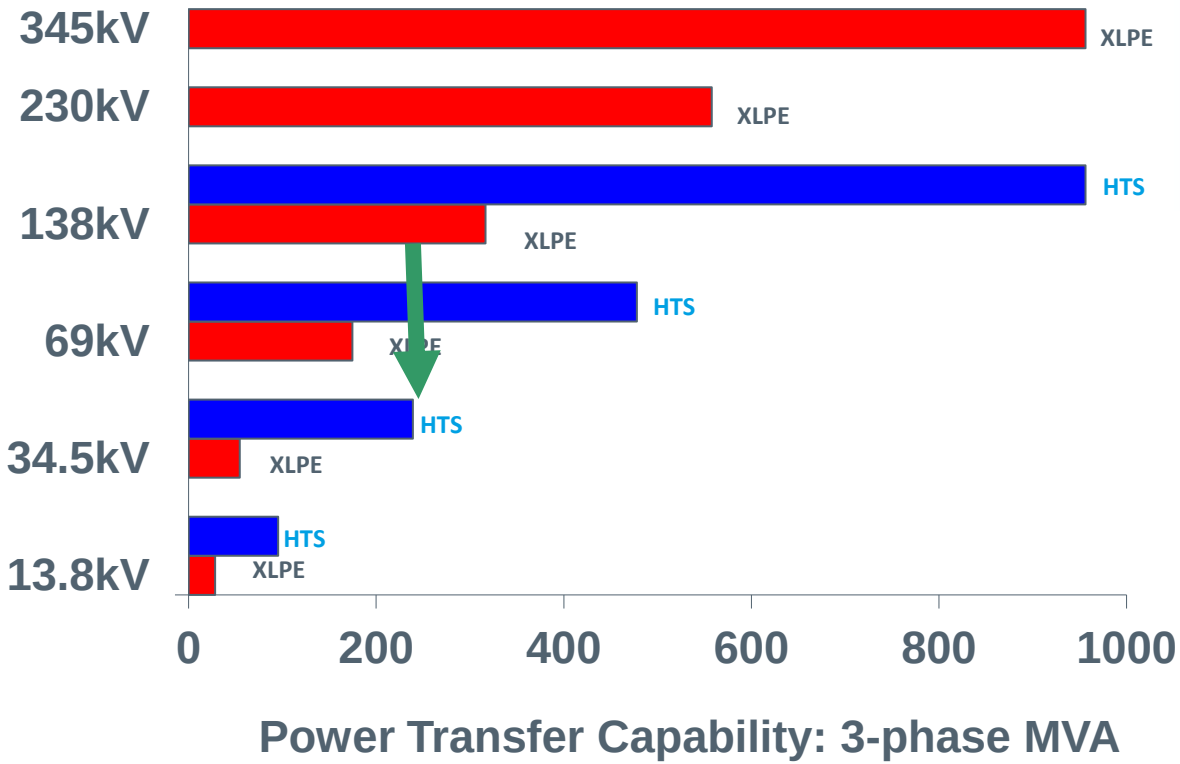
13.8 kV Termination





HTS Cable Applications
Utility Scale

Power Transfer Equivalency of Superconductor Cables



Same Voltage, More Power

Greatly increased power transfer capacity at any voltage level

Same Power, Lower Voltage

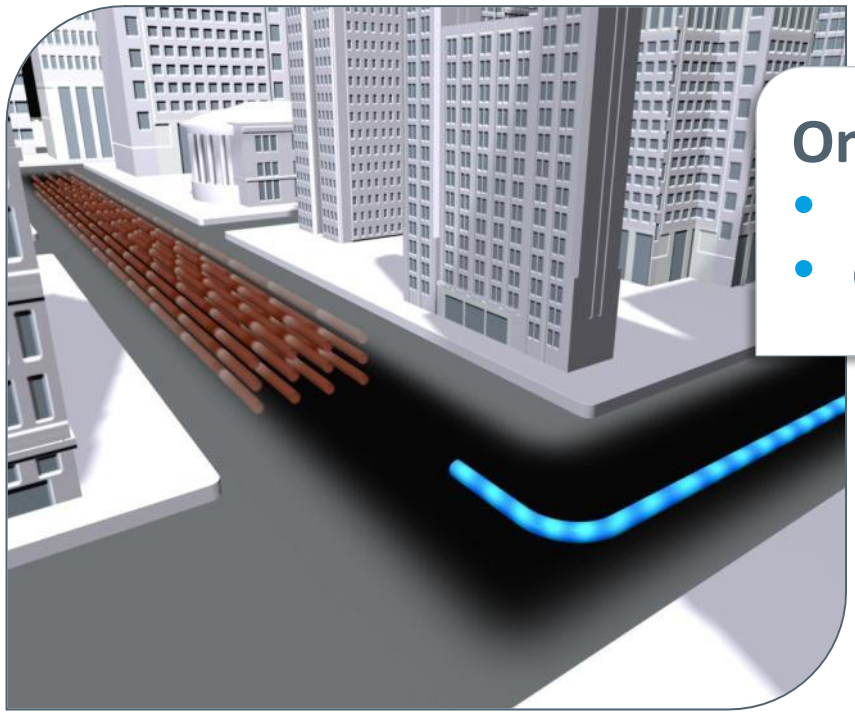
New MV versus HV Siting Opportunity

- "MV Transmission"
- Ideal for NIMBY & ROW sparse environments

* **No XLPE cable de-rating factors applied**.
Superconductor rating based on conventional 4000A breaker rating

HTS Cables provide transmission-level power at distribution voltages

Simplifying Transmission Siting



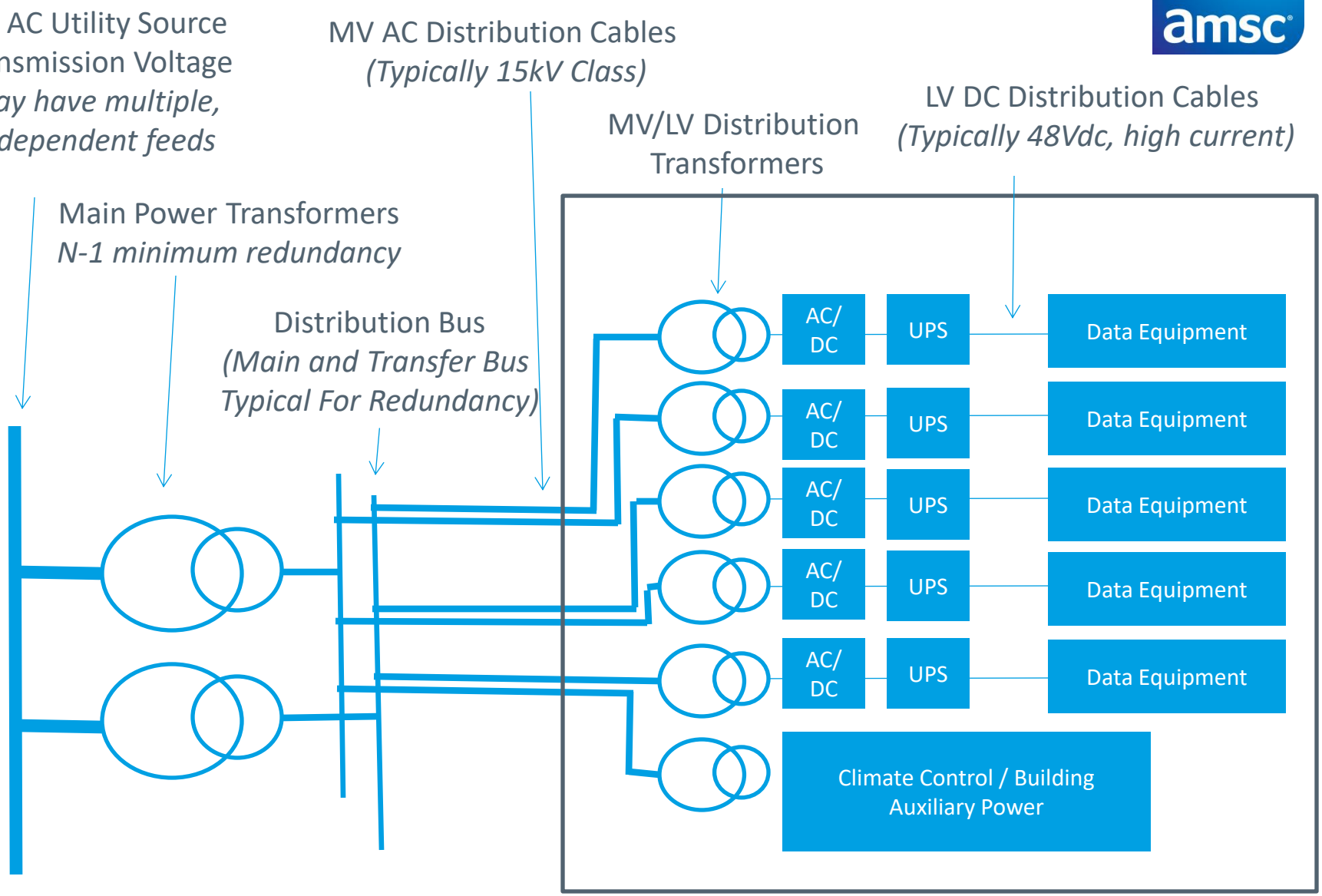
One MV HTS Cable can replace:

- Many conventional underground circuits
- Overhead transmission line

Photo courtesy Consolidated Edison

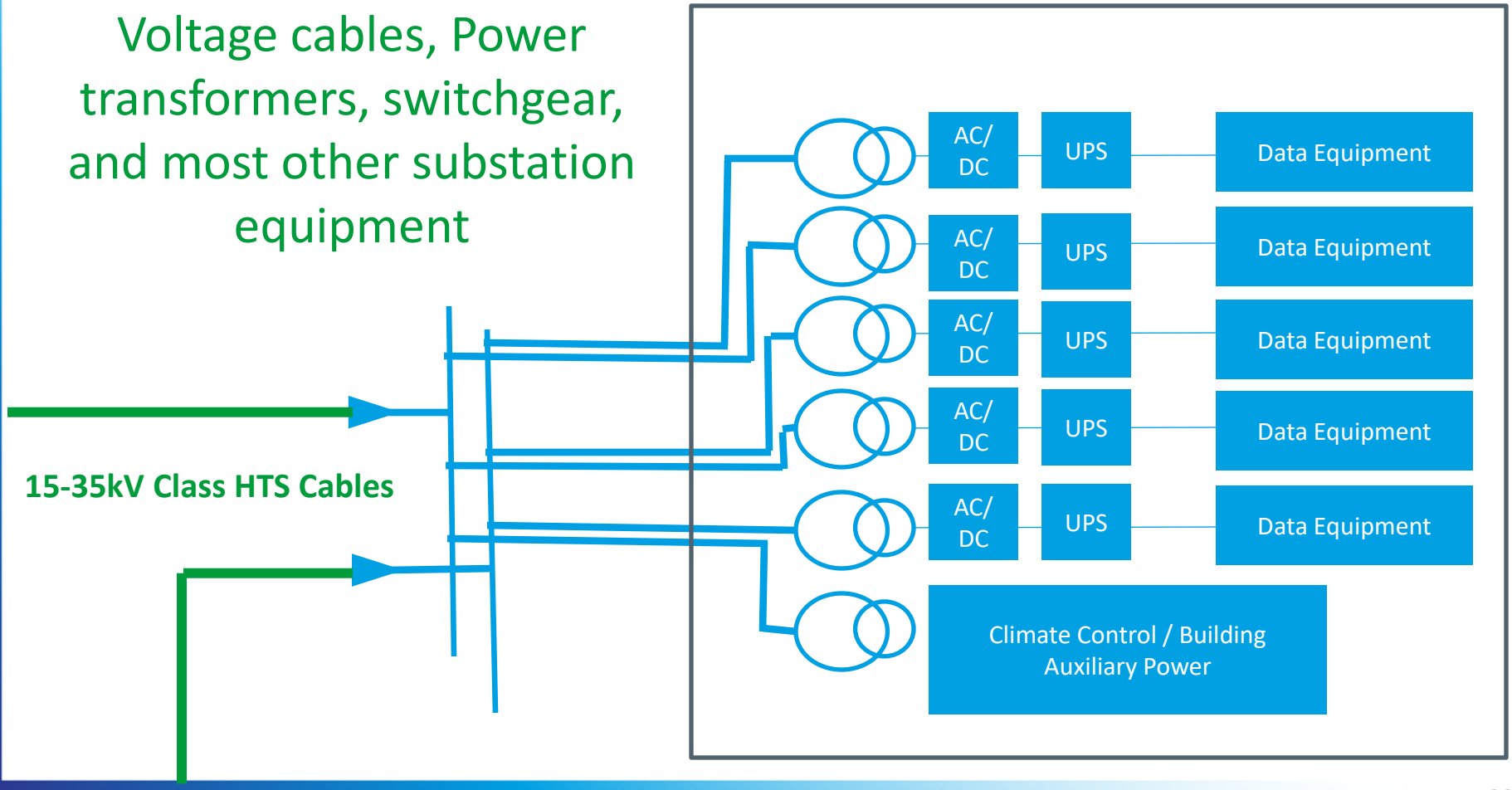
HTS Cables Offer New Options to Siting Power Lines

Typical Datacenter Electrical System



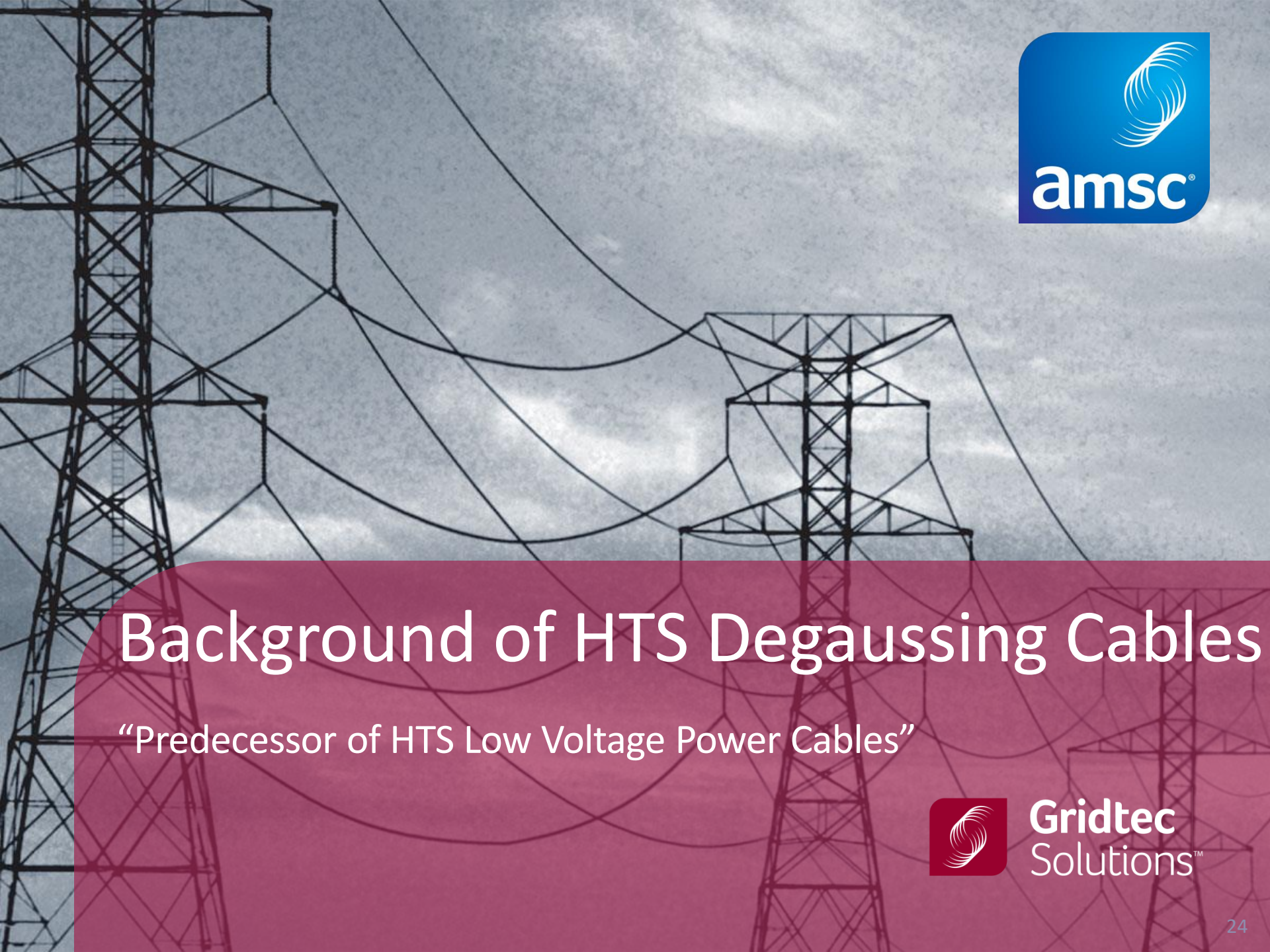
Datacenter Served by HTS Cables

Eliminate Transmission Voltage cables, Power transformers, switchgear, and most other substation equipment



HTS Cables to Connect Datacenters

- **Superconductor cables have benefits over conventional cables.**
  - *Particularly in dense, urban areas*
- **Superconductor cables can provide an "Alternative to Transmission"**
  - *Transmission Power at Distribution Voltages*
  - *Simplified Permitting / Less Disruptive Installation*
- **Applications of Superconductor cables include:**
  - *Interconnecting new Datacenters to existing substations*
  - *Providing second sources (reliability/redundancy)*
- **Superconductor cable projects are often lower cost that projects using Conventional Transmission**



Background of HTS Degaussing Cables

"Predecessor of HTS Low Voltage Power Cables"

Navy Application - Degaussing

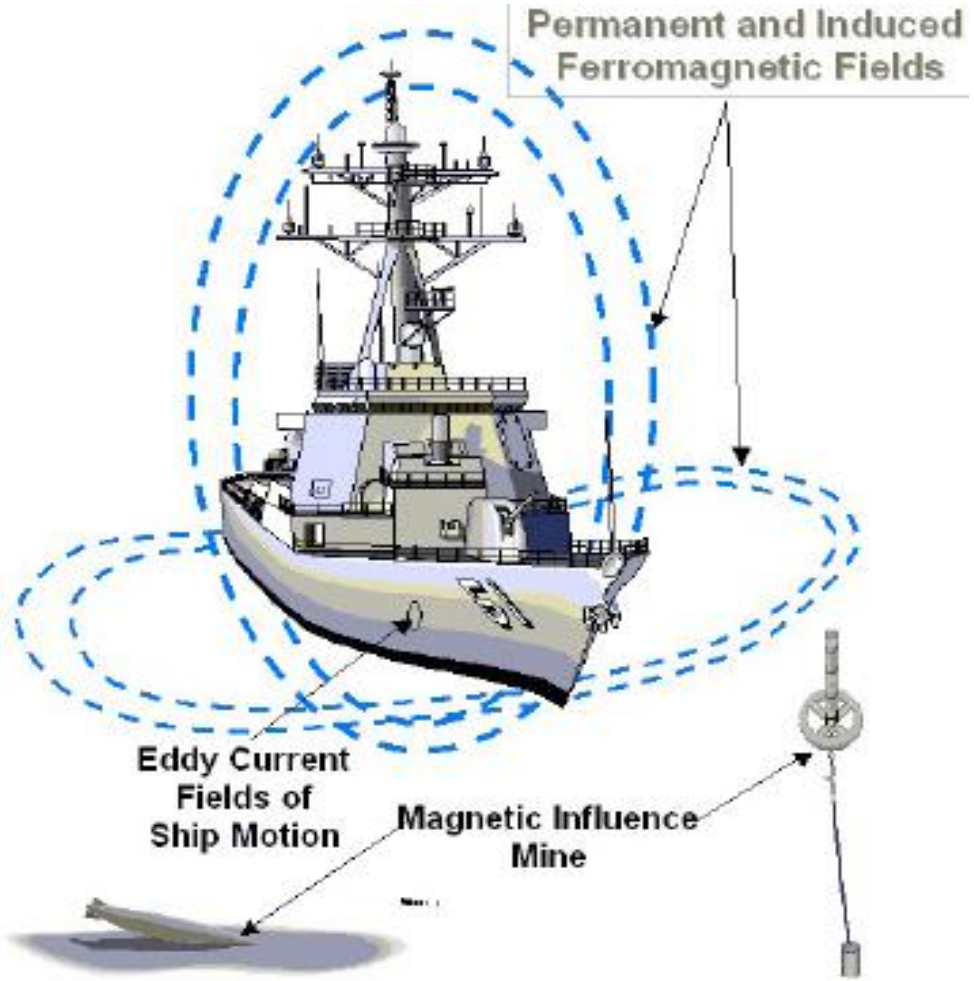
Understanding the Inherent Problem

Problem

Ship moving though the earth's magnetic field creates a magnetic disturbance that is detectable by enemy magnetic mines

Solution

Generate magnetic field with degaussing coils to mask ship's magnetic signature



Gulf War

USS Tripoli (LPH-10)

- US flagship for airborne mine CM
- First responder to gulf war – Dec, 90
- Hit by mine Feb 91, with HM-14 on board

- 20 x 16 foot hole in starboard bow
- 20 hours of damage control to stabilize
- Active warzone, in enemy silkworm missile range
- $5M in repairs, 30 days dry dock @ ~$1M/day

•USS Princeton (CG-59)

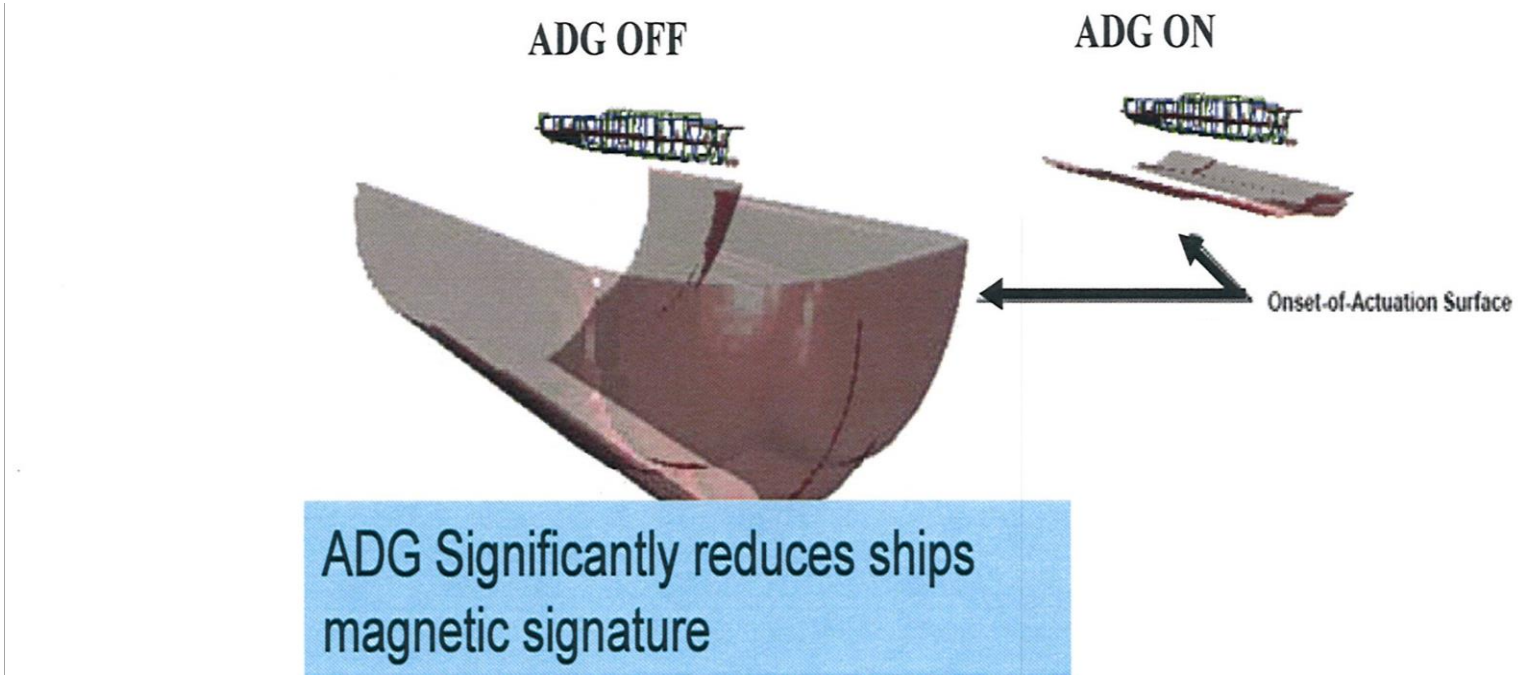
- Hit by mine same day
- Also in active warzone
- Navy Launches ADG program

Mines are the single largest threat US Warships face in modern warfare

Advanced Degaussing Performance

ADG Works

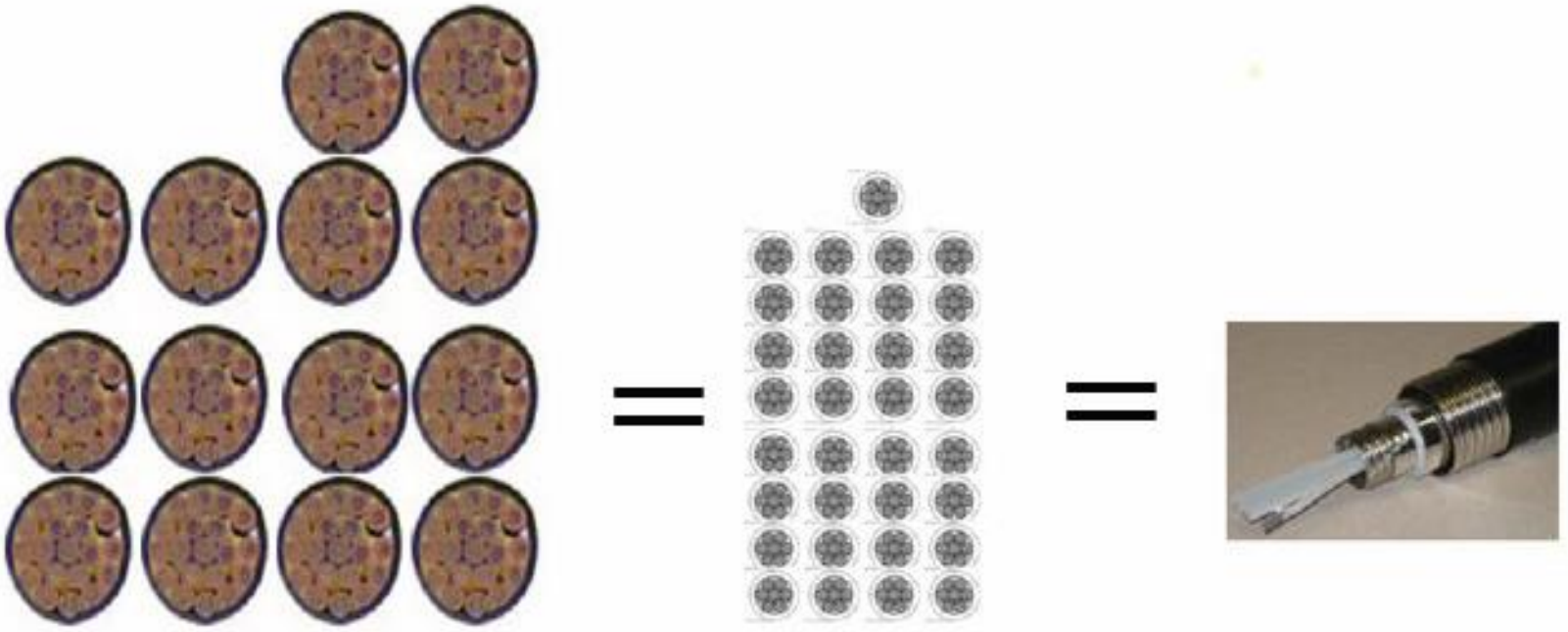
- Improved signature reduction, but weight penalty is significant
- Cable light weighting essential



HTS Advanced Degaussing

Replace Heavy Copper Cables with Lightweight HTS

- Significantly reduces cable weight
- Flexible and small enough to use conventional degaussing conduit
- Can carry current of multiple copper cables in one HTS cable
  - Reduced install cost

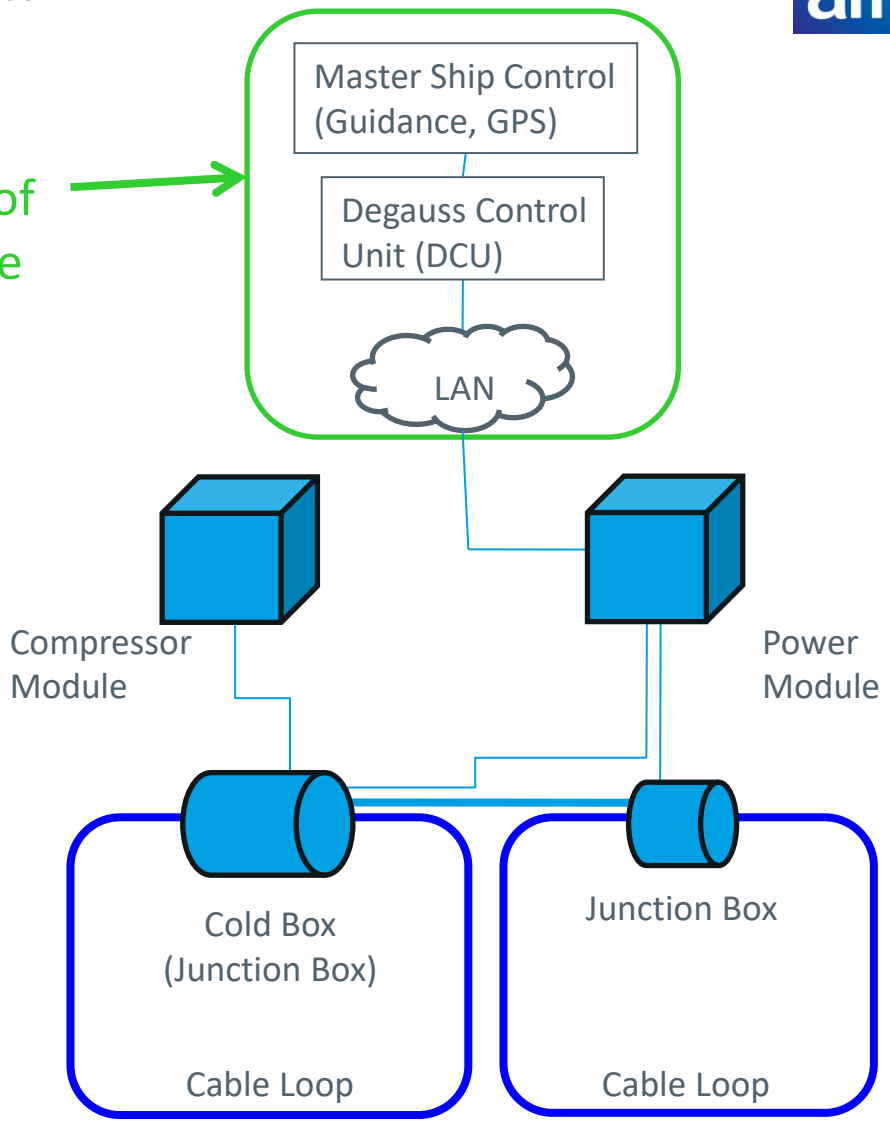


Copper Cable Cross Section | LS7SGU-7 | HTS

HTS Advanced Degaussing

Integrated Product Approach

Seamless replacement of copper system, interface unchanged



HTS ADG Advantages

- Lower weight
- Less power
- Reduced install cost
  - Less cable to pull
  - Lighter cable to pull
  - Connector eliminates on board junction box wiring

USS Higgins Demonstration

- USS Higgins DDG76 used as test platform HTS ADG
- Demonstration replaced 30 meter copper “L” coil in stern of DDG76 with HTS Cable.
- Demonstration proved reliability and operation in a relevant environment.
- Installation and Testing funded – ONR
- Installed June 2008
- Magnetic Range Run April 1, 2010

Shipboard Operation	
HTS DG System hours	8979 hours
HTS DG Continuous hours during deployment	5962 Hours
Seas Encountered	8-10 ft
Miles traveled on deployment	37,073 miles

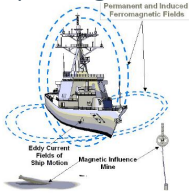
HTS Degaussing

A Decade of Development and Investment

2005
Feasibility Testing

2007
Prototype Cable Test

2009
Alpha Mfg & Test

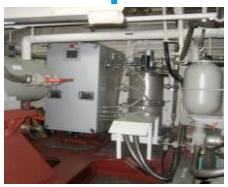


2011
Beta Sea Trials

2013/14
Mfg Infrastructure

Production

Prototype Cable Fab
2006



USS Higgins Trials
2008

Beta Mfg & Test
2010

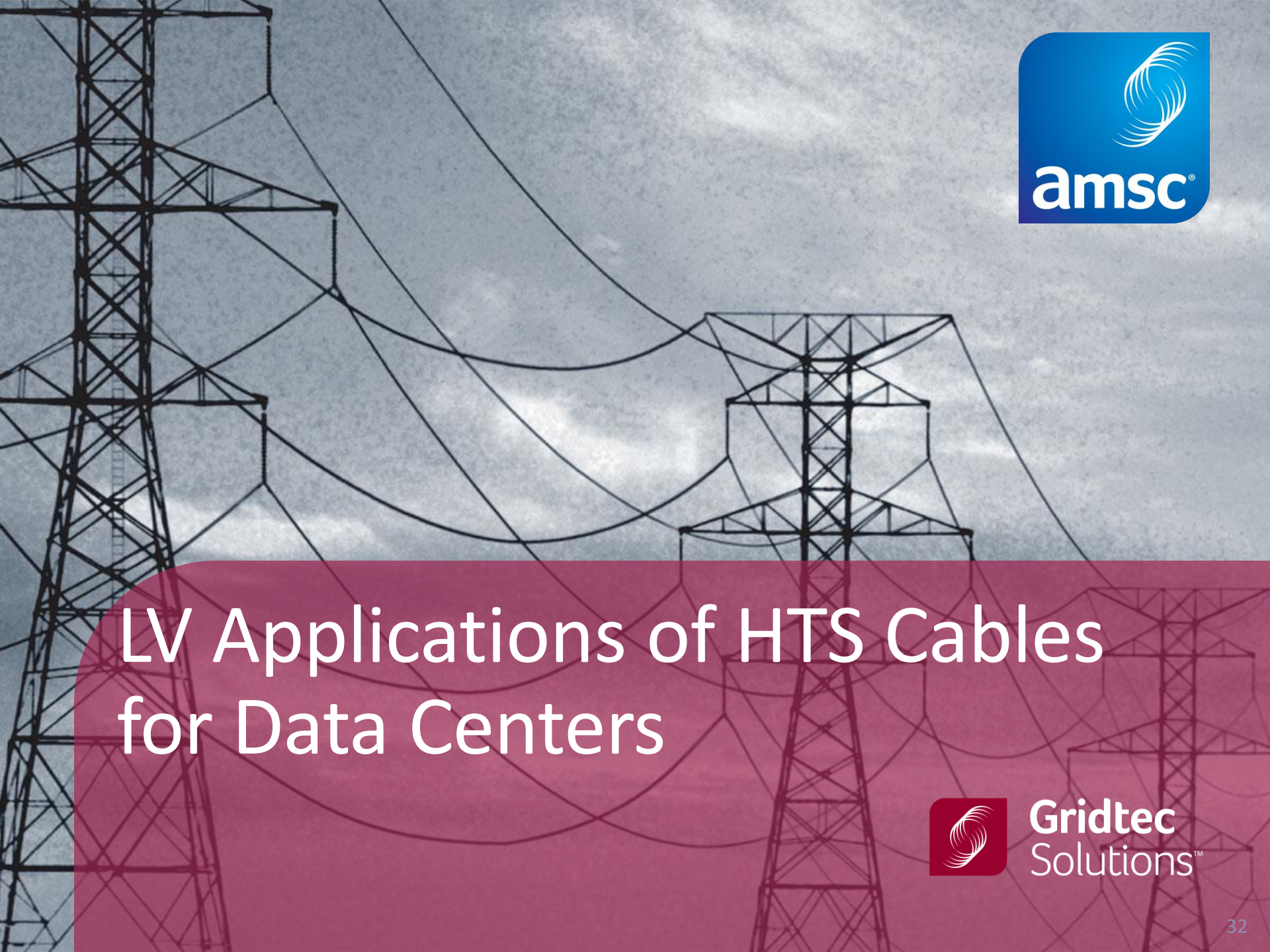
Qual Testing
2012

COMMON CRYOGENIC BUILDING BLOCKS (C^2B^2) USED IN HTS DG

→ Propulsion Motors

→ Power Cables

→ ADV. Degaussing



LV Applications of HTS Cables for Data Centers

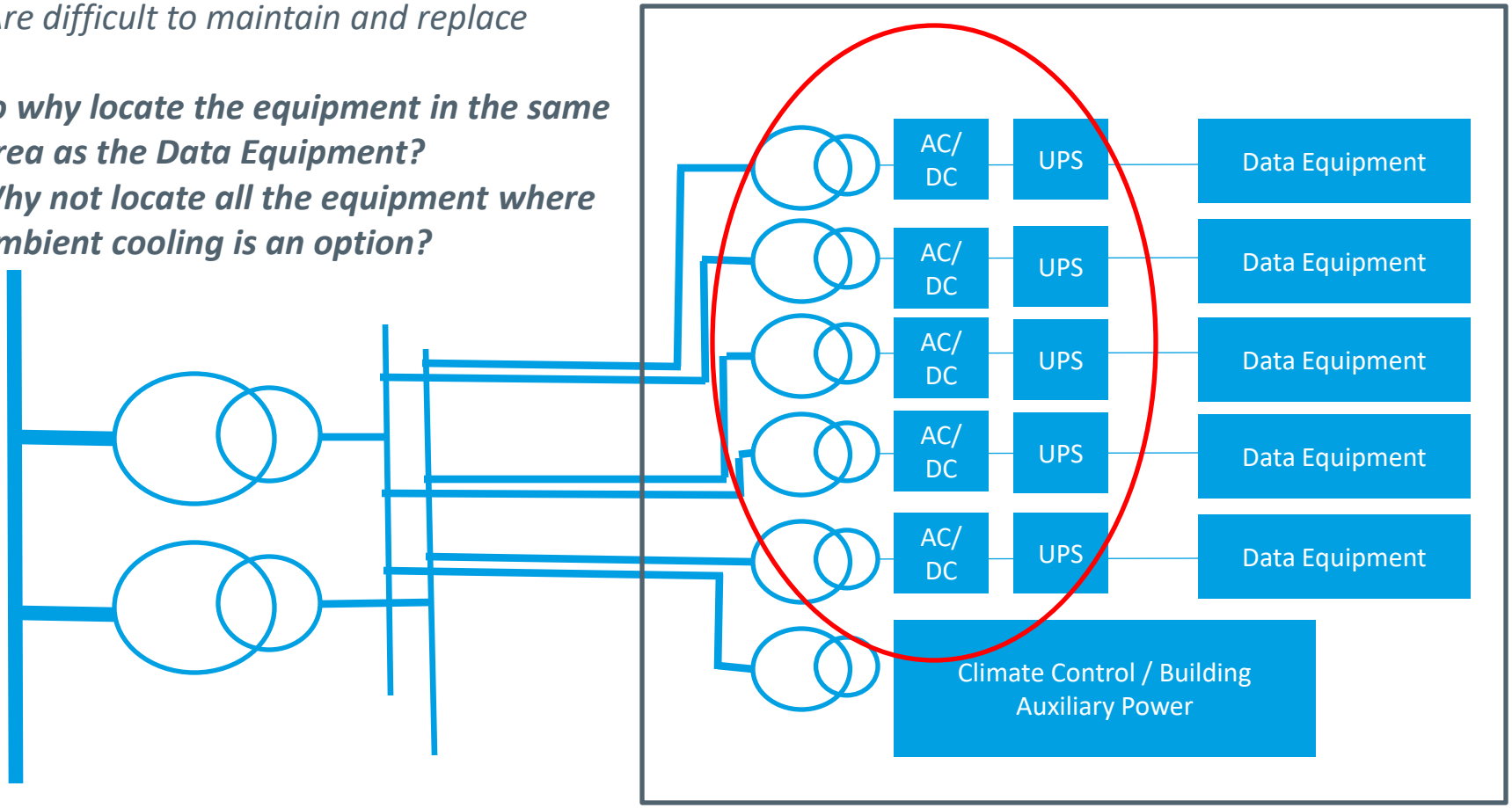
Gridtec Solutions™

Datacenter Design Challenges

MV to LV Transformers, Power Converters, and UPS systems ALL:

-Are Physically Large and take up significant space on each floor
-Are very heavy and require reinforced floors in data center building
-Generate substantial heat that must be removed by Air Condition Systems
-Are potential fire hazards & arc flash
-Are difficult to maintain and replace

So why locate the equipment in the same Area as the Data Equipment?
Why not locate all the equipment where Ambient cooling is an option?



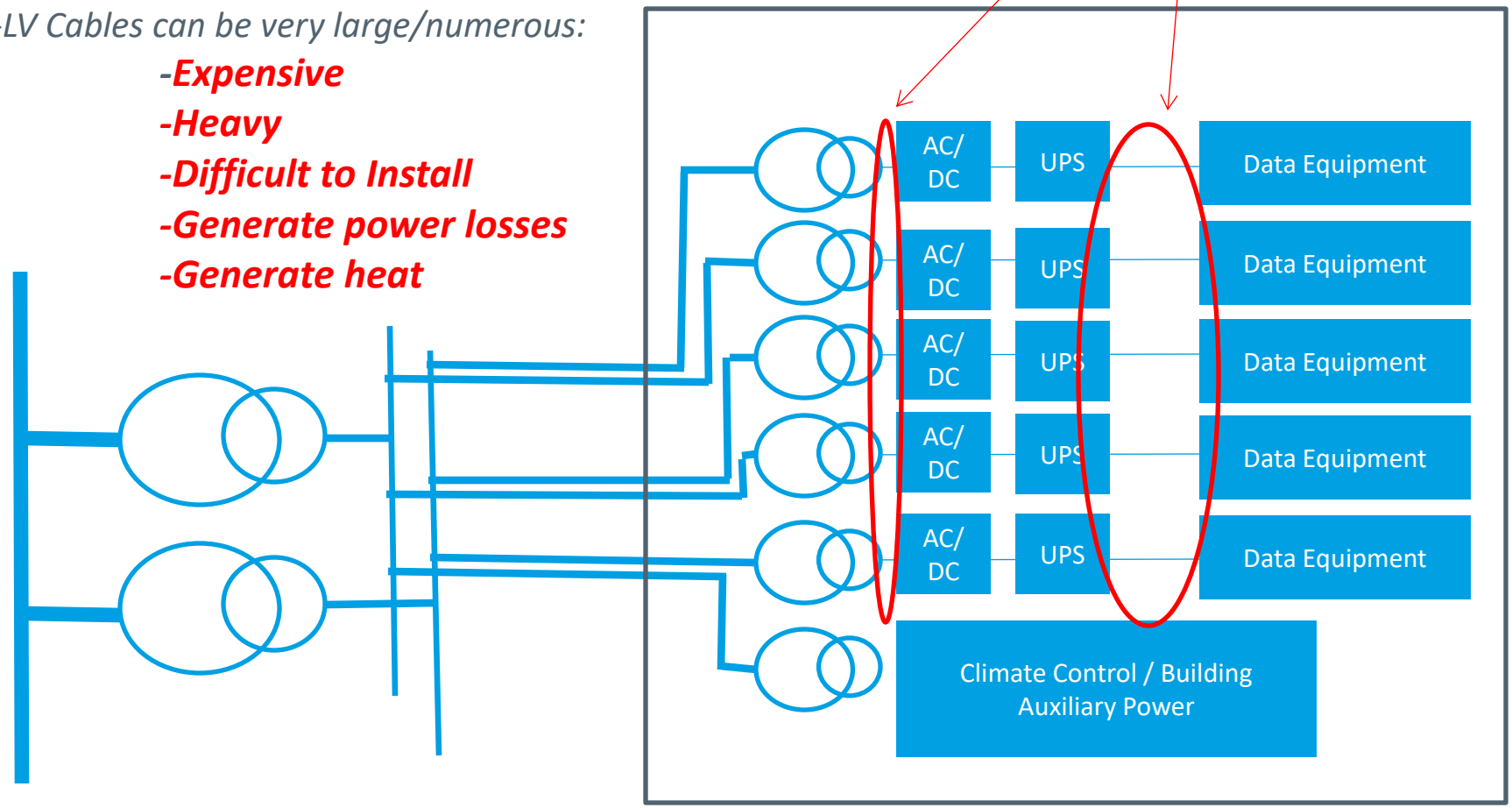
Datacenter Design Challenges

Location of Power conditioning Equipment Driven by Capability of LV Cables

*-LVAC & LVDC cables cause **voltage drop**; if located too far from Data equipment, the voltage delivered is too low.*

-LV Cables can be very large/numerous:

- ***Expensive***
- ***Heavy***
- ***Difficult to Install***
- ***Generate power losses***
- ***Generate heat***

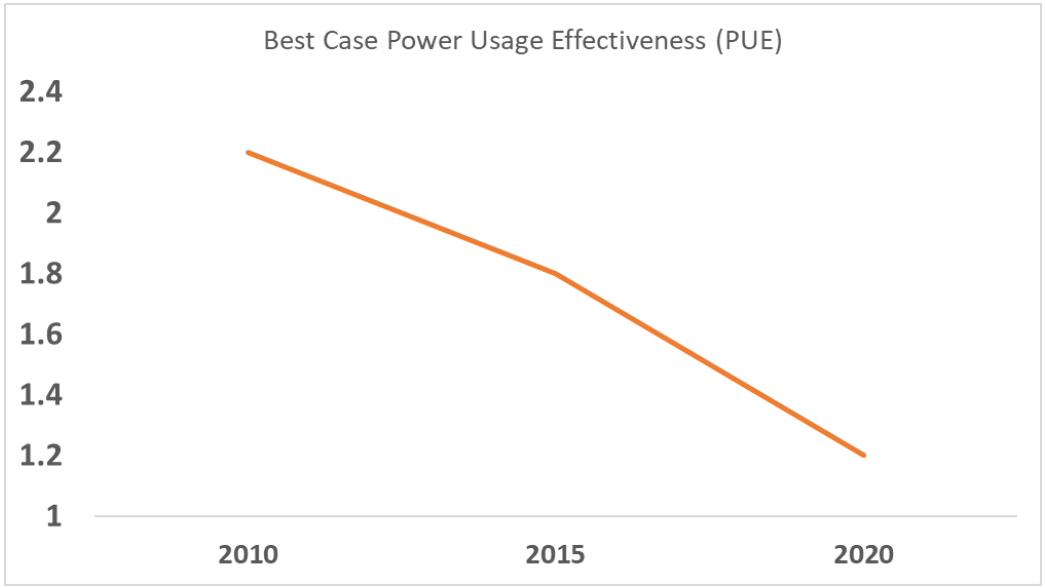


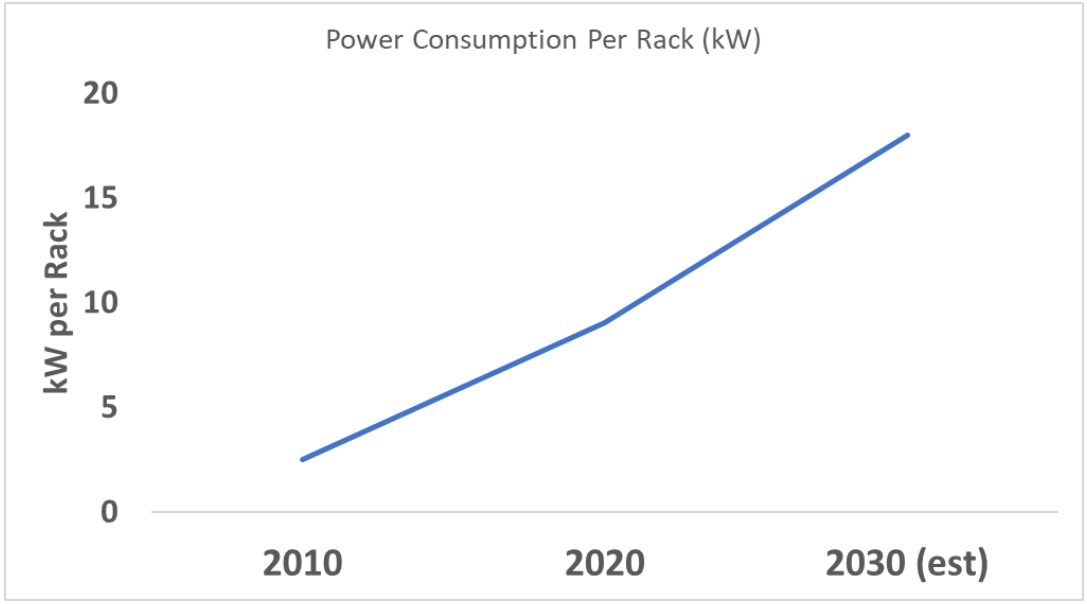
HTS Cables and Data Centers

How Could Data Center Designs Change if the LV Cables Were Available:

-Had **Zero Voltage Drop** regardless of length?
-Had **Zero Power Losses?**
-Had **Zero Heat Contribution?**
-Were **Highly Compact?**
-Were **Very Light** in Weight?

HTS Cables and Data Centers





HTS Cables and Data Centers

Could Such Cables:

-Allow heavy power conditioning equipment to be more ideally located?

-Increase Efficiency?

-Reduce Data Center Air Conditioning Requirements?

-Reduce Electrical Losses?

-Reduce Cost of Data Center Construction?

-Allow more power dense racks on each floor?

-Allow for redundancy options previously unavailable?

-Make replacement and maintenance of equipment easier and quicker?

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