High Temperature / Low Sag (HTLS) Conductors

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Introduction

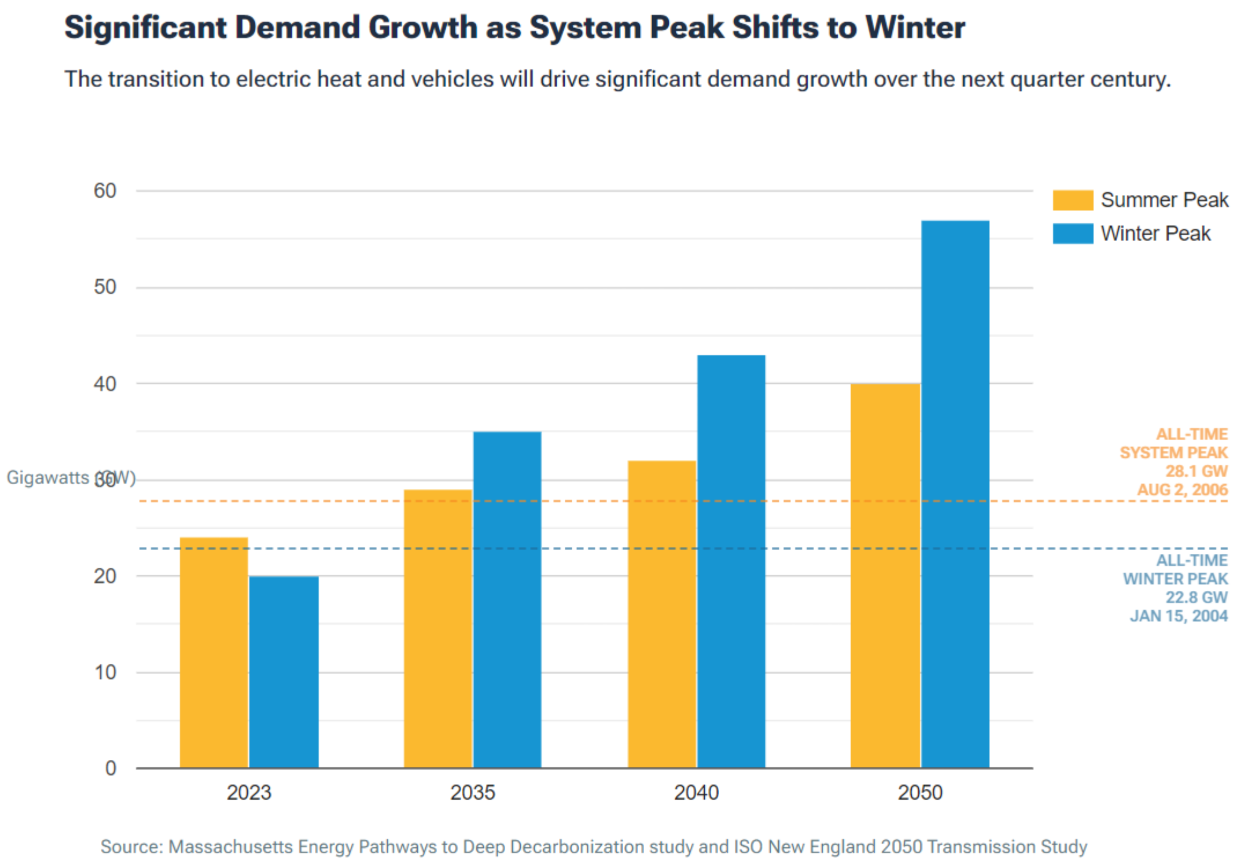
- Underscore the growing need for advanced High Temperature Low Sag (HTLS) conductors
- Describe the evolution of conductor technology from early conductors to today’s advanced conductor technology
- Discuss the design considerations of HTLS conductors at National Grid US
- Provide a glimpse into future conductor technology

Introduction

CHALLENGE:

Power consumption is expected to increase substantially as we progress the clean energy transition and begin to address emergent issues associated with electrification (e.g., Data Centers, EV infrastructure, natural gas conversion, new solar and wind power sources etc.)

Rights-of-way are mature making green field line builds unrealistic and voltage uprates challenging.



Introduction

SOLUTION:

Advanced conductors such as High Temperature Low Sag (HTLS) conductors will play an integral role in our future Transmission Line design to meet forecasted load demand and provide economical solutions.

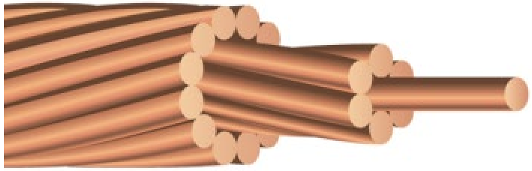
- **HOW:**

The use of lighter weight advanced HTLS conductors allows:

- Doubling the capacity of existing lines
- Elimination or limiting the number of existing support structure modifications / replacements.

"*Reconductoring projects not only cost roughly half what a new line or a rebuilt line may cost, they can also be executed in a fraction of the time and with fewer regulatory and permitting burdens." Richelle Elberg*

Traditional Conductors - Overview



Copper

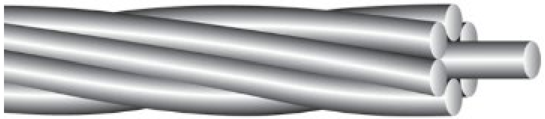
Use: 1900 – 1940

Low Resistivity: 1.68 μΩ -cm.

High weight: Specific gravity = 8.96 gm /cm^3

Cost: Low (1900 – 1940). Higher present day

Max Operating temperature: 100 - 125° C



AAC – All Aluminum Conductor

Sufficient Resistivity: 2.65 μΩ -cm.

Low Weight: Specific gravity = 2.70 gm /cm^3

Cost: Low

Use: Early 20^{th} Century to 1970's

Max Operating temperature: 105 – 120° C

ACSR – Aluminum Conductor Steel Reinforced

Aluminum conductor with a galvanized steel core

Allows for higher cable strength and lower sag

Use: Early 20^{th} Century to date

Max Operating temperature: 125 - 140° C

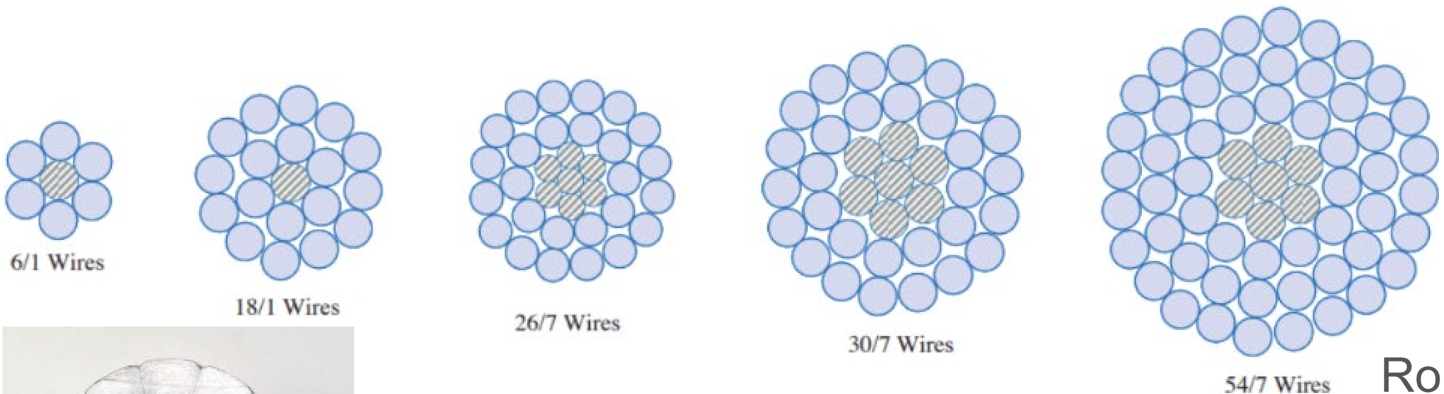
Characteristics of Copper and Aluminum

Characteristics	Copper	Aluminum
Tensile strength (lb/in^2)	50,000	32,000
Tensile strength for same conductivity (lb.)	50,000	50,000
Weight for same conductivity, (lb)	100	54
Cross section for same conductivity	100	156
Specific resistance (ohms-cir/mil ft) (20° C ref)	10.6	18.52
Coefficient of thermal expansion (per deg. C x 106)	16.6	23

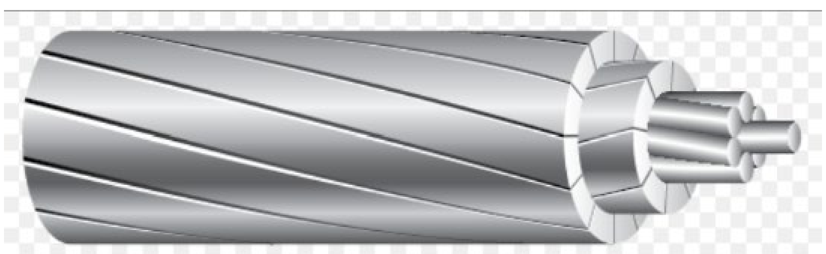
Saggy

HTLS 1.0 or less

Conductor Stranding Options

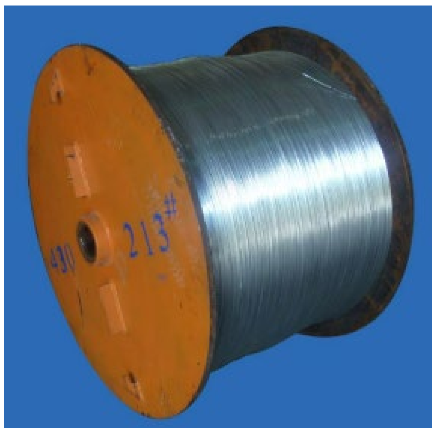


Round Wire Stranding



Trapezoidal “Trap” Wire Stranding

Manufacturing Process



ACSS – Aluminum Conductor Steel Supported

- One of the first generation HTLS conductors
- Introduced in 1974 – ACSS is much like ACSR except that it utilizes annealed aluminum (heat treated)
- Annealed aluminum loses about 3 times its tensile strength allowing the steel to contribute more to the strength of the conductor. Aluminum is “along for the ride.”
- The result: less sag and high temperature 200 – 250° C

Design Considerations - HTLS Properties

ACSS - mid-70's

Reduced sag
High Amp
Light weight
High Strength
Bending
Cost
Std Hardware

ACCR - early 90's

Reduced sag
High Amp
Light weight
High Strength
Bending
Cost
Std Hardware

ACCC - mid-90's

Reduced sag
High Amp
Light weight
High Strength
Bending
Cost
Std Hardware

AECC - today

Reduced sag
High Amp
Light weight
High Strength
Bending
Cost
Std Hardware

Advanced Conductors

Design Considerations

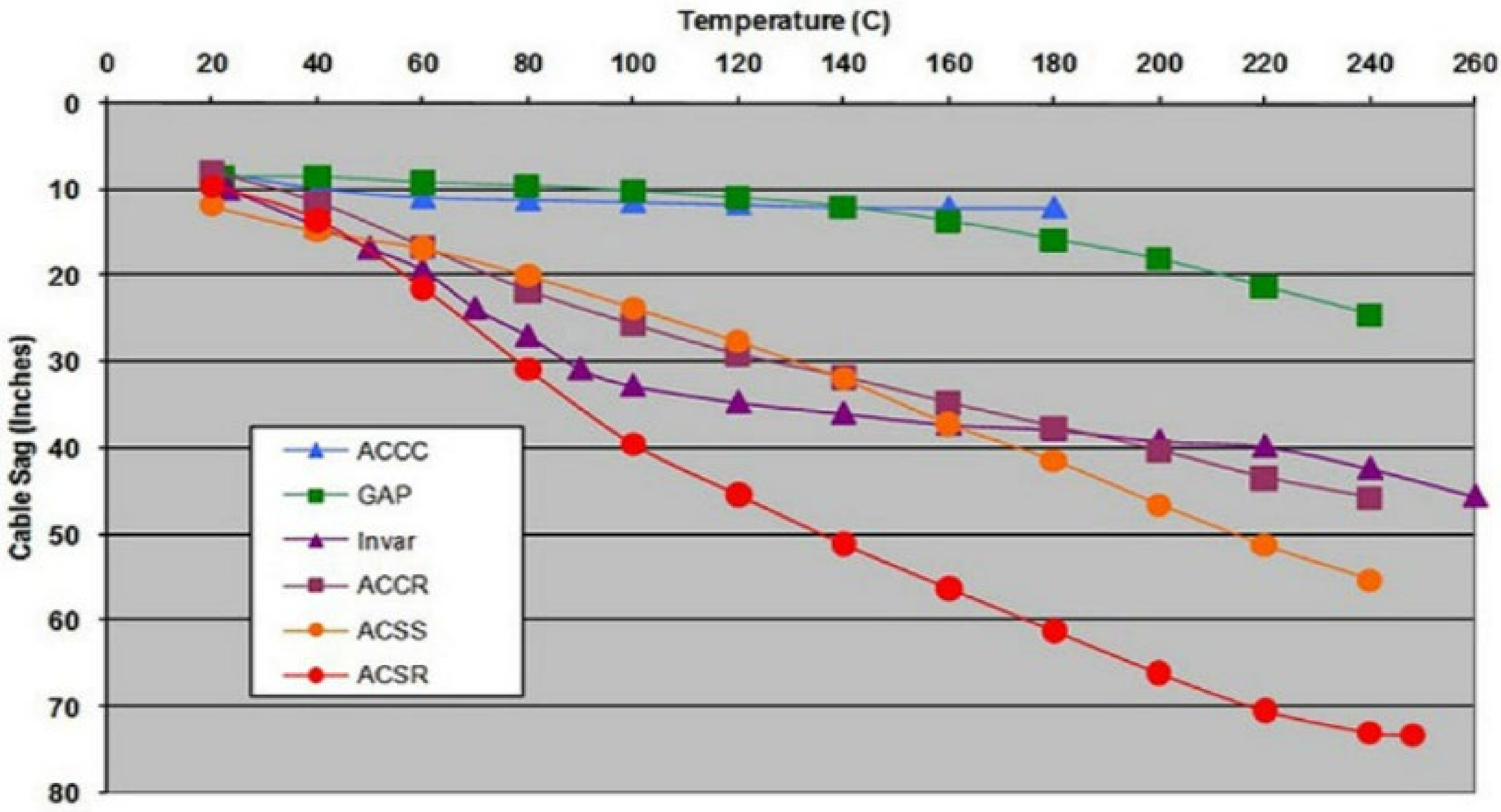


Image: CTC Global

TS Conductor Comparison Chart

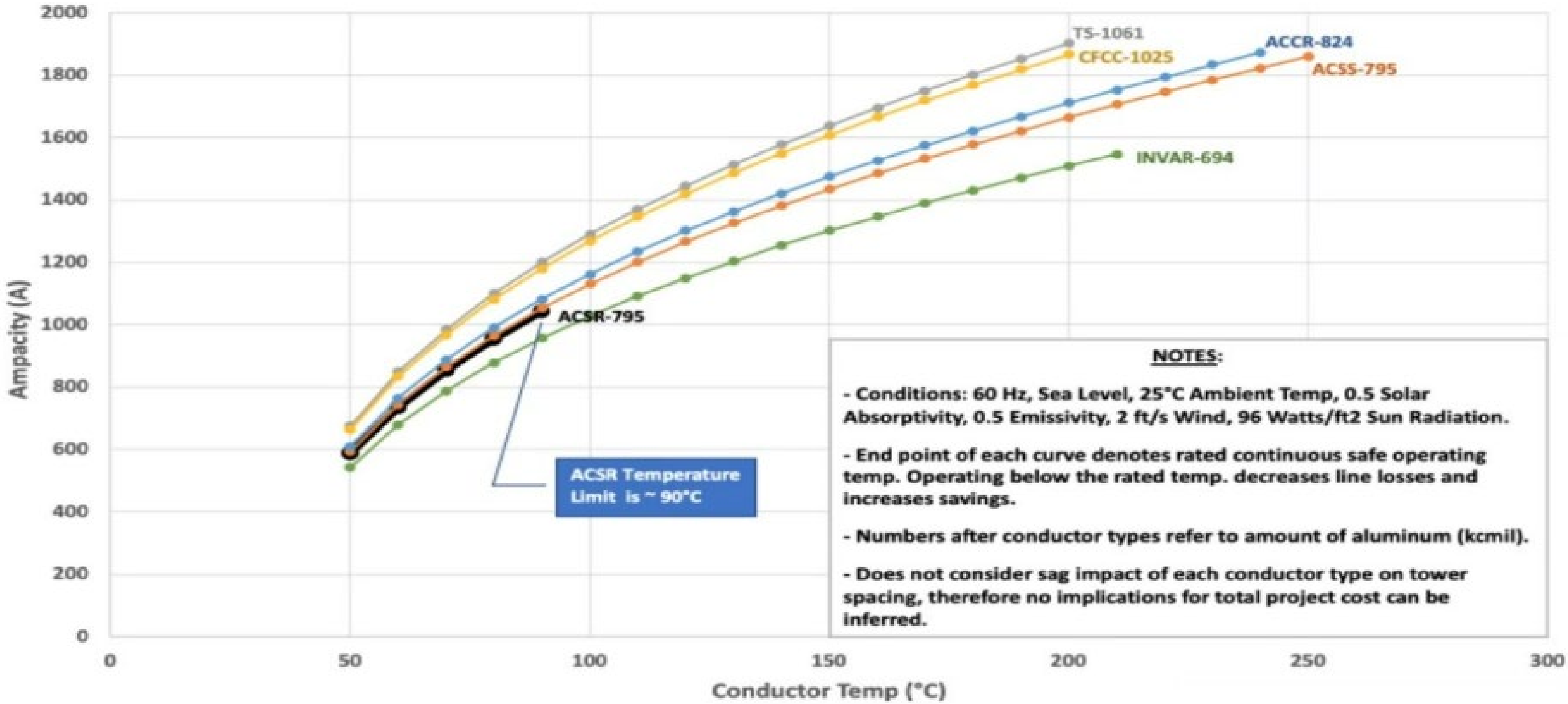


Image: TS Conductor

General National Grid US Conductor Types

Total Circuit Miles, NE	2,850
ACSS Conductor	500
Other HTLS Conductor	200

Design Considerations

Location	Conductor Type	Thermal Operating Limits (°C)		
		Normal	Long Term Emergency (LTE)	Short Term Emergency (STE)
New England	AAC	95	120	120
	AAAC/ACAR	95	120	120
	ACSR	105	140*	140*
	Copper	80	100	100
	ACSS	200	200	200
	ACCC	150	180	180
	ACCR	210	240	240

National Grid Thermal Operating limits for conductor various types

Sag Comparison

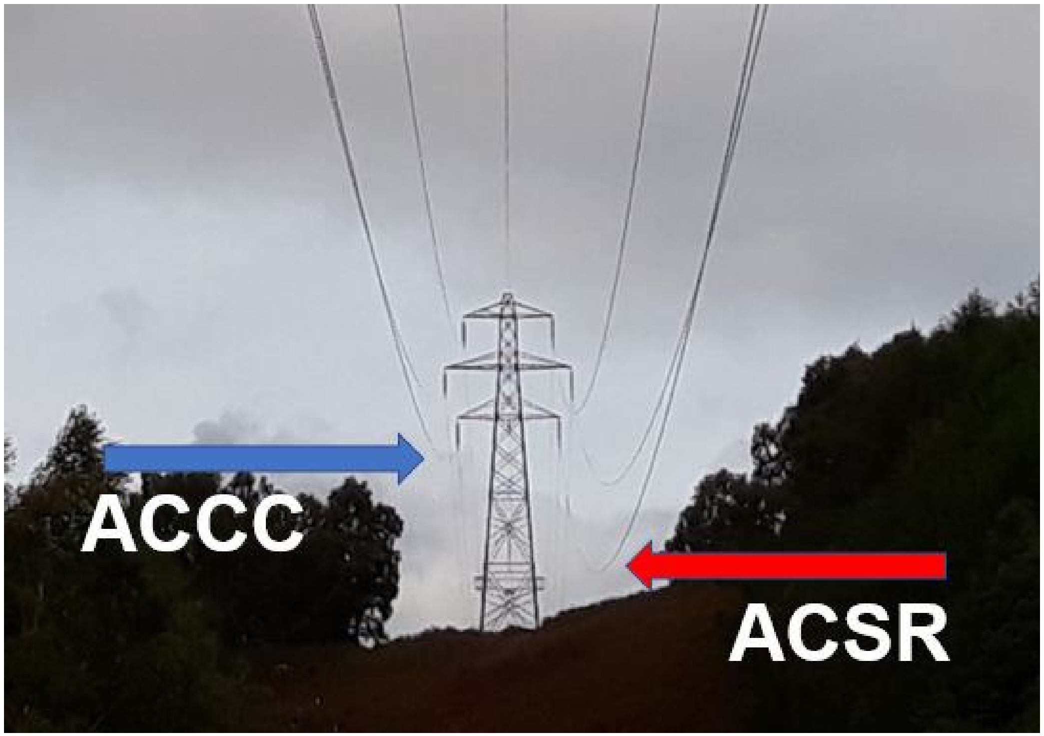


Image: CTC Global

Low sag makes HTLS conductors popular for **retrofitting an existing electric power transmission line** without needing to change the existing towers and insulators.

Hardware and Installation

- The engineer must work closely with the construction team to ensure that appropriate hardware and installation methods are done to manufacturer specifications
- Dead-end and suspension hardware compatible with conductor
- Correct size pulling blocks and swivels
- Pulling plan and set up

National Grid First Installation of ACSS

National Grid first installation of “SSAC” conductor, Saugus River crossing, Revere/Lynn, MA 1977. 950 ft span. (Image: Google Streets View.)

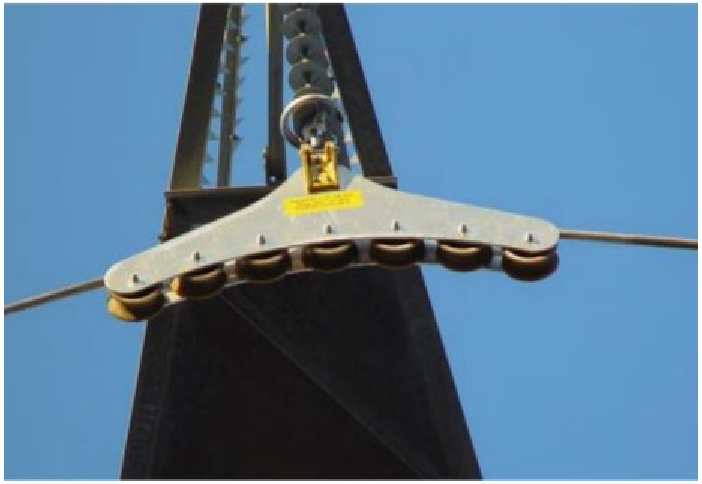
Larger Diameter Pulling Blocks Required

ACCC installation on S145 / T146 Line Wakefield, MA

Larger pulling block and shallow line angle used

Array Pulling Blocks

Array pulling blocks may be required for heavier line angles

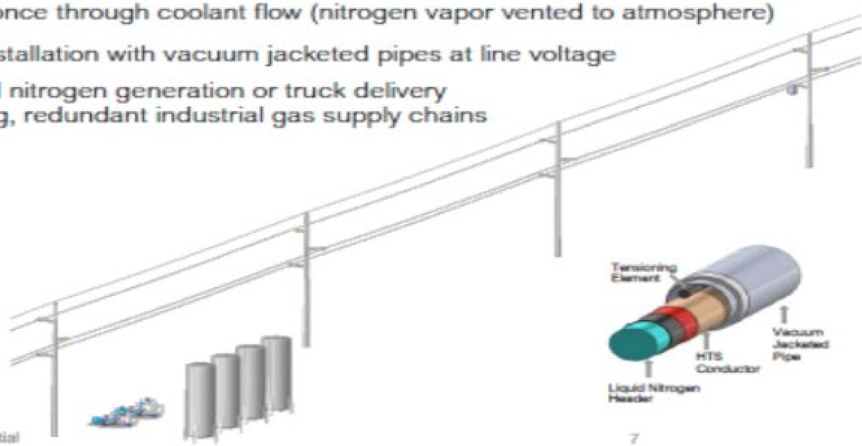


Next Generation - Superconductor

The VEIR Approach

VEIR is developing a new generation of HTS-based transmission lines using evaporative cooling

- Nitrogen latent heat of vaporization (**204 kJ/kg**) vs. sensible heat (**2 kJ/kg/°C**)
- Open loop, once through coolant flow (nitrogen vapor vented to atmosphere)
- Overhead installation with vacuum jacketed pipes at line voltage
- On site liquid nitrogen generation or truck delivery using existing, redundant industrial gas supply chains



Company Confidential 7

VEIR's overcomes historical HTS transmission limitations

- **Reduced coolant flow:** 20x the cooling power per kg*
- **Reduced weight:** Enables overhead installation, eliminating cable dielectric
- **Simplified system operation:** Evaporates nitrogen back to the air
- **Improved reliability:** Eliminates mechanical subcooling equipment
- **Reduced cost:** Smaller pipes, fewer cooling stations (every 100 km), simplified installation and repair
- **Longer distances:** Enables long lines, accelerating HTS cost reduction

* Assumes 5 °C temperature increase limit in conventional HTS transmission approaches.

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