Electricity
Transmission

Assessment of Superconducting Technologies for Standards Development

Strategic Innovation Fund (SIF)

Show & Tell Webinar

08/08/25

SUPERNODE™

VEIR

FRAZER-NASH CONSULTANCY
A KBR COMPANY

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The University of Manchester

nationalgrid

Presentation outline

- Project problem statement
- Project context
- Alpha phase project overview
- System overview and operational requirements
- Failure modes and effects analysis
- Standards gap analysis
- Planned next steps
- Q&A & Discussion

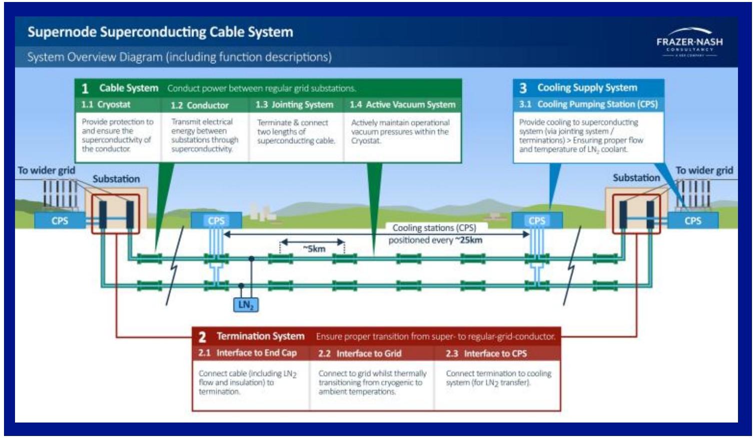


Figure 1. SCADENT

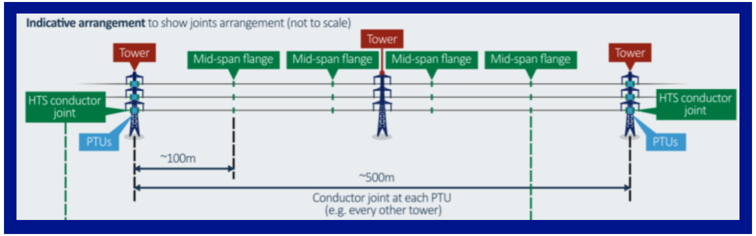


Figure 2. SCOHL

Problem statement

The GB energy system requires significant network reinforcements to meet future energy demand, avoid constraints, and support the uptake of renewable generation.

New circuit upgrades face challenges with consenting and long project timeframes, potentially constraining the rate of infrastructure development.

High-Temperature Superconducting (HTS) technology can provide 5-10x more power over the same footprint, potentially enabling faster infrastructure development at a lower costs

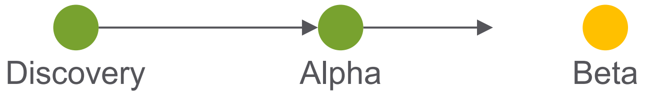
For HTS technology to be considered as credible solution, we need to understand:

- Where could HTS technology be deployed?
- What does a functioning system consist of and how would it be operated?
- What is the lifetime cost for an HTS circuit?
- How does an HTS system integrate within the wider Transmission network?
- What standards would an HTS system be built to?
- What testing is required to qualify and justify an installation?
- What capabilities are required, across industry, to enable adoption?

Project context – SCADENT & SCOHL

Historically, NGET have supported two HTS projects through the strategic innovation fund:

Superconducting Applications for Dense Energy Transmission **(SCADENT)**: HTS AC cable systems.



Superconducting Overhead Lines **(SCOHL)**: HTS AC OHL systems. (Discovery phase complete)

Common feedback identified three core areas of focus:

- **Technical**: Greater detail and understanding of how an HTS system could be implemented, and the existing and required standards for implementation.
- **Costs**: Greater certainty of total costs for such systems, and the CBA associated with specific use cases.
- **Project**: Delivery needs to be more specific, addressing the challenges that needed to be overcome. Lack of clarity around route from a Beta demonstrator to BAU.

Alpha phase project overview

WP2: Understand operation system requirements

- System Overview KO Workshop
- Dissection of System Specifics
- Production of System Diagram & Technical Note

WP3: System FMEA

- Identify potential failure modes for the considered HTS systems.
- Assess the impact of each failure from an operational and safety perspective.
- Prioritise risks based on severity, occurrence, and detection ratings.
- Identify improvements to reduce or manage high-risk failure modes.

WP4: Standards Gap Analysis

- Identification of thematic areas identified through the FMEA
- Review of existing available standards, identifying gaps.
- Recommended on future testing approaches & activities.

Parallel NIA project

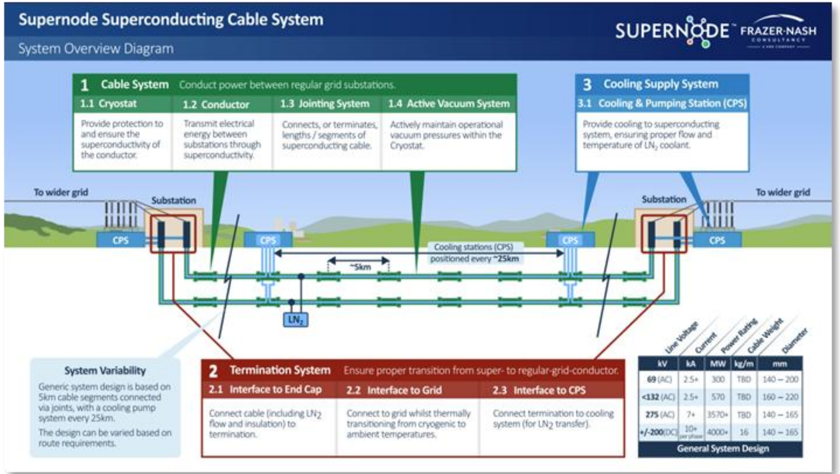
- Exploration and development of future use cases
- In depth CBA analysis for identified candidate circuits and technologies.

WP2: Understand operational system requirements

- Review system design for each of the technology providers.
- Improve understanding of each system detailing operational considerations.
- Identify new / niche components within the HTS system that need additional considerations.
- Provide a baseline system definition as a basis for FMEA.

WP2: Cable System

- Clear and accessible overview of SuperNode HTS cable system, and sub-systems. (Figure 3-5)
- Provides a basis for engagement with future stakeholders.



kV	kA	MW	kg/m	mm
69 (AC)	2.5+	300	TBD	140 – 200
<132 (AC)	2.5+	570	TBD	160 – 220
275 (AC)	7+	3570+	TBD	140 – 165
+/-200 (DC)	10+ per phase	4000+	16	140 – 165

General System Design

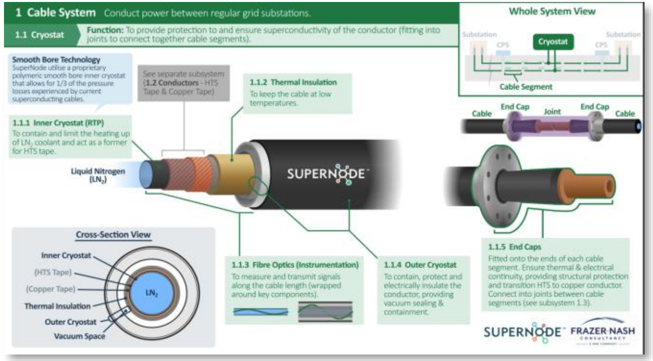


Figure 3. Cable sub-system (inc. cryostat)

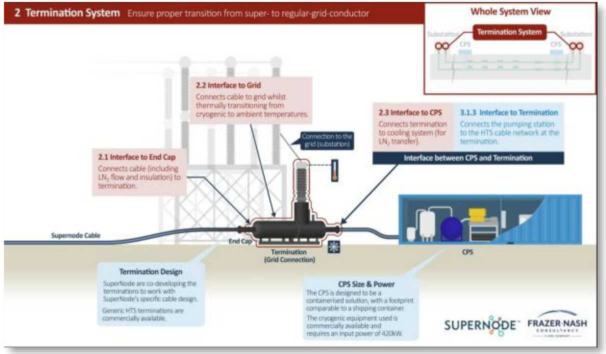


Figure 4. Termination sub-system

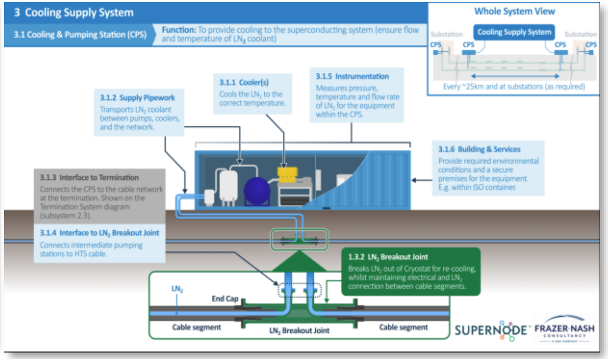
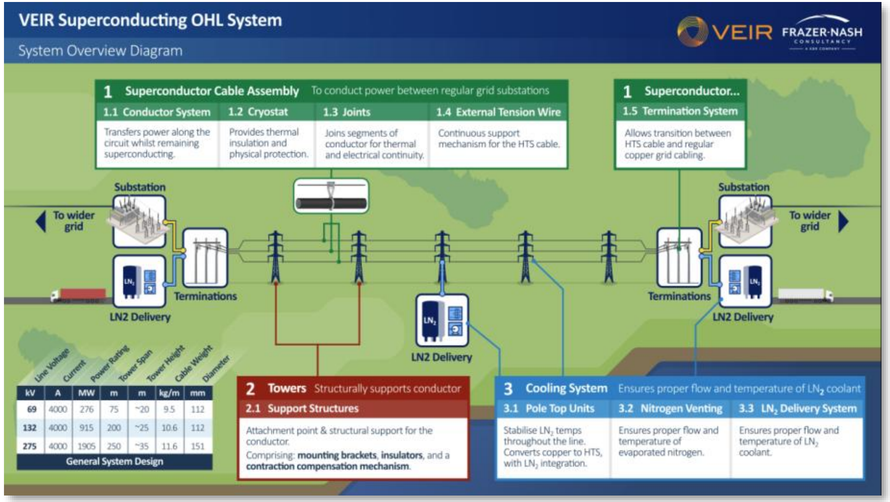


Figure 5. Cooling supply sub-system

WP2: OHL System



- Clear and accessible overview of VEIR HTS cable system, and sub-systems. (Figure 6-8)
- Provides a basis for engagement with future stakeholders.

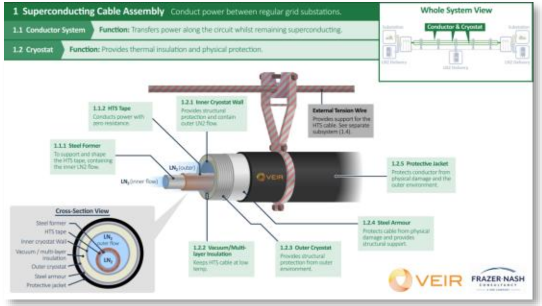


Figure 6. Conductor sub-system (inc. cryostat)

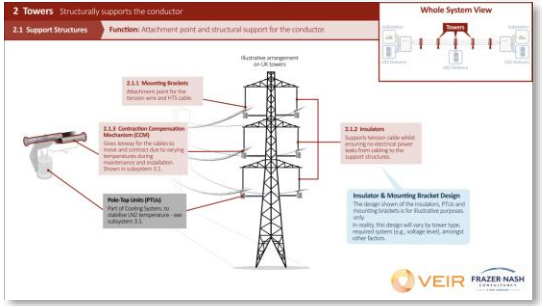


Figure 7. Tower sub-system

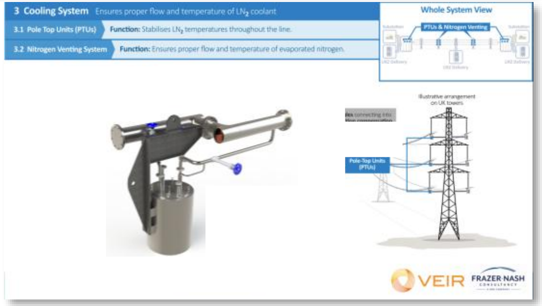


Figure 8. Cooling sub-system

WP3: FMEA

WP3 Objectives

- Design and plan FMEA workshops.
- Review HTS system in more detail.
- Outline critical components to inform gap analysis.

WP3 Outputs

- Understanding of current standards landscape
- Identification of gaps in existing testing regimes

Based on principles of BS EN IC 60812:2018 ‘Failure Modes and Effects Analysis (FMEA and FMECA)’.

Utilising experience from facilitating, authoring and delivering FMEA activities into design programmes and in-service.

Tailored to benefit from collaboration across academic and industry partners in a concise and repeatable way.

WP3: FMEA

- Dedicated FMEA sessions were facilitated for both OHL and Cable systems
- 146 FMEA line entries across both systems
- Outputs ranked and prioritised in terms of TRL in isolation & TRL in context
- **Outcome:** Informed direction for Standards gap analysis.

The University of Manchester

University of Strathclyde Glasgow

Prior to workshops: System information based on material shared to-date, and input/review from technology providers.

Workshop Day 1: How the system might fail and its consequences of failure.

Workshop Day 2: Criticality / risk components. Risk Management and identification of programmes of work.

System	Sub-system 1	Sub-stem 2	TRL in isolation	TRL in context	Function	Failure Mode	Local Effect	End Effect	Likelihood	Severity	Risk Score	Risk Owner	Risk Owner Justification	Mitigation actions

Consolidate and agree.

Post-workshops

WP4: Standards Gap Analysis

WP4 Objectives

Split FMEA outcomes into thematic areas for investigation.

Investigate suitability of existing standards.

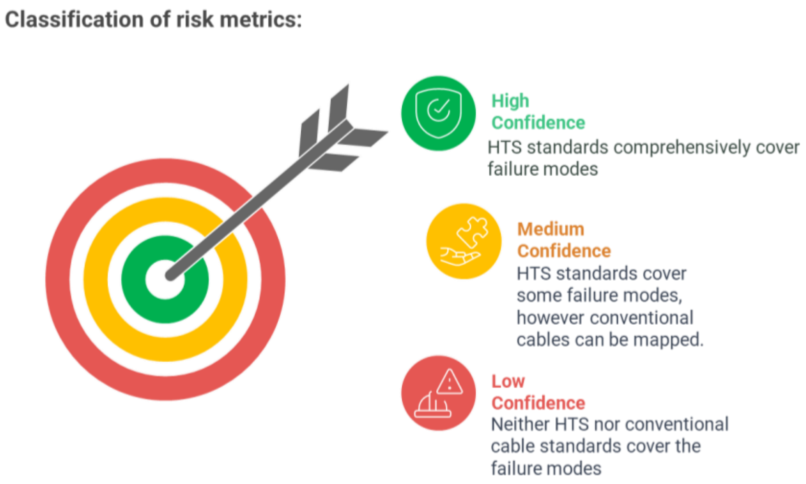
Identifying gaps in testing regimes.

Develop next steps.

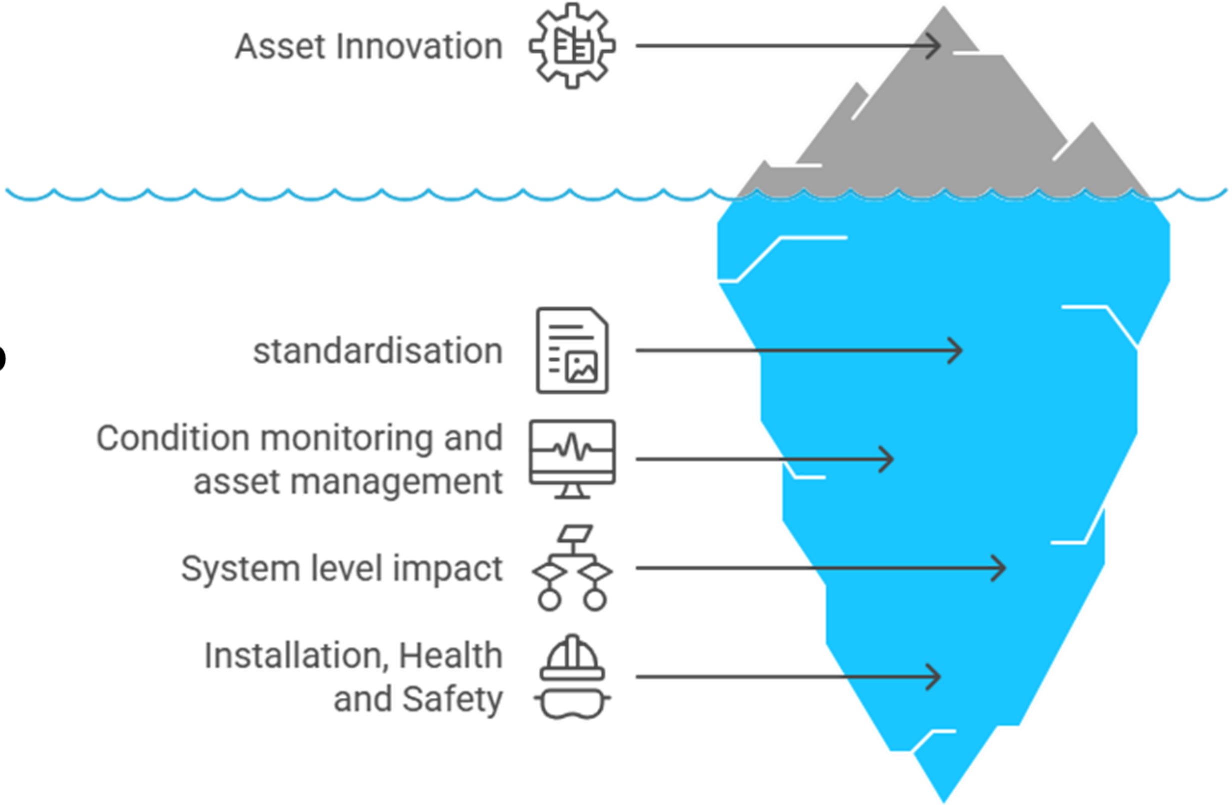
WP4 Outputs

FMEA found three primary failure categories:

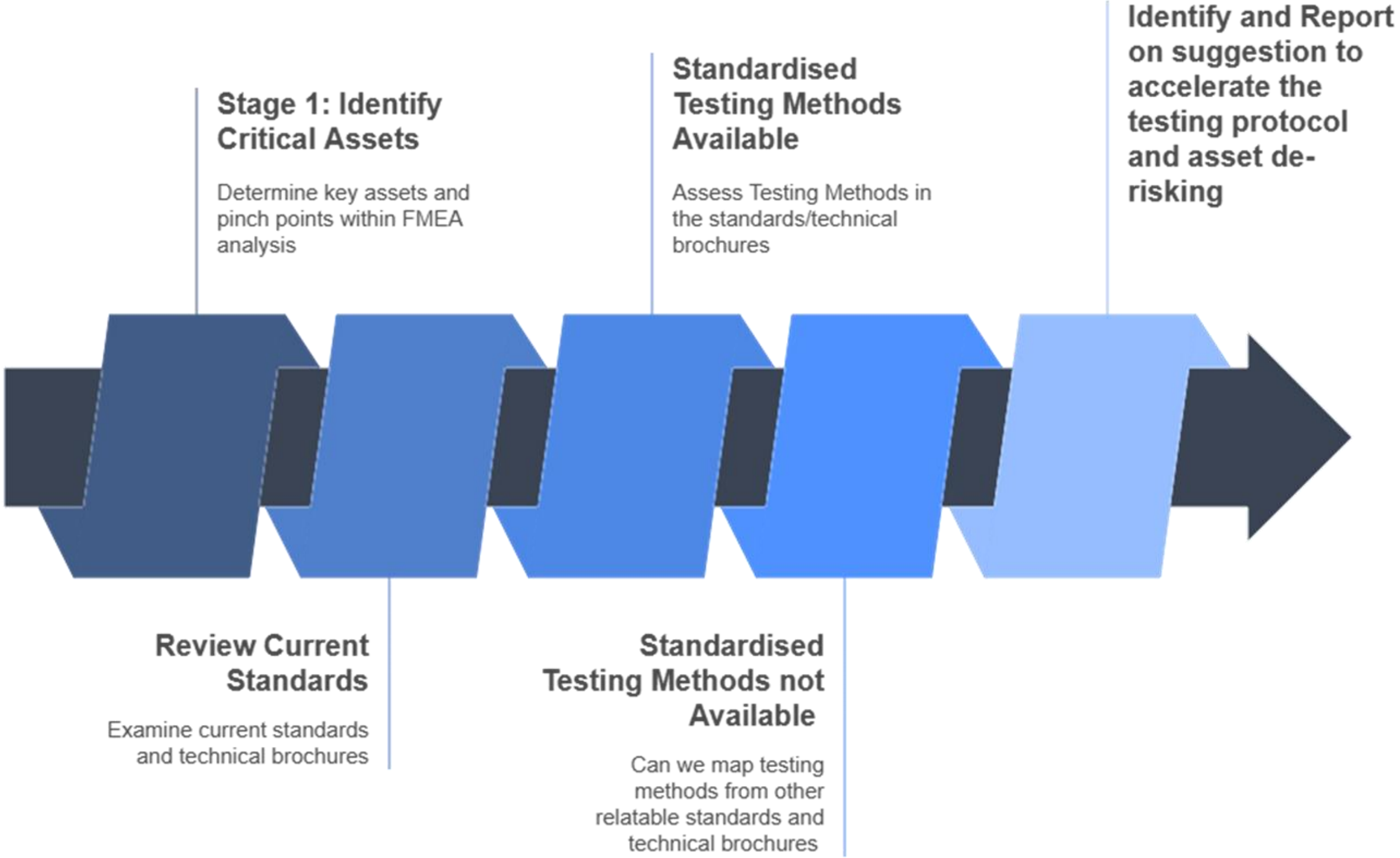
- **Mechanical (including thermal)**
  - e.g. fatigue, ruptures, interface failures etc
- **Electro-Mechanical (thermal/electrical ageing)**
  - e.g. thermal degradation, differential thermal expansions etc
- **Electrical**
  - e.g. dielectric breakdown, arcing, tracking, partial discharge etc



The FMEA process also provided an opportunity to discuss further areas of acceleration.



Standard review process



So what do we have in literature…

Limited superconductivity standards for transmissions systems

Current standard and TB for SC systems

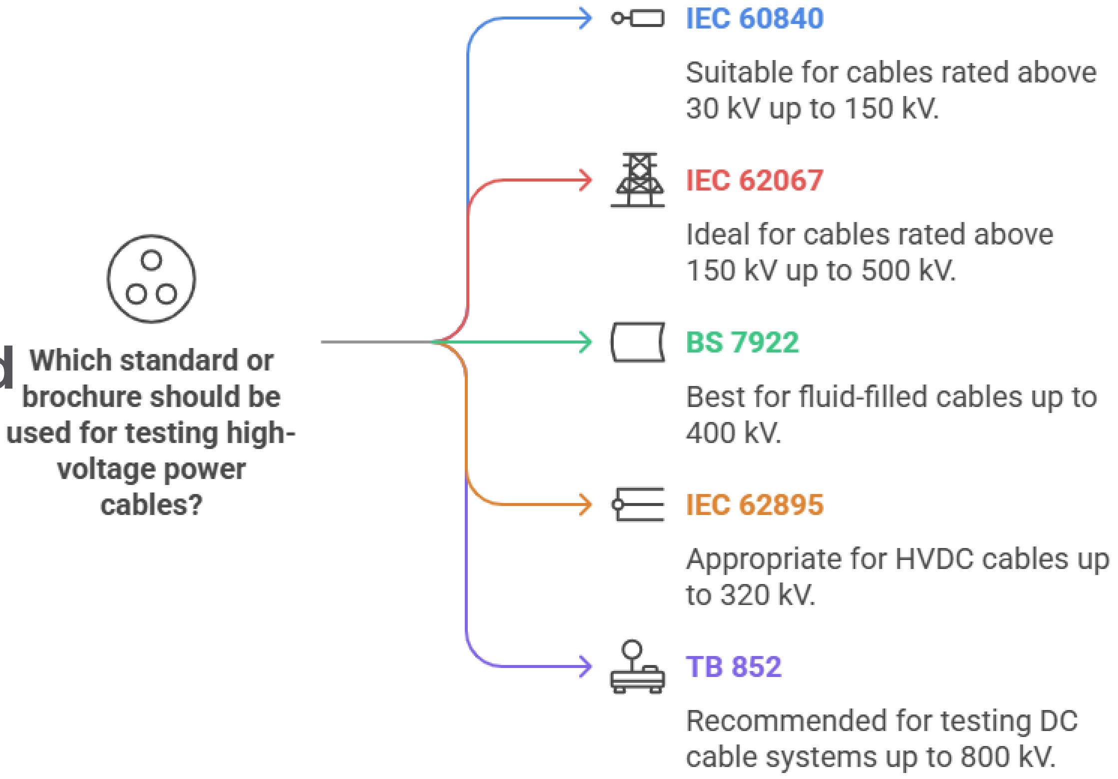
Full Standard

Provides comprehensive test methods and requirements for rated voltages from 6 kV to 500 kV.

Technical Brochure

Focuses on high-temperature superconducting cable systems but is limited to AC applications.

Significant literature for traditional AC and DC Systems…eg



WP4: Standards Gap Analysis

Developed a risk matrix of “high to low” on key asset de-risking and tests.

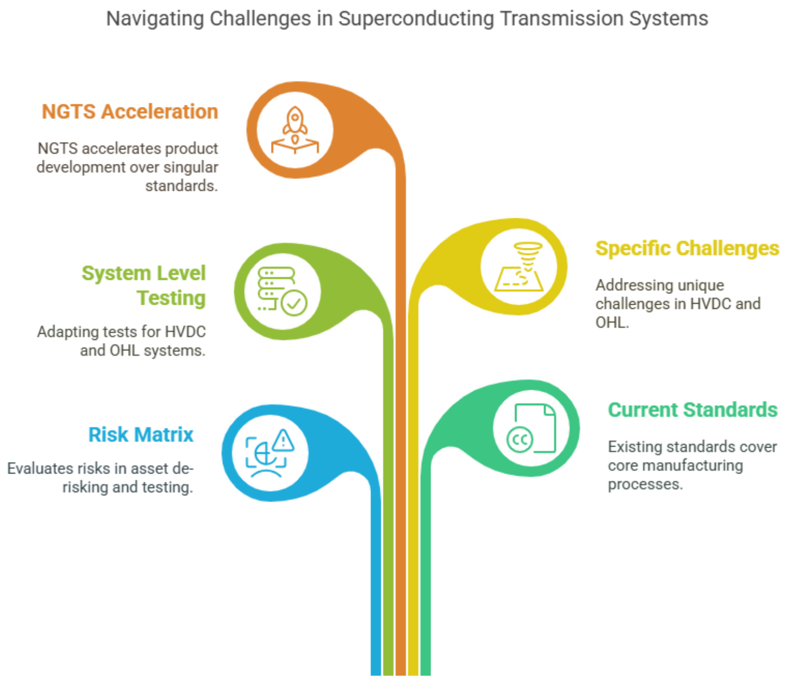
Current HTS standards do cover many aspects of the manufacturing process and the main cryostat/current carrying elements.

However, system level testing and scope, needs to be adapted for high-voltage direct current (HVDC) and OHL options.

Further areas of specific challenges: pole top venting unit (OHL) and the breakout joint (HVDC cable), need specialist testing requirements. These will not be available in any standard.

Specific NGTS development could be a faster acceleration of the product(s), rather than expecting a singular IEC/BS standard that covers all specialised system.

NGTS could also consider condition monitoring, asset management and end-of-life disposal as part of the work.



Next steps - plan for Beta application

Decision to move into a Beta phase currently in review by NGET, with the aim of the **Autumn application window**.

Round 5, Innovation Challenge 1: Advanced Energy Transmission and Networks: How can we leverage breakthroughs in semiconductor, superconductor, and wireless power transmission technologies to enhance grid performance?

Initial outline Beta scope

Project	Aims
Dissemination of Learnings & Findings	Broaden UK understanding of HTS as a solution.
Public Facing Engagement	Develop public engagement strategy.
Network Analysis for Security, Stability, Resilience and Access & Cost Impacts	Understand HTS impacts on the UK networks.
Transmission Operational Impacts	Understand HTS impacts on TO operations.
Testing (Demonstrator)	Demonstration of HTS system.
Technical specs	Development of NGET technical specs.
HTS Asset Management	Develop tools and frameworks to manage HTS asset over its life.

Conclusions

Through this alpha phase project, we have:

- **Defined what an operational HTS system would consist of and how it would be operated,** producing accessible system overviews of each technology to support future engagements.
- **Examined the operational failure modes and effects for each HTS system,** identifying measures that can be implemented to manage risk and focus areas for testing and qualification.
- **Undertaken a comprehensive review of existing standards,** aligned to thematic areas emerging from the FMEA, identifying gaps that must be addressed before BAU adoption.

Thank you for your attention

Q&A / Discussion

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