SIF Alpha Round 3 Project Registration

Date of Submission

Jul 2025

Project Reference Number

10128658

Initial Project Details

Project Title

Assessment of Superconducting Technologies for Standards Development

Project Contact

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Challenge Area

Novel technical, process and market approaches to deliver an equitable and secure net zero power system

Strategy Theme

Net zero and the energy system transition

Lead Sector

Electricity Transmission

Project Start Date

01/11/2024

Project Duration (Months)

6

Lead Funding Licensee

NGET - National Grid Electricity Transmission

Funding Licensee(s)

NGET - National Grid Electricity Transmission

Funding Mechanism

SIF Alpha - Round 3

Collaborating Networks

National Grid Electricity Transmission

Technology Areas

Conductors

Overhead Lines

Electricity Transmission Networks

Project Summary

Superconducting systems have five to ten times higher power density than the equivalent voltage conductor, meaning they deliver higher capacity at lower voltage levels and via a lower number of routes. This will allow faster network capacity increase, delivering time, cost, and carbon savings. Superconducting systems can also deliver a reduction in energy losses to virtually zero and ultimately realise greater environmental benefits. This project aims to investigate these systems in more detail, outlining their operational requirements, technical risks, and next steps in overcoming these barriers for use on the GB grid.

Add Preceding Project(s)

NGET/SCOHL/SIFIESRR/Rd2_Discovery - SCOHL

10027601 - SCADENT - Super Conductor Applications for Dense Energy Transmission

NGET/SCADENT/SIFWholeSystem/Rd1_Alpha - SCADENT - SuperConductor Applications for Dense Energy Transmission

Add Third Party Collaborator(s)

SuperNode Ltd

University of Strathclyde

VEIR

Frazer-Nash Consultancy

The University of Manchester

Project Budget

£493,127.00

SIF Funding

£443,086.00

Project Approaches and Desired Outcomes

Animal testing (not scored)

- ○ Yes
- ◉ No

Problem statement

Considering the Future Energy Scenarios it is clear that, to avoid constraining the uptake of renewable generation, there is a pressing need for significant network reinforcements. These reinforcements are being driven by the increased electrification of many sectors including heating (13x more heat pumps), transport (23x more EVs) and industry. In parallel, there are ambitions for 4x increase of solar and onshore wind, 10x more battery storage and offshore wind targets of 50GW by 2030 and potentially 125GW* by 2050 (Climate Change Committee (2020), The Sixth Carbon Budget: The UK's path to Net Zero).

Current GB grid constraints mean there is limited potential for power flow increase without major infrastructure upgrades. Estimates indicate that we will require 5x more overhead lines (OHLs) than have been built in the past 30 years. Building this infrastructure comes with challenges in lead times and costs as well as planning and consents.

Against the context of the challenge theme "novel market and technical approaches to cost effectively minimise renewable energy curtailment", high-temperature superconducting (HTS) technologies could provide a solution to the above through significantly increased power transfer in an existing footprint with minimal electrical losses.

This project builds upon the findings from two previous projects investigating HTS technologies, namely:

Superconducting Applications for Dense Energy Transmission (SCADENT): A previous SIF Discovery & Alpha project investigating AC HTS underground cable. Key findings from this project included:

*Understanding of HTS technology maturity, including requirements for future development, risk and cost reduction steps.

*CBA results showed that the technology was primarily financial viable in situations such as: large network upgrades where a new cable routes through urban area was required (e.g., the Birkenhead-Lister Drive substation upgrade), and potentially in areas of environmental beauty;

*A number of standards do exist, especially with regards to HV, from which to build upon;

*That management of cryogenics is new to the energy sector, and would require upskilling of workforce (or contracting suitably qualified personnel).

Superconducting Overhead Lines (SCOHL): A previous SIF Discovery project investigating AC HTS overhead line technology. Key findings from this projects includes:

*Current maturity of the SCOHL system is lower (compared to SCADENT), and requires more technical development across its electrical and structural implementation.

*Initial feasibility studies (CBA included) have highlighted the most promising areas for HTS, including connection to offshore wind farms, and specific transformer upgrades.

*Standards mapping exercise identified several significant gaps, in both electrical and structural coverage

SCOHL includes bespoke assets that require designing, testing and de-risking.

Previous application feedback highlighted that there was still significant work required to progress HTS system towards BAU. This project will focus on the technical barriers to HTS deployment, through the development of system requirements and standards for HTS AC OHLs and HTS DC cables for increasing network capacity. AC HTS cables are excluded this has already been adequately investigated during the SCADENT project. This project will build on the findings from SCOHL and SCADENT, leveraging the information and assumptions gathered during these phases of work.

The findings from this project will be combined with the findings from previous projects to form a comprehensive view of the HTS operational system, across its associated technologies. The aim of this project is to understand the HTS operational system from which to develop future HTS system to enable a faster roll-out of renewables.

Innovation justification

This project addresses the challenge theme "novel market and technical approaches to cost effectively minimise renewable energy curtailment" by exploring novel superconductor technology that can provide bulk power transfer for future renewable connections. High-temperature superconductor (HTS) technology can deliver increased power density without increasing voltage, and has the potential to reduce connection lead times, simplify planning (by negating the need for high voltage reinforcements, e.g., 400kV), and reduce upgrade costs associated with ancillary equipment upgrades (e.g. transformers, circuit breakers). The culmination of these has the potential to minimise curtailment and contribute to a faster roll out of renewables.

Building on the learning from previous SIF projects, SCADENT and SCOHL, the project will investigate the next generation of HTS technologies, in DC cable and OHL conductors. More established HTS cable technology have limitations in their applications due to fundamental design principles which restrict long length, direct current, and bulk power deployment. Accelerating HTS DC transmission, could have significant benefits, specifically for future large offshore connections.

SIF funding can accelerate the development of these technologies to overcome previously defined challenges, whilst mitigating future network risks. Benefits include:

- Unlocking superconducting technology for broader grid application increases options for grid planners (vastly increased power densities, DC and AC voltages, overhead lines, buried cables);
- Superconducting transmission lines or cables could be rebuilt in existing corridors to increase capacity five to tenfold;
- New corridors could carry high amounts of power within the same or smaller rights-of-way as incumbent technology (e.g., smaller towers for OHLs, smaller cable trench footprint).
- Superconducting lines could provide low-sag options that consistently carry power despite ambient temperature change - eliminating need to dynamically rate lines and act as a climate mitigation in increasingly warm summers.
- Superconducting DC cables operate in a single bipole configuration regardless of power transfer requirements.

Currently industry standards for superconducting DC cables or OHL do not exist. This project is an essential stepping stone to technology acceptance by UK transmission system operators and their grid planning teams.

The current tiered SIF funding mechanism allows this project to de-risk the technology and assess potential viability for further targeted research and exploration (e.g. potential small-scale demonstrator).

Funding support for these activities is critical to accelerating the required TRL increase and allow next-gen HTS technologies to become a strategic tool for decarbonizing the UK energy system reliably, on timescales that will meet its Net Zero commitments.

A parallel project (utilising NGET's NIA funding) will investigate the potential use cases of these technologies. An overview of these projects alignment in reaching BAU is included in the attachment. The combined outputs from these projects will inform the commercial and technical feasibility of HTS systems on the GB grid, and outline the roadmap for overcoming the technical and commercial barriers to realising an HTS installation on the GB grid. Additionally, SuperNode is currently in the process of working with NGET to test their technology at NGET's Deeside facility.

Previous grid-integrated HTS projects are international, meaning that UK industry is missing the resulting knowledge. Most of these installations are experimental, deploying only short cable lengths and operating at relatively low voltages. This project focuses on the less mature technologies of DC cables and AC OHLs, but builds on existing established knowledge.

The project will deliver whole system value through standardisation of future HTS systems that can be used across GB, lowering the cost of superconducting cable deployment through repeatability and modularity. Current deployments operate at different voltages, based on international grid standards; the project will also investigate whether standardisation at these voltages could be adapted for use in GB.

Impact and benefits (not scored)

Financial - future reductions in the cost of operating the network

Environmental - carbon reduction – direct CO_2 savings per annum

Environmental - carbon reduction – indirect CO2 savings per annum

New to market – products

New to market – processes

Impacts and benefits description

This project is looking to deliver the following benefits:

Financial (future reductions in the cost of operating the network) -- These benefits will be realised from three main areas:

1) The reduction in transmission losses due to using superconducting lines;

2) The reduction in network constraints (thereby reducing constraint payments);and,

3) The use of lower voltage infrastructure in place of costly high voltage upgrades.

The latter allows the use of smaller, cheaper substations, and can potentially allow the reuse of existing infrastructure such as towers.

Environmental (carbon reduction -- direct CO2 savings per annum) -- these benefits will be realised from the reduction in transmission losses and the reuse of infrastructure as outlined above. Additionally, the use of lower-voltage systems will allow a reduction in the use of SF6, which is a greenhouse gas 23,900 times more potent than CO2.

Environmental (carbon reduction -- indirect CO2 savings per annum) -These benefits will be realised from the achievement of faster transmission upgrades and quicker new connections, allowing the transfer of more power from remote renewable generation and a reduction in such generation being constrained off.

New to market (products) -- High power HTS systems do not currently exist. VEIR and Supernode are developing solutions, though they are not yet commercially deployed. However, the impetus provided by this SIF project is enabling the companies to invest in an accelerated programme to enable higher voltage solutions get to market faster. Potential access to the Deeside Innovation Centre test facilities via this project will further assist in progressing HTS systems for the GB market.

New to market (processes) -- Previous analysis has shown that there are a number of gaps in the standards that apply to electrical and structural elements of HTS systems, and how solutions could be implemented on the grid. This project will investigate how to best address these gaps, and in doing so will potentially provide benefits for other future network upgrades by developing processes in this area. This project could also enable a novel solution for updating existing cable and OHL infrastructure, reducing connection lead time and leading to faster demand (and supply) connections.

Teams and resources

The team for delivery of the Alpha Phase comprises:

National Grid Electricity Transmission (NGET): Transmission network owner and transmission licensee. NGET will lead the project; provide expertise on the GB transmission network, provide access to existing asset data where necessary, and facilitating the strategic direction of the project (such as utilising the ESO's future energy scenarios assessment). Moreover, NGET could also provide access to the Deeside Centre for Innovation, where testing could be used to demonstrate prototypes.

VEIR: Developers of the AC HTS technology. They will provide expertise and data on AC HTS OHL systems and what would be required for those systems to meet NGET requirements. As technology provider, VEIR will be able to provide insight into the operational requirements of the HTS OHL system.

SuperNode: Developers of the DC HTS cable technology. They will provide expertise and data on DC HTS cable systems and what would be required for those systems to meet NGET requirements. As technology provider, SuperNode will be able to provide insight into the operational requirements of the HTS DC cable system.

The University of Strathclyde: Experts in power system analysis and thermal modelling. They will be responsible for leading understanding of the requirements of HTS systems with respects to their deployment on the GB grid.

The University of Manchester: Experts in electrical systems standards and testing. They will lead the review of the standards landscape as it applies to the identified HTS technologies, identifying any gaps and propose routes to fill those gaps.

Frazer-Nash Consultancy: Experts in systems engineering and technology road-mapping. They will project manage the Alpha Phase and will carry out the required systems engineering to aid delivery of the WPs (detailed later in Q9).

Orsted: To provide a generation licensee perspective on improved transmission corridors for wind generation. This will ensure discussion is guided so as to enable solutions most applicable to enabling future renewable development. Due to the contractual complexity, Orsted have opted not to partner during the SIF Alpha phase. However they have provided a letter of support to highlight their support of the project. Orsted will remain as part of the projects advisory group, and attend the FMEA workshops to ensure their concerns are understood and included for consideration.

The team will also need access to relevant standards -- however provision of these has been included with the teams costings. We do not foresee overprotective behaviours with respect to IP causing significant issues, as all project partners have entered the project on the understanding that knowledge transfer is a key aim of the SIF. We do not plan to test any equipment in delivery of the Alpha Phase so do not see any issues related to any consumer energy supply.

Project Plans and Milestones

Project management and delivery

The key milestones and dependences of this project include:

Project Kick-off: Initial project kick-off will be held to re-align on the overall aims of the project. This will also aid with rapidly agreeing on initial next steps and potential data/information requirements.

Delivery of Technical Note of HTS Operational System: Systems analysis which produces visual and associated requirements of both the AC OHL and DC cable HTS systems. The aim of this milestone is to aid with overall understanding of the HTS systems (for applicability on the GB grid), bound the scope of further analysis and aid with the development and planning of the FMEA workshops. This milestone is dependent on the gathering of relevant data by the technology providers (which has been captured and mitigated in the risk register).

Delivery of FMEA workshops: In-person FMEA workshops to aid with understanding the previous HTS systems to increase understanding and highlight highest risk areas or components. This milestone is dependant on sufficient completion of the previous milestone, so the system is well-understood enough to enable the assessment of risks.

Breakdown of Thematic Areas of Investigation: Developing work conducted during the previous milestones, breakdown of reviewed information into thematic areas to aid with standards gap analysis, followed by an investigation into the current level of standards within these areas.

Definition of Next Steps for Understanding the Development of HTS Standards: Development of a plan (based upon previous investigation) into required next steps to enable the development of standards for the safe and reliable operation of HTS systems in the GB grid.

UKRI Show & Tell: Participation and presentation of the project outcomes during the UKRI show and Tell.

End-of-Phase Report / Beta Application: Final report or Beta application outlining key findings and next steps.

The main stage gate will be the near the end of the Alpha phase (around March), where a decision will be made whether or not to apply for Beta. This will be informed by the findings of the technical and commercial analysis performed during the Alpha phase (and associated NIA project).

In their Project Management role on this project, Frazer-Nash will implement their ISO 9001:2015 Accredited Risk Management Process. This is a rigorous process to identify, manage, mitigate, monitor and communicate project risks throughout delivery. All project partners will input to the process on a regular basis to assure that the risk register remains up to date and that risk mitigation effort is focussed where it can provide most benefit to the project aims.

Risk Identification: Proactive identification of risks via engagement with all stakeholders. This will take place both via dedicated risk workshops and ad-hoc identification during day-to-day project business. All partners will be briefed on the importance of proactive risk identification and the need to raise potential risks to Frazer-Nash.

Risk Monitoring and Mitigation: Each identified risk will be logged on the risk register and a mitigation plan will be agreed. An owner will be assigned to each risk and mitigation plan, assigning this responsibility will promote a proactive approach to risk management. Project leads from each partner will regularly review the mitigation plans, check progress and reassess if necessary.

Risk Communication: Proactive, early communication of risks to relevant stakeholders is key to effective risk management. The risk register will be updated and shared with the project partners on a regular basis to foster a common understanding. This will provide early warning of any potential issues. A stakeholder engagement plan will be developed and used to determine any required risk communication over and above normal project business.

Key outputs and dissemination

By project closure, we wish to achieve:

- Increased technology readiness of HTS Cable systems as deployable technology options on the network.
- Decrease the commercial, EPC and O&M barriers and risks of HTS technology deployment through developing UK industry understanding of the technology at all lifecycle phases.
- Exploit standardisation and modularity of HTS solutions to use learning rates and contractor knowledge to drive down HTS technology cost.

Key outputs from this project include:

WP2 - Systems Diagrams & Requirements: The development of systems diagrams and associated requirements to aid with the future operation of HTS systems on the GB grid. Building upon the work conducted during SCOHL and SCADENT, this output will form a technical note that should provide a comprehensive guide for GB operators to understand a future HTS system (primarily TOs, with a starting point from which DNOs could develop their understanding). This deliverable will be led by the University of Strathclyde, with the responsibilities of tasks as followed:

- The technology providers (VEIR and SuperNode) will be responsible for providing information and understanding of their systems (in a generalised format), from which to base the system requirements. This will be based upon work conducted by the providers to date.
- The universities will be responsible for understanding the details of the system and querying any gaps or nuances.
- Frazer-Nash Consultancy will be responsible for deconstructing the resulting information into a high-level systems diagram and associated requirements.
- National Grid will be responsible for accepting the final deliverable and signing off that the system is adequately deconstructed and can be sufficiently understood (at this moment in technology development) to enable future operation.

WP3 - FMEA of HTS Systems: An FMEA of the HTS system from which to understand critical elements of the system further -- this will aid with the direction of future work to close these gaps. Frazer-Nash will lead this WP, and be responsible for the overall planning and design of the FMEA sessions. The workshops will be held in Manchester (through the support of the University of Manchester), and supported in attendance by all project partners (and Orsted). National Grid will be responsible for final sign off of the project deliverable -- completion of FMEA's for both the AC OHL and DC cable HTS systems.

WP4 - Standards Gap Analysis & Next Steps: A review of current standards from which to inform the next steps. This will primarily highlight the gaps with regards to standards required to ensure the safe and reliable operation of the associated HTS systems. Plan of next steps of how to overcome current gaps and enable a future HTS system on the GB grid. The University of Manchester will lead this deliverable, with support from Frazer-Nash and the University of Strathclyde in investigating the current standards landscape. National Grid will be responsible for the overall sign off of this, and the decision on whether (and how) to proceed with a Beta phase.

The outputs will be disseminated via the SIF processes (led by National Grid and supported by the rest of the partners), such as 'show and tell' sessions, reporting, and via the ENA portal. If there are project outputs that would benefit other innovation projects, they will be shared directly with those project teams. Furthermore, this technology is of interest to transmission operators worldwide. We will therefore look to disseminate findings through relevant academic or industry conferences, following the approach taken in the SCADENT project. The consortium will also work with wider "customers" (i.e., organisations who have a vested interest in the technology, without being responsible for its overall development) such as Orsted.

Commercials

Intellectual property rights, procurement and contracting (not scored)

VEIR has been awarded three patents:

1. 17/524,262: Systems and Methods for Cooling of Superconducting Power Transmission Lines

2. 17/524,267: Conductor Systems for Suspended or Underground Transmission Lines

3. 17/524,261: Suspended Superconducting Transmission Lines

SuperNode have eleven active patents, four of which are in the public domain, and the other seven which will be published within the next year. Those in the public domain are:

1.EP2021154142 - Monitoring apparatus for superconducting cables

2.EP2021209191 - A superconducting cable system

3.EP2022085848 - A superconducting cable system with evaporative cooling

4.EP2023061767 - A cryogenic cooling system and method

The above patents pave the way for the commercialisation of VEIR and SuperNodes' superconducting electric transmission technologies. However, should the project result in new inventions, the appropriate inventors would apply for additional patents. VEIR and SuperNode do not anticipate needing to license their technology to other project participants for the purposes of this work.

Commercialisation, route to market and business as usual

Our route to market is outlined in Figure 2 of the attachment in Q4. This work builds upon that previously conducted in the SCOHL and SCADENT projects to advance the technical feasibility of operating HTS systems on the GB grid. Tangentially , National Grid will fund (TBC following contract acceptance), an NIA project investigating the market, and producing a quantitative CBA identifying commercially viable use cases for first deployment of HTS systems. Following the completion of these project, the technical and commercial gaps regarding HTS will have been assessed, from which to help inform National Grid whether a Beta phase is appropriate, and the required direction of said phase. This will form the next tier in developing HTS systems as outlined in the roadmap.

From the perspective of deploying onshore transmission assets, this project does not affect the energy market structure, undermine the market's development or provide unfair competitive advantage to any participant in the market. It enables the possibility of a more cost effective technology solutions to resolve some reinforcement requirements on the network which would otherwise be delivered by more expensive conventional reinforcement options. This project is seeking to deliver a core transmission owner business function (i.e. the provision of transmission capacity) using a more innovative technical solution, however this will not preclude third parties delivering similar solutions through contestable works. It is envisaged that the industry as a whole should benefit from the work on this project through both the broad partnership on the project and knowledge dissemination.

The project does not undermine the development of competitive markets because it aims to develop a standard set of requirements for HTS systems that are to be used for transmission and distribution connections on the GB grid. It will then be up to the various manufacturers and installers of the system components to develop their own optimal solutions to meet the required parameters in terms of cost and performance. Any implementation of HTS technology on the GB grid would be subject to standard competitive tendering processes.

Sectors who could benefit from this innovation include:

Cable manufacturers: Development of new cable solutions and expansion of markets;
Providers of supporting technology (such as refrigeration systems): Development of new solutions and expansion of markets.

The project will bring value to networks (such as the system planning teams) and consumers by enabling the construction of high-capacity transmission infrastructure, particularly in space-constrained urban areas, thereby helping to accelerate the transition to net-zero. This will have a significant environmental benefit which will be explored further in the Alpha.

Policy, standards and regulations (not scored)

The proposed solution is a technology to address a core TNO business requirement, to increase the network capacity in a cost-effective manner and with lowest disruption to local consumer communities.

However, it is a novel application of superconductors. The standards and regulatory review carried out in the previous projects (SCOHL and SCADENT) identified some issues that need to be addressed as HTS technologies develops towards commercial applicability. Some current standards and regulations are likely to need adaptation to apply appropriately to both overhead superconducting lines and DC superconducting cables. For example, standard overhead conductor cable rating tests based on conductor temperature will not be relevant to cryostat-encased superconductor cables.

Another area of study which is currently not understood across the networks is handling, installation and maintenance of liquid nitrogen (LN2). Although this is a common industrial chemical (within other sectors), it will require work to ensure it safe handling and operation across the power networks. The Alpha phase will carry out a detailed gap analysis on the standards and regulatory landscape and will develop a plan for ensuring development in these areas is aligned with the commercial scale development, testing and rollout of HTS systems. Successful execution of this plan will ensure that regulatory issues do not provide a barrier to the progress of HTS to full commercial use.

Value for money

The total project costs are £493,127, with the total value of funding sought for this project £443,086 (as each partner has contributed a minimum of 10%). The details of the partner costs (as funding sought) are outlined as followed:

National Grid - £34,887

University of Strathclyde - £83,151

University of Manchester - £81,930

Frazer-Nash Consultancy - £147,496

SuperNode - £38,008

VEIR - £57,614

This is split of funding across Work Packages (WPs) is as follows:

WP1: Project Management & Reporting - £96, 462
WP2: Understand Operational System Requirements - £110, 772
WP3: FMEA - £110, 772
WP4: Standards Gap Analysis - £125, 080
The project provides value to customers by exploring the opportunity for a generalised future HTS system and targeting the development of them specifically for the grid. As these technologies are currently at a low TRL, funding them is not a 'business as usual' process, and development of these systems would not be possible without innovation grant funding.

This initial investment has the potential to be recouped many times over if HTS systems can be implemented on the GB grid. This will be realised in a number of areas - via the savings made from lower losses in power transfer; via the repurposing of existing transmission assets to deliver higher power transmission capability without increasing footprint; via the faster connection of additional renewable generation.

Value can be derived from areas that are necessary for this project but can also be useful elsewhere, for example the work on the mechanical loading capability of GB transmission assets will be useful for other projects relating to transmission upgrades.

Associated Innovation Projects

- ○ Yes (Please remember to upload all required documentation)
- ◉ No (please upload your approved ANIP form as an appendix)

Supporting documents

File Upload

SIF Alpha Round 3 Project Registration 2025-07-11 1_34 - 77.7 KB

Documents uploaded where applicable?

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