SIF Alpha Project Registration

Date of Submission

Dec 2022

Project Reference Number

NGET/SCADENT/SIFWholeSystem/Rd1_Alpha

Project Registration

Project Title

SCADENT - SuperConductor Applications for Dense Energy Transmission

Project Reference Number

NGET/SCADENT/SIFWholeSystem/Rd1_Alpha

Project Licensee(s)

National Grid Electricity Transmission

Project Start

Aug 2022

Project Duration

6 Months

Nominated Project Contact(s)

Sean Coleman

Project Budget

£499,097.00

Funding Mechanism

SIF Alpha - Round 1

SIF Funding

£449,000.00

Strategy Theme

Whole energy systems

Challenge Area

Whole system integration

Project Summary

This project addresses two key aims set out in the SIF Innovation Challenge:
***Improve coordination between networks and other system participants:** the project achieves this through innovative technology to enable future grid reinforcement needs for heat, power, and transport while reducing the carbon impact of electricity system.
***Reduce duplication and excessive variation of products, processes or services:** the project achieves this through evaluating the costs and opportunities of repurposing existing infrastructure and/or assets -- such as existing cable routes, tunnels and substations, leading to lower costs for upgrading infrastructure.

The network innovation involved is the innovative deployment of High Temperature Superconductor (HTS) cable technology to increase network capacity on the GB electricity network. Full achievement of the project's aims will require technology innovation to drive down cost, deployment innovation to reduce Engineering, Procurement and Construction (EPC) risk, and operation and

maintenance (O&M) innovation to allow continued support of the novel cable technology. We build on international innovative experience drawn from a number of HTS projects are in operation worldwide. We aim to extend the experience at higher voltages (only four projects are at voltages higher than 80kV) and with longer lengths of cable (the longest AC installation is 1200m long).

The project has evolved during the discovery phase as follows:
*The partners have a shared understanding of the maturity of HTS technology, the requirements for future development and the needed cost and risk reduction steps.
*A plan to mature the technical and commercial viability of HTS technology through demonstration a realistic field test environment has been established.
*The challenges of developing HTS systems for the GB grid are better understood and the Alpha phase plan has been adjusted to deal with them, including testing and modelling and additional expertise to reinforce some experience gaps within the project team.
*An outline cost and benefit model has been produced, identifying the areas for largest potential cost reductions.

The project has engaged a range of key partners with the knowledge and expertise to deliver the project and implement outcomes. These partners are:
1.**Transmission and distribution network owners:** (NGET, WPD, SPEN, UKPN) driving the requirements for the technology and identifying operating conditions and future use cases.
2.**HTS Technology providers:** Nexans and AMSC, experts in superconducting cable systems, technology expertise on current costs and technology readiness level (TRL).
3.**Academic partners:** Universities of Manchester and Strathclyde research and expertise in power system technologies, modelling and simulation of solution.
4.**Project Management & Benefits Assessment:** Frazer-Nash Consultancy, programme management, technology lifecycle development, and cost/benefit analyses.
5.***Generation Licence Holder:*** Ørsted generation licence holder supporting this project.

The partners combine knowledge and capabilities and a strong interest in advancing HTS technology. NGET, SPEN, WPD, UKPN can deploy the solution on the respective networks, Ørsted can develop understanding of the potential uses of HTS technology in generation contexts, Nexans and AMSC can design and produce innovative HTS solutions to suit GB grid requirements, The Universities of Strathclyde and Manchester can expand their research in the area of superconductor technology and its impacts on the grid, and Frazer-Nash ensure the capabilities of the supporting consultancy ecosystem.

The proposed solution addresses the challenges held by its potential users: NGET and other network operators (TOs and DNOs). These users benefit from a wider range of options to enable future grid reinforcement, including the replacement of existing assets reaching the end of life. Consumers benefit from faster progress towards a net-zero electricity system, experience reduced disruption in upgrading network assets and will be supplied by a more resilient and sustainable network.

Project Description

Policy Context: Achieving the UK's net-zero ambition, articulated in the Government's Energy White Paper (2020) and Net Zero Strategy (2021), will require the widescale electrification of heat and transport. This will mean substantially increased demand for electricity by 2050, particularly in densely populated urban environments.

Infrastructure Challenge: The primary policy focus has been the generation of clean electricity to meet anticipated increase in demand. However, the network infrastructure required to connect that generation to centres of demand will be equally important. Without developing innovative infrastructure solutions, there is the possibility that Net Zero will be constrained by the grid's lack of capacity.

Problem: Much of the existing electricity network consists of ageing technology which is difficult to reinforce due to physical limitations and constraints (particularly in urban locations) and may not be able to deal with the level of capacity that electrification of heat and transport will demand.

There are a number of key challenges:
Cost and time: Conventional reinforcement methods for urban electricity networks are often costly and time-consuming due to the extensive civil engineering, land use permits and cost required.
Capacity: Conventional reinforcements may not be able to deliver the required capacity and build out speeds needed to accommodate fast charging of electric vehicles, expected by consumers and stakeholders.
Efficiency: Current cabling solutions have relatively high-resistance, leading to energy losses which require more energy (and peak power) generation to meet consumer demand.
Environmental: The thermal footprint of conventional cables and their emission of electromagnetic fields (EMFs) can impact on habitats and surrounding infrastructure along the cable route.

SCADENT Solution: Upgrading the electricity network infrastructure will be required to increase capacity. There is the opportunity for innovative deployment of emerging technologies that are able to reduce disruption, costs, and time. This project proposes the innovative deployment of High Temperature Superconductor (HTS) cable technology to increase network capacity in the urban environment. It will require technology innovation to drive down cost, deployment innovation to reduce Engineering, Procurement and Construction (EPC) risk, and operation and maintenance (O&M) innovation to allow continued support of the novel cable technology.

Compared to conventional alternatives, superconducting cables have three to ten times higher power density, 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. HTS technology can also deliver reduced energy losses and environmental benefits.

Preceding Projects

10027601 - SCADENT - Super Conductor Applications for Dense Energy Transmission

Third Party Collaborators

University of Strathclyde

The University of Manchester

Nexans

American Superconductor (AMSC)

Frazer-Nash Consultancy

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Project Approaches And Desired Outcomes

Innovation Justification

The anticipated increase in consumer demand for electricity particularly for heat and transport, as a result of a drive to Net Zero will require the reinforcement of urban grids. Increasing capacity using existing technology solutions is difficult as they are often physically constrained in dense city environments. This problem requires novel and innovative technology solutions with higher power density, to deliver higher capacity at lower voltage levels and via a lower number of routes.

HTS Cable provides a potentially valuable novel technology solution, although innovation is required to reduce its adoption risks on the GB network. There is no superconducting cable system currently operational in the UK, meaning that the partners need a programme of technology innovation to drive down cost, deployment innovation to reduce Engineering, Procurement and Construction (EPC) risk, and operation and maintenance (O&M) innovation to allow continued support of the novel cable technology. To support the HTS cable technology the project will design innovative HTS cable joints, and cable sealing ends; this would be a world-first outcome if successful.
The energy sector needs to expand its suite of technology options to reinforce constrained urban networks. HTS cable solutions address these constraint problems with 3-10 times higher power density than conventional solutions: improving reinforcement effectiveness directly and through the repurposing of existing civil infrastructure on cable routes leading to lower costs for upgrading infrastructure.
Previous grid-integrated HTS projects are international, meaning that UK industry is missing the resulting knowledge. Furthermore, a majority of these installations are experimental, deploying only short cable lengths and operating at relatively low voltages. The longest AC HTS cable on a power network is 1.2km at 35kV/77MVA, installed in Shanghai in early 2021. Project partners AMSC are proposing a 1.5km cable in Chicago, subject to a successful test of a prototype. A 1km, 10kV/40MVA system in Essen, Germany, is the longest-running HTS Cable project, installed by project partners Nexans in 2014.
For urban network reinforcements, it is common for cable length to be from 1-10km, without this project industry would not have confidence to deploy HTS cable over these distances. This project will also consider jointing: due to the short lengths of most HTS projects to date, there is very limited research and learning into effective jointing of cables, a critical consideration for longer cables.
The project will deliver whole system value through standardising solutions for 11, 33 and 132kV that can be used across GB, lowering the cost of superconducting cable deployment through repeatability and modularity. Current HTS cables operate at different voltages, such as 150kV, based on international grid standards; the project will also investigate whether standardisation at these voltages could be adapted for use in GB. If such standardisation can be applied to worldwide markets it enables much greater cost savings to be realised.
The low technology readiness and EPC understanding of HTS technology means that the necessary developments are beyond the scope of NGET's Business as Usual. It requires extensive, industry wide collaboration, both to develop a shared objective, and to embed outcomes in individual business plans and strategies. This could potentially unlock industry investment downstream as part of BAU activity. Clear understanding of target component costs and a roadmap to achieve cost reduction will help demonstrate to the industry when HTS systems become a
competitive solution.

Benefits

The key benefits of this project are to:

-Increase the technology readiness of HTS Cable systems as deployable technology options on the GB electricity 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.
-Develop a more mature understanding of the characteristics of a grid reinforcement project which would make it cost effective for HTS technology deployment (required power density, physical and infrastructure constraints, available footprint for substations, etc.)
Compared to equivalent existing cabling technology solutions, HTS has the following benefits:
-significant power density and space efficiency advantages which are its main benefit,
-negligible thermal cycling compared to underground cables (UGCs), which should prove more resilient and reliable in long-term operation. This will be explored in detail via a system lifetime assessment to be carried out in Work Package 1 of the Alpha Phase.
-lower power transmission losses allow more of the electricity generated to reach the consumer, providing cost savings and environmental benefits.
The potential benefits to consumers and stakeholders are faster progress towards net-zero and a more effective, future-proofed and sustainable network, with lower associated disruption and environmental impact during the construction of network upgrades.
A cost/benefit analysis (CBA) was developed during the Discovery Phase to provide rough order of magnitude (ROM) costs for further development and refinement during the Alpha Phase. The CBA is provided in the attached spreadsheet: it is recognised that the ROM values do not constitute a quantified business case, as the fidelity of the data captured during the Discovery phasedoes not enable like-for-like comparison with a reference case. The ROM figures
show that HTS systems are currently more expensive than the equivalent UGC. However, the costs are of a comparable order, and there are opportunities through technology learning rates, economies of scale and contractor familiarity to reduce HTS costs to achieve parity with UGC in particular project locations and circumstances. Project costs are sensitive to the actual location, so identifying a suitable site on the GB grid for the application of HTS technology will allow costings to be refined. The detailed investment case will be developed in Work Package 2 of the Alpha Phase.
A wider programme of HTS technology roll-out, the ultimate goal of this technology development programme, would create additional value for the wider UK economy. Direct economic growth would be facilitated through HTS enabling previously constrained deployment of new, low carbon infrastructure. Indirectly, UK industry developing construction and operating experience of HTS technology would create exploitable IP, know-how and expertise with export potential to support other nations' Net Zero transition.

Risks And Issues

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.
The above process was followed during the Discovery Phase and the resulting risk register is attached. This lists the risks and issues we are currently aware of, provides our agreed mitigation plans for each risk and includes an reassessment of the risk once the mitigations are in place.
The top two risks identified during Discovery are:
Risk 1: Network compliance -- The loss of a high-capacity HTC circuit may have greater network impact than the loss of a lower capacity cable circuit
Mitigation 1: Consider HTS network impacts and identify suitable sites where impact of loss is acceptable
Risk 2: Component cost -- HTS components may be expensive, reducing the costbenefit viability of the project
Mitigation 2: Research component costs and identify main areas which are contributing to high cost. Understand drivers for cost reduction.
Risks and potential issues relating to Intellectual Property will be raised and captured through the same Risk Management Process outlined above. In addition to this, all project partners are contractually obliged by the terms agreed with National Grid (Lead Partner) to raise risks or issues which may affect successful project delivery, including IP related risks and issues.
All project partners have entered the project on the understanding that knowledge transfer is a key aim of the SIF, and that the learning from this project must be made available to other licensees and other interested parties to maximise the benefit to consumers delivered by the funding. On this basis, we do not foresee
overprotective behaviours with respect to IP causing significant issues.
We do not plan to use any subcontractors in delivery of the Alpha Phase so do not see any related IP issues arising in this regard.

Project Plans And Milestones

Project Plans And Milestones

The project plan for the SCADENT Alpha phase is as attached as an Appendix to the submission. It shows the tasks and resources needed to address the technical challenges identified during the Discovery Phase.
In summary, we propose three Work Packages (WPs) for delivery during the Alpha Phase.
*WP1, to be led by the University of Strathclyde, will focus on the technological challenges for HTS system design, such as understanding the detailed electrical properties of the solution and its interaction with the wider power system
*WP2, to be led by Frazer-Nash, will develop a detailed benefits case for HTS to be installed on the GB grid
*WP3, to be led by Frazer-Nash, will focus on the development of an HTS field demonstrator, which will be designed to test the issues identified by WPs 1 and 2 as those needing to be resolved before the proposed HTS solution can be implemented successfully on the GB grid. WP3 will also develop comprehensive plans for the Beta Phase of the project.
Success criteria and validation processes will be defined and agreed at the kickoff meeting for each WP. Agreeing short term objectives on a work package basis will enable flexibility in the delivery of this phase, in line with an agile approach to working. During the discovery phase we have established open and communicative working patterns between the partners which will enable this flexibility during the Alpha phase.
The project will be managed by Frazer-Nash, who have significant experience delivering innovation, research and development projects through network funding mechanisms, including strategic change, technology policy and systems roadmap development. They will manage the project using an agile methodology in accordance with their ISO 9001:2015 Accredited Quality Management System (QMS). Frazer-Nash's QMS has supported their successful operations for over twenty-five years, and is independently assessed and approved to the International Standard for Quality Management Systems, ISO 9001:2015.
Regular project steering and oversight is an essential component of successful agile project management. As Lead-Partner, National Grid will be responsible for providing regular input and support to the day-to-day project management delivered by Frazer-Nash. This will ensure that the WPs remain on track to meet their strategic objectives and that technical challenges are resolved in a manner consistent with the end-user's innovation requirements.

Regulatory Barriers (Not scored)

We do not foresee any insurmountable regulatory barriers for this project. 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.
A key finding in the Discovery Phase was that it would be necessary to review relevant regulations and standards (e.g. IEC standards for type testing) to identify any potential gaps arising between the applicable international standards and the standards that NGET and other network owners use for technology that is deployed on their networks. There may also be a longer-term requirement to extend existing Relevant Electrical Standards on transmission system equipment to provide additional guidance on the use of HTS cables and the ancillary equipment which supports its operation.
Neither do we foresee any significant policy issues for longer term implementation of the technology. Whilst the use of HTS technology is novel for the GB grid, there are various successful projects operating worldwide that were identified in the Discovery Phase. Learning on any policy issues from these projects can be investigated and findings adapted to suit the UK policy context.

Business As Usual

One of the main outputs that the Discovery Phase developed, was a technology roadmap detailing the steps required to develop HTS technology from its current state to a business-as-usual option for network owners and operators to consider when increased network capacity is required.
The roadmap outlines a route to realizing TRL 9 for a SEGIL technology by following these steps:

Stage 1: Outline SCADENT technology concept -- Evaluate potential benefits, risks, costs and Deployment, Operation and Maintenance (D,O&M) impacts of HTS technology (completed during Discovery Phase).
Stage 2: Develop evidence to support continued development of HTS technology -- Quantify benefits, assess D,O&M impacts, develop technology risk mitigation plan and detailed cost breakdown for specific application and user-requirement set. The overall system requirements for the end user will be defined, including system performance metrics and a testing and commissioning plan. Key technology parameters (voltage and current level of the cable, network performance and resilience requirements, cooling system structure and redundancy levels) will be optimised to meet both system performance and cost requirements, providing a concept design for field testing. This is planned for the Alpha Phase of the project.
Stage 3: Plan for demonstration of HTS technology -- Detailed design of a field demonstrator and definition of Integrated Testing and Evaluation Plan (ITEAP), benchmark performance, finalise D,O&M plans, deliver investment business case for representative grid location. This is planned for the Beta phase of the project.
Stage 4: Demonstrate HTS technology -- EPC of field demonstrator including installation testing and commissioning. Performance validated via ITEAP evidence. Business case validated or refined. This is planned for the Beta phase of the project.
Stage 5: Refine SCADENT technology design -- Refine design based on outcomes of stage 4, develop operating procedures and operational business case. Use CBA to identify key sites where HTS project costings and benefits make economic sense. Continuous improvement of formal asset management plans and risk management and mitigation strategies for the lifetime of the technology. This is planned for the Beta phase of the project.
The Discovery Phase engaged with stakeholders from across our project partners, including transmission network owners and their operational staff. This will continue during the Alpha Phase, assuring that business and operational requirements are taken into account. The project has also commenced engagement with the owners of National Grid's New Technology Approval Process, enabling early visibility of the process's requirements and assuring that these will be embedded into future stages of the project. Within National Grid, the project is being delivered through the innovation team with close engagement from other areas of the business as required. The innovation team are the natural choice to lead projects such as this. Our project partners include other licensees who are likely to have similar use cases for HTS technology to National Grid, their involvement will enable learnings to be applied more widely across interested industry stakeholders.

Commercials

Commercialisation

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 converntional 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 and consumers by enabling the construction of high-capacity transmission infrastructure, particularly in spaceconstrained 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 phase once potential network sites have been detailed further. There may be additional benefits in improved network resilience due to the reliability of HTS technology, or its use in interconnecting substations where there is not the space for conventional cable solutions.

The indicative lifetime cost comparison developed for Discovery Phase suggests that, for the type of deployment studied, HTS costs would need to reduce by at least 15% to be comparable with those for a conventional UGC. It should be noted that there is a high degree of uncertainty in these cost projections and that further work is needed to refine these estimates. A small number of demonstration HTS systems have so far been developed globally. It is therefore expected that the anticipated costs of deploying an HTS solution will fall as the technology is adopted, with savings realised through mass production of components,

improvements in technology, de-risking for investors and familiarity with installation. HTS systems have the potential to radically alter grid performance and design, with the principal benefits of significantly reduced losses and higher transmission capacity compared with UGC. Fully understanding and monetising these benefits will accelerate the progress of HTS towards becoming a costeffective transmission solution.

Intellectual Property Rights (Not scored)

It is understood by the project partners that knowledge transfer is one of the key aims of the SIF, and that the benefits of the project will be maximised by the ability of other licensees and interested parties to be able to use learning from the project to create improved outcomes or reduce costs for consumers.

Foreground IPR which is produced by the project, such as a description of the application of HTS technology to a network and the benefits that can accrue, will be identified in the Alpha Phase reporting in sufficient detail to enable others to identify whether they wish to use that IPR. Confidential details of IPR will not be disclosed, however sufficient information will be provided to enable other licensees to understand the technology being developed and its applicability to their own networks.

Compliance with the IPR arrangements as defined in Chapter 9 of the SIF governance document will be ensured for each of the project partners via the contract that they will each sign with NGET in order to participate in the project.

Costs and Value for Money

For the Alpha Phase of this project we are requesting £493,577 of funding. The total cost of delivering the work scoped for the Alpha Phase is estimated to be in excess of £500,000 once the 10% contribution from all partners is accounted for.
The majority of the funding requested will enable our partners leading the individual WPs to fund their support. This includes University of Strathclyde and Frazer-Nash Consultancy's delivery of the three Work Packages outlined in the project plan. The other partners will deliver individual tasks and provide data and support commensurate with the funding they have requested.
Our partners' have costed their funding requests based on normal industry rates reduced by 10%, representing a 10% contribution from private funds. This also provides assurance that the costs compare favourably with normal industry rates.
The total project cost £499,093 requested will be split across project partners as follows:
Partner Funding Requested
National Grid Electricity Transmission £35,000
Ørsted £10,000
Scottish Power Energy Networks £2,124
University of Strathclyde £84,986
UKPN £15,351
Nexans £110,500
University of Manchester £43,920
Frazer-Nash Consultancy £164,712
AMSC £20,000
WPD £7,500
This project is complementary to, but provides additional value over business as usual activities as it aims to deliver a core transmission owner business function (i.e. the provision of transmission capacity) using a more innovative technical solution. Development of this technical solution has the potential to deliver additional value to the transmission networks and their customers by enabling higher capacity connections than conventional alternatives, thereby accelerating the transition to net-zero.

Supporting Documents

Documents Uploaded Where Applicable

Yes

Documents:

10037761 - SCADENT.pdf

10037761 SCADENT Alpha Risk Register.pdf

10037761 application.pdf

SIF Alpha Project Registration 2022-12-12 4_24

SIF Alpha Project Registration 2024-02-20 11_17

This project has been approved by a senior member of staff

☑ Yes