SIF Project Registration

Date of Submission

Apr 2022

Project Reference Number

10027601

Project Registration

Project Title

SCADENT - Super Conductor Applications for Dense Energy Transmission

Project Reference Number

10027601

Project Licensee(s)

National Grid Electricity Transmission

Project Start

March 2022

Project Duration

2 Months

Nominated Project Contact(s)

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Project Budget

£148,437.00

Project Summary

Summary: This Discovery Phase project, led by National Grid Electricity Transmission (NGET), will develop an understanding of the barriers, opportunities, and benefits of modernising existing electricity infrastructure by replacing conventional cables with High Temperature Superconductor (HTS) cables.

This will help meet the anticipated increase in demand for electricity, especially in highly populated urban areas, that will result from a shift towards electrification for heat and transport. The project will aim at investigating and developing a technology that will allow more rapid progress to be made towards decarbonisation whilst minimising costs and disruption to local consumers.

Scope: Our project will investigate a number of key questions:

- Evaluation of the costs and benefits of using HTS cabling for urban electricity networks for consumers and stakeholders.
- Modelling the impact on other parts of the network infrastructure, such as potential replacement of existing high voltage substations with a medium voltage (MV) option.
- Assessing the benefits and technical issues of using HTS technology to provide additional capacity for 132kV applications. As a 132kV HTS system has higher capacity than a 400kV conventional option, these applications cover the majority of power delivery requirements in future cities.
- Opportunity to develop standardised designs and installation techniques for HTS technology to address current high installation costs. Standardisation is one of the most effective ways in helping network operators deliver power where it is needed in the most efficient way.

Results: The key results for the Discovery Phase would be a detailed suite of reports, and a technology roadmap identifying key opportunities, barriers, and further work required to mainstream HTS cabling solutions.

Third Party Collaborators

University of Strathclyde

The University of Manchester

Nexans

American Superconductor (AMSC)

Frazer-Nash Consultancy

Orsted

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Problem Being Solved

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

The Infrastructure Challenge: Currently the primary policy focus is on the generation of clean electricity to meet this anticipated increase in demand. However, equally as important will be the network infrastructure required to ensure that demand can be met. Without developing new infrastructure solutions, there will potentially be challenges connecting consumers to a supply of cleaner electricity.

Problem: Much of the existing electricity network was developed 40-50 years ago. This means it is an ageing technology which 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 very costly and time-consuming due to the extensive civil engineering required and the land use permits and cost.
- Capacity: To accommodate fast charging of electric vehicles, conventional reinforcement may not be able to deliver the required capacity and speed of change expected by consumers and stakeholders.
- Efficiency: Current cabling solutions have relatively high-resistance, leading to energy losses which ultimately require higher-levels of generation.
- Environmental: The thermal footprint of conventional cables and their emission of electromagnetic fields (EMFs) can impact on surrounding infrastructure and nature along the cable route.

Opportunity: We know that upgrading the electricity network infrastructure will be required to increase capacity. This creates an opportunity to investigate new, emerging technologies that are able to reduce disruption, costs, and time, and which can more efficiently deliver the capacity that heating and transport electrification will demand.

Our Solution: This Discovery Phase project will investigate the feasibility of use of High Temperature Superconductor (HTS) cable technology to increase network capacity in the urban environment. Superconducting cables have three to ten times higher power density than conventional cable systems, meaning they deliver higher capacity at lower voltage levels and via a lower number of routes. Lower voltage substations have smaller footprint, which is very beneficial for densely populated areas. HTS technology will allow faster network capacity increase, delivering time, cost, and carbon savings with reduced energy losses and wider environmental benefits.

Project Approaches And Desired Outcomes

The Big Idea

Aims: The project will develop an understanding of the barriers, opportunities, and benefits of modernising the existing electricity infrastructure by implementing HTS cables. It delivers benefits for Whole System integration on two key aims set out in the competition scope:

- Facilitating electrification of "current and future needs for energy provision for heat, power, and transport" while reducing the carbon impact of electricity system.
- "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 with HTS cabling.

Context: Conventional reinforcement approaches are expensive, time-consuming, inefficient, and disruptive to local communities. This drives the need to investigate alternative solutions while reusing existing infrastructure where possible.

Technology Readiness: Early superconducting materials required cooling to temperatures close to absolute zero. This made them difficult and expensive to use, restricting them to small or highly specialist applications. However, the development of high temperature superconductors (HTSs) in the 1980s enabled operation at temperatures around 77K, meaning that they can be cooled using liquid nitrogen, a common, low cost and environmentally friendly industrial coolant. Significant advances in HTS cable technologies have taken place since then. Cables have now been developed that are suitable for use in large-scale electricity transmission and distribution networks, particularly in space-restricted urban areas. These characteristics include:

- A current-carrying capability 3-5 times higher than conventional copper cables at the same voltage level. This means either:
  - A single HTS cable could replace a number of conventional cables, requiring less installation space.
  - A lower-voltage HTS cable could replace a high-voltage conventional equivalent, again carrying the same amount of power in a smaller space
- Due to their low impedance, HTS cables carry AC power with much lower losses than conventional cables and have very limited thermal impact on their surroundings.
- Energised HTS cables generate very low electromagnetic fields (EMFs), minimising any issues that may arise from EMF emissions.

HTS cable technology is at a high TRL for 11 to 33kV applications that have been demonstrated in a number of international projects (see Appendix 1). However, the project will address the lack of experience with the HTS technology for long cable lengths at 132kV voltage levels that is yet has limited applications on public networks.

The project will adopt a default IP position as per SIF Governance Document, results of the project will be accessible to all GB Networks.

Innovation Justification

Current situation: There is no superconductor cable system currently operational in the UK as part of the power network. Barriers to previous adoption of this technology have been high installation costs, high risk of adopting a disruptive technology and the effectiveness of the current solutions in responding to previous levels of demand.

However, with an anticipated exponential increase in consumer demand for electricity, particularly in heat and transport, as a result of a drive to net zero there is now a pressing need to explore new solutions to facilitate future supply challenges.

Existing Research: The project team investigated similar projects that been delivered internationally (see Appendix 1). A majority of these installations are experimental, utilising only short cable lengths and operating at lower voltages. The longest AC HTS cable in a power network is 1.2km at 35kV/77MVA, installed in Shanghai in early 2021. Project partners AMSC and Nexans have just delivered a 0.2km 12kV/62MVA cable in Chicago and in 2014 the longest continuously running HTS cable on a power network 1km, 10kV/40MVA system in Essen, Germany.

Research Gap: For urban network reinforcements, it is common for cable length to be from 1-10km, and this project will investigate the feasibility of using HTS cable over these distances. An important consideration for longer cables is the jointing process. Due to the short lengths of most HTS projects to date, there is very limited research and learning into effective jointing of cables. The innovation project (WPD_NIA_015) investigated by WPD concluded that LV and MV applications are less financially competitive and suggested to investigate higher power/voltage applications where benefit case could be stronger.

Standardised Solutions: This project will investigate how to lower the cost of superconducting cable installation by standardising solutions for 132kV applications that can be used by both TOs and DNOs across GB. As well as investigating current cable technology, it will list potential standardised solutions for currently custom-made cable joints, cable sealing ends and protection equipment. This has never been done before and would be a ground-breaking outcome if successful.

Need for Support: The current development level of HTS technology means that early-stage R&D in this area is beyond the scope of NGET's BAU. It requires extensive, industry wide collaboration, both to develop a shared objective, and also to embed outcomes in individual business plans and strategies. This could potentially unlock industry investment downstream as part of BAU activity.

Project Plans And Milestones

Project Plan And Milestones

The SCADENT project will conduct a feasibility study of implementing HTS cable systems into electricity networks. It will use the most up-to-date information and will run case studies on two different scenarios to assess the potential benefits (both quantifiable and non-quantifiable).

The project plan is summarised as:

Work Package 1: Technical Assessment and Information Gathering

- Lead resources: University of Strathclyde,
- Support: AMSC, Nexans, University of Manchester, Networks
- Success criteria: An assessment of the technology readiness of HTS technologies and their feasibility for use in electricity networks

Task 1.1: Market research on the technology readiness and cost of installation of superconducting cables.

Task 1.2: Network assessment for the impact from superconducting cables, including but not limited to: impact on fault levels, impact on security of supply of electricity, impact on low voltage network resilience.

Task 1.3: Review potential locations for GB HTS applications

Deliverable 1: Technical feasibility report on routes to demonstrating viability of HTS in a GB grid context

Work Package 2: Benefit Case Study

- Lead resources: Frazer-Nash Consultancy, University of Strathclyde,
- Support: NGET, WPD, UKPN, SPT
- Success criteria: This work package shall generate two different adoption scenarios for HTS technologies and carry out a high-level benefits assessment of each scenario

Task 2.1: High-level benefits assessment of the scenario of replacing conventional HV cable systems with MV HST cable systems

Task 2.2: High-level benefits assessment of the scenario of increasing capacity of an existing conventional HV cable route with HV HST cable solution

Deliverable 2: Report on high-level benefits analysis of two options, compared to other cable/system equivalents

Work Package 3: Adoption Roadmap

- Lead resources: Frazer-Nash Consultancy,
- Support: Nexans, AMSC, University of Strathclyde, NGET, Ørsted
- Success criteria: This work package shall deliver a roadmap for adoption of the HST cable technologies

Task 3.1: Identify technology supply and installation process

Task 3.2: Identify key standardisation opportunities

Deliverable 3: Report assessing opportunities for improvement and an adoption roadmap for HTS cable technologies into the GB grid

A detailed project plan can be found in the Appendix 2.

The main risks for delivery of this project are resource availability and data availability (see Appendix 3). These are mitigated by having diverse teams working on the project and having access to both the latest academic research and the latest manufacturing and industrial data through the different project partners.

Route To Market

This project involves a wide range of project partners with the industry profile and reach to provide a clear route to market. In particular, the network partners are experienced in network upgrading and the technology providers have track records of successful HTS projects internationally.

Discovery Phase: The project will evaluate the supply chain capacity and ability to deliver HTS cable systems. We will also create a roadmap for implementing the innovation into business as usual on both an organisational and sector-wide basis.

Alpha Phase: The project team intend to investigate innovation opportunities to improve technology performance as well as draft standardised designs for 132kV applications that can be late adopted for lower voltage systems.

Beta Phase: The approved designs will be developed into prototypes to be trialled within test or live sites.

As standard practice prior to technology roll-out, parallel trials and first deployment trials need to be considered (as stated in National Grid policy PS(T)013). Further factors include:

- Training requirements: The new technology will have new operational requirements. Training will need to be rolled out to the workforce. This incurs costs and time.
- Spares holdings: Spares need to be available.
- Anticipated asset life and expected population: Defining the design life of the new asset will be required and written into to company policies and technical specifications.
- Failure mode, effect analysis (FMEA): The new technology’s failure modes will need to be understood so that new assets can be managed, suitable maintenance routines developed, and appropriate health & safety protocols established.
- Technology impacts: Impacts on business processes, systems and data need to be determined during the innovation phase, before implementing the new technology as “business as usual”.
- Resilience: Avoidance of long term, single supplier dependency; manufacturing assurance and capability. The supply chain will need to be evaluated and deemed competitive with a range of providers.
- Warranties: Warranties will need to be arranged to support investor confidence.
- Post-delivery support agreements: PDSA and system/asset recovery will need to be established for the new technology.
- Decommissioning decisions: Grey spares, disposal, forensics, and recycling all require full consideration for “whole life” asset management.

Once the Beta phase of the project is successfully delivered the HTS technology could become a regular option for network reinforcement, meaning standardised procurement procedures and processes could be used for future projects with minimal modifications. This would de-risk industry investment, reduce costs, and ultimately facilitate the wider adoption of the technology.

Costs

Total Project Costs

148440

SIF Funding

148440

This project has been approved by a senior member of staff

☑ Yes