SIF Beta Project Registration

Date of Submission

Oct 2023

Project Reference Number

10067854

Project Registration

Project Title

Network-DC Circuit Breakers

Project Reference Number

10067854

Project Licensee(s)

Scottish and Southern Electricity Networks Transmission

Project Start

Sep 2023

Project Duration

45 Months

Nominated Project Contact(s)

Adnan.mahmood@sse.com

Project Budget

£6,097,127.00

Funding Mechanism

SIF Beta - Round 1

SIF Funding

£5,486,794.00

Strategy Theme

Whole energy systems

Challenge Area

Whole system integration

Lead Sector

Electricity Transmission

Other Related Sectors

Lead Funding Licensee

SSEN - Scottish Hydro Electric Transmission

Funding Licensees

NG ESO - National Grid ESO

Collaborating Networks

National Grid Electricity System Operator

Technology Areas

Electricity Transmission Networks, HVDC, Offshore Transmission, Substations, Transformers

Summary

Meeting SIF Innovation Challenge aims

The whole system innovation challenge requires the coordination of design, to reduce the duplication and complexity of networks. This will help deliver an integrated system capable of providing net-zero electricity generation. Network-DC will support the coordination of offshore and onshore networks by connecting multiple wind farms into higher-capacity DC substations.

How the energy network innovation evolved

Offshore wind developers rely on the GB transmission system to reach energy markets. Without the careful design of the system, there can be an impact on the ability to utilise all the power generated by wind farms and system reliability can be compromised. Projects seek to make landfall close to offshore wind areas and establish substations to access the GB electricity network. This situation will create network congestion and environmental and social impacts on nearby coastal areas.

One solution is adopting HVDC technology to export power to shore and move power from remote locations, over large distances, to nodes of energy demand. To minimise landfalls and onshore substations, the recent Holistic Network Design (HND) created by the NGESO recommends the use of a Direct Current Switching Station (DCSS) to act as a terminal for gathering and distributing DC power. This requirement presents some limitations: while more wind farms and interconnectors could be added to the same DCSS, the connections at the DCSS become a single point of failure and could increase the total amount of potential power infeed losses.

By adding DC Circuit Breakers (DCCBs) to the DCSS it would be possible to connect more offshore wind at a DCSS without increasing the risk of infeed losses. Therefore, combining a DCCB with a DCSS could reduce point-to-point connections and prevent new infrastructure from being built. While the installation at a DCSS is not the only use case for DCCBs, it is the most tangible use case available and makes a good case for bringing DCCBs forward as a viable option for network design.

Alpha Phase solution

In Alpha Phase, we developed the use case of a DCSS constructed with two modifications: a) provisioning space for DCCBs and b) including switches allowing connection of DCCBs.

The Alpha Phase highlighted the best arrangement and number of DCCBs optimising electrical circuit selectivity: should a major fault occur, the fault can be isolated immediately by the DCCBs, preventing a shock to the system. As a result, the network users are unaffected and wind farms can continue operating while repairs are made.

Once proven, DCSSs with DCCBs could operate up to an increased loss of infeed limit agreed with National Grid ESO, potentially allowing exploitation of unused capacity in onshore connection points and simplifying and accelerating new customer connections, as well as reducing grid balancing service requirements.

Into Beta Phase

In the Alpha Phase, responses from Original Equipment Manufacturers (OEMs) and NGESO have emphasised uncertainty. While the OEMs agree that the task is achievable with appropriate support, they highlight a contingency problem: a market cannot develop without manufactured and specified devices, but a manufacturer cannot invest in DCCBs without the certainty of market requirements.

Our Beta Phase project will address confidence issues by demonstrating the performance of DCCBs through detailed testing of a DCCB Replica as part of a UK network model.

Project Description

To support the government's ambitious targets to increase offshore wind to 50GW by 2030, Network-DC will develop the UK's first High Voltage DC circuit breakers (DCCBs), enabling a more efficient and sophisticated HVDC network design that reduces the impact on coastal communities, reduces system costs and has the potential to lower the costs to consumers.

Preceding Projects

10036946 - Network-DC Circuit Breakers

Third Party Collaborators

The Carbon Trust

University of Edinburgh

SuperGrid Institute

Nominated Contact Email Address(es)

transmissioninnovation@sse.com

Project Description And Benefits

Applicants Location

Lead Network: Scottish Southern Electricity Networks Transmission Plc (SSEN-T)

Locations: Perth and Glasgow

The National HVDC Centre

Location: Cumbernauld, North Lanarkshire

The Carbon Trust

Location: London, Edinburgh and Cardiff

The University of Edinburgh

Location: Edinburgh

SuperGrid Institute

Location: Villeurbanne, France

(Subcontractors)

Mott MacDonald Limited

Locations: Brighton, London, Birmingham, Derby, York, Glasgow and Edinburgh

Project Short Description

To support the government's ambitious targets to increase offshore wind to 50GW by 2030, Network-DC will develop the UK's first High Voltage DC circuit breakers (DCCBs), enabling a more efficient and sophisticated HVDC network design that reduces the impact on coastal communities, reduces system costs and has the potential to lower the costs to consumers.

Innovation Justification

State of the art

The current strategy for accommodating increased offshore power generation is to construct more high voltage Direct Current Switching Stations (DCSS) reliant on conventional AC-side circuit breakers and conventional High Voltage Direct Current (HVDC) technology. Direct Current Circuit Breakers (DCCBs) increase the flexibility of these offshore or onshore HVDC networks. So far, DCCBs have been implemented only in China and are the cutting edge of HVDC transmission technology.

This Project will pave the way for a new market, using a commercially risky technology that may have significant benefits but is unlikely to come into use through normal competitive markets without significant support from SIF funding.

Innovation statement

Introducing DCCBs into the GB market is an innovative approach to improve system security and connect more energy generation with a more efficient network design. Alternatives to DCCB use have been considered: (1) building DCSSs at additional coastal locations, or (2) offsetting reliability issues stemming from increased use of existing DCSSs by expanded ancillary service provision. We have found that these options are costly, incremental, and uncertain in the case of ancillary services. The cost-benefit analysis highlighted that DCCBs are more cost-effective, except under the most conservative and restrictive assumptions. DCCBs allow better use of existing infrastructure and stimulate a new market.

DCCB technology is novel in the UK. Despite DCCB use in China, the Alpha Phase project confirmed that DCCB deployment is not a simple "lift and shift" exercise.

This Project will spur innovation by increasing confidence in the technical, commercial, and regulatory aspects of DCCB use for manufacturers, the operator, and owners. The Beta Phase will increase confidence in the following areas:

Confidence to specify

NGESO emphasises that its existing Holistic Network Design could be re-visited and use DCCBs, delivering flexibility and reduced substation construction. However, ESO lacks sufficient evidence to classify DCCBs as proven and is reluctant to include DCCBs in the long-term network plan.

Confidence to customers

The Carbon Trust's stakeholder engagement highlighted that offshore wind developers are unaware of the advantages of DCCB. Exploring the commercial and regulatory standards will increase confidence to specify and fund DCCBs.

Confidence to design

Modelling, simulation, and technical review carried out between The National HVDC Centre, SuperGrid Institute, and the University of Edinburgh highlighted that before introducing DCCBs to offshore GB networks, there is a need to address a wide range of performance and integration challenges. The experience of installing DCCBs in China is based on overhead DC links. The use case of subsea cables is more applicable to GB due to the increase in demand and the need to connect more offshore wind. Subsea connections bring different challenges, and therefore we cannot directly translate the experience in China to the UK market.

Confidence to own and operate

Whilst the Alpha Phase has demonstrated positive benefits, the levels of reliability and suitable network designs are not yet agreed by the Transmission Owners' (TOs') engineering teams.

IRL and CRL

We currently assess DCCB Integration Readiness Level (IRL) as 3, and Commercial Readiness Level (CRL) as 5. Beta Phase intends to raise IRL to 6 (Integration of Technologies Verified and Validated) and CRL to 7 (Financial Model Validation).

Technological maturity levels differ significantly among manufacturers from China, Japan, and Europe. Although China has made more progress regarding technology readiness, the integration and commercial implementation of the technology in GB's de-verticalised and privatised energy system is lagging. The OEM responses to a set of questions posed by SSEN-T illustrate disparities and areas lacking confidence. The five OEMs contacted are interested in participating but had varying reactions to the project scope, timelines, and costs.

This wide variation in responses and readiness and the relative lack of confidence implies that the use of DCCBs is unlikely to happen in GB without SIF funding. The novel use of DCCBs as an effective solution to grid design requires funding and support.

Project scale

The technical barriers and risks can be reduced by demonstrating the control and protection equipment in a system replica at the HVDC Centre. This approach does not require the construction of a full-scale DCCB (including its high-voltage equipment). Testing a replica at the HVDC centre avoids disrupting energy transmission or creating the risk of system failure. This approach enables physical testing that will give more confidence than continued simulation and represent a cost-efficient and lower-risk approach to demonstrating system reliability.

Market creation

This Project can stimulate a new competitive supplier market for DCCBs in GB and Europe. The budget has been set to allow several manufacturers to participate in the Beta Phase Project. We will complete the contracting strategy at the start of the Beta Phase, leading to the selection of preferred suppliers.

Impacts and benefits

The benefit of implementing Direct Current Circuit Breakers (DCCB) is that more offshore wind can be connected at lower costs and with a reduced environmental impact. This approach addresses the Government's net-zero targets by enabling the connection of more renewable technologies and reducing energy transmission costs, which could lead to savings by end consumers.

The benefits of this Project and the long-term adoption of DCCBs into the energy grid are understood by comparison with counterfactual design cases. Alternative to DCCBs, the expansion of offshore wind can be accommodated by:

1. Increasing the number of converter stations or Direct Current Switching Stations (DCSS) built around the coastline (necessitating correspondingly greater quantities of transmission infrastructure),

2. Allowing more connections to existing DCSSs and offsetting the resulting risk of grid instability with increased contracting of ancillary service providers, or

Compared to the preferred use case of:

· Using DCCB to connect more generation capacity to existing DCSS (or other connection nodes), managing the risks, and increasing operational flexibility.

Compared with (1), using DCCBs can save valuable space by reducing the number of transmission assets, thus reducing impacts on local coastal communities and those who would otherwise be disrupted by expanded transmission infrastructure. It also reduces costs by avoiding the need to build additional infrastructure. This approach increases the Direct Current (DC) network's flexibility, allowing wind power to be routed more efficiently to centres of demand with reduced constraints and likely reduced curtailment on wind generation. Cost savings can be passed on to consumers.

Compared with (2), DCCBs can reduce expenditure on ancillary services. Given some of these services are provided by high inertia fossil-fuel powered turbines, there is also the potential to save on greenhouse emissions.

We have quantified the benefits relating to differences in infrastructure expenditure and ancillary service provision (see the Cost-Benefit Analysis (CBA) worksheet in the Project Management Book). This CBA is based on a use case study of the Peterhead DCSS and compared against a counterfactual case of increased infrastructure and a case where more ancillary services are purchased to provide system protection and stability.

This analysis of asset costs and ancillary services indicates that using DCCBs can unlock benefits of several hundred million pounds in the central scenario over a 50-year period.

We performed a sensitivity analysis of the CBA using various scenarios, some favourable for adopting DCCBs and others unfavourable. Favourable cases involved reduced DCCB costs and increased switching station and ancillary service costs, while unfavourable cases featured the opposite. The results of this analysis are set out in the CBA analysis in the project management workbook.

Qualitative benefits of operational flexibility reduced curtailment and network constraints, and reduced impacts on coastal communities will be quantified in Beta Phase and are expected to bolster the quantitative argument for DCCBs.

By opening up DCCBs as an option for network designers via further work, benefits can be realised in other locations and situations. Enabling such a first-of- a-kind project somewhere like Peterhead will scale up across other sites bringing much larger benefits.

We have taken a conservative approach to calculating the benefits based on a single use case at the Peterhead switching station and the approach to cost estimation (high-cost estimate). We have not included additional qualitative benefits listed in the CBA summary in the project management workbook. The quantified benefits are:

1. Avoided costs for building point-to-point links and

2. Avoided losses in the event of a system fault

The included CBA analysis (see project management workbook) shows a combined positive benefit of NPV(3.5%) ~£3.5 million over the first ten years of operation and NPV(3%) ~£350 million in the expected 35-year lifetime of operation. The alternative case is to accommodate more connections at a DCSS through the provision of ancillary services to back up any losses due to faults. However, this is will incur a cost of negative ~£1200 million compared to the base case, and therefore is not a realistic choice compared to either (1) an increased number of point-to-point connections or (2) our preferred case of using DCCB's.

In Beta Phase, additional benefits will be tracked using the following metrics for key stakeholders:

· Reduced network and consumer costs: the unit cost estimate for a DCCB provided by OEMs participating in the Beta Phase, compared to our estimate and sensitivity ranges in the Alpha Phase.

· Reduced network operator costs: the equipment redundancy requirements evidenced by an OEM in their Failure Mode Effects Analysis, compared with our conservative redundancy assumptions in Alpha Phase.

· Benefits expansion across implementations: the continued evolution of the Holistic Network Design and the number of coastal DCSSs foreseen under a "Business as Usual" scenario without DCCBs.

Reduced constraints for network operators and curtailment for developers: assessing more rigorously the under-utilisation of converter capacity of existing DCSSs.

Project Plans And Milestones

Project Plans, Milestones & Risks

We will work with manufacturers to demonstrate their designs for a 525kV Direct Current Circuit Breaker (DCCB) as replicas. Replicas are used in conventional High Voltage Direct Current (HVDC) projects to enable testing and solution development without interfering with the in-service equipment. They rely on "Hardware in the Loop (HIL)" or "Software in the Loop (SIL)". HIL uses the real control and protection (C&P) hardware, while SIL uses the production software, but not physically running on the production hardware.

Each DCCB is a system, requiring a sub-system that can generate a zerocrossing (the conditions under which the DCCB can open and interrupt the flow of fault current). A second sub-system, much like an AC circuit breaker, opens when this zero-crossing occurs; A third sub-system dissipates the stored energy in the system. Each sub-system requires C&P equipment within the DCCB. To respond correctly, the C&P equipment within the DCCB relies on measurements and signals provided by other C&P equipment as part of the wider scheme that will circuit selection, circuit cut-off, and fault isolation for various connections.

Replica testing will progress through incremental steps providing more detail and greater confidence.

WP1: Appoint OEMs.

· Lead resource: SSEN-Transmission.

· Aim: Appoint one or more manufacturers to provide equipment for testing.

· Success criteria: Manufacturers contracted with legally binding terms.

WP2: Design of a scheme-wide control & protection philosophy.

· Lead resource: The National HVDC Centre.

· Aim: Design a scheme-wide control & protection philosophy.

· Success criteria: Control and protection arrangement agreed.

Stage Gate 1: will check that the scheme remains feasible in simulation.

WP3: Design of DCCBs.

· Lead resource: The HVDC Centre is supported by SSEN Transmission and OEMS.

· Aim: Design DCCBs to meet the Minimum Functional Specification required by the Control & Protection Philosophy agreed in the WBS2.0 philosophy.

· Success criteria: Provide confidence around technical maturity, ability to provide a hardware or software replica, and reliability of an eventual product.

Stage Gate 2: Check that the manufacturers' proposals meet the minimum functional requirements. There will be a check that the proposals for replica testing will add value.

WP4: Use OEM's proprietary equivalent models to validate the DCCB parameters.

· Lead resource: HVDC Centre supported by the University of Edinburgh.

· Aim: Re-run dynamic performance modelling developed in the Alpha phase and in WBS2.0, but replacing generic models of DCCBs with vendor-supplied models.

· Success criteria: Updated simulations re-confirm the Minimum Functional Specification and protection and control arrangements meet the standard required. Open-source models developed during the Alpha phase will be developed and made available to others.

Stage Gate 3: checks whether more realistic models have revealed any new issues before proceeding.

WP5: Establish Replica.

· Lead Resource: The HVDC Centre is supported by SSEN Transmission and OEMS.

· Aim: Installation and configuration of hardware and/or software at the HVDC Centre.

· Success Criteria: Replica provides significantly more detail and performance realism than the software models analysed in WBS4.0.

WP6: Use the replica to demonstrate performance in the GB network.

· Lead Resource: The HVDC Centre supported by OEM's.

· Aim: Use the replica to demonstrate performance in the GB network for up to two DCCBs.

· Success Criteria: Confidence that replica testing can be carried out and applied to DCCBs at the GB industry's existing test facilities.

WP7: Regulatory Barriers and Cost Benefit Analysis.

· Lead Resource: Mott MacDonald supported by The Carbon Trust.

· Aim: Address concerns identified in Alpha Phase for Asset Management, System Planning, Connections and Capital Projects delivery teams.

· Success Criteria: Updated cost-benefit, using a more accurate cost estimate for the equipment and realistic estimates, and additional benefits captured and quantified. The highest priority regulatory and commercial barriers have been addressed.

WP8: Innovation roll-out and scale-up.

· Lead Resource: All project partners.

· Aim: Develop a clear path to a first DCCB installation within a project contracted on a similar basis

· Success Criteria: Clear technical and engineering policies are developed, and the implementation plan has been established. A Risk Register has existed since Discovery Phase and is provided in the Project Management Workbook. It manages, rates, and reviews all identified risks and assumptions, categorised as 11 commercial, 10 technical, 7 regulatory, and 6 managerial risks.

Key risks:

1. Risk that manufacturers are insufficiently motivated to develop the equipment due to lack of commercial incentives. Mitigation: Responses were received from nine OEMs expressing interest in participation.

2. Risk that converter and DCCB models are incompatible if not sourced from a single vendor and that vendors are unwilling to cooperate. Mitigation: Seek converter models and DCCB models from a single OEM.

3. Finance and insurance sectors are not aware of DCCBs and do not have specific knowledge/views about the asset type. Mitigation: Develop accessible material to introduce stakeholders to DCCBs.

Regular risk management meetings will take place throughout the Beta Phase to review the project plan as risks are realised/mitigated.

Regulatory Barriers

Regulatory barriers or regulatory uncertainties affecting the delivery of the Beta Phase Project

No specific regulatory barriers would prevent the Beta phase of Network-DC from being carried out. However, it is plausible that the lack of regulatory clarity may dissuade Transmission operators from accepting DCCBs and thereby dissuading the manufacturers of High Voltage Direct Current (HVDC) circuit breakers from investing in technology development. Furthermore, the lack of regulatory clarity disincentivises the network owners from investing in the infrastructure.

Longer-term regulatory barriers to the adoption of HVDC Circuit Breakers

In the Alpha phase of the Network-DC project, we identified a number of regulatory and commercial obstacles to the uptake of HVDC circuit breakers in the UK electricity network; these obstacles still exist. We identified three key regulatory and technical obstacles as follows:

1. The requirement for the development of legal and regulatory frameworks for DCCBs.

2. The uncertainty of the technical specifications for HVDC Hubs containing DCCBs in the GB network.

3. The uncertainty in commitment to the evolution of infrastructure and how this impacts the delivery model for DCCBs.

Regulatory conditions for Beta Phase delivery

The proposed scope and activities require no derogation, license exemption or sandbox for the Network-DC project Beta Phase.

Involvement of Government, Ofgem, and other relevant organisations

In addition to the regulatory obstacles that were identified, we also identified a series of recommendations, actions, and action owners who are required to overcome the obstacles. Many recommendations require input from parties outside the project team, including Ofgem, Department for Energy Security and Net Zero (DESNZ), and others.

In order to obtain greater clarity on the regulatory landscape governing the use of HVDC circuit breakers, we strongly advocate the greater involvement of Ofgem in the Beta Phase of the Network-DC project. Furthermore, we recommend formalising these relationships with other HVDC projects in the UK and Europe, for example, READY4DC.

Business As Usual

Steps to Business As Usual (BAU) adoption

The integration of Direct Current Circuit Breakers (DCCBs) into the network, whilst having significant advantages, is a substantial and disruptive change to the architecture of the UK transmission grid. DCCBs are not yet at the requisite technical, commercial, or integration readiness levels to be included in the holistic planning of the UK's transmission network.

This Project cannot guarantee the selection of DCCBs as a part of the network's future design. However, without this Project and without raising the readiness level of DCCBs and progressing the work packages set out in this project application, DCCBs may never be a viable option for the UK network. The risk is that without this optionality, the UK may never reach optimal configuration for the benefit of the network and the consumer.

Therefore, this Project considers that BAU is ensuring that DCCBs will be viable in designing the UK's future network. Whether or not they are then subsequently selected depends on the 'whole network assessment' of the potential benefits as set out in this Application.

This Project will engage with the key stakeholders to ensure that the equipment manufacturers can meet the technical and commercial standards required to install DCCBs on the UK network. We will work with the subject matter experts in the transmission networks and the Electricity System Operator (ESO) to ensure we meet all the appropriate engineering standards. SSEN-T is already considering options for retrofit of DCCBs in the design of proposed DC switching stations in the North of Scotland. The UK transmission network, the ESO, European subject matter experts, and equipment manufacturers will primarily support this innovation. We will also draw on Chinese manufacturers' experience in using DCCBs in the Chinese transmission network. We will work with BEIS and Ofgem to ensure that consultation with Chinese manufacturers does not compromise the UK network security and stability.

As this Project design will set the technical and commercial standards for implementing DCCBs, the results will be disseminated to the ESO (who are project partners) and other transmission networks to establish appropriate industry codes and standards. These codes and standards will be publicly available. It is also the case that through this Project, a range of equipment manufacturers will come to understand how best to design the equipment and controls required for the UK market. Therefore, this Project can de-risk the supply chain for DCCBs. This approach will maintain a competitive market for the supply of DCCBs. Equipment manufacturers will be engaged in the Project and provide a benefit-in-kind through the equipment supply for Beta Phase testing and the technical development of equipment to the required standards. However, this Project will treat equipment manufacturers as suppliers rather than project partners to maintain a competitive market in the future.

Through stakeholder engagement in the Alpha Stage, the ESO has confirmed they would like to have DCCBs as an option for network design. The equipment manufacturers have issued letters of support for the Project.

As indicated in the cost benefits section of this report, establishing DCCBs as a viable network engineering option could benefit the consumer by (1) lowering the cost of bringing on more intermittent renewable energy, (2) reducing the size of the network, with fewer landfall sites bringing environment and sustainability benefits; and (3) maintain the reliability of energy supply through improvements in the ability to manage faults.

Commercials

Consumer interaction and engagement

This Project aims to increase energy security whilst maintaining electricity system reliability and reducing costs. Therefore, while energy consumers will not directly interact with this Project, they will benefit from the roll-out of DCCB once proven.

Increasing generation on GB waters from offshore wind, and the associated offshore and onshore networks, are a key part of the British energy security strategy published in 2022.

Whilst there may be a perceived risk in inserting DCCBs into critical national infrastructure, the extendable DCSS design removes the DCCBs as a single point of failure. In the event of a product defect, a safety issue, or planned maintenance, the DCCBs can be taken out of service. The DCSS continues as a 'conventional' DCSS with its original capacity until the DCCB is restored to operation. This situation equally provides a shield against DCCBs becoming a cyber-security risk: they can be switched out with some limited reduction in functionality of the DCSS but cannot create a "lights out" situation.

In addition to these GB energy security considerations, consumers will benefit indirectly from the increased efficiency of investment in offshore wind. Since fewer stations will have to be built, and no additional (and uncertain) grid ancillary services will be procured, the overall cost of energy transmission is better than the alternative cases.

Some consumers will also benefit through the reduced impact on coastal communities. Reducing the number of DCSSs constructed and reducing transmission infrastructure near offshore wind sites will have clear environmental benefits.

Supply shortages and interruptions

There will be no supply interruptions as the Beta Phase of this project will not install equipment onto the network, as clearly stated in this Project plan. The primary purpose of this Project in Beta is to de-risk the design and engineering of DC Circuit Breakers (DCCBs) to make them a viable option for the GB network. This work will therefore lower the risk of supply disruption to As Low As Reasonably Practicable (ALARP) for future installation of a DCCB, which is beyond the possible scope of the Beta Phase project. During the equipment and control systems testing at the HVDC centre in Scotland, the equipment will be isolated from the network and its control systems, so there is no possible risk to the GB network or the consumer.

The Beta Phase project is designed to de-risk the implementation of DCCBs, and therefore, this Project is the best way to reduce or avoid the need for planned, or the occurrence, of unplanned interruptions.

Commercialisation

Two groups can be considered customers of our innovation:

1. Developers of offshore wind.

2. Developers of interconnectors between GB and Northern Ireland or Ireland; or GB and the continent.

The customer value proposition is aimed at developers who have elected to use High Voltage Direct Current (HVDC). Developers with Projects that reach landfall close to the planned Direct Current Switching Station (DCSS) can connect to that DCSS, rather than being connected via a new point-to-point link or a new DCSS. Developing a new point-to-point link or DCSS requires additional land purchases, consenting, and Alternating Current (AC) reinforcement works and will take longer compared to exploiting additional potential capacity in the existing DCSS.

Additional capacity could be created at the DCSS if Direct Current Circuit Breakers (DCCBs) are used to unlock the capacity for various stakeholders connecting to the system. As such, the risk of new technology is spread across all customers of the DCSS, at the Transmission Owner's (TO's) risk. The TO will own the DCCBs. In the event of an unplanned outage of the DCCBs; a maintenance outage of the DCCBs; or a fleet defect requiring the DCCBs to be taken out of service whilst remedial actions are taken; the DCSS falls back to operating as it did initially, with its original capacity and capability.

The route-to-market strategy is based on DCCBs being supplied like conventional HVDC substation equipment. Traditional HVDC substation equipment is competitively tendered, typically as a turnkey equipment supply agreement and Long-term Service Agreement (LTSA). Procurement of conventional HVDC onshore and offshore substation equipment in GB is based on a credible market of three leading European HVDC suppliers and challenger suppliers from China. Options remain for the TOs to split activities, such as enabling works, civils, and construction of a building to contain the HVDC converter, from the supply of the core equipment if desired.

It is a pre-condition of our commercialisation strategy that DCCBs are selfcontained and can be added to any existing Direct Current Switching Station (DCSS), irrespective of which manufacturer(s) provided the equipment for the original DCSS. This pre-condition has been shared with manufacturers in the scope of work issued for consultation. We foresee that the first DCCB installations will comprise a single supplier winning the contract to supply all DCCBs required at a particular DCSS, to a single common design. We will nevertheless seek to avoid any designs which prevent a multi-vendor approach from being pursued in the future, whereby multiple suppliers provide the DCCBs into a single DCSS, to increase the speed of delivery and resilience to fleet defects.

During Discovery and Alpha, we consulted with:

· SciBreak, who in 2020 successfully demonstrated an 80kV DCCB breaker in Kema's laboratories and is embarking on a 525kV DCCB development project.

· Siemens Energy, a leading HVDC converter supplier currently developing a technical concept for a DCCB and system integration concept.

· Hitachi Energy, who have demonstrated a system prototype of a 350kV DCCB breaker. GE, who developed and demonstrated an early prototype several years ago, but did not proceed at that time in the absence of market pull outside Asia.

· Mitsubishi Electric Power Comhas, which has developed and carried out highvoltage testing on a 200kV DCCB.

· State Grid Smart Grid Research Institute, who developed the design, procured, installed, and commissioned for the Zhangbei 525kV DCCB scheme which has been operational for 2 years.

· NR Electric, supplied the key DCCB components to the Zhangbei Project.

To commercialise the product, equipment will need to be type-tested against the Minimum Functional Specification (MFS). In our scope of work for manufacturers, we have encouraged them to carry out High Voltage testing of their design (in a laboratory such as the DNV GL (ex. KEMA) laboratories in the Netherlands). We are however not providing funding from the SIF for this, to avoid distorting the market. Players will be expected to "catch up" on their own funds, where necessary, in time for the first DCCB procurement in GB.

It is expected that in the long term, since turnkey DCCB units would simply extend a conventional DCSS, the market could readily scale to anywhere where there is a DCSS.

Intellectual Property Rights

We have developed a commercial term sheet summarising the key contractual terms and circulated it with the OEMs. The terms state that the supplier will retain all rights to their pre-existing intellectual property (Background IPR) and will own any new intellectual property (Foreground IPR) created during the Project, either individually or jointly. They may be required to provide a royalty-free license to certain parties for any Foreground IPR necessary to implement the project methods.

The stakeholder engagement carried out so far has been positive. Though some manufacturers have declined to take a position on IPR until their commercial teams have reviewed it, the majority have already agreed to abide by the SIF Governance document and the IPR terms in the term sheet. The project has the budget to allow several OEMs to take part in the Beta phase project. The expectation is that a least two OEMs will be able to agree to the IPR in terms of SIF governance.

SuperGrid retains the rights to knowledge, tools, and know how to produce the DCCB security and operation guidelines. This tacit knowledge is considered non-relevant background IP.

A summary report of the findings and conclusions will be made available on the public Energy Networks Association website. The detailed findings of the project and project reports will be made available on request subject to appropriate security checks and confidentiality agreements being in a place with third parties requesting the information (at no cost to the requestors). Open-source models for Direct Current Circuit Breakers will be made available by Edinburgh University.

Costs and Value for Money

Direct Current Circuit Breakers (DCCBs) provide additional value by allowing new system designs to add greater capacity to connect new energy generators while reducing the need for additional infrastructure. This design approach reduces the environmental impacts, makes connections more efficient, and reduces costs. This approach can maximise the value that could be obtained from High Voltage Direct Current (HVDC) transmission.

The total cost is £6,097,127 Given the complexity of demonstrating that DCCBs can be incorporated into the UK network, and given the potential benefits in terms of cost savings, ability to flexibly connect more offshore wind, improvements in energy security and resilience, and reduced environmental impact, this cost is value for money for the following reasons:

As described in Q7, demonstrating that DCCBs can meet UK performance standards requires state-of-the-art testing equipment (only available in the UK at the HVDC Centre) and many iterations of testing and validation, which is timeconsuming. It also requires manufacturers to supply and install equipment for testing. Which again is time-consuming and costly. The alternative to testing at the HVDC centre is testing a fully constructed DCCB live in the network or a test facility in Europe. This would be much more expensive, with additional risks of equipment failure and no obvious benefits in terms of system qualification and time.

The costs submitted in the budget are in full accordance with the terms set out in the UKRI costs guidance.

The project contribution from partners will be £610,333 (10%) with most of that funding coming from Scottish Hydro Electric Transmission (SSEN-T). Given the high risk of the project and the risk that DCCBs might not be selected for network design, 10% is an appropriate project contribution. If successful, almost all of the benefits will accrue to the consumer. Without the SIF funding, this project carries too much financial risk for SSEN-T to fund.

SIF funding requested by work package:

· WP1. Appointment of Original Equipment. £100,757

· WP2 Design of a scheme-wide control & protection philosophy £640,232

· WP3. Design DCCBs to meet the Minimum Functional Specification required by the Control & Protection Philosophy and propose a means of representing the DCCB design as a replica: £809,269

· WP4: Use OEM's proprietary equivalent models to validate the DCCB parameters £745,349

· WP5. Installation and configuration of hardware and/or software and EMT models at the National HVDC Centre, of an agreed number of DCCBs. £1,938,687

· WP6. For up to 2 DCCBs: Use the replica to demonstrate performance in the GB network. £401,214

· WP7. Regulatory barriers and Cost Benefit Analysis. £537,718

· WP8. Innovation roll-out and scale-up. Develop a clear path to a first DCCB installation within a project contracted on a similar basis with the Department of Energy/Ofgem to an Offshore Transmission Network relevant project £313,568

Most of the cost is absorbed by testing at the HVDC Centre (SSEN-T), £1.4 million, (including the provision of high-powered computer equipment) and the work that Original Equipment Manufacturers (OEMs) will need to do in supplying and installing the equipment costs £2.4 million. The work includes the use of the National The Centre as an established state-of-the-art testing centre, to establish a similar facility elsewhere would require considerable investment.

Our procurement strategy for OEM equipment is developed from an extensive review of the procurement process that supported the T2 business plan and was approved by Ofgem. We decided to subcontract OEMs so that we do not favour any one manufacturer at this stage, to ensure that competition is maintained for the supply DCCBs thereby ensuring the best opportunity for a cost-competitive market for DCCBs. Contracting costs are £0.1 million.

Edinburgh University and SuperGrid provide specialist expertise in system design and fault protection (£1.5 million). Edinburgh will give support to simulation with the development of Open-Source DC Circuit Breaker Models. SuperGrid will add value by providing an experience in protection system design and technoeconomic evaluation of the DC network switching station for the GB use case.

The remaining expenditure (£0.5 million) is related to the establishment of opensource models for DCCBs so that a wider range of equipment can be simulated and the work required to establish the commercial and regulatory environment for installing DCCBs. Researching and developing open-source models is labour intensive and will cost £1.2 million, but it brings the benefit value as these models will be made available to other networks and researchers in the UK.

We have chosen Mott-MacDonald as a subcontractor to deliver both the CBA and route map to roll out of DCCBs. Mott Macdonald is a global engineering, management, and development consultancy with a dedicated HVDC team with extensive experience in this field. This can be seen through the work they supported for SSEN-T Caithness-Moray project. Mott-MacDonald is contracted through our established procurement process and the negotiated framework agreement and has been selected for Beta Phase to provide project continuity.

Document upload

Documents Uploaded Where Applicable

Yes

Documents:

SIF Beta Project Registration 2023-10-11 11_48

10067854 - Network DC - SIF Annual Report 2024.pdf

This project has been approved by a senior member of staff

- [x] Yes