SIF Project Registration

Date of Submission

Mar 2022

Project Reference Number

10020383

Project Registration

Project Title

Network-DC Circuit Breakers

Project Reference Number

10020383

Project Licensee(s)

Scottish and Southern Electricity Networks Transmission

Project Start

March 2022

Project Duration

2 Months

Nominated Project Contact(s)

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Project Budget

£142,288.00

Project Summary

To combat climate change, the UK needs clean energy. The UK is very well positioned to generate clean electricity because our coasts provide a large potential for offshore wind. The UK currently has an installed offshore wind capacity of 12GW and is targeting increasing the total capacity to 40GW by 2030. Given the scale of the developments proposed and their increasing distance from the onshore grid, the most efficient option is to connect these to the network using Direct Current (DC) cables. The electricity used by the consumer is alternating current (AC) and there is a need to convert the DC to AC at a convertor station, usually positioned on the coast and connected point-to-point to the wind farm via an offshore cable. The current method of connection is to connect each wind farm to an AC convertor station with an AC circuit breaker to protect the electricity grid from faults. However, as the number of wind farms increases, so the number of AC convertor stations increases in a point-to-point system. This has impacts on coastal communities through ever increasing number of convertor stations and cables. It is also costly to install and maintain many convertor stations, which will increase the cost of electricity to consumers.

The big idea is to create DC networks that can connect multiple wind farms into a DC substation, that then can connect to fewer convertor stations. This will reduce the impact on coastal communities, reduce costs and has the potential to deliver lower cost wind energy to consumers. It will also help us open new areas for developing windfarms. To do this we need to use DC circuit breakers (DCCB), which are an innovative technology that is untested in the UK and European market. DCCB will allow us to bring multiple windfarms into a DC system, containing the impact of any single failure safely and securely. We will need to develop and test these DCCBs before we can develop a DC network. This project will test and prove the use of DC breakers so that we can implement our big idea of DC networks that can deliver safe, reliable, and cost-effective energy to the consumer.

Third Party Collaborators

The Carbon Trust

Transmission Investment

University of Edinburgh

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Problem Being Solved

The problem that the Network DC Project is trying to solve is how to reduce the high cost of delivering tomorrows DC networks, whilst improving network resilience. It will do so by enabling integrated DC meshed networks of offshore wind farms that can be more efficiently connected to the onshore transmission network with a reduced asset base. A key component, and the ultimate deliverable of this project, will be the ability to install DCCBs, which can be used to isolate sections of network in the event of a fault and maintain network resilience.

The UK currently has an installed offshore wind capacity of 12GW and is targeting increasing that capacity to 40GW by 2030. Given the scale of the developments proposed and their increasing distance from the onshore grid, the most efficient option to connect these to the network is via a DC network.

Offshore wind farms traditionally have a point-to-point (PtP) connection via a DC cable with the onshore AC network. This has been successful to date as it is operationally straightforward to isolate the DC circuit at the onshore AC connection point using a proven low-risk AC circuit breaker (ACCB). The drawback of this network design is it results in stand-alone assets connected directly to the transmission grid PtP, increasing the total number of required AC convertor stations. The alternative is to connect multiple dispersed wind farms to the grid in a meshed network to a single AC convertor station.

An integrated meshed DC network has the advantages of:

- Reduced onshore infrastructure:
- Potential for a smaller footprint
- Reduced operational expenditure
- Reduced environmental impact on coastal communities
- The ability to expand offshore networks quicker and easier

However, in a DC network, where numerous windfarms are connected to the AC network using a single AC convertor station with an ACCB, there is the risk that if a fault develops in the network, multiple windfarms will be disconnected at the ACCB. This problem could be solved using DCCBs within the DC network that would simplify fault isolation and increase network reliability.

However, DCCBs are at a technology readiness level (TRL) of 5 and would present an unquantified risk to network stability without further testing and assessment. This project aims to raise the TRL of DCCBs to TRL 7 by the end of Beta phase, with a DCCB system prototype demonstration and implementation engineering in an operational environment.

Project Approaches And Desired Outcomes

The Big Idea

The big idea is to connect multiple windfarms to an AC convertor station via a DC network protected by DCCBs. This innovation will significantly reduce the cost of new offshore windfarm sites. This project will:

Decarbonise gas and electric energy distribution and transmission networks - reduced infrastructure requirements reduce resources required to expand offshore wind and therefore reduces the amount of embodied carbon associated with networks. Facilitates accelerated expansion of windfarms.

Benefit the consumer - less infrastructure, enabling faster roll-out and reduced costs. Further, DCCBs will facilitate the expansion of offshore wind using fewer onshore connectors de-risking implementation of projects needed for the UK to achieve 40GW of offshore wind by 2030 and 80GW+ by 2050. This expansion has been estimated to contribute a £6bn benefit to consumers with 50% saving on overall assets and reduced environmental impacts to coastal communities in Scotland and wider a field.

Improve coordination between networks and other system participants by simplifying connection to existing DC networks allowing expansion to support offshore wind targets and in turn, enable the development of offshore/coastal hydrogen production. Consistent with Net Zero targets, offshore wind connections are increasing in scale and distance from mainland GB, this is driving the need for increasingly high-capacity DC circuits. Without DCCBs, in the event of faults or outages the whole DC arrangement is lost. Regulations limit the allowable loss of an offshore network to 1320MW, the scale of DC arrangements is currently constrained.

Circuit Breakers (CBs) limit the extent of network disruption during faults or switching. Both ACCBs and DCCBs interrupt a fault by breaking the circuit. ACCBs interrupt power at the point of zero voltage however, since DC circuits occupy a constant voltage, the energy is much higher thus DCCBs introduce a zero voltage to safely limit the energy requiring interruption.

DCCBs are currently being deployed for the first time onshore in China but have never been implemented at the scale required or de-risked for networks in GB or Europe. As a result, the TRL for implementation is currently a 5. By the end of Beta phase, the aim is to raise this to TRL 7 by de-risking the front-end engineering (FEE) and defining the required standards and specifications for DCCB use across GB.

The background IP for the DCCBs is already established by the vendors, this project explores the implementation of DCCBs, and the output will be shared with wider industry.

Innovation Justification

Whilst DCCBs have never been deployed on GB or European networks, they have been deployed at a smaller scale onshore in China and so learnings from this operational experience can be utilised. The EU PROMOTioN project simulated the use of DCCBs using generic models, demonstrating their success in a test facility, thus learnings were centred around the concept of DCCBs as opposed to their implementation. A gap therefore remains in exploring specific cases to determine how implementation of DCCBs would be de-risked and to establish both specification and installation in the context of GB. For full detail of similar projects and associated learnings see Table 1 of Appendix Q5.

The need for a project of this kind is supported by BEIS and its commissioning of a Coordinated Offshore Strategy document by the HVDC Centre, which lists priority areas for HVDC development. This identifies gaps in knowledge and experience which must be addressed before HVDC can fulfil its recognised potential and has the development of DCCBs as a key action. In addition, the Offshore Coordination Project identified that most of the technology required for an integrated offshore network design is available now or will be by 2030, but "a key component to release the full benefits of an integrated solution are DCCBs."

The gap from previous projects alongside the support from BEIS and the Offshore Coordination Project indicates that significant barriers to deploying DCCBs on GB networks remain. This project aims to address these by shifting the TRL from a 5 to a 7 (see Figure 1 of Appendix 5). There is a clear requirement for exploration of DCCBs to define how a GB based integrated HVDC network would be designed to replace the counterfactual onerous PtP approach (see Figure 2 of Appendix 5). Work of this sort does not currently exist, deeming this project truly innovative and essential.

In terms of funding, as there are no other DCCBs deployed in Europe, to develop one for application within GB would involve a significant level of risk. That level of risk is not commensurate with the rates of return associated with the RIIO-T2 price control and our investors, as we are a low return, low risk company. Furthermore, we have no existing allowances or uncertainty mechanisms that could be used to develop DCCBs, therefore external funding is required.

Project Plans And Milestones

Project Plan And Milestones

Discovery phase milestones:

- Cost benefit analysis of DCCB.
- Create a statement of requirements (SOR) to support the Alpha phase pilot project.
- Review current options available from the supply chain, and the likely developments in the area.
- Recommendation on proceeding to Alpha phase.
- Dissemination of learning to network operators.
- The Discovery phase is designed to provide a CBA and SOR so that the technical and economic feasibility can be evaluated, and a decision taken on proceeding to Alpha Phase.

The Discovery Phase will be split into three work packages (WPs):

WP1: Explore and identify cost benefit of DCCB use (SSEN-T lead) - SSEN-T will appoint a consultant to provide a CBA for up to three DCCB use cases, to be compared against three counterfactuals.

WP2: Explore and identify roadmap to de-risk DCCB FEE (SSEN-T lead) - Here consideration will be given to the technical requirements for DCCBs to mitigate the risks associated with their deployment on the GB system. A consultant, with experience in supporting previous HVDC projects and FEE de-risking will be appointed.

WP3: Project Management

<u>Alpha Phase milestones:</u>

- Delivering the FEE for case studies, with clear cost-benefit up to the point that the requirements for a given vendor solution can be defined.
- Supply chain engagement and develop a procurement strategy
- Environmental engineering and value engineering- addressing the activities as defined in the roadmap that would occur ahead of engaging a supplier

The output of the Alpha phase will be the vendor specification of the work related to DCCB implementation.

Beta Phase milestones:

- One or more vendors would develop proposals based on the specification which would be both refined and reviewed.
- Physical DCCB test and real-time demonstration of replica DCCB control and protection simulation within the loop of network study of the given cases

The output of the Beta stage will be a process for OEM (Original Equipment Manufacturer) engagement.

<u>The key project risks with mitigations are:</u>

- The scope of work is misunderstood, mitigated by involving consultants and partners in early discussions to address any issues.
- The project deliverables are not delivered on time or to an acceptable standard, mitigated through regular engagement between SSEN-T and consultants.

We have not identified any current regulatory constraints that would impact the delivery of the Discovery phase. However, we are mindful that consulting on improved Offshore Coordination has not yet concluded and will continue to monitor this developing throughout the project delivery.

Route To Market

DCCBs are not commercially available for installation on the GB system and have not been deployed on any network in Europe. Significant barriers must therefore be addressed before these can become business as usual (BaU). Specification and installation requirements for DCCBs do not currently exist in GB and the technology requires de-risking to inform overall design and use cases.

This project is designed to de-risk and demonstrate the use of DCCBs and bring their implementation to market. Subject to the development of the FEE roadmap in the Discovery phase, some outcomes to address the barriers which currently exist could include the development of:

Codes and standards for implementation of DCCB technology in GB - this refers to the requirements that DCCB technology must satisfy for installation on the GB network.
DCCB design specifications for manufacturers - focusing on how DCCBs should be designed for operation in GB.

Drawings detailing the installation process for DCCBs - including stage-by-stage layouts detailing how to implement DCCBs and potentially the creation of a 3D timelapse to visualise the work required in each time period.

Replica DCCBs tested in a real environment (the HVDC centre) - this refers to a physical representation of a real control code which drives the creation of a zero voltage and protection which signals the CB to open. Testing this in a real environment specifies DCCB performance and how this should be achieved.

As with ACCBs, whilst each Transmission Owner (TO) can develop their own approach and specifications, this material would provide a common route for implementing DCCBs in GB, equipping the industry with the necessary tools and information to enable DCCBs to become BaU.

To achieve procurement and utilisation of DCCBs, new processes, standards, and tools, together with replica DCCB control and protection would be made available to the industry through, for example, the publishing of CIGRE papers. This dissemination would be targeted to ensure material is shared with the relevant industry parties.

The material can then be applied ahead of any intended application to de-risk both its investment decision and ensure technical design and testing is robust and relevant. As a result, this would enable efficient delivery of DCCBs by removing "first adopter hesitancy."

Costs

Total Project Costs

146038

SIF Funding

142287

This project has been approved by a senior member of staff

☑ Yes