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NIA Project Registration and PEA Document

Date of Submission

Sep 2018

Project Reference Number

NIA_WPD_033

Project Registration

Project Title

EDGE-FCLi (Embedded Distributed Generation Electronic Fault Current Limiting interrupter)

Project Reference Number

NIA_WPD_033

Project Licensee(s)

National Grid Electricity Distribution

Project Start

September 2018

Project Duration

3 years and 7 months

Nominated Project Contact(s)

Yiango Mavrocostanti - Western Power Distribution, Jack McKellar - UK Power Networks

Project Budget

£3,016,472.00

Summary

The ever increasing penetration of embedded generation coupled with recent improvements in network interconnectivity, have led to rising distribution network fault levels, close to the rated capability of existing equipment, and pose several challenges to both DNOs and independent power producers (IPPs). More specifically, connection requests by IPPs are often rejected by DNOs due to lack of fault current headroom in their networks. In some cases, connections are made possible through conventional resource-intensive and often disruptive network reinforcement, with substantial cost and delays to the IPPs. This leaves available generation capacity underutilised, inhibiting in this way the further decarbonisation of the network.

In order to enable a scalable and long term path for such connections, the fault current contribution from new generators needs to be reduced to near zero. While some generation sources contribute little fault current (inverter based generation like solar), synchronous ones (such as CHP) contribute significant fault current.

Third Party Collaborators

GridON Ltd

GHD

Problem Being Solved

The ever increasing penetration of embedded generation coupled with recent improvements in network interconnectivity, have led to rising distribution network fault levels, close to the rated capability of existing equipment which pose several challenges to both DNOs and Independent Power Producers (IPPs). More specifically, new connections are made possible through conventional resource-intensive and often disruptive network reinforcement, with substantial cost and delays to the IPPs which can make these connections unviable. This leaves available generation capacity underutilised, inhibiting the further decarbonisation of the network. In order to enable a scalable and long term path for such connections, the fault current contribution from new generators needs to be reduced to near zero. While some generation sources contribute little fault current (inverter based generation like solar), synchronous ones (such

as combined heat and power, CHP) contribute significant fault current.

Method(s)

The project aims to design and test a newly developed solid state Fault Current Limiting Interrupter (FCLi), that can limit the fault current contribution of distributed generators and therefore overcome fault level issues that can limit the network capacity and prevent future connections. The three phase FCLi will be designed for 11kV generator connections ≤ 5 MW and will be robustly tested to provide learning on the suitability of the technology for implementation in distribution networks. If the complete testing of the device is successful, it will then be trialled within WPD's 11kV network.

The project is to be delivered collaboratively between WPD and UKPN to ensure that a device is developed to suitably be deployed throughout GB. The project scope is described in more detail below but will consist of collaborative working on the design of the FCLi device as well as factory and laboratory testing to ensure that it is suitable for longer-term testing and site trial.

Scope

The project will consist of the following Work Packages:

1. Device specifications – Specifications will be defined to cover all the device requirements.
2. Preliminary FCLi design and review – This includes the identification of key components, high level electrical, thermal and control design, and detailed test plan preparation.
3. Detailed FCLi design and review – This involves full design of all parts including power modules, insulation, control system and operator interface, fault detection system, enclosures, thermal and ventilation detailed design.
4. FCLi device manufacture.
5. Testing – The FCLi will undergo a number of rigorous tests including: Factory Testing, Laboratory/Type Testing and Internal Arc Testing.
6. At this point, if all elements (1-5) have been successful then the following will take place: a. WPD – long term 'soak' testing of the device to ensure stability of operation of the device and wider system b. UKPN – register separate NIA project to trial the installation and operation of the FCLi within the 11kV network.
7. Trial of the FCLi within WPD's 11kV network where 6a is successful

Objective(s)

- Design an 11kV FCLi for a ≤ 5 MW generator.
- Manufacture the FCLi.
- Perform detailed testing on the manufactured FCLi including Factory Acceptance Testing, external lab testing and 'soak' testing.
- Complete Internal Arc Testing of a prototype device.
- Provide learning and recommendations for the suitability of such a device for implementation in the distribution network.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

The project will be deemed successful if during the trial period:

- The FCLi limits and reduces down to zero before the first peak the fault current contribution of the generator during a network fault.
- The FCLi introduces minimal disturbance to the network and the generator during normal operation.
- The FCLi remains in normal conduction mode for transient non-fault related events and for faults outside the 11kV network on to which it is connected.
- Any device failures are minor and do not render the plant unavailable for more than a few hours.

Project Partners and External Funding

GridON Ltd, GHD

Potential for New Learning

The knowledge gained through this project will relate to:

- The design considerations for the integration of a power electronics (PE) FCLi into a DG connection.

- The necessary site preparation works.
- The FCLi- Generator compatibility requirements.
- The performance and response of the FCLi to real-life network conditions.
- The analysis of FCLi performance to identify replicability and suitability for different network topologies.

Scale of Project

The project will run for three years and six months and will involve the design and testing of the FCLi device.

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL6 Large Scale

Geographical Area

If the project progresses to Work Package 7 depending on the success of Work Packages 5 and 6, the trial will take place in WPD's East Midlands Licence area.

Revenue Allowed for the RIIO Settlement

£0

Indicative Total NIA Project Expenditure

WPD Project Cost: £2,173,854

UKPN Project Cost: £842,618

Total Project Cost: £3,016,472

Total NIA Funding: £2,714,824.80

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

n/a

How the Project has potential to benefit consumer in vulnerable situations:

n/a

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

The EDGE-FCLi solution has the potential to enable savings of:

- Approximately £ 950k per primary substation for Western Power Distribution; and
- Approximately, £ 1,557.3k per primary substation for UK Power Networks

These are savings relate to the reduced network reinforcement costs. The savings for the customer and for the network operator will depend on the Cost Apportionment Factor, which is determined on a case-by-case basis.

Provided all other connection works can be completed within the FCLi manufacture and installation timescales, an IPP can be connected within six months as opposed to an average of two years in the case of network reinforcement, hence the IPP can start making revenue 18 months earlier. Moreover, the FCLi cost can be recovered within six months of operation.

Please provide a calculation of the expected benefits the Solution

The problem of high fault levels is more prominent in urban networks.

Western Power Distribution

An urban substation with 25 circuit breakers (CBs) is assumed with 8 Ring Main Units (RMUs) per 11kV feeder (20 in total). Within the GB distribution network the majority of the old 11kV switchgear is rated at 13.1kA (250MVA). The typical reinforcement approach includes upgrading switchgear that is rated at 25kA (476MVA). Close-up RMUs also need upgrading.

The typical cost of replacing an 11kV circuit breaker and all peripheral equipment is £50k. Similarly, the typical cost of replacing an 11kV RMU is £20k, while it is assumed that 25% of them will need replacing.

Base Cost= 11kV switchgear cost+ 11kV RMUs cost= (25*50)+(0.25*20*8*20)= £2050k.

The fault level headroom enabled by the 25kA switchgear is 226 MVA and this can accommodate approximately six 5MW synchronous generators. Due to other technical constraints it is reasonable to assume that there will be a 33% reduction in allowed DG connections, hence allowing only four additional 5MW DGs.

The business as usual cost of an 11kV, 5MW FCLi is expected to be £275k, hence:

Method Cost= 4*275= £1100k Saving= £950k

UK Power Networks

An average substation in London Power Networks has 64 circuit breakers (CBs) and is connected to 159 Ring Main Units (RMUs). Within the GB distribution network the majority of the old 11kV switchgear is rated at 13.1kA (250MVA). The typical reinforcement approach includes upgrading switchgear that is rated at 25kA (476MVA). Close-up RMUs also need upgrading.

The typical cost of replacing an 11kV circuit breaker and all peripheral equipment is £32.7k. Similarly, the typical cost of replacing an 11kV RMU is £14.2k, while it is assumed that 25% of them will need replacing.

Base Cost = 11kV switchgear cost + 11kV RMUs cost = (64*32.7k)+(0.25*159*14.2k) = £ 2,657.3k per substation.

The fault level headroom enabled by the 25kA switchgear is 226MVA and this can accommodate approximately six 5MW synchronous generators. Due to other technical constraints it is reasonable to assume that there will be a 33% reduction in allowed DG connections, hence allowing only four additional 5MW DGs.

The business as usual cost of an 11kV, 5MW FCLi is expected to be £275k, hence:

Method Cost= 4*275k = £1,100 k Saving= £1,557.3k

Please provide an estimate of how replicable the Method is across GB

The device will be designed for 11kV connected synchronous generators on to networks with limited fault level headroom. This is an increasingly common scenario, as demonstrated by the partnership of two of the largest distribution network operators, and the method is thus applicable and replicable across all GB Electricity Distribution areas.

Please provide an outline of the costs of rolling out the Method across GB.

The business as usual cost of an 11kV, 5MVA FCLi is expected to be £275k

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

- A specific piece of new (i.e. unproven in GB, or where a method has been trialed outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).
- A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)
- A specific novel operational practice directly related to the operation of the Network Licensees system
- A specific novel commercial arrangement

RIIO-2 Projects

- A specific piece of new equipment (including monitoring, control and communications systems and software)
- A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven
- A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)
- A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology
- A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution
- A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

The project will provide learning on the network integration requirements, performance and scalability of a new fault current mitigation device. This will be designed to be applicable to any 11kV DG connection $\leq 5\text{MW}$ and therefore the learning will be useful for all Network Licensees. avoided/emphasised

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

N/A

Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

Is the default IPR position being applied?

Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

As part of the de-scoping of Method 2 from the Powerful-CB project, UK Power Networks have decided to collaborate with Western Power Distribution on their EDGE FCLi project (similar to Method 2) and transfer all learnings to date. This will ensure all progress on Method 2 can be directly utilised on another innovation project, which will unlock benefits for our customers.

At the point of project registration, Western Power Distribution acknowledged UK Power Networks' Powerful- CB NIC project, which includes a PE based customer's premises connected FCL solution; however UK Power Networks' solution is at a TRL of 6, while the one proposed for this project has a TRL of 4. UK Power Networks and Western Power Distribution see value in developing an alternative at a lower TRL.

The EDGE-FCLi solution offers limitation and initial interruption solely by means of power-electronics and will greatly add to the learning developed from other fault-limiting projects.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

n/a

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

• If the testing is successful the demonstration on a customer's site will be the first in GB; • More compact and with a BAU cost lower than that of similar products before; and • Power-electronics based FCLi technology hasn't reached a maturity level to be commercialised to date.

Relevant Foreground IPR

n/a

Data Access Details

n/a

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

• Unproven technology that poses technical and commercial risks and uncertainties. • Both Network Licensee and IPP exposed to the operational and financial impacts of a potential failure. • Trial project incurs high cost and long timescales that would be borne by Network Licensee and IPP.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

- Technically, the significant prospective TRL advancement and hence risk would discourage different stakeholders from investing and generally supporting such a project.
- On a regulatory basis any operational shortfalls would be subjected to complaints and penalties.
- Financially, the high cost of such a trial project, its long time-scales and operational risks would prevent IPPs from investing and exposing themselves to it.
- Legally, due to the IPR involved any third-party funding entity could restrict the dissemination of knowledge and would be entitled to royalty payments at the expense of other network customers.

This project has been approved by a senior member of staff

Yes