WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

Date of Submission

Dec 2019

NIA Project Registration and PEA Document

Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

Project Registration

Project Title

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

Project Reference

NIA_WPD_033

Project Licensee(s)

Western Power Distribution

Project Start Date

September 2018

Project Duration

3 years and 6 months

Nominated Project Contact(s)

Yiango Mavrocostanti

Project Budget

£3,016,472.00

Nominated Contact Email Address(es)

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Problem(s)

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 investigate the integration of FCLi technology into the WPD network at the Point of Common Coupling of a synchronous Distributed Generation (DG) plant and assess the extent to which the fault infeed from the Generator can indeed be limited and then interrupted. The project comprises 2 phases:

In Phase 1 the functional specifications for use in an 11kV connection of capacity ≤5 MW will be determined and the FLCi design will be produced. At the same time, the design for the interface between the FLCi and the WPD metering substation equipment will be produced.

Phase 2 will look into the build and meticulous testing of the FCLi followed by site installation, commissioning and energisation. The proposed solution will be trialled on an existing DG site or one which is to be connected on a network with no fault level constraints. This eliminates the risk of overstressing the network if the FCLi fails to operate. The behaviour of the device and its response to network events will be monitored and assessed against the design performance criteria. Following the completion of the design work the scope of the project will be re-assessed and if deemed required, it will be widened.

Objectives(s)

- Design an 11kV FCLi for a <=5MW 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.

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.

Technology Readiness Level at Start

TRL 4

Technology Readiness Level at Completion

TRL 8

Project Partners and External Funding

GridON Ltd, RINA Consulting Ltd

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 identity replicability and suitability for different network topologies.

Scale of Project

The project will run for 2 years and 3 months in total and is broken down into 2 main phases. Phase 1, mainly consisting of design, network studies and site selection activities, will be 9 months long. Phase 2, consisting of the device building and installation, site preparation and energisation works and data collection and analysis, will be 18 months long. The aforementioned activities will involve, apart from the project partners, significant resources from WPD planning, design and operational teams. The scale is subject to extension following completion of the design review activity.

A smaller scale project could compromise the careful design and refinement of the EDGE- FCLi to meet the distribution network needs and provide a reliable and effective solution to the rising fault level contribution from DG. Furthermore, a smaller scale project might not capture the challenges of integrating this technology into the existing DNO- Customer interface and associated solutions. Allocating less time to monitoring and analysis would also limit our understanding of the unit's response to various network steady-state and dynamic events.

Geographical Area

The trial site, which could be in any of WPD's licence areas, is yet to be determined. Following consultation with WPD planning teams regarding prospective 11kV DG connections, the selected site must satisfy certain criteria, while the IPP and the WPD timescales need to be aligned to avoid unnecessary delays. It is likely that the above approach could pose significant commercial and time challenges; therefore a parallel engagement with academic institutions in WPD's area with connected generation can provide an alternative option.

Revenue Allowed for in 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

Specific Requirements 1

1a. A 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 trialled outside the GB the Network Licensee must justify repeating it as part of a Project) equipment (including control and communications systems and software)	X
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 Licensee's System	
A specific novel commercial arrangement	

Specific Requirements 2

2a. Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

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

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 ≤5MW and therefore the learning will be useful for all Network Licensees. avoided/emphasised

Please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the Project.

N/A

2b. Is the default IPR position being applied?

Yes	X

2c. Has the Potential to Deliver Net Financial Benefits to Customers?

Yes	X

Please provide an estimate of the saving if the Problem is solved.

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 financial benefits of a Development or Demonstration Project (not required for Research Projects). (Base Cost - Method Cost, Against Agreed Baseline).

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 in terms of the number of sites, the sort of site the method could be applied to, or the percentage of the Network Licensees system where it could be rolled-out.

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

2d. Does not Lead to Unnecessary Duplication

Yes	X

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.

Following the unsuccessful development of a PE FCL device as part of Western Power Distribution's FlexDGrid project, a significant amount of the budget was returned. The project partners believe is that there is value in a PE solution and based on the knowledge gained from previous and current projects in the industry (UK Power Networks` Powerful-CB, Electricity North West`s Respond)

Additional Governance Requirements

Please identify

that the project is innovative (ie not business as usual) and has an unproven business case where the risk warrants a limited Research and Development or Demonstration Project to demonstrate its effectiveness	X

i) 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.

ii) Please identify why the Network Licensee will not fund such a Project as part of its business as 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.

iii) Please identify why the Project can only be undertaken with the support of the NIA, including reference to the specific risks (eg 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