Powerful-CB

SDRC 9.3.1 Learning Report
Understanding customers' requirements
October 2017

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Delivering your electricity

Project overview

The Powerful-CB (Power Electronic Fault Limiting Circuit Breaker) project aims to demonstrate that Fault-Limiting Circuit Breakers (FLCBs) can enable more Distributed Generation (DG) to connect to fault-level constrained networks.

A power electronic FLCB is a solid-state circuit breaker that operates 20 times faster than traditional vacuum circuit breakers. It can block 100% of fault level contribution but allows load current to flow normally before and after the fault as soon as the fault has been cleared.

We will be trialling two methods to allow generators to connect to fault-level constrained 11kV networks:

- Method 1 – Installing a device at a substation, to allow multiple generators to connect; and
- Method 2 – Installing a device at a customer site, to allow a single generator to connect.

The journey towards a low carbon economy is revolutionising the way we produce, distribute and consume electricity. Whilst we continue to operate and invest in our network to maintain a safe, secure, and sustainable power supply to 8.2 million homes and businesses, we need to make use of smart, flexible, and innovative techniques to ensure delivery of our outputs, minimise the cost impact on consumers, and manage the increased complexity of this low carbon world.

To date we have over 300MW of combined heat and power (CHP) connected to our London network but the ability to connect more may be limited as a result of fault level constraints. The traditional fault level solutions are an inhibit agreement (therefore restricting output), connection at a higher voltage level and network reinforcement with the latter two resulting in an expensive connection which may make projects financially unfeasible.

We are transforming our business into a Distribution System Operator[1] to respond to the needs of our customers, both now and in the future, and working with the wider industry to help deliver decarbonisation of the electricity system at the least cost. The Government's Carbon Plan and the Department of Energy & Climate Change (now known as BEIS) Community Energy Strategy report[2] highlight the importance of CHP in achieving the UK's carbon targets. The Mayor of London's target[3] is to generate 25% of London's heat and power requirements locally by 2025. We expect this to encourage CHP and district heating for new developments.

[1] http://futuresmart.ukpowernetworks.co.uk/
[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275163/20140126Community_Energy_Strategy.pdf
[3] https://www.london.gov.uk/what-we-do/planning/london-plan/current-london-plan/london-plan-chapter-five-londons-response/poli-0

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1 Executive summary

This is the first Powerful-CB Successful Delivery Reward Criteria (SDRC) report which outlines the engagement we have had with customers to understand their requirements and showcases some of the key results and learning points that have been made so far in the project. Understanding customer requirements is an important activitity in the project and we have had discussions and feedback from customers and other stakeholders on the FLCB device cost, operation, maintenance, and BAU rollout plans amongst other topics. Method 2 trial participation has been a key engagement point for many customers and these engagement activities have naturally run in conjunction with trial recruitment.

Since the project initiation, we have engaged with customers and other stakeholders at a number of external events, through social media, mailing lists, our Powerful-CB online survey and the launch of a project customer working group. Our key learning points have arisen from data across engagement with multiple customers through survey answers as well as individual conversations. The key areas and learning points which are discussed in detail in the report are shown below:

Powerful-CB has wide scale applicability

FLCB technology is of interest to a wide range of customer types from a geographic spread

Identified customers opinions on benefits and concerns

Customers have expressed a range of potential benefits and concerns relating to Powerful-CB but some key themes emerged relating to finance and technology maturity

Explored potential commercial and logistical arrangements

Future success will depend on appropriate tailoring of commercial and logistical options and arrangements

We have gained valuable feedback from customers and other stakeholders on the merits and challenges of both methods through a variety of engagement activities. We have seen positive engagement and interest from a range of different customers. This report is designed to outline our learning so far from engaging with customers and stakeholders and we will report further in project progress reports and future SDRC reports as the project develops.

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3 Glossary

Term	Description
ADE	Association for Decentralised Energy
BAU	Business As Usual
CB	**Circuit Breaker** – Protection device that interrupts the flow of current in an electric circuit in the event of a fault.
CHP	**Combined Heat and Power** – Simultaneous generation of usable heat and power (usually electricity) in a single process; more efficient than generating heat and power separately.
DG	**Distributed Generation** – Generators that are connected to the distribution network.
DNO	Distribution Network Operator
ENWL	Electricity North West Limited
Fault Current	A surge of energy that flows through the network in the event of a fault. The energy comes from the momentum of rotating generators and motors connected to the network.
Fault Level	The maximum fault current that could theoretically flow during a fault. **"Make"** fault level is the maximum fault current that could flow during the first current peak of the fault, and that a circuit breaker closing onto a fault would need to safely handle. **"Break"** fault level is the maximum fault current that could be flowing 100ms after the start of the fault, and that a circuit breaker clearing the fault would need to be able to interrupt.
Fault Level Headroom	The difference between fault level and fault rating at a particular substation or part of the network; corresponding to the amount of generation that can be connected to the network without exceeding its fault rating.
FCL	**Fault Current Limiter** – a FLMT that attenuates fault current by increasing its impedance (only) during a fault.
FLCB	**Fault Limiting Circuit Breaker** – a FLMT that blocks fault level contributions from a transformer / bus coupler / generator by disconnecting it before the first current peak of the fault.
FLMT	**Fault Level Mitigation Technology** – a technical solution that reduces fault levels on the network.
GB	Great Britain
GLA	The Greater London Authority
Inhibit / Intertrip Scheme	A hard-wired protection system that automatically disconnects generators from the network under pre-defined conditions, typically in the event of a transformer outage or other abnormal network configuration that causes elevated fault levels.
M1	Method 1 - Installation of a FLCB at a substation
M2	Method 2 - Installation of a FLCB at a customer's premises
RIIO-ED1	The current electricity distribution price control, running from 2015 to 2023
Rotating DG	A generator that converts mechanical energy to electrical energy using a synchronous AC rotating alternator, e.g. CHP and diesel standby generators. These types of generators have a much larger impact on fault levels than inverter-connected generators e.g. solar PV.
SDRC	Successful Delivery Reward Criteria
Triad	The Triads are the three half-hour settlement periods with highest system demand between November and February, separated by at least ten clear days. National Grid uses the Triads to determine Transmission Network Use of System charges for customers with half-hour metering.
TRL	Technology Readiness Level
UKPN	UK Power Networks
UPS	Uninterruptible Power Supply
WPD	Western Power Distribution

4 About us

UK Power Networks provides power to a quarter of the UK's population via its electricity distribution networks and is committed to:

- Maintaining a safe, secure and sustainable power supply to over eight million homes and businesses in London, the South East and the East of England;
- Developing what is already Britain's biggest electricity network – including over 112,000 11kV secondary circuit breakers;
- Strengthening our links with the local communities we serve and building on the skills base of the 5,500 people who work for us across the network; and
- Giving our customer the best possible service and maintaining operational efficiency across our network areas.

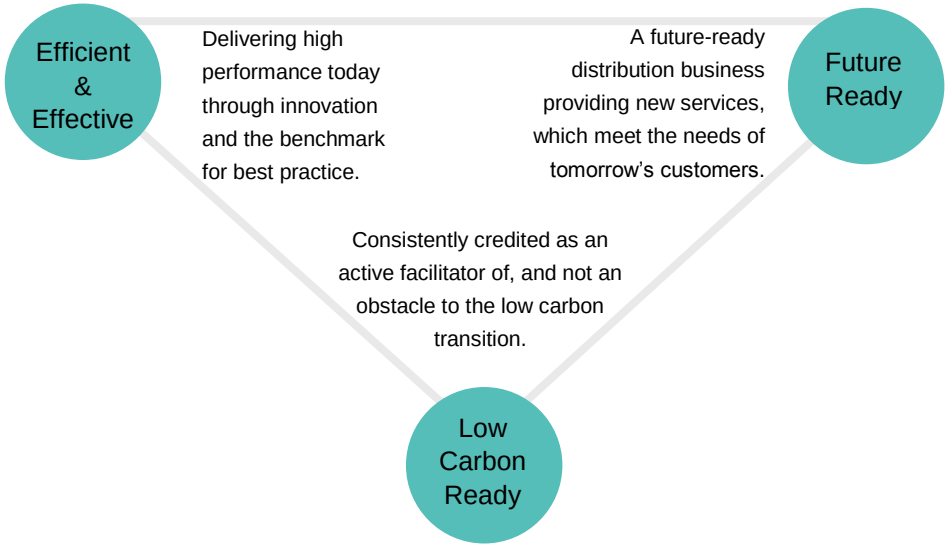
We have a clear vision to be the best performing Distribution Network Operator (DNO) in the UK over the 2015/16 to 2018/19 regulatory period, the first four years of RIIO-ED1. We will achieve this by demonstrating industry leadership in the three areas below:

- The safest
- The best employer

- The most reliable
- The best service
- **The most innovative**
- The most socially responsible

- The lowest cost

Our innovation strategy follows our corporate vision, which underpins our mission and provides clarity of purpose. A key success indicator in delivering our vision is to be classed as the "Most Innovative DNO"; as such it is core to how we do business. A successful innovation programme will support all three elements of our corporate vision; for example innovation is a central component of our strategy continuing to be the lowest cost electricity distributor. Our innovation procedure outlines the objectives of innovation – showing why we innovate.



5 Workstream 3 (WS3) summary

The activities in WS3 are designed to engage with customers and other external stakeholders on matters relating to the Powerful-CB trial and the wider use of FLCBs in the UKPN area and the rest of GB. Specifically, the activities are broken down into two categories, which were explained in the Full Submission Proposal[4] as:

WS3a - Customer dialogue

WS3a is designed to both inform stakeholders of what the two Methods are and what they can technically accomplish for them, as well as gather information on what their criteria would be to assess the suitability of the two Methods if connecting new generation. It aims to gain an insight on the customer requirements and expectations for potentially using either of the two Methods for a new connection. This will be achieved by engaging with relevant customers through focus groups and workshops. Our approach will be to target specifically those people most likely to connect new CHP generation and also those generation customers who see connections costs as a primary barrier to new connections. The result will be an open dialogue with customers to understand their decision parameters. These may include space, cost/security trade-off, etc.

Additionally, through our relationship with the Greater London Authority we will seek to better understand CHP and district heating use cases for both Methods, considering the needs of councils and developers. The user requirements and expectations will inform the work in WS3b.

The technical requirements will be based on the results from WS1 and WS2. These requirements define the constraints which are inevitable with the technology. The customer expectations for how the technologies will work best for their needs will be gained through customer dialogue in WS3a, from feedback from the trial participant, and from reviewing other similar projects like ENWL's Respond project's customer survey[5]. The information gathering will be designed with the purpose of demonstrating the commercial feasibility of the FLCB technology. This may include cost benefit analysis of the FLCBs technology, market size and receptiveness.

WS3b - Suitability assessment

Once we have learned what customer needs are for using the two different Methods, we will conduct a desktop based exercise to match these expectations against technical constraints and variations. We will then combine those requirements against how the devices best meet customer needs from WS3a to develop the inputs which customers can use for their own individual commercial business cases. Specifically, the assessment will explore the trade-offs between different needs and technical constraints. The results and learning will be captured in the 'Learning Report – suitability assessment' report, presenting the assessment of the suitability of the different trialled solutions. This will be based on the measured technical performance and identified customers' needs. The end result will present information DG customers can use as part of potential business cases to support investment in DG.

[4] https://www.ofgem.gov.uk/system/files/docs/2016/11/powerful-cb_nic_fsp_resubmission_2016-10-20-1700_non-confidential.pdf
[5] http://www.enwl.co.uk/docs/default-source/respond-key-documents/respond-customer-report-may-2017.pdf?sfvrsn=4

6 Stakeholder engagement

Stakeholder engagement and learning dissemination activities are key to the successful delivery of Innovation projects. Below are our four stages to successful engagement.

1. Identify stakeholders	2. Assess interest	3. Develop plan	4. Engage

• Customers
• Project sponsors
• Suppliers
• DNOs
	• Collaborate
	• Consult
	• Inform
		• Clear direction
		• Identify methods of communication
		• Frequency of communications
			• Listen "you said"
			• Deliver
			  ○ We did
			  ○ We will do

Appendix 11.1, 11.2, 11.3 & 11.4	Appendix 11.5	Appendix 11.1	Appendix 11.2, 11.3, 11.4, 11.5 & 11.6

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7 Our engagement timeline

Jan-17

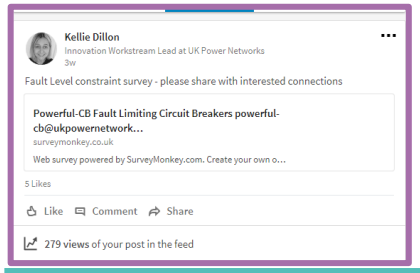
Network external online

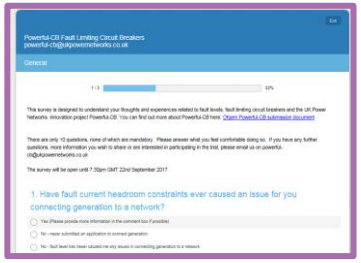
Feb-17

We were keen to spread the word with our well-established DG mailing list in addition to releasing a news article. The platform for our initial face-to-face communication was the bi-annual DG customer forum. This event identified a potential trial participant and detailed customer dialogue then commenced. See Appendix 11.2

Attended ENWL RESPOND learning event and WPD FlexDGrid final dissemination event.
Peer learning was an important aspect and we attended two DNO events; concerns around Triad revenue for existing customers were identified by ENWL and this encouraged us to ask the 'right questions' early on.

Jul-17





Emailed to the DG mailing list (circa 780 stakeholders)

SurveyMonkey published

We collated an FAQ document (see Appendix 11.8). It is understandable and expected that many of the queries and much of the interest lay in the commercial arrangements of the technology and its applications on the electricity distribution networks.

In order for customers to engage without a face-to-face meeting and to provide the ability for anonymity, the project team launched the Powerful-CB survey, which we circulated to customers and other stakeholders through a range of internal and external mailing lists, social media outlets and via direct conversation. The survey asked nine simple questions, none of which were mandatory. The aim of the survey was to assess customer interest in and the understanding of the project, the technology and the trial. See Appendix 11.4

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77% of attendees rated the topic 'very useful'

DG customer forum

Returning to the DG customer forum in July provided us with an opportunity to engage further with this community. We explained the problem some customers are facing and the methods we wish to trial. Referring to the feedback provided at the event, 77% of the audience rated the topic as "very useful" and we followed up with 16 customers who asked to be kept informed about the project. Arranging surgeries to provide customers with the opportunity to discuss their requirements and concerns proved worthwhile. To date 10 customers have met with us to discuss their experiences and nine potential sites have been identified to trial M2. See Appendix 11.3

Our first customer working group was held Wednesday 6 September 2017. Seven stakeholders from a variety of backgrounds joined us. Our presentation covered previous fault level limiting technologies tried and tested, how our London 11kV network operates, the current mitigation solutions offered, what power electronics are and the terms of reference for the group.
Many customers who we have engaged with, from the initial DG Customer Forum in February through to the working group, have shown interest in the technology once maturity levels have increased and the technology can be used in a BAU situation.

Next event Mar-18

Sept-17

See next steps section 9.2

8 Key learning

Engaging with customers has been a vital aspect of this project to date. In addition to finding a customer site for the M2 trial, it is important to the ongoing success of the technology and the trial, that customer requirements and needs are discussed and shared in the early stages of prototyping. In order to achieve this, we have undertaken a number of different customer engagement activities in order to engage with a wide range of customers, but also to talk more in depth with stakeholders who expressed a particular interest. The learning which we have gained from customer engagement to date has been insightful and this section discusses our key learning points.

We have showcased a sample of the data as evidence for these learning points, sourced from our customer survey, surgeries, DG customer forum presentations and Powerful-CB customer working group. A full set of data from these sources, including a breakdown of customer surgery attendance by customer type and a full survey response dataset can be found in our Appendices.

General Feedback

CHEAPER, QUICKER connections were the major incentives

Survey result

77% of those who attended the DG customer forum Jul-17 rated the project 'very useful'

DG customer forum Jul-17

"UKPN have taken a positive pro-active approach to this serious problem. The results should assist the growth of DG on the congested GB distribution network."

Powerful-CB customer working group Sept-17

"There are a few [site] options, within the broader GB area, where I know fault level has been an issue."

Customer surgery

23% of survey respondents said fault level constraints were the most important issue on the networks at present

Survey result

79% of survey respondents said finance was a concern

Survey result

"This project is extremely interesting, in that it offers solutions to a growing problem within the UK electricity networks."

Powerful-CB customer working group Sept-17

86% of survey respondents said fault level constraints had caused issues in them connecting to the network

Survey result

NUISANCE TRIPPING was listed as the second top concern of survey respondents

Survey result

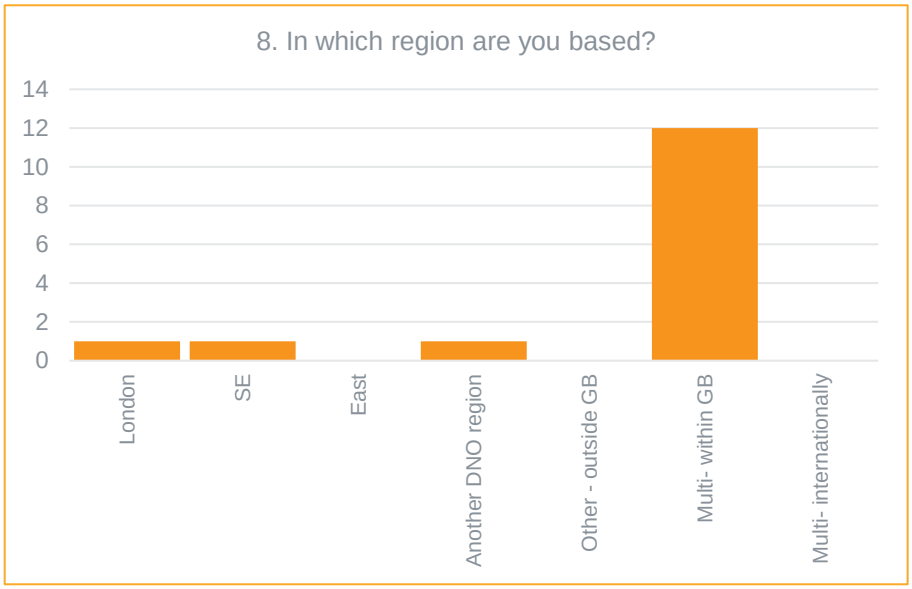
"I think it is really positive, that you realise, you can have a wonderful technical solution, but it's really "hearts and minds" with the customer to ensure that they're on board, and they understand, what it is you are providing and where the benefits to them are, because quite often you can stumble on that point!"

Customer surgery

8.1 Powerful-CB has wide scale applicability

Key Learning Point: FLCB technology is of interest to a wide range of customer types from a geographic spread

Response to the engagement activities has been positive, with strong interest in the project. 86% of survey respondents have previously encountered issues with fault level. 23% of customers shared their opinion that fault level constraints were the most important network issue at present, as well as 62% answering that it was an issue equal to others the network is currently facing. This is encouraging, indicating that there may be many applications of the technology once the project concludes. It solidifies the justification of the project and shows there is a need to tackle fault level constraints using new technology.



It has been particularly notable that many customers were interested in the wider application of this technology, beyond the London network and even beyond the UK Power Networks' licensee areas. This encouraging customer feedback will mean that engagement with other DNOs throughout the project will be vital to see the future success of the technology in the rest of the country. For our project, it means that engagement beyond our networks' boundaries will be important for future dissemination events.

In addition to this, we have had the opportunity to discuss this project with a number of customers who own or operate inverter-fed generation and storage, both at events and at customer surgeries. While these generation types are generally not seen to contribute significantly to fault levels, the interest from these generators in FLCB technology shows that fault level constraints are beginning to be of concern to a range of customer types.

> "Fault level headroom is frequently a problem for our energy storage sites, and we have been looking at devices to reduce our fault contribution."
>
> *Customer email*

Inverter-fed generators contribute significantly less to fault level than synchronous generators. This means that if an inverter-fed generator is unable to connect because of fault level issues, it is because there is zero fault level headroom, hence they can only connect if they can reduce their fault level contribution to zero. For customers wishing to use fault limiting technology to enable their network connection in these cases, an FLCB is the only device that can achieve the 100% reduction in fault contribution that is required.

We will continue to engage with the wide customer base throughout the project, through the customer working group and other external events to continue to gain insight to the applicability of FLCB devices beyond the Powerful-CB trial.

8.2 Identified customers opinions on benefits and concerns

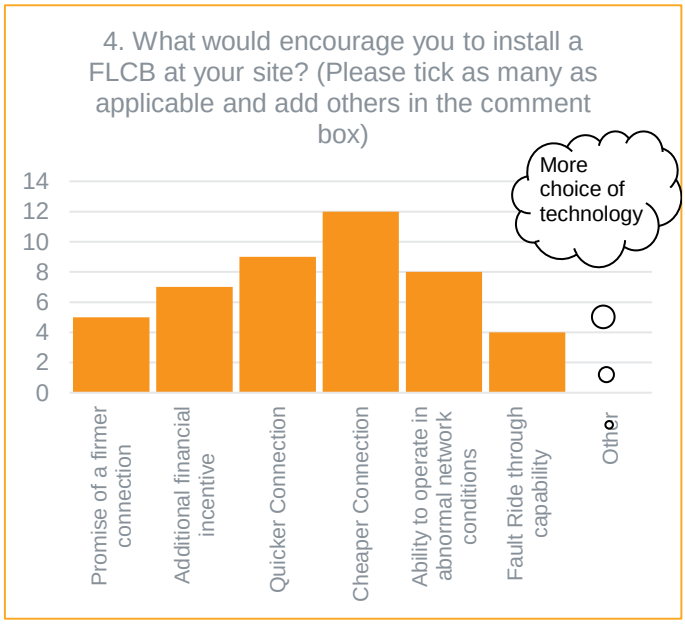
Key Learning Point: Customers have expressed a range of potential preferences and business drivers relating to Powerful-CB but some key themes emerged relating to finance and technology maturity

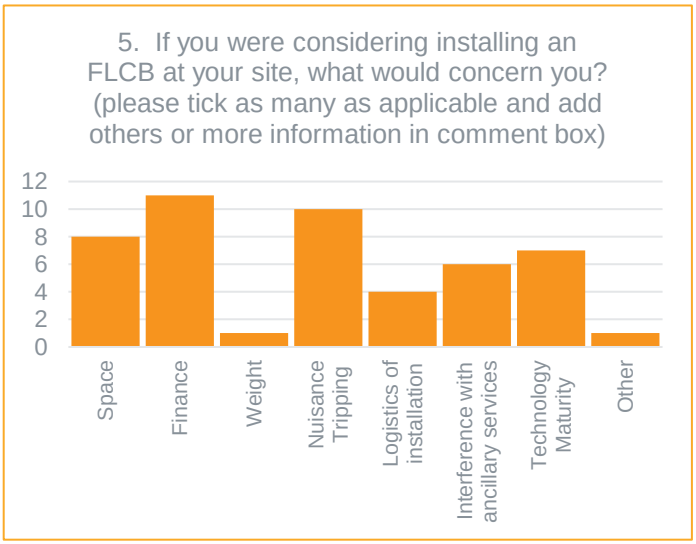
One of the key aims of customer engagement activities to date has been to understand customers' views on potential benefits and concerns relating to trial participation and the wider use of FLCB technology.

> "The fault limiting idea is something I've had an interest in for some time now. It has always appeared too costly especially for larger generators."
>
> *Customer email*

> "If it allows connection in areas we could not do before, then £300k [projected cost for Method 2] is fine"
>
> *Powerful-CB customer working group feedback*

Feedback and data on this theme has reflected customer interests surrounding costs and connection offers; survey results have shown that cheaper and quicker connections are the key drivers in terms of expected benefits. While this is not surprising, the fact that only 36% of customers showed firmer connections being a driver is linked to the wide interest discussed in the previous section.





> "How will the [cost] change over time? Will the cost vary depending on [generator] size?"
>
> *Powerful-CB customer working group feedback*

In terms of technology concerns, finance is rated as the greatest concern, as 79% of respondents listed this in their survey answer. A close second, nuisance tripping at 77% shows operational concerns which are discussed further in the below section.

Our project attracted interest from customers in other DNO regions and we were pleased to hear the solution already has an appetite for deployment outside of our area.

> "Fault levels are also a large issue in other DNO regions, we are curious as to if this might help us in the future."
>
> *Customer email*

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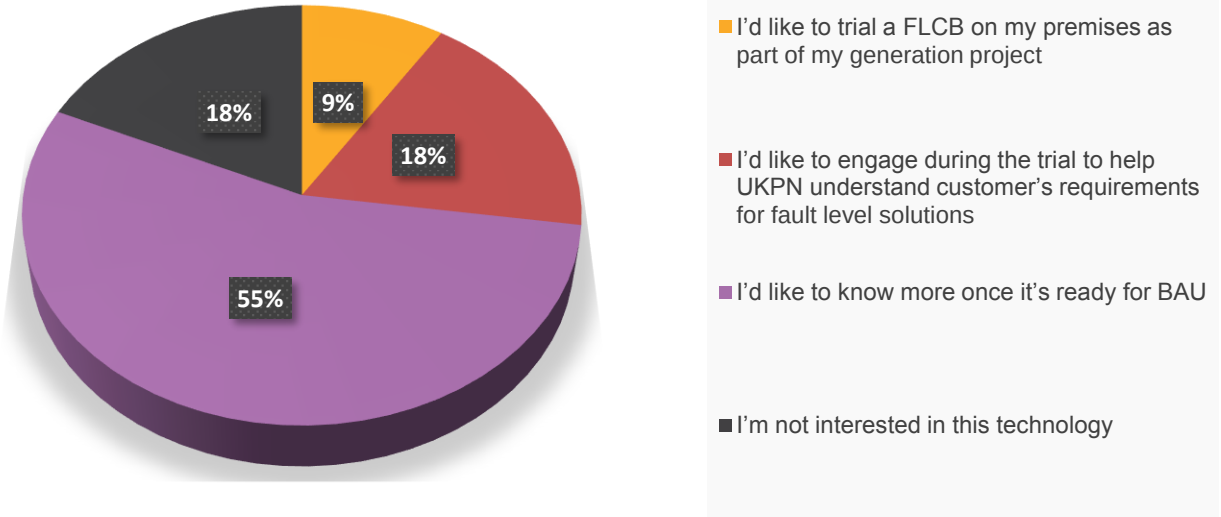
As noted in the survey responses, interaction with ancillary services is a concern for a number of customers. When discussing this in more detail during customer surgeries, it has been interesting to listen to different customer views on this matter – with some accepting interactions with ancillary service contracts as an acceptable part of their risk profile. This potential area of concern is one we would like to address further with customers at a future customer working group event.

"We are used to living in a world of planned and unplanned outages... For us, adding more capacity is worth small additional risk"

Customer surgery

How are you able to help?



From initial engagement, it has been encouraging that customers who do not have a suitable trial site would still be interested in engaging further with the project and technology as the technology progresses upwards along the TRL scale and into BAU applications. This evidence continued into survey results where 21% respondents showed they would be interested once the FLCB technology is BAU and 37% were interested in engaging with UKPN throughout the trial on defining requirements.

Throughout surgeries with customers, it has been useful to explore customer concerns surrounding technology operations further. Discussions surrounding the device operation have often alleviated customer concerns, and have allowed us to determine where future effort is required in communications and project awareness. A concern around the environmental conditions for the M2 device to be situated in, for example in a boiler room, will be addressed in a future design meeting.

Question: Will the FLCB disconnect the generator or does it just provide an enhanced level of monitoring and control to shut off any faults should it occur at time of network abnormalities?

Customer surgery

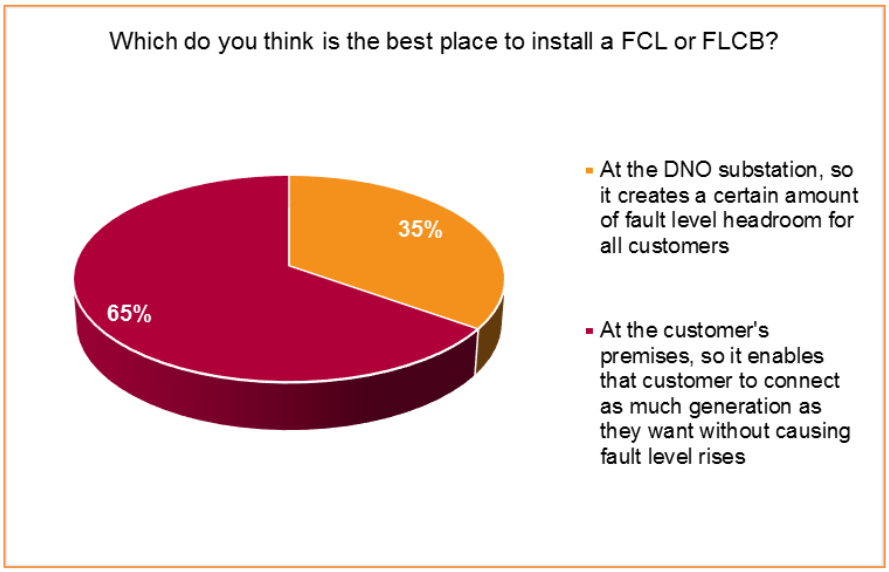
Answer: The idea is that it disconnects really quickly, so it does not actually contribute to fault level, so rather than trip you when we are running abnormally, we would allow you to continue operating until we actually get a fault. Under these conditions, your generator is tripped, before you can contribute current to the fault.

Customer surgery

8.3 Explored potential commercial and logistical arrangements

Key Learning Point: Future success will depend on appropriate commercial and logistical options and arrangements

Customers have been keen to discuss the connection offer and agreement arrangements for sites using M2 FLCB devices.



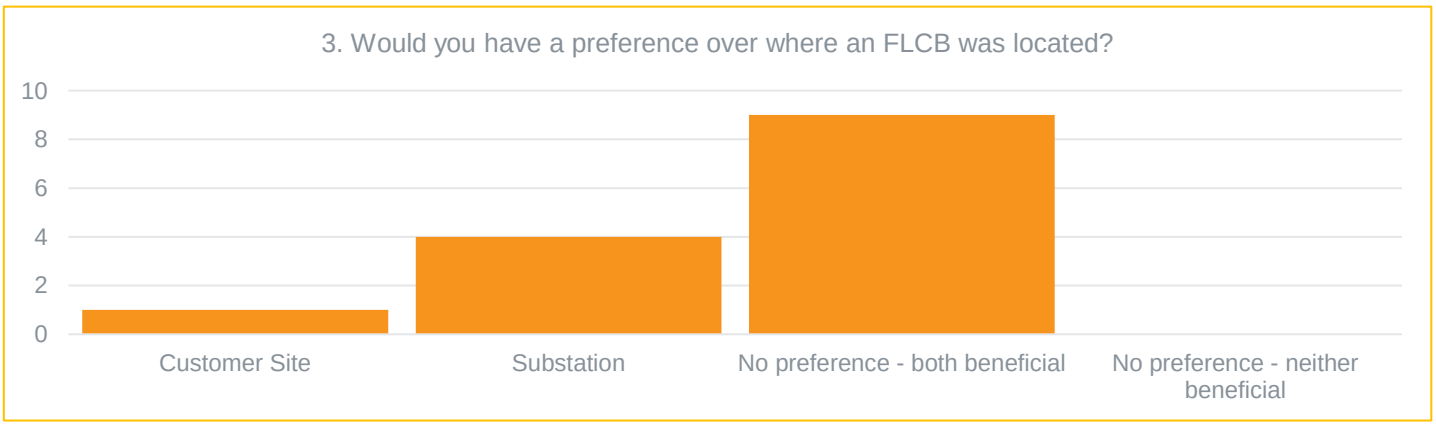
Customers' opinions on the differing benefits of the two methods has been a focus area of engagement activities. Our initial interaction with customers at the DG Customer Forum in February 2017 showed that the majority of customers favoured the M2 customer located solution. The survey results show that the majority of respondents see benefits in both M1 and M2. These differing results could have a number of influencing factors including more answer options (the ability to answer 'both' in the survey) and more understanding of the M1 substation solution.

"I have seen it happen before, it all goes swimmingly and then there is different perceptions of responsibilities for the asset, who owns it and what happens if it breaks. It would be good to get [those issues] out of the way now."

Customer surgery

"From my perspective … as an end user or developer, I am interested in the customer version [M2]"

Customer surgery



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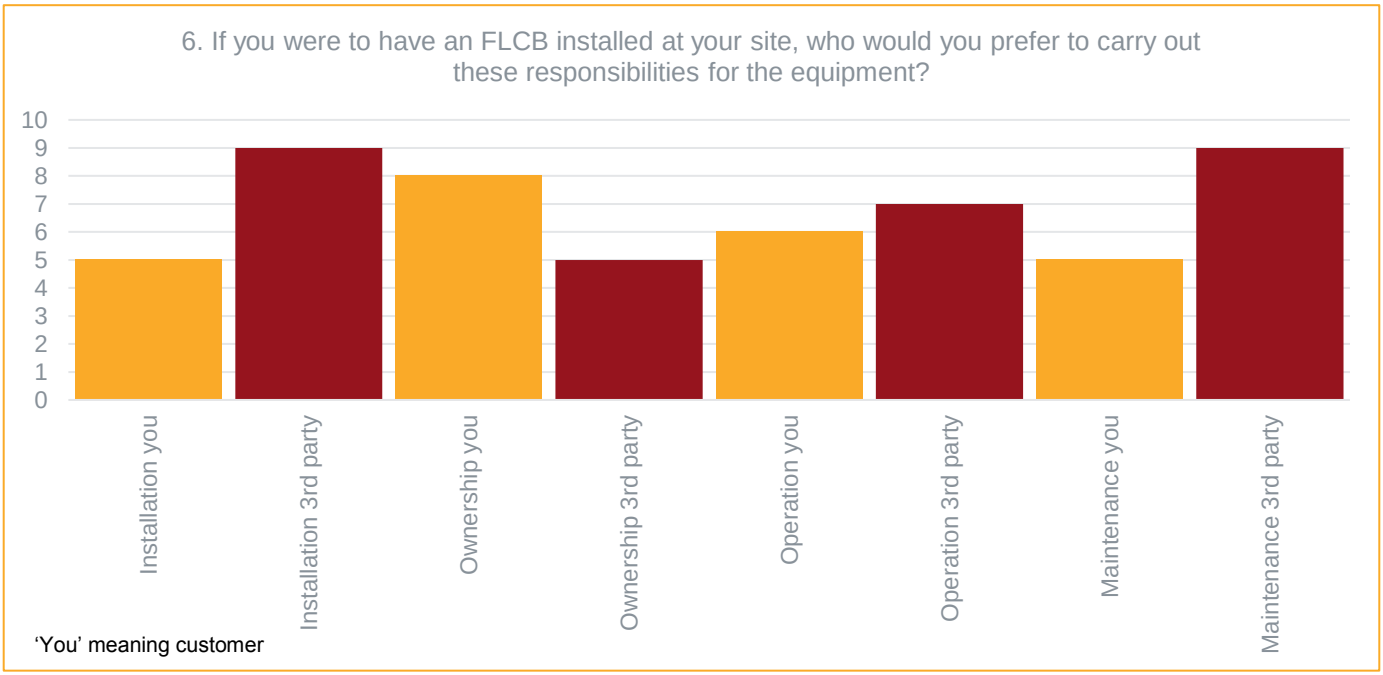
Discussions surrounding connection offers and connection agreements have been prevalent in engagement activities. Although the initial target customer base for M2 trial participation consisted of customers on inhibit connection agreements, it has been promising to hear from a number of customers to whom this criteria does not apply. In fact, many of the customers who have come forward with potential trial sites are not on such a connection agreement and only 36% of survey respondents indicated that a firmer connection would be an incentive of interest. Instead, many customers operate sites where existing generation is connected but there is a desire to increase the export capacity in the coming years, and they may not be able to due to fault level. The exact nature of connection offers for sites with FLCB devices installed will be a focus area of work when engaging with customers and internal stakeholders as the project progresses.

> "From a financial point of view, you want to know how often your generator will be switched off; no one will lend money if the business case does not stack up!"
>
> *Powerful-CB customer working group*

> "I would expect the installation works to be a contestable element [of the connection offer]"
>
> *Powerful-CB customer working group*

Survey answers surrounding the installation/ownership/operation/maintenance responsibilities were diverse – there was no clear preference amongst survey respondents and this continues to provide varying preferences as we continue further discussions with customers. This is certainly an area that will need more focus moving forwards, particularly when looking beyond the trial site. Decisions into the offerings made to customers will be vital in ensuring successful uptake of the FLCB technology.



9 Challenges, mitigations and next steps

The financial considerations around the installation and operation of FLCB devices and the connection agreement that follows is of particular interest to the project team moving forwards.

9.1 Challenges and mitigation methods

When discussing the needs of customers in relation to the trial, the project team have aimed to ensure participation from a wide stakeholder group. In order to achieve this, we have identified a number of potential challenges that could prevent achieving wider stakeholder engagement and accordingly a number of methods to mitigate the potential impact of these challenges.

Potential Challenge	Mitigation Methods
Customers have engaged with us more about M2 than M1	- Our survey asks questions relating to both methods - We plan to hold a customer working group focusing on M1 in the future - We engaged with a number of customers, not only those interested in participating in the trial
The customers who engage are not representative of the wider generator community	- By making use of existing internal communication channels such as the DG customer forums, DG customer mailing list, we engaged with a number of different customer types - By making use of external communication channels through our connections with the Association of Decentralised Energy
Customers may not want to engage face to face	- By publishing a SurveyMonkey which allowed anonymity - By providing paper copies of the survey for people to complete and return offline
Customers only want to engage through channels they already know	- By working with the relevant UKPN connections teams to engage with customers - Having members of the connections teams present during customer surgeries
Reduced interest from customers due to capacity range of device	- Ensuring conversation with customers is open to both M1 and M2 devices to widen the interest and participation - Capturing future requirements for product evolution

Throughout the remainder of the trial, we will continue to manage these challenges as well as update with new challenges that we become aware of. We will publish these in our project progress reports.

9.2 Next steps

The work in understanding customer needs will continue and develop as the trial moves forward. We will continue to engage with customers and other stakeholders on this topic and continue to report on learnings through project progress reports. To date, our activities in understanding customer needs have given us a good overview and introduction to the key requirements and concerns of customers.

Our next steps will be to dig deeper into the areas that interest stakeholders, in particular surrounding the financial aspects of the technology and its application on our electricity networks. We will review customers' technical questions and concerns with our technology partners and aim to modify the design where possible, to best meet customers' decision parameters.

Those who attended the customer working group event held 6 September 2017 were engaged and willing to interact in an open forum to discuss their concerns. We plan to run further customer working group events with invited guest speakers from a number of organisations, including a site visit of the trial sites at a later point during the project.

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The range of customer engagement activities and approach has enabled breadth and depth in discussion, and we will continue with this approach as we move forwards in the project. The activities currently planned are outlined below:

Planned Activity	Description	Indicative dates/milestones
Further customer working groups	- Plan a schedule of future working group events - Engage with external speakers on relevant topics	- Target March 2018 for next working group to include details on trial participants
Public Seminar/Webinar	- Plan a schedule of learning events	- Target summer 2018 for dissemination of trial learning to far
Further Customer Surgeries	- Continue to engage with customers who are interested in becoming trial participants	- Site Selection to be carried out in November 2017
Draft Trial Contract / Connection Agreement	- Contract negotiation also allows for commercial arrangements to be open to discussion for the BAU case	- Internal stakeholder engagement required

10 Conclusion

This first Powerful-CB SDRC report has showcased our learning so far in the task of understanding customer needs of the Powerful-CB methods – an area where the project team have made good progress to date. A number of formal customer engagement activities have taken place which have led to a better understanding of customer requirements and a greater awareness of the project amongst potential M2 trial participants. Customer and wider stakeholder engagement has been positive, with a wide range of different stakeholders expressing interest in the technology even if they are not eligible to be trial participants for M2. This interest shows good promise in transitioning the technology from innovation trial to BAU.

We will continue to refine our understanding of customers' requirements as the project progresses. Customer engagement so far has identified a number of areas that require further focus and attention, in particular surrounding the commercial aspect of the technology, not just capital expenditure but connection agreements for future projects using the technology in both methods. A number of other activities will attract focus in WS3 moving forwards, noticeably engagement with other DNOs and better understanding of CHP and district heating applications through interactions with the ADE and the GLA. WS3 activities will continue to be reported in project progress reports and future SDRCs.

In summary, the aims of WS3 and how and when they will be evidenced is shown in the below table:

Workstream 3 Aim	Evidence	Where evidence is found
Inform stakeholders of what the two methods are and what they can technically accomplish for them	- Engagement activities - Slide deck used in customer working group	- Appendix 11.2 & 11.3 - Appendix 11.6
Gather information on customer requirements and criteria for assessing the suitability of the two methods	- Answers to survey questions - Data from customer surgeries	- Appendix 11.4 - Appendix 11.5
Better understand the CHP and district heating use case for both methods	Engagement with: - ADE - GLA membership	- Appendix 11.7 - Introduction meeting 30 November 2016, participation in customer working group 6 September 2017. Follow up meeting to be arranged
Gather insight on the customer expectations for how the technologies will work best for their needs	- Answers to survey questions - Data from customer surgeries	- Appendix 11.4 - Appendix 11.5
Explore trade-offs between different needs and technical constraints	- Discussions at customer working group	- Appendix 11.6
Delivery of the agreed number of engagement activities with customers	- Customer engagement overview	- Section 8

11 Appendix

11.1 Stakeholder engagement summary

Our plan captures whom we have engaged with, their interest level and if they wished to collaborate, to consult or if they wish to be kept informed about the project.

Internal stakeholders include our Major Connections teams, Distribution Planners and Service Development team. We have attended two other DNO dissemination events (WPD FlexDGrid and ENWL RESPOND).

55 stakeholders, covering developers, installers, consultants, independent connection providers, government, associations and universities have engaged with us, with the following roles:

- Collaborate 17;
- Consult 8; and
- Inform 30.

Communication channels we have used include, the DG customer forums, SurveyMonkey, LinkedIn, EventBrite and the ADE.

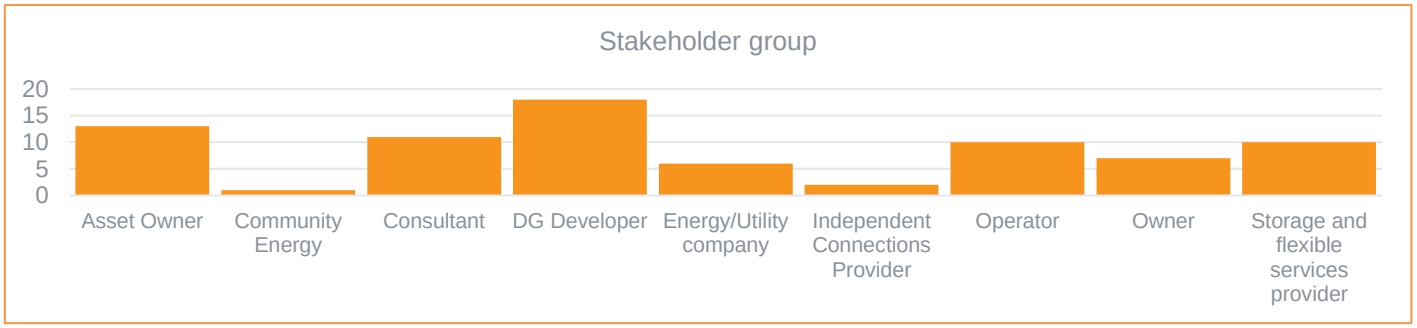
We have also shared details of our project with the DG mailing list. This distribution list is managed by our Service Development team and incorporates over 700 stakeholders subscribed to receive information related to DG.

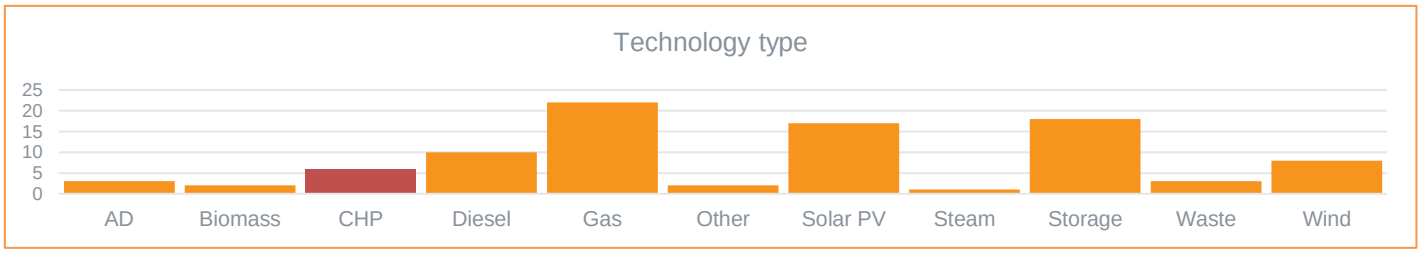
We will be presenting at The Low Carbon Networks & Innovation conference 6 December 2017. This event will provide us with the opportunity to further disseminate the project's learning to date.

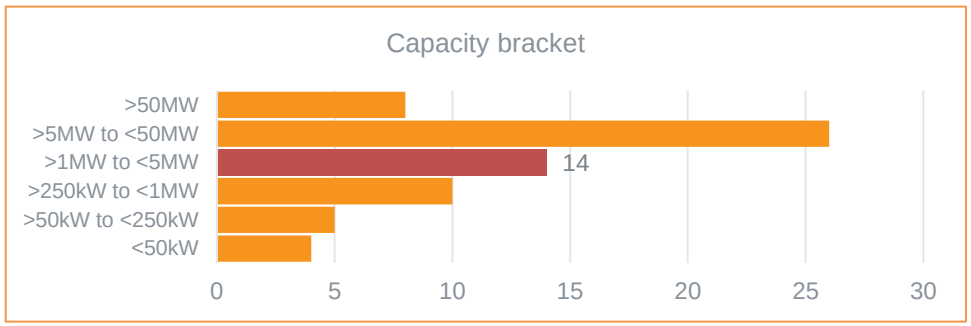
11.2 DG customer forum 9 February 2017

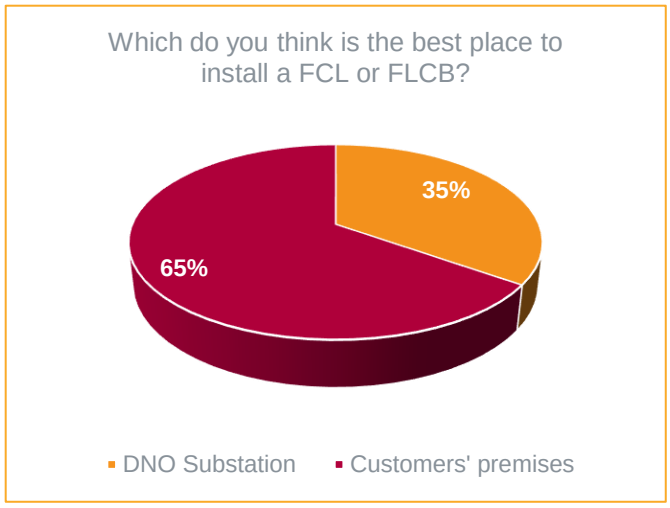
The DG customer forum is a UKPN event held bi-annually, to provide our DG stakeholders the opportunity to give their feedback on our service, consult on our processes and procedures, hear our plans and help us to develop future initiatives. The event was open to all, which means the audience was diverse covering asset owners, connection providers, consultants, community energy groups, developers, local authorities and utility companies.

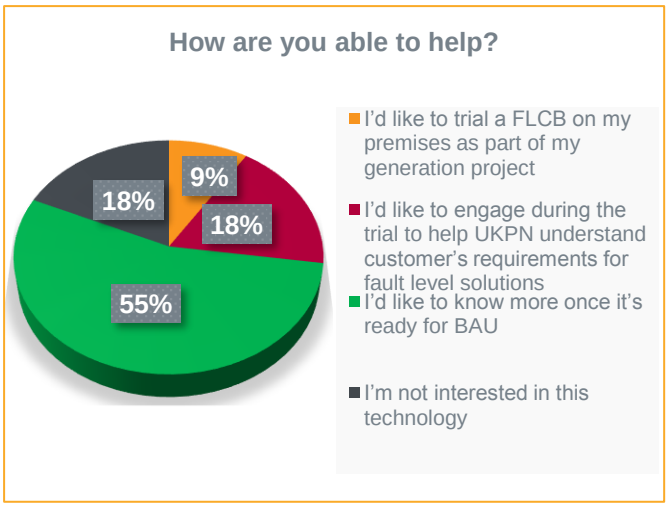
We utilised this event[6] to assess the interest of the project and to help identify potential trial participants.





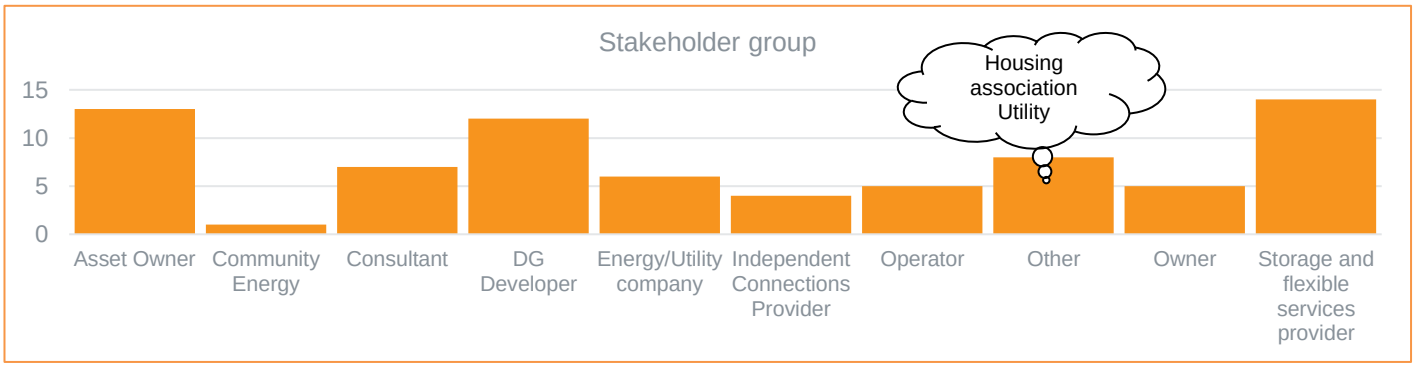


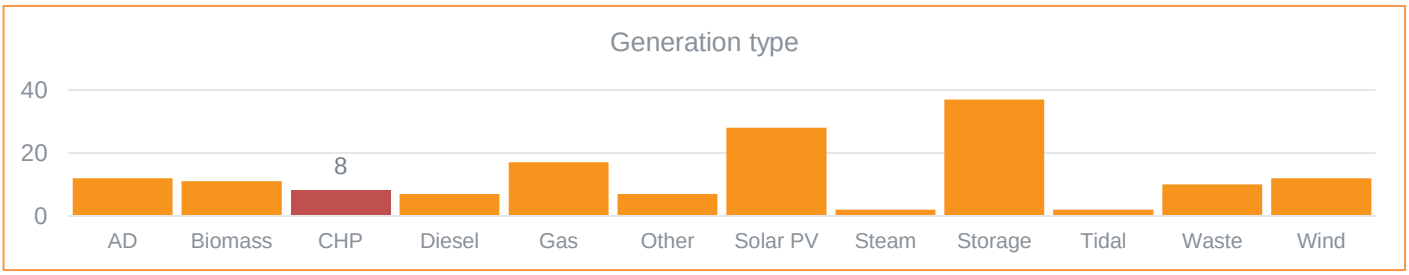


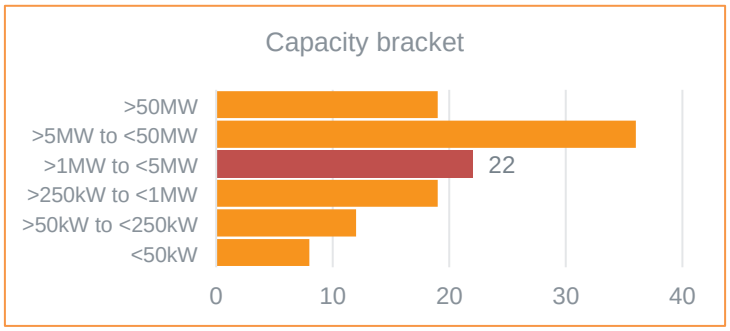


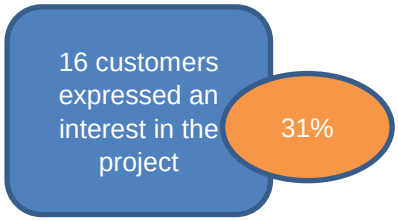
[6] http://www.ukpowernetworks.co.uk/internet/en/our-services/documents/DG_customer_forum_presentation_9_February_2017.pdf

11.3 DG customer forum 18 July 2017





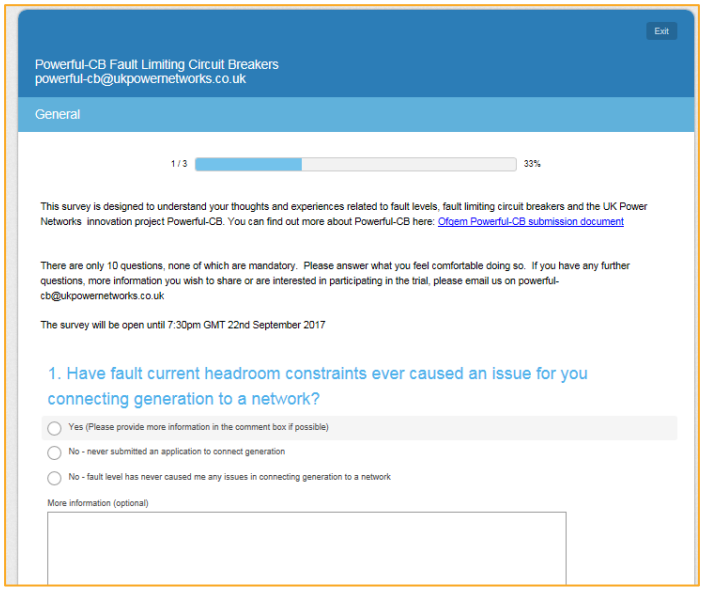




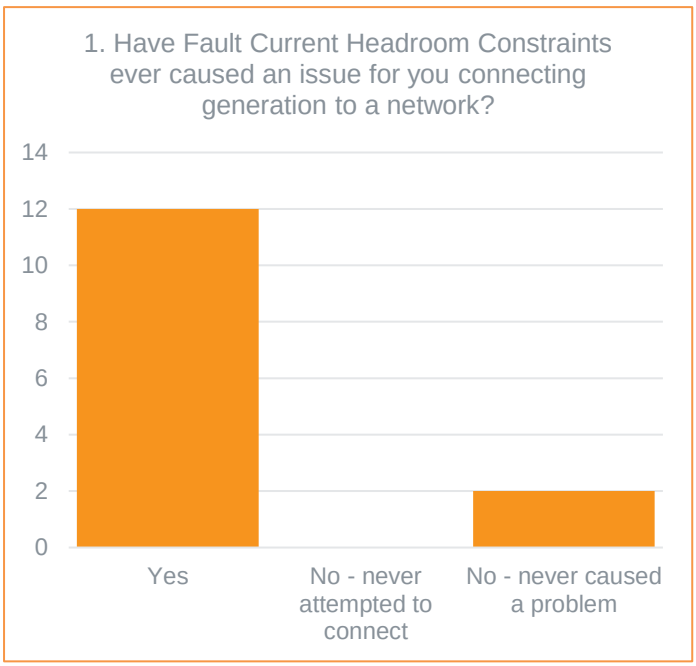
Customers who showed particular interest through any other engagement activity were invited to participate in an individual customer surgery with the Powerful-CB team, to discuss any particular interest or concern further. These surgeries have been predominantly used to discuss potential trial sites for M2 with 8 surgeries resulting in 9 potential trial sites being identified. A number of relevant thoughts and comments have been raised and noted by the project team.

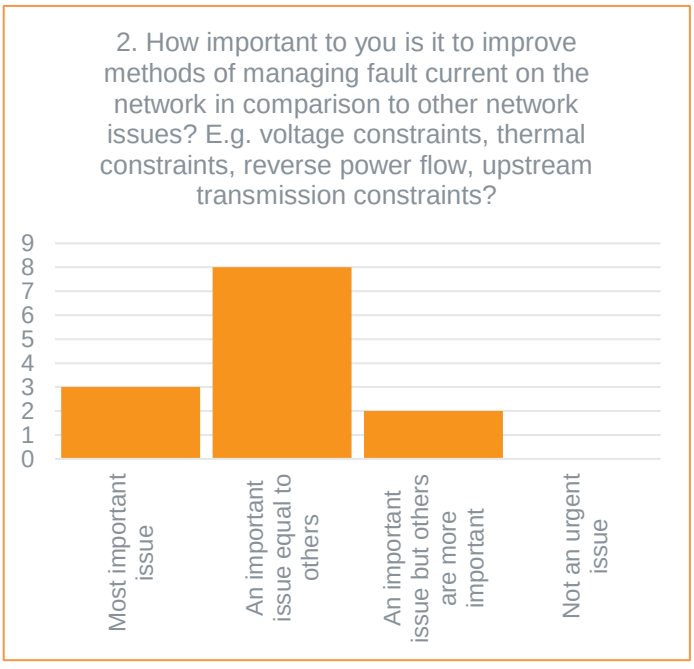
11.4 Powerful-CB survey

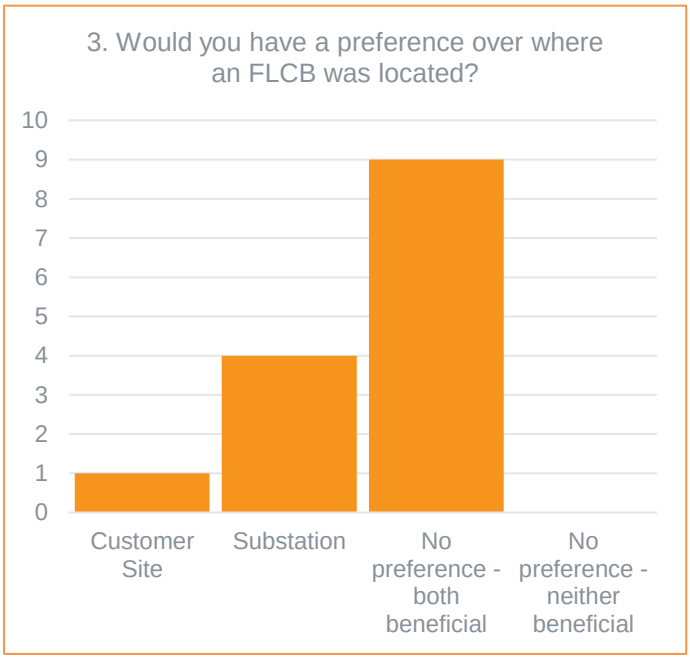
The survey questions and answers are found in the following pages:

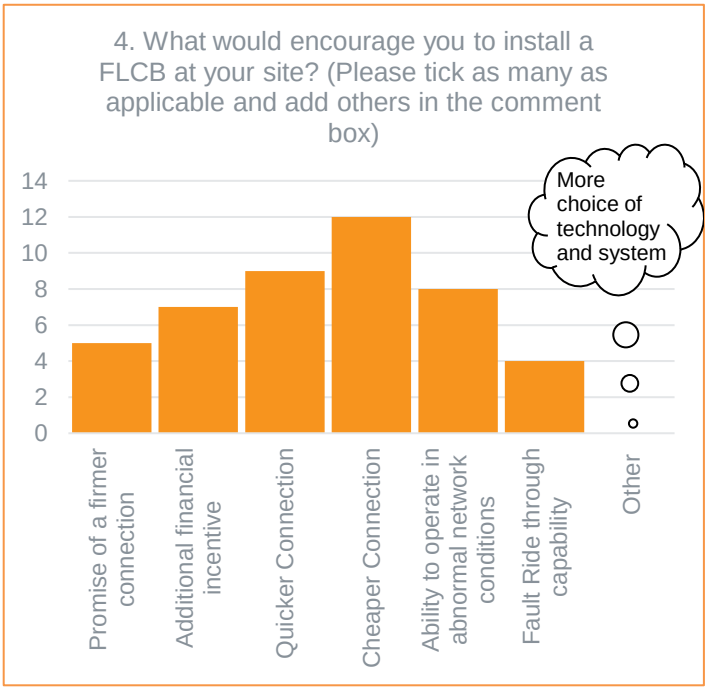


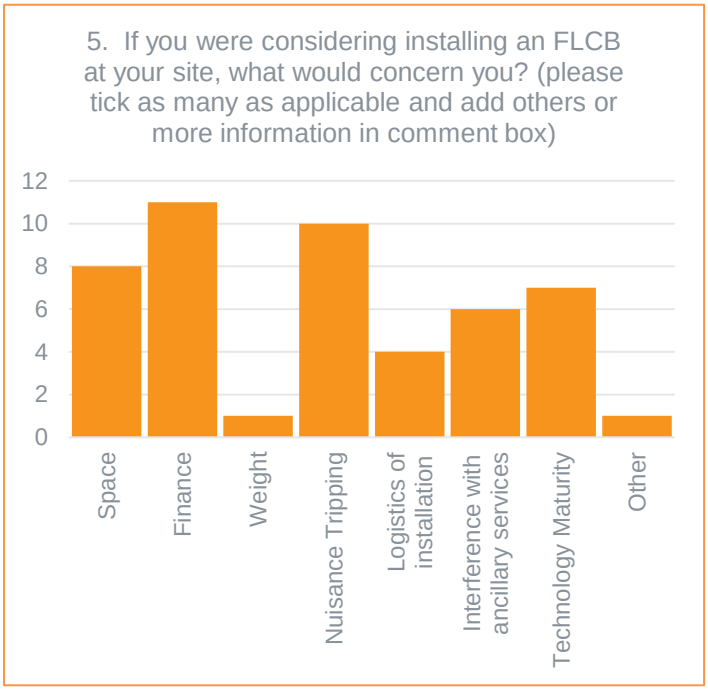
Screen shot of online survey

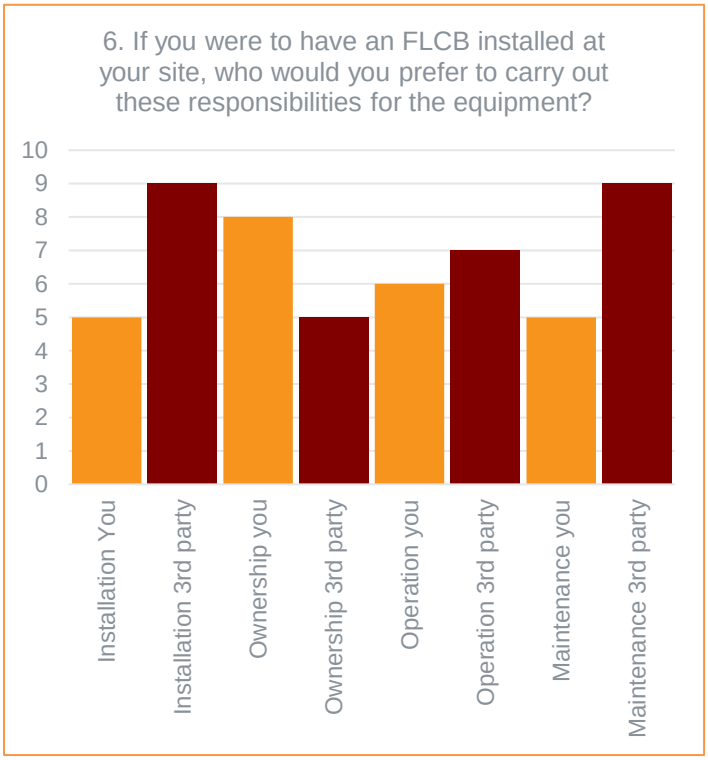


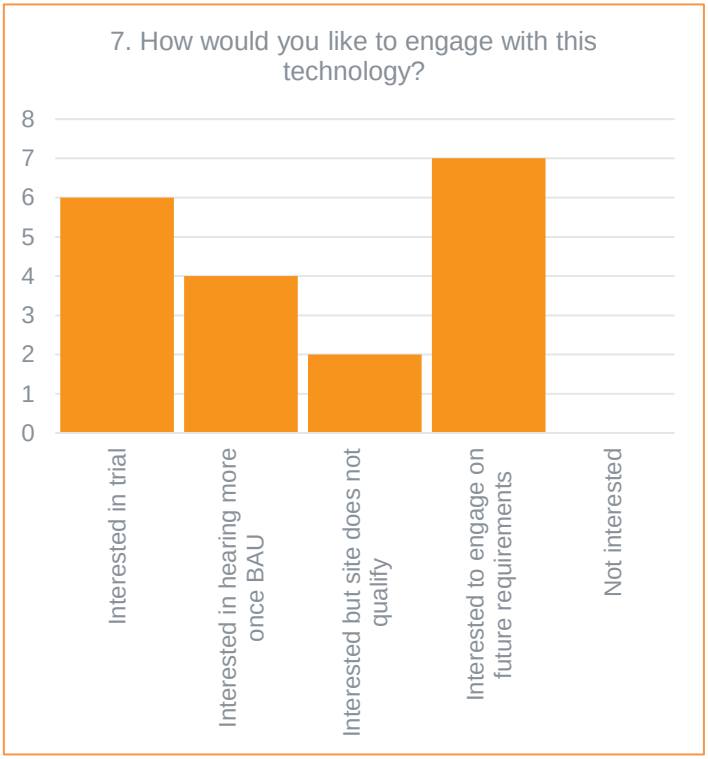


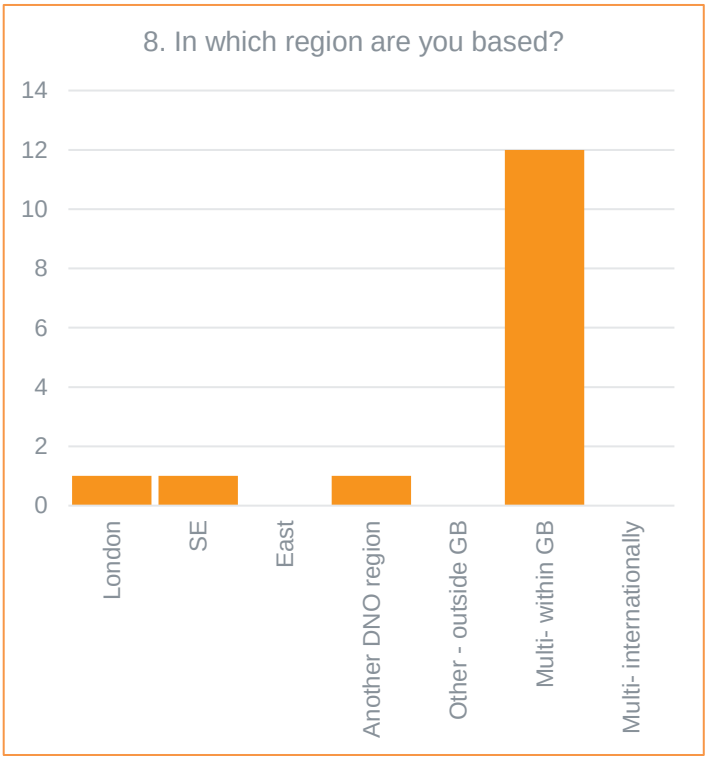


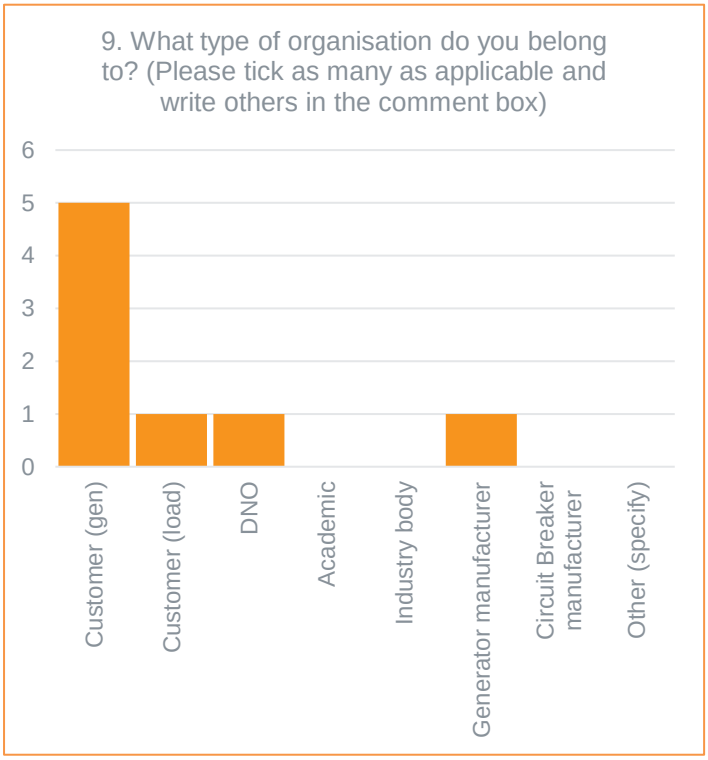

4. What would encourage you to install a FLCB at your site? (Please tick as many as applicable and add others in the comment box)
14
12
10
8
6
4
2
0
More choice of technology and system
Promise of a firmer connection
Additional financial incentive
Quicker Connection
Cheaper Connection
Ability to operate in abnormal network conditions
Fault Ride through capability
Other


5. If you were considering installing an FLCB at your site, what would concern you? (please tick as many as applicable and add others or more information in comment box)
12
10
8
6
4
2
0
Space
Finance
Weight
Nuisance Tripping
Logistics of installation
Interference with ancillary services
Technology Maturity
Other


6. If you were to have an FLCB installed at your site, who would you prefer to carry out these responsibilities for the equipment?
10
9
8
7
6
5
4
3
2
1
0
Installation You
Installation 3rd party
Ownership you
Ownership 3rd party
Operation you
Operation 3rd party
Maintenance you
Maintenance 3rd party


7. How would you like to engage with this technology?
8
7
6
5
4
3
2
1
0
Interested in trial
Interested in hearing more once BAU
Interested but site does not qualify
Interested to engage on future requirements
Not interested


8. In which region are you based?
14
12
10
8
6
4
2
0
London
SE
East
Another DNO region
Other - outside GB
Multi- within GB
Multi- internationally


9. What type of organisation do you belong to? (Please tick as many as applicable and write others in the comment box)
6
5
4
3
2
1
0
Customer (gen)
Customer (load)
DNO
Academic
Industry body
Generator manufacturer
Circuit Breaker manufacturer
Other (specify)

11.5 Customer surgeries

We followed up with interested stakeholders by inviting them to join us either by Skype call or in person to a customer surgery. The surgeries were hosted by, the Project Lead, Workstream Lead and a Distribution Planning Engineer. By having the right people in the room, we were able to answer questions and alleviate some concerns as well as capture issues that need addressing. The quotes and comments from these surgeries are provided throughout the document.

Surgery Breakdown:

Surgery	Customer Type (e.g. generator, consultant)	Potential M2 trial site identified? (Y/N)
1	Manufacturer and Energy Management Advisor	Yes
2	Consultant	Yes
3	Provider	Yes
4	Consultant	Yes
5	Consumer	Yes
6	Industry body	No
7	Energy Development Company	Yes
8	Facilities Manager	Yes

11.6 Customer working group 6 September 2017

Invitation shared with:

- DG mailing list (782 stakeholders); and
- Kellie Dillon's (Innovation Workstream Lead 3 & 4) LinkedIn connections (circa 400).

Eventbrite:

- 204 views of invitation; and
- 7 attendees.

Feedback questions	Satisfaction
The location & facilities were accessible & satisfactory	86%
The forum was appropriate for my job role	92%
The information coverage was relevant & necessary	94%
The facilitator(s) responded to questions in an information & satisfactory manner	96%
I felt engaged throughout the workshop	90%
The facilitator(s) encouraged healthy & effective discussions	94%
Overall I felt the session was productive and valuable	94%
Would you be interested in attending future customer working groups?	90%

Powerful-CB customer working group presentation http://bit.ly/P-CB_CWG_presentation_06-09-17

11.7 Association of Decentralised Energy (ADE) membership forums

We were invited to speak about Powerful-CB at two ADE events through our relationship with the ADE and their support of this project.

ADE District Heating and Cooling forum: 11 October 2017

14 members attended the forum. We previously shared the link to our survey and invitation to our customer working group, with the ADE mailing list.

"Does the device have to be installed inside or can it be outside?"

ADE District Heating and Cooling forum

"We are at the early design stage so can adapt to suit the environment"

UKPN response

ADE Commercial forum 18 October 2017

We presented to 11 members of the Commercial forum.

"We have a fault level issue outside of your area, what should we do?"

ADE Commercial forum

"Talk to us, we still need to capture the issues you are facing to help us evolve the solution"

UKPN response

"I thought your presentation at the ADE was about the best piece of technical news for CHP developers in the last couple of years"

Customer email

11.8 Frequently Asked Questions – Method 2 (Applied Materials)

What is the technology about?

Connecting generators to electricity networks requires that the network has the capacity to accept the generator connection. A number of criteria need to be met, including voltage control, thermal capacity of the conductors and that the network infrastructure can handle the force and heating effects of a short circuit. The device we are trialing is designed to switch off the generator *very quickly* when there is a network fault or disturbance such that the generator does not provide any energy into the fault.

How does it work?

Power electronic switches (Insulated Gate Bipolar Transistors) are stacked in series and parallel configurations to carry the current and switch it off when a fault occurs. Current transformers measure the magnitude and derive the rate of change of current and when thresholds are exceeded. The switching process is very fast - 6µs, so there is sufficient time to determine if the current will exceed the capacity of the switches.

Are these IGBTs new technology?

Not really – they have been used since the 1980s and form the basis of many variable speed industrial drives and generators. They are however new to the electricity distribution network industry.

Industrial variable speed drives have harmonics associated with them. Will your system cause harmonics on my site?

No – this is not an issue as the switches are on (or off) continuously.

IGBTs have failure modes which include failure to short circuit – how do I know that the device will work?

We engineer the device to avoid stressing the IGBTs with over-voltage, over-current and heat. We also periodically test the operation of the device seamlessly so that the generator is not disturbed, but we prove the operation of the switches.

How do you remove the heat from the unit?

We marshal the heat to an exit point on the top of the unit and from there ducts are needed to take it out of the room.

How do you connect the unit into my network?

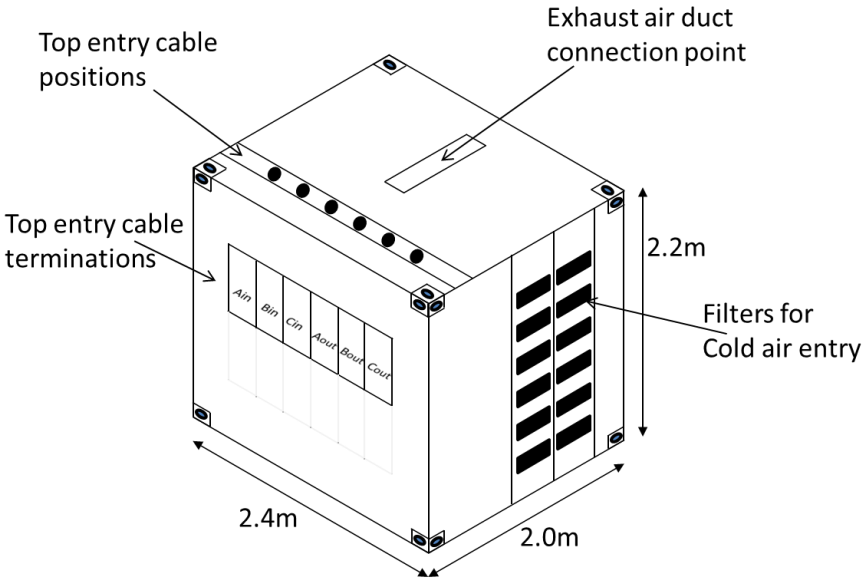
The device is cable connected. We are providing top or bottom cable entry points.

How much current and voltage can it take?

Up to 400A, (maybe 500A with some testing), so about 7.5MVA at 11kV.

How big is the unit?

We are targeting a device that is 2.4m deep x 2m long x 2.2m tall. A possible re-configuration would be 1.2m deep x 4m long x 2.2m tall. The squarer configuration would need front and rear ventilation and access (about 1m), with cable connection access at one end (about 1m). The long, thin configuration would need front ventilation and access with cable connection access at both ends.



In addition there will be for this installation, isolators and a bypass circuit breaker. The details of the installation will be site specific.

Can the unit be delivered/assembled in/from parts?

The unit is designed to be delivered/assembled as a single unit, or broken down into parts that can be carried through a standard door. We recognize for retro-fit installations that unusual solutions to space constraints, e.g. installing into a substation basement may be necessary.

How heavy is the unit?

This has not yet been calculated but a few tonnes is likely to be the answer.

What are the risks to my site?

While there are a whole range of risks associated with installing new equipment, we think that we will address most of them in the design and installation procedures. Residual risks result from the fast acting nature and limited overload capability of the base switching technology.

Nuisance tripping may occur when there is a fast rising spike caused by partial discharge, lightning, energizing transformers or starting motors.

Site challenges will be captured and disseminated in future reports.

What are the advantages to my site?

The site will be protected from the grid were there to be a fault on the site side of the limiter. This will mitigate damage to the rest of the site infrastructure. The site (or future sites) will also be able to connect to the UKPN network without further reinforcement work. Finally, the technology can potentially be developed to integrate fault ride-through capability, allowing future connections to the grid.

What are the benefits to UKPN and Applied Materials?

UKPN will have another tool in the toolbox to allow the connection of generation, desirable to support the expansion of CHP in London. Applied Materials get a showcase for their mark 2 solid state fault current limiter.

Is this the first installation?

A similar piece of technology has been installed on a transformer neutral in Victoria, Australia. It was designed to detect fault current flowing to earth and disconnect the neutral point with the hope that this would prevent bush fires. The site in Australia is a bush fire testing site where they drop a cable to the ground to try to ignite a specially prepared piece of the bush (in a container). The limiter has seen over 800 faults, and works as intended but sadly the capacitance in the cable leaves enough residual current to discharge resulting in bush fires.

How does the installation differ from mine?

The Australian installation is at 22kV, in a transformer neutral point and sees little load current. Yours has much more current and three phases, and the periodic testing of the IGBTs is new for this project to meet the UK safety case. In fact there is an independent assessment of the safety case for deploying IGBTs in this application for this project.

Can I visit the installation?

Arrangements for site visits will be discussed with the trial participant. Site access will depend on a number of factors and those who wish to visit the operational site should register their interest with the Powerful-CB team.

What impact will it have on site protection schemes?

This will be investigated on a site by site basis once a potential trial site is identified.

What happens if it develops a fault or I no longer want to use it?

We will install a bypass and isolation system around the limiter. Operation of the bypass would require the network fault level to remain within limits.

How do I bypass it?

This will be worked out with UKPN later in the trial.

How do I operate it?

The operations of the device have not been completely specified, however it is likely to require little operation if any at all. An automatic re-closing scheme is likely to be part of the device once any residual safety issues are resolved.

Can I use it as a circuit breaker?

No – this is a specialist piece of equipment which provides a huge reduction in fault current contribution (nearly 100%) but does not completely isolate the fault from the generator. It does not for example provide galvanic isolation.

What maintenance does it need?

The unit has fans that suck in filtered air. The filters need to be replaced/cleaned on a frequent basis (as yet undetermined). The cooling fans also have a working lifetime and will require replacement after several years (again, frequency undetermined). Likewise uninterruptable power supply batteries only have a finite life and will require replacement too. The latter two maintenance activities will require outages and are expected to be undertaken by Applied Materials or its associates. Fan replacement/cleaning could be done by the customer.

Who owns the unit at the end of the project?

Assuming the project is successful, a reference site is more important to Applied Materials than the cost of the equipment. They will be willing to gift the device to either UKPN or the customer as appropriate.

What power does the unit consume?

Energy consumed will include 36 x 20W for the cooling fans, + PLC, Communication equipment, display and, potentially, a duct fan. Approximate total consumption will be under 3kW in total.

Are there any other losses?

There are some losses associated with the semi-conductor devices, hence the cooling. Approximately 1kW in terms of power consumption for the fans and control and around 4kW at full load for thermal losses. A high impedance transformer or a current limiting reactor may be 10X these losses.

Applied Materials is an American Company, is there a local contact?

Yes – Applied Materials has a UK presence and a specialist engineer based in the UK.

What do you want from me?

A demonstration site location, acceptance of the losses/power requirements, access to site for installation, maintenance, customer visits and the like, photographs and videos, background information on your installation and access to the data gathered by the system (like currents, faults, etc.) along with background data which we can use for publications, marketing, etc.

11.9 Understanding Customers' Requirements information gathering form

Safety is at the heart of everything we do. We will be working closely with our safety case expert Frazer-Nash Consultancy Ltd, to develop the engineering knowledge necessary to safely and effectively demonstrate Fault Limiting Circuit Breakers (FLCBs). Switchgear will be installed to enable the FLCB to be isolated and by passed if necessary.	
Decision parameters	
Inhibit/Intertrip A hard-wired protection system that automatically disconnects generators from the network under pre-defined conditions, typically in the event of a transformer outage or other abnormal network configuration that causes elevated fault levels. **Powerful-CB relationship to inhibit** Under traditional "inhibit scheme", your generator would need to disconnect and would be unable to export whenever our network is running in an abnormal configuration. If you installed a FLCB through Powerful-CB, your generator would be tripped only if a fault occurs on our network, and you would be allowed to restart your generator after a few seconds.	
1.	How long would it take you to restart and resynchronise your generator after an unplanned generator trip?
2.	Can you resync your generator remotely and is this done through a third party?
3.	Would an inhibit scheme ever be preferable to Powerful-CB?
4.	What are your biggest concerns and why? a. Damage to the generator b. Restarting time c. Impact on site operations d. Contractual obligations e. Penalty payments from capacity and balancing services contracts f. Logistics of installation g. Commercial arrangements
Cost	
5.	What generation capacity would make your business case feasible if you were to incorporate Powerful-CB at a cost of circa £300k? Please give details if possible
6.	For your business case, what is the optimal cost? Please give details if possible
7.	How would you prefer financing work for the substation solution? Shared amongst generators, based on capacity or other? Please share any thoughts or requirements you have on this matter.

Space The Powerful-CB is modular and can be stacked in two ways: • 2.4 deep x 2m long x 2.2m tall • 1.2m deep x 4m long x 2.2m tall	
8.	Do you have a preference? Please explain:
9.	Would your site accommodate either solution?
Weight	
10.	The unit is likely to weigh a few tonnes, would this hinder its use at your site(s)?
Technical	
11.	Would your generator be impacted from being abruptly disconnected?
12.	Is ride-through faults something in which you are or would be interested in? a. Would the additional footprint of this device be a showstopper? b. What level of fault limiting can your generator handle without causing a load rejection trip?
Frequency Response	
13.	Is your generator used for ancillary services? If yes How many unplanned trips/ how many interrupted minutes per year would cause a problem for your ancillary services contracts? Is your contract via an aggregator?
Commercial	
14.	As part of the trial, we, our partner (Applied Materials) and potentially other clients would need to access the trial site. Do you envisage any of the above to be an issue for you? What kind of access arrangements would you want in place? (host arrangements, access cards, CSCS)
Operation	
15.	Are you looking to convert an existing connection agreement from Short Term Parallel to Long Term Parallel?

11.10 Site Selection Criteria form

Criteria	Essential	Desirable
Location	Within UKPN network area	• Within London • Connected to a fault-level constrained substation
Generation Type		Synchronous
Generation Rating	1MW minimum 5MW maximum	
Connection Type		Non-Firm (inhibit)
Generator Operation		Regular
Customer Operation	• Critical business activities not impacted by trial activities • Willingness to be involved in media/outreach	
Space	Enough space to install the FLCB 2.4m deep x 2m long by 2.2m tall	

Site name and address	
Meter Point Administration Number (Export and Import)	
Generator type	
Fuel type	
Maximum Export Capacity	
Maximum Import Capacity	
How many hours per year does your generator run?	
Any special Connection Agreement terms?	

Please note the cost of the installation and device will be covered by the project. If you have any questions please contact us on the details below:

Kellie Dillon | Innovation Workstream Lead | 07875 116 657 | kellie.dillon@ukpowernetworks.co.uk
Laura Daniels | Innovation Project Lead | 07840 386 059 | laura.daniels@ukpowernetworks.co.uk

You can contact us with any questions by email to innovation@ukpowernetworks.co.uk