Question No.	Proforma section	Criteria	Topic	Question	Date question asked	Date response required	Date received	Follow up to Question #	Confi-dential (Y/N)
1	4.2.2	b) value for money		Please confirm the total values and make up of project partner contributions. Section 4.2.2 and table 6 appear contradictory.	16 August 2016	18 August 2016	18 August 2016		
2	n/a	g) Robust methodology/ready to implement		Please confirm the expected number of trial sites and units expected to be tested during the project.	16 August 2016	18 August 2016	18 August 2016		
3	n/a	e) Partners and ext. funding		Has the project engaged with Scottish DNOs about the project and considered factors that may affect the efficacy of the solution in Scotland?	16 August 2016	18 August 2016	18 August 2016		
4	n/a	g) Robust methodology/ready to implement		Please describe the typical size and ratings of CHP plants (installed and expected) in the LPN area.	16 August 2016	18 August 2016	18 August 2016		
5	n/a	e) Partners and ext. funding		Has consideration been given to involving CHPQA in WS3a?	16 August 2016	18 August 2016	18 August 2016		
6	2.1.1	c) Generates new knowledge		Page 6 states that existing smart solutions are not feasible due to operational and physical space constraints. Please provide details of the smart solutions compared against in the submission. Does it take into account only proven solutions or also new systems being trialled at present?	16 August 2016	18 August 2016	18 August 2016		
7	10.2.2	g) Robust methodology/ready to implement	n/a	It is indicated in your proposal (p.46) refers to 64 breakers per substation. That seems like a very large 11kV switchboard. Please clarify the basis for this number.	23 August 2016	25 August 2016	25 August 2016		
8	10.2.2	g) Robust methodology/ready to implement	n/a	Please clarify if the analysis described in Table 13 is the sole basis of calculating the GB wide number of substations that are or will be headroom constrained (Table 14).	23 August 2016	25 August 2016	25 August 2016		
9	n/a	g) Robust methodology/ready to implement	n/a	Please provide the effective response time of the AMAT unit.	23 August 2016	25 August 2016	25 August 2016		
10	3.4	g) Robust methodology/ready to implement	n/a	Page 17 states that the harmonics would be far less severe. Please can you explain this assumption.	23 August 2016	25 August 2016	25 August 2016		

Question No.	Proforma section	Criteria	Topic	Question	Date question asked	Date response required	Date received	Follow up to Question #	Confi-dential (Y/N)
11	4.5.1	g) Robust methodology/ready to implement	n/a	Section 4.5.1 discusses intertrip schemes. Intertrip schemes usually manage thermal constraints. Please explain how you are currently using it to manage fault level issues. Is it under N-1 when split points are closed?	23 August 2016	25 August 2016	25 August 2016		
12	2.2	b) value for money	n/a	What benefits do the AMAT FCLB offer over an Is-limiter at a customer premice other than quicker reconnection to network and not requiring replaceing after use?	23 August 2016	25 August 2016	25 August 2016		
13	2.2	b) value for money	n/a	Why have the financial benefits of the AMAT FCLB been calculated as an alternative to network reinforcement rather than the use of Is-limiters?	23 August 2016	25 August 2016	25 August 2016		
14	2 & 4	c) new learning and d) is innovative	n/a	Given the level of learning transferred from existing projects (FlexDGrid & Respond), please justify calculating the benefits case as an alternative to network reinforcement rather than an alternative to an existing FLCB solution	23 August 2016	25 August 2016	25 August 2016		
15	n/a	b) Value for money	n/a	The Full Submission Guidance states 'Enough information should be included in this [NPV] summary so that it can be used in conjunction with the data in the Full Submission Spreadsheet to enable the Panel to independently calculate the Net Present Value of each Method.' Please direct us to where you have provided this information in your submission.	25 August 2016	30 August 2016	30 August 2016		
16	n/a		n/a	Can you please provide information on:o the assumed life of the power electronic equipment included in the deviceso how that assumption compares with devices in other applications and industrieso how these assumptions affect the CBA and breakeven analysis	08 September 2016	13 September 2016	13 September 2016		
17	n/a	g) Robust methodology/ready to implement	n/a	Is the proposed design modular and at present for how long will spare parts be provided?	08 September 2016	13 September 2016	13 September 2016		

Question No.	Proforma section	Criteria	Topic	Question	Date question asked	Date response required	Date received	Follow up to Question #	Confi-dential (Y/N)
18	n/a	Mulitple	n/a	Can you please provide information regarding the use of this device in the system and in particular: o How will the normal back-up of protection and protective devices (eg. in the event of CB fail or loss of dc in a sub) be managed? o What is the impact of these devices in existing protection schemes and how will it work with existing schemes like breaker fail schemes and what is its impact on protection grading on networks. o How will the devices be tripped by conventional protection schemes and has the typical dc burdens and allowable dc voltage regulation typically applied for conventional CBs been part of the PowerFuL-CB system definition.	08 September 2016	13 September 2016	13 September 2016		
19	n/a	d) Is innovative	n/a	Will the ABB CB be adaptable to other boards without the use of a joggle box? It seems that its interchangeability with the breaker panels of other manufacturers is a key advantage for this device over fault current limiters.	08 September 2016	13 September 2016	13 September 2016		
20	n/a	b) Value for money	n/a	Can you please provide a cost breakdown for the two Methods down to the set-up cost and provide the partner contributions (where it hasn't already been done) for the two Methods.	08 September 2016	13 September 2016	13 September 2016		
21	n/a	g) Robust methodology/ready to implement	n/a	Do you think it would be efficient to manage the two methods as separate projects and what problems would you foresee in doing so, ie. what are the common elements of the two methods?	08 September 2016	13 September 2016	13 September 2016		
22	n/a	a) Enviro+consumer bens	n/a	How much of the capacity and carbon savings are truly NET ADDITIONAL to GB?	20 September 2016	22 September 2016	22 September 2016		
23	n/a	g) Robust methodology/ready to implement	n/a	Is there a risk that to satisfy the safety case the solution becomes bigger and therefore less useful?	27 September 2016	29 September 2016	29 September 2016		

Question No.	Proforma section	Criteria	Topic	Question	Date question asked	Date response required	Date received	Follow up to Question #	Confi-dential (Y/N)
24	5	c) Generates new knowledge	IPR	We note that the project intends to conform to the default IPR arrangements. As per the governance document and full submission guidance, when updating Section 5 in your resubmission, please explain: - how the project intends to conform to the default IPR arrangements; and - your approach to agree fair and reasonable terms for the future use of any Background IPR and Commercial Products needed for other Licensees to reproduce the Project outcomes.	13 October 2016	N/A - resubmission	N/A - resubmission		

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	1
Question date	16 August 2016	Answer date	18 August 2016
Submission section question relates to			
Topic			
Question	Please confirm the total values and make up of project partner contributions. Section 4.2.2 and table 6 appear contradictory.		
Notes on question			
Answer	ABB's contribution of £300k will be applied as an offset to their overall expenditure and is not associated with any particular costs or activities. AMAT's contribution of £388k covers 100% of the cost of building and testing the Method 2 trial prototype. The balance of £29k covers AMAT's other costs not directly related to building and testing the Method 2 trial prototype, e.g. project management, customer engagement. NB we have discovered an error in Table 6 - see corrected version below. This results in a slight decrease to the amount of NIC funding requested. We will update this in our resubmission.		

Attachments

Existing:

Project Participant	Total Costs Incurred	Voluntary Contribution	DNO Compulsory Contribution	NIC funding requested
AMAT	417	379	4	34
ABB	2,614	300	231	2,083
UK Power Networks	3,158	98	306	2,754
Total	**6,189**	**776**	**541**	**4,871**

Updated:

Project Participant	Total Costs Incurred	Voluntary Contribution	DNO Compulsory Contribution	NIC funding requested
AMAT	417	388	3	26
ABB	2,614	300	231	2,083
UK Power Networks	3,158	98	306	2,754
Total	**6,189**	**785**	**540**	**4,863**

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	2
Question date	16 August 2016	Answer date	18 August 2016
Submission section question relates to			
Topic			
Question	Please confirm the expected number of trial sites and units expected to be tested during the project.		
Notes on question			
Answer	**Expected no. of FLCB trial sites: Two** • One substation trial site for Method 1 FLCB • One customer trial site for Method 2 FLCB We may also collect baseline data from a generator at a separate site i.e. without a FLCB - refer details on page 65. **Expected no. of devices to be tested during the project: Four** • Up to two Method 1 devices will be destructively type tested • One Method 1 device will be installed at the Method 1 trial site • One Method 2 device will be non-destructively type tested and (the same device) will be installed at the Method 2 trial site		
Attachments			

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	3
Question date	16 August 2016	Answer date	18 August 2016
Submission section question relates to			
Topic			
Question	Has the project engaged with Scottish DNOs about the project and considered factors that may affect the efficacy of the solution in Scotland?		
Notes on question			
Answer	Whilst we haven't yet engaged directly with the Scottish DNOs, we have used their LTDS data to determine exactly which of their substations would experience fault level constraints under the various NGET Future Energy Scenarios and hence calculate the project's potential benefits to their networks, i.e. we didn't just extrapolate from the LPN benefits. We are not aware of any factors that may affect the efficacy of the solution in Scotland. We would expect to engage all GB DNOs via WS3 and WS4.		
Attachments			

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	4
Question date	16 August 2016	Answer date	18 August 2016
Submission section question relates to			
Topic			
Question	Please describe the typical size and ratings of CHP plants (installed and expected) in the LPN area.		
Notes on question			
Answer	There are currently 253 CHP plants connected or with accepted connections offers in the LPN area. Of these, 188 (74%) are non-domestic CHP rated less than 5MW. Please see the table below for a full breakdown.		
Attachments			

Size	Accepted	Connected	Total	% of Total
Micro CHP (domestic)	19	13	32	13%
Mini CHP (<1MW)	79	68	147	58%
Small CHP (<5MW)	17	24	41	16%
Medium CHP (<50MW)	11	19	30	12%
Large CHP (>=50MW)	0	3	3	1%
Total	**126**	**127**	**253**	

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	5
Question date	16 August 2016	Answer date	18 August 2016
Submission section question relates to			
Topic			
Question	Has consideration been given to involving CHPQA in WS3a?		
Notes on question			
Answer	We have reached out to the CHPQA (CHP Quality Assurance Programme) at your suggestion. We would appreciate your thoughts behind the suggestion, as we had previously seen the CHPQA as only an indirect stakeholder.		
Attachments			

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

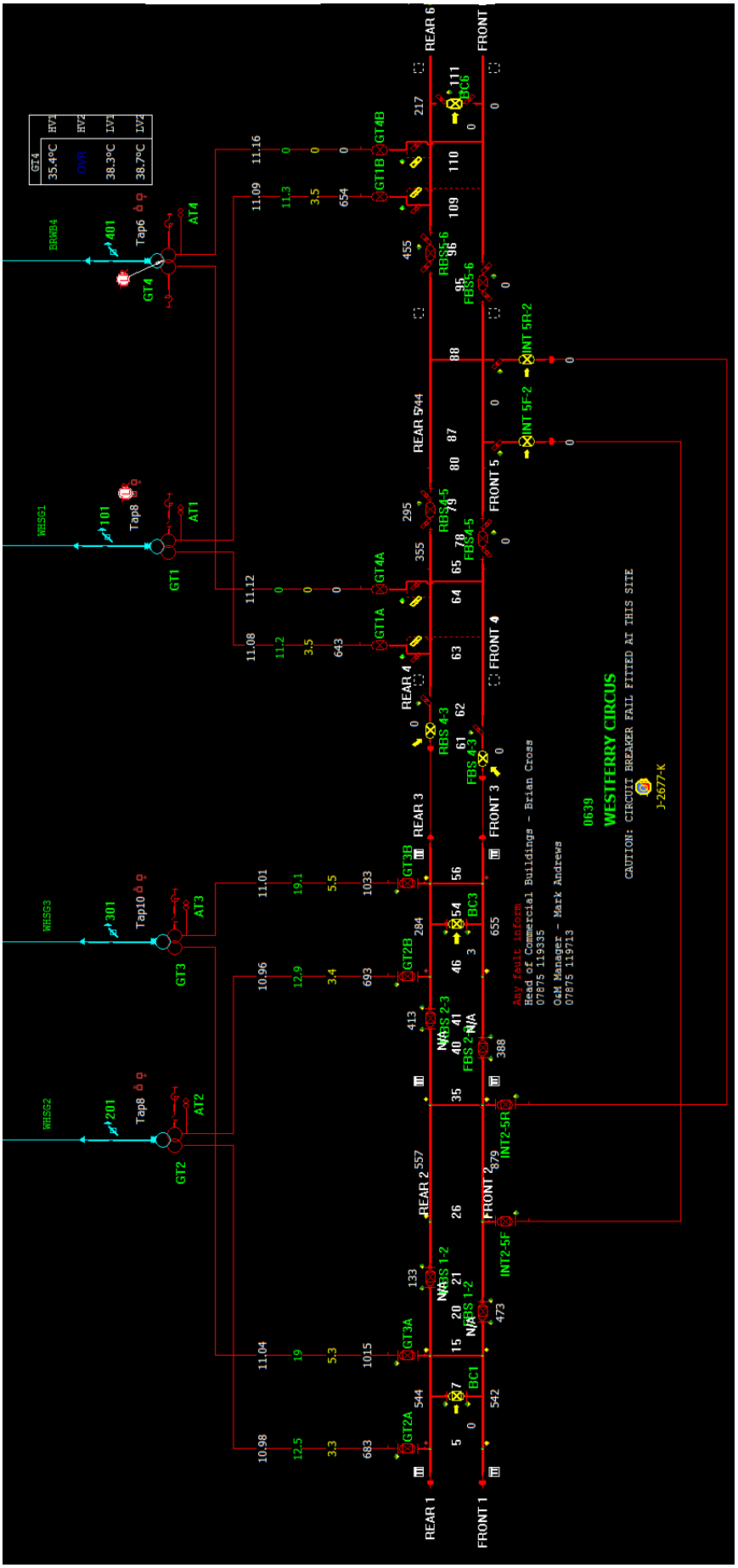
Project code	UKPNEN01	Question Number	6
Question date	16 August 2016	Answer date	18 August 2016
Submission section question relates to			
Topic			
Question	Page 6 states that existing smart solutions are not feasible due to operational and physical space constraints. Please provide details of the smart solutions compared against in the submission. Does it take into account only proven solutions or also new systems being trialled at present?		
Notes on question			
Answer	Details of the smart solutions compared against in the submission are provided in Appendix 10.6. We can provide further/more-specific details if required. We have considered all smart solutions that have been proven or are currently being trialled in GB.		
Attachments			

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	7
Question date	23 August 2016	Answer date	25 August 2016
Submission section question relates to	10.2.2		
Topic	n/a		
Question	It is indicated in your proposal (p.46) refers to 64 breakers per substation. That seems like a very large 11kV switchboard. Please clarify the basis for this number.		
Notes on question			
Answer	LPN has 6304 11kV CBs across 99 primary substations = 64 CBs per primary substation. On average, about half of these CBs are located at downstream secondary 11kV substations: these CBs would also need to be replaced (if they have a low fault rating) to relieve the fault level constraint at the primary substation. Note we do have 11kV switchboards with over 100 CBs, see attached diagram of Westferry Circus substation which has 111 CBs (NB diagram only shows incomers, interconnectors, and bus couplers).		
Attachments			


WESTFERRY CIRCUS
CAUTION: CIRCUIT BREAKER FAIL FITTED AT THIS SITE
0639
J-2677-K
Any fault inform
Head of Commercial Buildings - Brian Cross
07875 119335
O&M Manager - Mark Andrews
07875 119713
GT4
35.4°C
OVR
38.3°C
HV1
HV2
LV1
LV2
REAR 6
FRONT 6
REAR 5
FRONT 5
REAR 4
FRONT 4
REAR 3
FRONT 3
REAR 2
FRONT 2
REAR 1
FRONT 1
GT1
GT2
GT3
GT4
AT1
AT2
AT3
AT4
WHSG1
WHSG2
WHSG3
BRWB4
INT 5R-2
INT 5F-2
INT2-5R
INT2-5F
RBS 4-3
FBS 4-3
RBS 2-3
FBS 2-3
RBS 1-2
FBS 1-2
RBS4-5
FBS4-5
RBS5-6
FBS5-6
BC1
BC3

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	8
Question date	23 August 2016	Answer date	25 August 2016
Submission section question relates to	10.2.2		
Topic	n/a		
Question	Please clarify if the analysis described in Table 13 is the sole basis of calculating the GB wide number of substations that are or will be headroom constrained (Table 14).		
Notes on question			
Answer	The GB-wide number of fault-level-constrained substations (Table 14) is based on: • The assumptions in Table 13; • UKPN's and other DNOs' Long Term Development Statements; and • National Grid's 2016 Future Energy Scenarios.		
Attachments			

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	9
Question date	23 August 2016	Answer date	25 August 2016
Submission section question relates to	10.4.1		
Topic	n/a		
Question	Please provide the effective response time of the AMAT unit.		
Notes on question			
Answer	The effective response time of the AMAT FLCB is 66μs (0.066ms) - refer section 10.4.1.b for full explanation.		
Attachments			

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	10
Question date	23 August 2016	Answer date	25 August 2016
Submission section question relates to	3.4		
Topic	n/a		
Question	Page 17 states that the harmonics would be far less severe. Please can you explain this assumption.		
Notes on question			
Answer	To clarify: **harmonic voltages** will be far less severe. Harmonic voltages are caused by non-linear loads or generators drawing harmonic currents through the network's impedance. Reducing the network's impedance (by designing/operating the network with a higher unrestrained fault level) will reduce harmonic voltages (for the same amount of non-linear load/generation).		
Attachments			

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	11
Question date	23 August 2016	Answer date	25 August 2016
Submission section question relates to	4.5.1		
Topic	n/a		
Question	Section 4.5.1 discusses intertrip schemes. Intertrip schemes usually manage thermal constraints. Please explain how you are currently using it to manage fault level issues. Is it under N-1 when split points are closed?		
Notes on question			
Answer	We currently use intertrip schemes to manage fault level constraints by disconnecting 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. Disconnecting the generators in these scenarios prevents them from contributing to network fault levels. Yes, normally-open points are closed under N-1 to maintain firm capacity, which causes elevated fault levels. This is illustrated in figures 8a, 8b, 9a, 9b.		
Attachments			

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	12
Question date	23 August 2016	Answer date	25 August 2016
Submission section question relates to	2.2		
Topic	n/a		
Question	What benefits do the AMAT FCLB offer over an Is-limiter at a customer premice other than quicker reconnection to network and not requiring replaceing after use?		
Notes on question			
Answer	Other benefits include: • Safety/reliability benefits - the FLCB can be routinely tested to detect hidden failures. • Generator can ride through faults (with mutual reactor) - this potentially eliminates operational impacts on the customer, and enables the customer to offer balancing services that require fault ride through capability.		
Attachments			

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	13
Question date	23 August 2016	Answer date	25 August 2016
Submission section question relates to	2.2		
Topic	n/a		
Question	Why have the financial benefits of the AMAT FCLB been calculated as an alternative to network reinforcement rather than the use of Is-limiters?		
Notes on question			
Answer	We used traditional reinforcement/asset replacement as our base case because it is the lowest cost method that has been proven on the GB Distribution System of enabling DG to connect to fault-level-constrained substations. We did not consider Is-limiters as the base case because the HSE has not approved their use to limit fault levels on GB DNO networks, and their operational limitations often make them unfeasible - regardless of whether the Is-limiter is installed on the DNO network, or on the customer's premises. Notes: 1. ENWL's Respond project is trialling an Is-limiter on a GB DNO network, but not on a customer's premises. 2. We are aware that Is-limiters are used on customers' premises in GB, but this is to limit fault levels on the customer's (private) network, not to limit fault levels on the DNO (public) network.		
Attachments			

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	14
Question date	23 August 2016	Answer date	25 August 2016
Submission section question relates to	2, 4		
Topic	n/a		
Question	Given the level of learning transferred from existing projects (FlexDGrid & Respond), please justify calculating the benefits case as an alternative to network reinforcement rather than an alternative to an existing FLCB solution		
Notes on question			
Answer	We used traditional reinforcement/asset replacement as our base case because it is the lowest cost method that has been proven on the GB Distribution System of enabling DG to connect to fault-level-constrained substations. We did not consider the Active Fault De-coupler (the only existing FLCB solution that we know of) as the base case because it is not yet proven, and its large size makes it unfeasible for substations with space constraints. We did not consider any other smart solutions as the base case because they are all currently unproven and/or have at least one shopstopper that make them unfeasible for substations with operational and space constraints such as those in LPN - refer last row of Table 25.		
Attachments			

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	15
Question date	25 August 2016	Answer date	30 August 2016
Submission section question relates to	n/a		
Topic	n/a		
Question	The Full Submission Guidance states 'Enough information should be included in this [NPV] summary so that it can be used in conjunction with the data in the Full Submission Spreadsheet to enable the Panel to independently calculate the Net Present Value of each Method.' Please direct us to where you have provided this information in your submission.		
Notes on question			
Answer	We have provided a summary of the NPV analysis in Appendix 10.2. We have provided overleaf a table summarising the key inputs needed to calculate the financial benefits stated in Tables 16 and 17 of our submission, and where they can be found in our submission document.		
Attachments			

Key inputs needed to calculate the financial benefits given in Tables 16 and 17:

Input	Details	Ref
Base case cost per substation	£2.48m	Table 11, p46
Method 1 cost per substation	£0.5m (4x15MVA) £1.25m (other configurations)	Table 12, p46
Method 2 cost per substation	£0.3m per year over five years	p46
Substations addressed by 2050	Total: 762 (18% of primary substations in GB)	Table 14, p49
	4x15MVA: 42 Other: 762 – 42 = 720	See table below
Substations addressed per year	We have assumed that an equal number of substations are addressed each year between 2021 and 2050, i.e. 4x15MVA: 42 / 30 = 1.4 per year Other configurations: 720 / 30 = 24 per year	-
Financial assumptions	All as per defaults in the Ofgem cost-benefit analysis spreadsheet.	-

Total number of constrained substations (4 x 15 MVA configuration only), across all DNOs:

	Gone Green		Slow Progression		No Progression		Consumer Power		
	Min (Best)	Max (Worst)	Min (Best)	Max (Worst)	Min (Best)	Max (Worst)	Min (Best)	Max (Worst)	Average
2020	40	40	40	40	40	40	40	40	40
2030	41	41	40	40	40	40	41	41	41
2040	43	44	40	44	41	45	41	45	43
2050	43	44	40	41	41	43	42	43	42

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	16
Question date	8 September 2016	Answer date	13 September 2016
Submission section question relates to	n/a		
Topic	n/a		
Question	Can you please provide information on: • the assumed life of the power electronic equipment included in the devices • how that assumption compares with devices in other applications and industries • how these assumptions affect the CBA and breakeven analysis		
Notes on question			
Answer	We expect that the FLCBs and the power electronic equipment they include will have a service life of at least 30 years. This is consistent with the design life for other medium voltage equipment. We hence expect no FLCBs will need to be replaced or refurbished before 2050 and have therefore not included this in the CBA. We expect power electronic equipment in FLCBs to have a much longer lifetime than in other applications (e.g. HVDC converter stations) for the following reasons: • Ageing of power electronic equipment is caused primarily by thermal cycling and continuous voltage stress. • In a Method 1 device, the power electronic equipment is normally bypassed by the fast commutating switch, and hence only experiences thermal cycling and voltage stress in the event of a network fault, i.e. a couple of times per year. • In a Method 2 device, the power electronic equipment are operated at a fraction of their design ratings, which minimises thermal and voltage stresses. We will of course aim to validate these assumptions during the trial.		

Attachments	

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	17
Question date	8 September 2016	Answer date	13 September 2016
Submission section question relates to	n/a		
Topic	n/a		
Question	Is the proposed design modular and at present for how long will spare parts be provided?		
Notes on question			
Answer	Power Electronic FLCB technolgies are modular in that: • They use standardised power electronic components that can be replaced individually. • They can be scaled to higher voltages and currents by increasing the specification and number of power electronic components. Regarding spare parts: • Both Methods use standardised power electronic components that are widely used and have a large installed base in other applications. We expect like-for-like spares of these components to be available for at least 10 years, and replacement strategies using compatible spares to be available until the end of the FLCB's life. • As per UK Power Networks' standard practice for trial and/or rollout of a new technology[1], we will assess the availability of spare parts and develop a spare parts strategy, including support agreements with manufacturers and holding our own stock. • We would not expect availablility of spare parts to be a significant risk to trial or rollout of either method.		
Attachments			

[1] UK Power Networks: EDS 08-0117 Introduction of New Technology and Equipment, http://goo.gl/Y5f7xH

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	18
Question date	8 September 2016	Answer date	13 September 2016
Submission section question relates to	n/a		
Topic	n/a		
Question	Can you please provide information regarding the use of this device in the system and in particular: • How will the normal back-up of protection and protective devices (eg. in the event of CB fail or loss of dc in a sub) be managed? • What is the impact of these devices in existing protection schemes and how will it work with existing schemes like breaker fail schemes and what is its impact on protection grading on networks. • How will the devices be tripped by conventional protection schemes and has the typical dc burdens and allowable dc voltage regulation typically applied for conventional CBs been part of the PowerFuL-CB system definition.		
Notes on question			
Answer	We have consulted with internal and external experts on these issues as part of our bid preparation in enough detail to satisfy ourselves that it is technically feasible to integrate FLCBs onto an existing distribution network and provide the required level of safety. Here are our **initial thoughts** on the issues you've raised. We empahsise that these will be further developed and refined during the project into detailed protection, control, and automation philosophies/designs in parallel with a detailed safety case to ensure that they provide the required level of safety. *How will the normal back-up of protection and protective devices (eg. in the event of CB fail or loss of dc in a sub) be managed?* • **Both Methods are designed with internal redundancy** which greatly reduces the likelihood of them failing to operate on demand. For example, they are designed to tolerate failure of a individual IGBT modules or surge arrestors in each pole.		

	• **We have already conducted a high-level (failure modes and effects analysis (FMEA)** for Method 1 as part of the safety case feasibility study and we can provide this on request.
	• **Backup protection** (in the event that a FLCB fails to operate on demand, causing a downstream feeder CB to exceed its breaking rating) could be provided by using the principles of ENWL/Respond's **Adaptive Protection** method:
	  ○ The FLCB's tripping unit would trip the FLCB and a series CB at the same time, so that in case the FLCB fails to operate, the series CB will interrupt the current several cycles later. Note that the FLCB and its series CB only see a contribution to the fault, not the entire fault current seen by the feeder CB, so the series CB's fault rating is not an issue.
	  ○ The FLCB's supervisory systems would detect a FLCB failure before the feeder CB protection operates, and block/delay the feeder CB trip until the upstream CB has tripped, thereby reducing the "break" fault level seen by the feeder CB.
	  ○ An upstream CB can't operate fast enough to reduce the "make" fault level seen by the feeder CB when energising a faulty circuit, so some additional mitigations may be needed for this scenario. These may include testing the FLCB to make sure it works before energising a feeder post-fault, or temporarily opening the FLCB whilst energising a feeder post-fault.
	• **Loss of DC supply in the substation:**
	  ○ Method 1 will be designed to use duplicated auxiliary supplies, as per existing standard practice.
	  ○ Method 2 is intrinsically fail safe for loss of auxiliary supply – the IGBTs will stop conducting if the gate signal is lost.
	
	What is the impact of these devices in existing protection schemes and how will it work with existing schemes like breaker fail schemes and what is its impact on protection grading on networks.
	
	• **Impact on breaker fail schemes:**
	  ○ A FLCB installed in series with an existing CB would have no impact on existing breaker fail schemes: the existing CB and its associated protection and breaker fail scheme would continue to operate as normal.
	  ○ A FLCB installed with no other CBs in series (e.g. connected directly between two busbars) would need to be integrated into any existing breaker fail schemes, just like any other CB added to an existing switchboard.
	• **Impact on protection grading:**
	  ○ FLCBs operate in completely different timescales to conventional protection (2ms vs 100ms+) hence they do not need to grade with each other.
	  ○ All fault level mitigation technologies have the potential to affect protection grading because they reduce fault levels. We will undertake protection studies to ensure that all existing protection continues to grade correctly in the presence of the FLCBs. This will include ensuring that the FLCB does not operate for high-impedance faults, to eliminate the risk that faults are cleared too slowly or not at all because of insufficient fault current.
	• **Other impacts on existing protection schemes:**

	○ Where a FLCB falls within the zone of an existing transformer/busbar unit protection scheme, we will conduct testing to ensure that the FLCB doesn't affect the stability of the unit protection scheme. *How will the devices be tripped by conventional protection schemes and has the typical dc burdens and allowable dc voltage regulation typically applied for conventional CBs been part of the PowerFuL-CB system definition.* • **How will the devices be tripped by conventional protection schemes:** ○ FLCBs include an integral tripping unit and hence do not rely on or interact with conventional protection schemes for normal fault-limiting operations. ○ We assume for now that FLCBs will always be installed in series with existing CBs to provide a point of isolation and handle conventional protection functions; hence there is no need for FLCBs to be tripped by conventional protection schemes. ○ However, if required in future, it is technically possible to design the FLCB's tripping unit to accept an external trip signal. • **DC burden and voltage regulation:** ○ Method 1's DC burden is similar to that of a conventional numerical protection relay and CB with a spring charge motor. ○ Method 2 has no moving parts (i.e. no mechanical actuators) and hence will not cause any DC voltage regulation. ○ We will of course review the DC burden and voltage regulation at each site and augment the existing DC supplies as necessary.
Attachments	

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	19
Question date	8 September 2016	Answer date	13 September 2016
Submission section question relates to	n/a		
Topic	n/a		
Question	Will the ABB CB be adaptable to other boards without the use of a joggle box? It seems that its interchangeability with the breaker panels of other manufacturers is a key advantage for this device over fault current limiters.		
Notes on question			
Answer	Yes, it is technically feasible to integrate ABB's FLCB device into any make/model of switchgear. Notes: • ABB already sell switchgear components to OEM partners to integrate into their own switchgear, e.g. circuit breakers and Is-limiters. A similar arrangement will be possible for FLCBs. • The three-phase FLCB prototype proposed for this project requires three 1m-wide panels; we expect the first-generation commercial product to be somewhat smaller. • The long-term ambition for FLCB technology is the eventual development (accelerated by the PowerFuL-CB project) of a three-phase FLCB that is small enough to directly replace a conventional incomer or bus coupler CB in an existing switchboard.		
Attachments			

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

<table>
<tr><td>Project code</td><td>UKPNEN01</td><td>Question Number</td><td>20</td></tr>
<tr><td>Question date</td><td>8 September 2016</td><td>Answer date</td><td>13 September 2016</td></tr>
<tr><td>Submission section question relates to</td><td colspan="3">n/a</td></tr>
<tr><td>Topic</td><td colspan="3">n/a</td></tr>
<tr><td>Question</td><td colspan="3">Can you please provide a cost breakdown for the two Methods down to the set-up cost and provide the partner contributions (where it hasn’t already been done) for the two Methods.</td></tr>
<tr><td>Notes on question</td><td colspan="3"></td></tr>
<tr><td>Answer</td><td colspan="3">The breakdown of expected BAU Method costs is as follows:

<table>
<tr><th>Type of cost</th><th>M1</th><th>M2</th></tr>
<tr><td>FLCB Device (Equipment)</td><td>300</td><td>200</td></tr>
<tr><td>Design & Planning (Labour)</td><td>20</td><td>20</td></tr>
<tr><td>Enabling works, installation, commissioning (Contractors)</td><td>80</td><td>60</td></tr>
<tr><td>Balance of Plant e.g. cables, switchboard extensions (Equipment)</td><td>100</td><td>20</td></tr>
<tr><td>Total</td><td>500</td><td>300</td></tr>
</table>

A detailed breakdown of Method trial costs is provided overleaf.

ABB is contributing £300k to Method 1.

Applied Materials is contributing £388k to Method 2.</td></tr>
<tr><td>Attachments</td><td colspan="3"></td></tr>
</table>

Workstream	Project Participant	Type of Cost	Trial (£k)				BAU (£k)	
			Total	OH	M1	M2	M1	M2
WS1	UK Power Networks	Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Travel & Expenses	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	ABB	Equipment	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Applied Materials	Equipment	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Safety Consultant	Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
WS2	UK Power Networks	Contingency	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Contractors	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Decommissioning	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Equipment	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Payments to users	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	ABB	Equipment	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Safety Consultant	Contingency	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
WS3	UK Power Networks	Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Travel & Expenses	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
WS4	UK Power Networks	Contractors	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Travel & Expenses	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
PM	UK Power Networks	Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Imperial College	Labour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
General Contingency	UK Power Networks	Contingency	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Totals		**Labour**	**3,037**	**717**	**1,942**	**378**	**20**	**20**
		Other	**3,152**	**462**	**1,652**	**1,038**	**480**	**280**
		Grand Total	**6,189**	**1,179**	**3,594**	**1,416**	**500**	**300**

Electricity Network Innovation Competition Full Submission

Supplementary Answer Form

Project: PowerFuL-CB

Tick if this answer has been provided verbally: ☐

Project code	UKPNEN01	Question Number	21
Question date	8 September 2016	Answer date	13 September 2016
Submission section question relates to	n/a		
Topic	n/a		
Question	Do you think it would be efficient to manage the two methods as separate projects and what problems would you foresee in doing so, ie. what are the common elements of the two methods?		
Notes on question			
Answer	We think that there are significant efficiencies in trialling the two methods under the one project, which would be lost for customers if trialled as two separate projects. These include: 1. Technical solution design and safety case development (WS1 and WS2) – both methods raise similar issues around network design, planning, protection, control, automation, and safety. We think it will be more efficient, and lead to better technical solutions, if we address both methods at the same time. 2. Understanding customer's requirements (WS3) – we think it will be more efficient to talk to customers about both methods at the same time, rather than as separate exercises. Developing and comparing both solutions as one exercise will also allow a more detailed comparison of the different solutions and more effective guidance for where each solution is most suited. 3. Lower total overheads for project management and knowledge dissemination. We also note: • We believe that to delay or abandon Method 2 would be a missed opportunity for our customers, because it is close to being ready to deliver BAU benefits, and just needs a trial to prove its safety and gain DNOs' approval. • We believe that to delay or abandon Method 1 would also be a missed opportunity: accelerating its development via the NIC will, if successful,		

	make it available in time for DNOs to consider as a smart solution in their business plans for RIIO-ED2; but without NIC support, this is unlikely. • We believe that both solutions will be needed in order to effectively serve the needs of our stakeholders.
Attachments	