

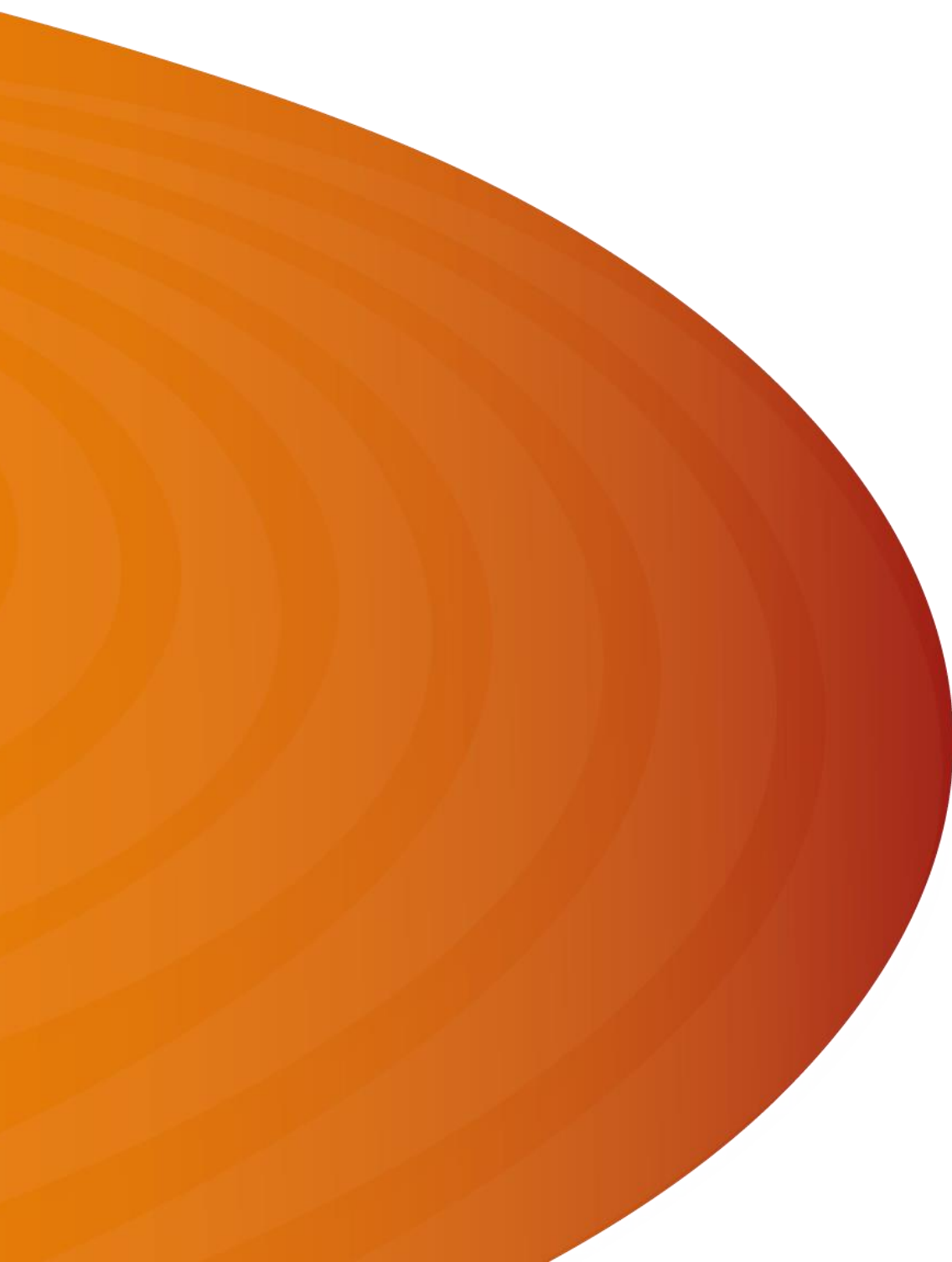
Powerful-CB

Project Progress Report – July to December 2021



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Glossary

Term	Description
ABB	Our technology partner for Method 1
AMAT	Applied Materials, our technology partner for Method 2 (this method has been de-scoped from project following Ofgem approval of change request)
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: is a highly efficient process that captures and utilises the heat that is a by-product of the electricity generation process
COVID-19	Corona Virus Disease 2019
CT	Current Transformer
DG	Distributed Generation
DNO	Distribution Network Operator
EMC	Electromagnetic Compatibility
ENA	The Energy Networks Association
EPN	Eastern Power Networks plc
ENWL	Electricity North West Limited
FATs	Factory Acceptance Test
FCL	Fault Current Limiter – a FLMT that attenuates fault current by increasing its impedance (only) during a fault.
FLMT	Fault Level Mitigation Technology – a technical solution that reduces fault levels on the network
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
FNC	Frazer-Nash Consultancy
FSP	The Powerful-CB Full Submission Proforma - http://bit.ly/Powerful CB-fsp
GB	Great Britain
GT	Grid Transformer
HAZID	Hazard Identification
HMI	Human Machine Interface
HSE	The Health and Safety Executive
HV	High Voltage
Imperial	Imperial Consultants (Imperial College London's consultancy company)
IPR	Intellectual Property Rights
LCNI	Low Carbon Networks & Innovation Conference
LPN	London Power Networks plc
M1	Method 1 – Installation of a FLCB at a substation
M2	Method 2 – Installation of a FLCB at a customer's premises (de-scoped from project following Ofgem approval of change request)

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Term	Description
NIC	Network Innovation Competition
PPR	Project Progress Report
RIIO-ED1	The current electricity distribution regulatory period, running from 2015 to 2023
SCADA	Supervisory Control and Data Acquisition
SDRC	Successful Delivery Reward Criteria
SPN	South Eastern Power Networks plc
TRL	Technology Readiness Level
UKPN	UK Power Networks
VT	Voltage Transformer
WPD	Western Power Distribution

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1. Executive summary

1.1 Project background

The Powerful-CB (Power Electronic Fault Limiting Circuit Breaker) project aims to demonstrate that fault limiting circuit breakers (FLCBs) can enable distribution network operators (DNOs) to connect more distributed generation (DG) to fault level constrained 11kV electricity networks without the need for reinforcement.

A FLCB is a solid-state circuit breaker that operates 20 times faster than existing vacuum circuit breakers (CBs). This high-speed operation can mitigate fault level contributions from distributed generation, allowing us to connect more DG, including Combined Heat and Power (CHP), to fault level constrained networks in dense urban areas. This will help accelerate the decarbonisation of heat, which is a key element of the Government's Carbon Plan.

The project team has been working with a technology partner to develop such a FLCB. ABB has now developed a FLCB for use at a primary substation, known as Method 1 (M1). Method 1 is the world's first demonstration of a FLCB with a fast-commutating switch.

The project team continues to work with Frazer-Nash Consultancy (FNC) to develop the safety cases for the M1 device.

1.2 Summary of progress

This Project Progress Report (PPR) covers the period from July to December 2021 and the previous PPR covering January to June 2021 is available [here](#). Collectively, these PPRs form the annual progress report required by Ofgem's Network Innovation Competition (NIC) Governance Document.

Overall, the project has made good progress during the reporting period, continuing the trial period, gathering trial data and analysing performance of the FLCB, and completing service and inspection.

Workstream 1 – Development of a FLCB Device

All Workstream 1 (WS1) activities for the development of the FLCB have been completed in the previous reporting periods.

Workstream 2 – Network Demonstration

During this reporting period, Workstream 2 (WS2) focused on continuing the trial period under the final running arrangement, Running Arrangement 3 (RA3). This arrangement as shown in *Figure 1*, sees the FLCB operated as a bus coupler by opening the existing bus coupler BC2 and requires the FLCB to break the short circuit current fed from two transformers for certain faults.

The installation completed a full year's service in August 2021. Site inspection and annual maintenance was carried out by ABB between 28 and 30 September 2021.

In this reporting period there were three network faults recorded, however none of them were of a high enough current to trip the FLCB (More detail on these can be found in Section 2.4).

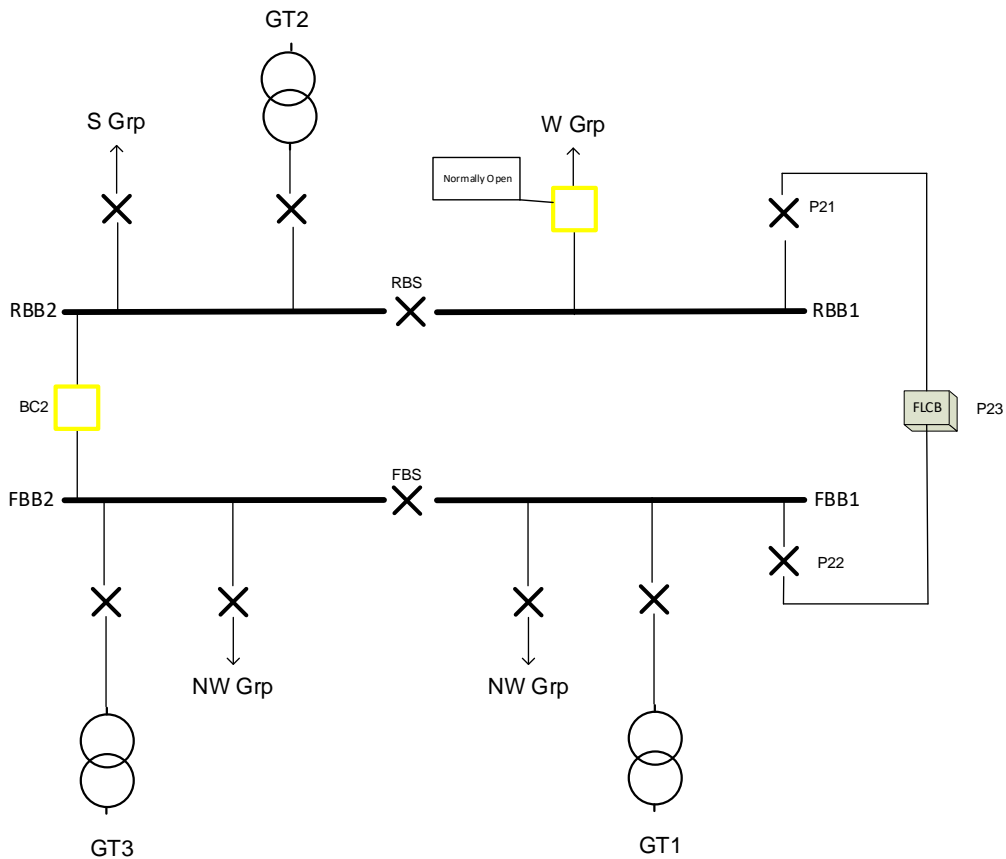


Figure 1: Running Arrangement 3. Note yellow indicates 'normally open'

Workstream 3 – Understanding Customers' Requirements

Following the removal of M2 from the project in the previous reporting period there are no remaining activities for Workstream 3 (WS3).

With the removal of M2 from the project, SDRC 9.3.2 – Assess the (commercial) business case based on the technical and customer findings, focusing on investment decision criteria and trade-offs, such as cost, time to connect, space and impact on security of supply, will no longer be produced and published.

UK Power Networks still intends to build upon the learnings generated from our engagements with customers willing to participate in such a trial, and continue to see real value in the customer placed FLCB. As such we have partnered with Western Power Distribution on an NIA project called EDGE-FCLi (Embedded Distributed Generation Electronic – Fault Current Limiter interrupter). The scope is similar to that of M2 and, although a different supplier is being used, we aim to deliver similar benefits to customers once the project is complete. The project is unique as the technology readiness level (TRL) of the device being developed is lower than what was originally proposed with AMAT in M2 and hence provides a great opportunity for the project to increase choice in the market for customers.

Workstream 4 – Knowledge Dissemination

During this reporting period, Workstream 4 (WS4) prepared and delivered two external webinars with ABB on the 22 October 2021 to share knowledge gained from the installation work, commissioning and operation of the FLCB to date.

On the last day of the service visit mentioned above, the opportunity was taken to deliver a third training and information session for operational staff, following a positive response to similar sessions delivered in previous reporting periods. The session provided an update on project progress and learning to date and allowed the project team to show how operational staff feedback had been incorporated into the trial.

Additionally, a Q&A session on the project was delivered at the Energy Networks Innovation Conference in October 2021.

The project won two awards during the reporting period:

- the 'Energy Tech – Innovation' award at the Better Society Energy Awards (**Error! Reference source not found.**)
- the "Electrify our world Award – first in innovation" – an internal ABB award made quarterly by the ELDS (Electrification – Distribution Solutions) Business Division. These awards aim to highlight exceptional examples of projects that embody "First for Customers"; "First for Innovation" and "First in Digital".



Figure 2: The project team winning the 'Energy Tech – Innovation' Award

The project team continued to engage with colleagues from Asset Management, Capital Programme and Procurement and Network Operations to share data captured, the ongoing performance of the FLCB and interaction with existing protection. This knowledge sharing is extremely valuable in understanding how the FLCB can be integrated into DNO networks and will help support the transition into BAU following completion of the project.

1.3 Risks and issues

The project continues to apply robust risk management procedures to reduce the probability and impact of risks materialising. The full risk register and status of each can be found in Section 11. The project team have taken

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mitigating actions to reduce the impact of issues and are closely managing high risk items. Further detail is provided below:

Table 1 Risks and issues identified for this reporting period

Ref	Issue	Impact	Mitigation
R47	Potential extension to project trial end date (this is also linked to R9 included within the full risk register in Section 11 of this report)	Extension of overall project end date. Delays encountered during type testing, approval to energise the retrofit circuit breakers due to the defect linked to R42 (outside the scope of the project), issues arising during commissioning have impacted the trial start date.	The project team will monitor performance of the FLCB. Based on the number of network faults that are experienced, the team will assess whether or not an extension to the project trial is required. The reliability of our network means that network faults occur infrequently. Performance data of the FLCB under network faults is vital as this maximises the learnings generated through the project and provides confidence in the reliability of the FLCB.

During the previous reporting period risk R47 impacted the project and overall schedule. Although the project saw two network faults with the FLCB performing as expected the project team wanted to maximise the opportunity to generate valuable insights and to monitor the reliability of the FLCB over time and hence decided to extend the project trial.

Based on this, all future planned activities and deliverables for the project will be delayed including the project completion date. The project team formally notified Ofgem with a non-material change letter on 15 July 2021 detailing the impact on project plan. The trial is now scheduled to be completed in May 2022, and the project end date has moved to August 2022.

1.4 Outlook for next reporting period

During the next reporting period, the project team will continue with the trial period, gather and analyse data and disseminate knowledge. The activities include:

- Continuing to trial the FLCB under Running Arrangement 3;
- Building on the publication of the preliminary safety case report in 2018, Phase 2 of the safety case will remain active for the remaining duration of the project. Phase 2 will include updating the preliminary safety case with any lessons learned and additional safety requirements identified during the preparation, installation, commissioning of the FLCB and any design changes during the trial; and
- Conclusion of the project trial.

The trial is due to complete during the next reporting period. Following a review of the trial data and discussions with internal UK Power Networks teams and ABB, a decision will be made whether to leave the FLCB in situ for an additional period beyond project closedown. This will go ahead if it is felt that additional learning can be achieved with the continuing deployment of the FLCB.

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2. Project Manager’s report

The project made good progress during this reporting period (July-December 2021) focusing on the following areas:

- Ongoing project planning for trial conclusion;
- Continuing the trial period under Running Arrangement 3;
- Data gathering and analysis;
- Performance analysis of the FLCB under network faults;
- Inspection and service of the FLCB; and
- Hosting external webinars for ABB and a Q&A session at the Energy Networks Innovation Conference to share experience to date of the project

The following sections present individual workstream reports covering progress made, challenges encountered, lessons learned and the outlook for the next reporting period.

2.1 Project Team

In this reporting period the project team has not changed and the core project team continues to comprise of three dedicated roles:

Table 2 Project team roles

Role	Status	Start Date
Project Manager	Appointed	4 February 2019 (note this date is when current project manager commenced. There were previous project managers prior to this date)
Workstream 1&2 Lead	Appointed	23 March 2018
Workstream 4 ¹ Lead	Appointed	3 July 2017

2.2 Project Partners

As highlighted in the December 2018 Project Progress Report (PPR) our project partner ABB has signed onto a collaboration agreement with UK Power Networks and has developed the FLCB and is progressing with trialling the FLCB.

The project continues to hold fortnightly Project Partner meetings to ensure successful delivery of the project. The Project Partner meeting covers a number of key points, including:

- Workstream updates – Report on progress to date, risks and issues;
- Technical discussions requiring input from all involved in the project, including internal stakeholders;
- Collaborative planning of tasks for upcoming project milestones;
- Planning for workshops and engagement with UK Power Networks’ stakeholders; and
- Risks, issues and mitigation plans.

¹ The Workstream 3 (WS3) Lead role no longer exists due to the change request submitted to Ofgem 5 July 2019 for the removal of M2 from the scope of the project.

2.3 Workstream 1 – Development of a FLCB Device

WS1 is responsible for designing, building and testing prototype devices suitable for installation and trial in both a primary substation and customer site within London Power Networks (LPN). Following the removal of M2 from the project, a device will no longer be developed for trial at a customer site. For the remainder of the project, WS1 will focus on developing and delivering M1 only.

ABB have progressed their technology from TRL 4 (single-phase proof-of-concept prototype) to TRL 7 (three-phase field prototype), in accordance with defined specifications provided by UK Power Networks. For WS1, ABB designed a three-phase prototype, built and integrated into modular switchgear cubicles and performed testing to ensure the prototype complies with UK Power Networks' requirements.

The learnings from WS1 including specifying the device, prototype development and testing have been disseminated via SDRC 9.1.1. The test reports generated from WS1 are available to other Network Licensees and stakeholders upon request.

Progress during this reporting period

All WS1 activities for the development of the FLCB have been completed in earlier reporting periods.

Challenges and lessons learned

No WS1 specific activities were completed during this period. The data collection and learnings generated as part of the network demonstration will be used for future development of the FLCB.

Outlook for next reporting period

The next reporting period will see minimal progress in WS1 as the FLCB has energised and will continue to be trialled under a number of running arrangements. The remaining activities include:

- Collating additional evidence documents required for the ongoing updates of the safety case (note that this has overlap with WS2).

2.4 Workstream 2 – Network Demonstration

WS2 is responsible for the following activities:

- Designing the interface between the FLCB and the existing network;
- The installation and commissioning of switchgear including the FLCB and ancillary equipment;
- Conducting the network demonstration;
- Collecting adequate data to prove the FLCB is safe and effective; and
- Updating the preliminary safety case.

Within WS2, UK Power Networks will continue to collaborate with ABB, and our safety case expert, to develop the engineering knowledge necessary to safely and effectively demonstrate FLCBs on GB networks. We will investigate issues such as:

- Use cases for FLCBs – for example in parallel with a bus section/coupler or in series with a transformer;
- Protection and control philosophy – FLCB trip settings, reclosing scheme, coordination and discrimination with existing protection and how to handle FLCB failure; and
- The safety case which will be developed in parallel with the engineering investigations to ensure that safety is considered in every aspect of the business as usual (BAU) solution.

Where appropriate we will seek to engage with the Health and Safety Executive (HSE), the Energy Networks Association (ENA), and other licensees, in particular Electricity North West (ENWL) and Western Power Distribution (WPD) who have investigated similar issues with the Respond and FlexDGrid projects respectively. The learning

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from this phase will be captured in engineering policies, standards, and procedures and shared via learning dissemination activities.

Progress during this reporting period

The FLCB reached a full year's service in August 2021.

During this reporting period, WS2 focused on the following activities:

- Continuing the trial period under the final running arrangement, Running Arrangement 3 (RA3). A site inspection and annual maintenance was carried out by ABB on 28-30 September 2021 (Figure 3). The inspection and maintenance covered the following areas:
 - Visual inspection of all parts of the FLCB – no issues were found;
 - Measurement of the contact resistance for all mechanical switches – found to be within expected values;
 - Measurement of the capacitor charging time for each individual drive unit – found to be within expected values;
 - Verification of the tripping set point of the QR6 protection relay in the FLCB;
 - Updating the software of the supervision unit that enables continuous monitoring of load current levels in the FLCB to trigger recording of current waveforms for overcurrent events with insufficient amplitude to trip the FLCB, an action identified as necessary during the previous reporting period; and
 - In addition, one of the mechanical switches (FCS L3-3) was replaced. Diagnostic data collected during the preceding months had shown its opening and closing times beginning to deviate from expected values. The FLCB was de-energised as a precautionary measure on 20 August 2021 to mitigate the risk of a mechanical failure until the switch could be replaced. The new switch was confirmed to be working correctly following installation and the FLCB was re-energised on 1 October 2021. The old switch will undergo accelerated testing at ABB to investigate its remaining life as this knowledge may help the judgement of similar trends observed in the future.



Figure 3: ABB Engineers carrying out the site inspection and maintenance. The picture on the right shows the mechanical switch that was replaced.

- Gathering data and monitoring the health of the FLCB. Twice a day, the supervision unit within the FLCB receives a data cluster, from the control system of each phase of the FLCB, containing the present status of

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a large number of signals. The data in the cluster is used to monitor all the components in the FLCB including the control system itself, the mechanical switches and semiconductors. In the event of an operation, each control system sends an updated cluster and a transient recording of the currents through the FLCB;

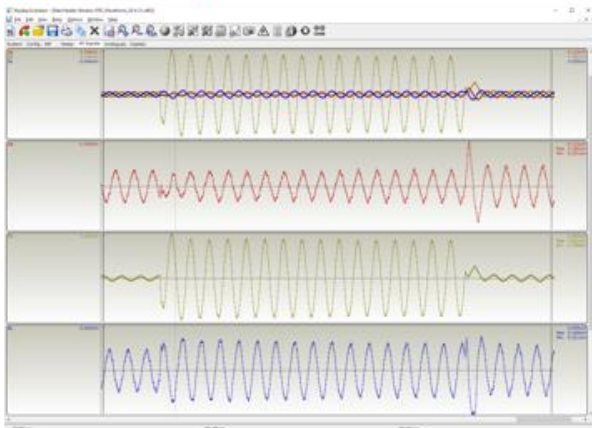
- As highlighted in previous reporting periods the project team have scheduled a monthly confidence switch where Network Control will send an open command to the FLCB and then close it a short time later; and
- Updating the safety case with FNC by information/data which form part of the required evidence documents.

Challenges and lessons learned

This section describes the main challenges and lessons learned in this workstream during this reporting period:

- Three network faults were recorded since the last reporting period, on 14 June, 28 June and 25 July. These faults were of magnitudes 3.7 kA, 3.8 kA and 0.68 kA respectively. The largest of these is shown in Figure 4. As the FLCB set point is 4 kA none of these faults were large enough to trigger it, although the first two were very close to doing so. The project team considered reducing the FLCB set point to potentially allow it to operate during a greater number of faults. However, this would require a lengthy recommissioning process, which would not be the best use of the remaining trial time, particularly as two FLCB-triggering faults have already been recorded in the previous reporting period. The set point will be left as is, and lower amplitude faults will be monitored using the updated supervision unit software described above.

FR2 – Panel 22 fault recorder – 28/06/2021, 16:32:12
Peak current: $1.911 \cdot I_n = 3822 \text{ A}$



FR2 – Panel 22 fault recorder – 28/06/2021, 16:32:12
Voltage waveforms

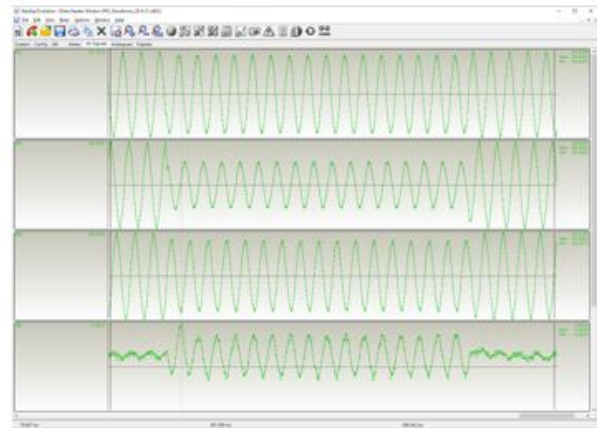


Figure 4: Current and voltage waveforms from non-FLCB triggering fault recorded on 28 June 2021

- Diagnostic data collected during the preceding months had shown the opening and closing times of one of the four mechanical switches in one phase beginning to deviate from expected values. The FLCB was de-energised as a precautionary measure on 20 August 2021 to mitigate the risk of a mechanical failure until the switch could be replaced. The new switch was confirmed to be working correctly following installation and the FLCB was re-energised on 1 October 2021. No network faults were experienced during the seven-week outage period, so the precautionary shutdown did not have any negative impact on the project. The old switch will undergo accelerated testing at ABB to investigate its remaining life. Knowledge from these tests will help the judgement of similar occurrences in the future, so this is a useful learning point for network reliability that has arisen from the project.

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- A further useful learning point that arose during the reporting period was that, whilst UK Power Networks staff had been carrying out some other routine maintenance on the 23 September 2021, the FLCB had been incorrectly powered down. Due to the control systems set-up on the FLCB, this could have serious consequences in certain circumstances. To prevent this happening in future, the MCB on the control systems 24V power supply was locked into the 'on' position and a cover placed over it (This does not raise any safety concerns as it is used purely as a switch and all the components supplied via it have their own self-protection systems). Additionally, a label was put next to the MCB detailing the correct shutdown procedure, and lockable handles have been fitted to the LV doors.

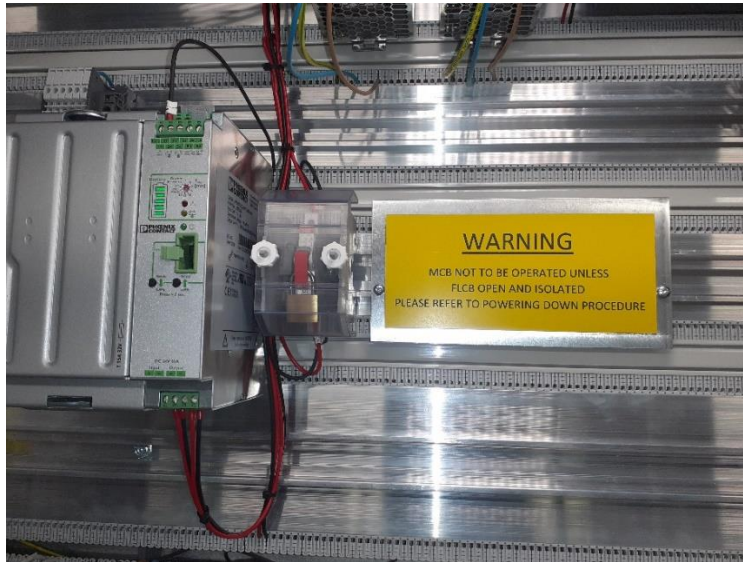


Figure 5 Control system power supply MCB locked in the 'on' position, cover placed over the front and labelling applied

Outlook for next reporting period

The next period will see the project team continue to monitor and analyse the performance of the FLCB while awaiting further occurrence of possible network faults. In this running arrangement, the device is likely to experience a fault fed from two transformers which is the running arrangement where the most benefits can be realised under BAU.

The trial is scheduled to end in May 2022. A decision will be taken during the next reporting period whether to decommission the FLCB or leave it in situ to collect further operational data.

2.5 Workstream 3 – Understanding Customers' Requirements

WS3 is responsible for understanding our customers' needs, ensuring that we design the solutions to meet our customers' needs and to recruit a trial participant for the M2 demonstration.

Following the removal of M2 from the project, SDRC 9.3.2 will no longer be produced and published. Further details of this SDRC can be found in section 7.

Progress during this reporting period

UK Power Networks still intends to build upon the learnings generated from our engagements with customers willing to participate in such a trial, and continue to see real value in the customer placed FLCB. As such we have partnered with Western Power Distribution for a NIA project called EDGE-FCLi (Embedded Distributed Generation Electronic – Fault Current Limiter interrupter). The scope is similar to that of M2 and we aim to deliver similar benefits to the customers once the project is complete and proved to be successful. The technology readiness level (TRL) of the

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device being developed is lower than what was originally proposed with AMAT in M2 which provides a great opportunity to increase choice for customers.

Challenges and lessons learned

The project team experienced no challenges under WS3.

Outlook for next reporting period

During the next reporting period the project team intends to continue engaging with all interested stakeholders as M1 progresses.

2.6 Workstream 4 – Knowledge Dissemination

WS4 oversees the dissemination and activities for learnings generated throughout the project. These are critical aspects of the project and will ensure that DNOs across GB can build on Powerful-CB learnings, avoiding unnecessary duplication of work. Internal stakeholder engagement activities also play an important role in guiding the development and deployment of the new FLCB within the business and support the successful transition into BAU. Key learning reports are published on UK Power Networks innovation [website](#).

Progress during this reporting period

We delivered two external webinars with ABB on 22 October 2021 with 100 attendees to share knowledge gained from the installation work, commissioning and operation of the FLCB to date.

We delivered a third training and information session at the end of the ABB site inspection on 30 September for operational staff, following a positive response to similar sessions delivered in previous reporting periods. The session provided an update on project progress and learning to date and allowed the project team to show how operational staff feedback had been incorporated into the trial.

Additionally, a Q&A session on the project was delivered at the Energy Networks Innovation Conference in October 2021.

In addition to the industry-facing knowledge dissemination webinar described above, Valuable engagement with UK Power Networks' internal stakeholders has been ongoing during the project. We continue to engage with colleagues from Asset Management, Capital Programme and Procurement and Network Operations to share data captured, the performance of the FLCB and interaction with existing protection. Engagement with internal stakeholders is vital to support the transition into BAU following completion of the project.

Powerful-CB continues to update the project website with any relevant information and deliverables to ensure these are easily accessible to all stakeholders.

Challenges and lessons learned

There were no challenges or lessons learned for this workstream during this reporting period.

Outlook for next reporting period

The following activities are planned for the next reporting period:

- Development of learning report SDRC 9.2.3: Demonstration of solution at an 11kV substation (Method 1); and
- Continued updating of the project website.

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3. Business case update

We have not discovered any new information that affects the business case; thus the business case remains consistent with our FSP. During this period a non-material change notification was made to Ofgem to extend the trial period until May 2022. The project assumes 100% deployment of M1 across GB and the delivery of committed benefits of up to £403m by 2050.

4. Progress against plan

This section summarises the project's progress in the period July to December 2021. It describes issues we faced and how we managed them, key achievements, notable events, key planned activities for the next reporting period and any issues we expect in the next reporting period.

4.1 Summary of changes since the last Project Progress Report

Figure 6 overleaf shows the key activities and changes to the project plan during the current reporting period.

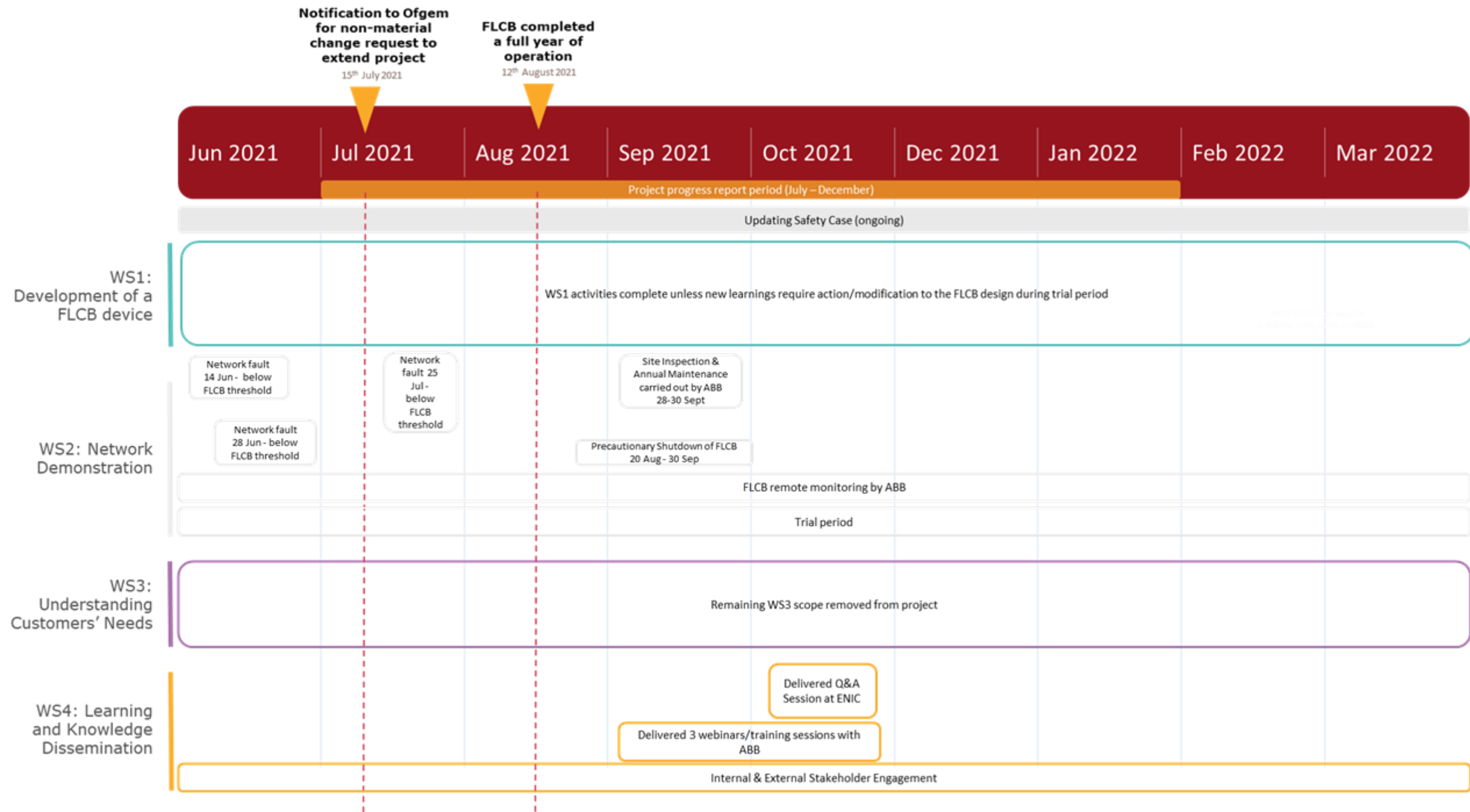


Figure 6: High level project plan highlighting changes during the current reporting period.

As previously highlighted in the June 2021 PPR, the project team decided to extend the project in order to maximise our learnings and continue to build confidence in the performance of the FLCB. The project team formally notified Ofgem with a non-material change letter during this reporting period, and the updated project timings have been included in the project plan and all remaining SDRCs and project completion dates have been rescheduled to be delivered later compared to the Project Direction.

4.2 Detailed progress in the reporting period

The project has made significant progress during this reporting period, as shown below:

Table 3 Project progress during this reporting period

Task description	Workstream	Status at start of period	Status at end of period
Trial – Running Arrangement 3 phase	2	In progress	In progress
Data monitoring and analysis of performance of FLCB	2	In progress	In progress
Inspection and maintenance of FLCB	2	Not started	Complete
Delivery of external webinars with ABB and Training session held for operational staff	4	Not started	Complete
Delivery of Q&A Session at ENIC 2021	4	Not started	Complete

4.3 Identification and management of issues

The project team recognises the importance of robust risk management methodologies for any project, but more specifically for complex innovation projects. Due to the nature of complex innovation projects, it is likely that certain risks will impact the overall project activities in some form. A full list of project risks identified for the project is provided in Section 11.

During this reporting period it can be reported that risk R47 has impacted the project and overall schedule. As highlighted in the previous reporting period, part of the mitigation for this risk was to assess whether a trial extension is required based on the number of network faults. As no additional faults that triggered the FLCB were experienced in that period, it was decided to extend the trial to maximise the opportunity to generate further valuable insights and monitor the reliability of the FLCB over time.

As highlighted in Section 4.1, Ofgem was notified of this decision by a non-material change letter in July 2021. The following issues have been recorded in the workstream reports and are also captured below:

Table 4 Risks and issues impacting project during this reporting period

Ref	Issue	Impact	Mitigation
R47	Extension to project trial end date (this is also linked to R9 included within the full risk register in Section 11 of this report)	Extension of overall project end date. Delays encountered during type testing, approval to energise the retrofit circuit breakers due to the defect linked to R42 (outside the scope of the project), issues arising during commissioning have impacted the trial start date.	The decision has been taken to extend the trial. This will increase the learning we can derive from the project with only a short delay to the completion date. Extra monitoring capability has been employed, meaning we can collect additional valuable data on system performance during the extension period.

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4.4 Key achievements and notable events

Key achievements and notable events in the reporting period are shown below:

- Continuation of the network demonstration period under Running Arrangement 3 (WS2);
- Collection of network data to monitor performance of the FLCB (WS2);
- Experienced three network faults: although none of these were large enough to trigger the FLCB, they still provide useful data. The supervision unit has been updated and two external fault recorders installed so we can collect information on lower-level faults for the remainder of the trial(WS2);
- Won two awards: The ‘Energy Tech – Innovation’ award at the Better Society Energy Awards and ABB’s internal ‘Distribution Solutions Award’;
- Delivered two webinars attended by 100 people with ABB, held training session for UK Power Networks operational staff (WS4); and
- Hosted a Project Q&A session at ENIC 2021 (WS4).

4.5 Look-ahead to next reporting period

The following major tasks and milestones are planned for the next reporting period:

- Continuing network demonstration of the FLCB (WS2);
- Updating Phase 2 of the safety case (WS1 and WS2); and
- Publishing the Final Learning Report – Demonstration of a FLCB for Substations, which will include results and learning from operating and maintaining a substation containing a FLCB, and technical performance of the FLCB and overall solution under real network conditions (WS4)

5. Progress against budget

This section is provided in the Confidential Appendix A.

6. Project bank account

This section is provided in the Confidential Appendix A.

7. Successful Delivery Reward Criteria (SDRCs)

This section provides a brief narrative against each of the SDRCs set out in the Project Direction. The narrative describes progress towards the SDRCs and any challenges we may face in the next reporting period. As demonstrated on the Table below, we have struck-through the SDRCs that were removed as part of the change request to remove M2.

Table 5 Project SDRCs

Project Deliverable	Deadline	Evidence	Progress
9.1 Work with industry to advance new FLMTs based on FLCB technology			
9.1.1 Prototype and lab test a substation-based solution (Method 1)	31 May 2019	Publish Learning Report – Development of a FLCB for substations , which will include: recommendations for specifying a substation-based FLCB; results and learning from type tests (including a short circuit test) conducted at an accredited high power laboratory; and requirements for integrating FLCBs into existing networks and ensuring safety.	Completed on time

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Project Deliverable	Deadline	Evidence	Progress
9.1.2 Prototype and lab test a customer-based solution (Method 2)	31 August 2019	Publish Learning Report – Development of a FLCB for customers, which will include: recommendations for specifying a customer-based FLCB; results and learning from type tests (including a short circuit test) conducted at an accredited high power laboratory; and requirements for integrating FLCBs into existing networks and ensuring safety.	Removed from project
9.1.3 Independent review of safety case	31 May 2018	Issue preliminary safety case to relevant ENA panel(s) for independent review which will include: Definition and justification of acceptable levels of risk; analysis of failure modes and effects; details of proposed mitigations; and claims, arguments, and evidence to demonstrate that the proposed mitigations reduce the overall level of risk to an acceptably low level.	Completed on time
9.1.4 Safety case for FLCB installation without back-up	31 May 2018	Publish preliminary safety case which will include the technological and operational safety case to the time when the trial equipment could be deployed as BAU without the FLCBs being installed in series with a back-up circuit breaker.	Completed on time
9.2 Trial the technical suitability of these two technologies including effectiveness and safety considerations for relieving fault level constraints for 11kV networks			
9.2.1 Install and commission solution at an 11kV substation (Method 1)	30 November 2020 <i>changed from 31 July 2020</i>	Publish Interim Learning Report – Demonstration of a FLCB for substations , which will include results and learning from installation, commissioning, and operation to date of a FLCB at a substation.	Completed on time Delayed by four months due to COVID-19 as notified in the non-material change request letter to Ofgem on 8 July 2020
9.2.2 Install and commission solution at a customer's premises (Method 2)	31 July 2020	Publish Interim Learning Report – Demonstration of a FLCB for customers, which will include results and learning from installation, commissioning, and operation to date of a FLCB at a customer's premises.	Removed from project
9.2.3 Demonstration of solution at an 11kV substation (Method 1)	30 June 2022 <i>Changed from 31 October 2021</i>	Publish Final Learning Report – Demonstration of a FLCB for substations , which will include results and learning from operating and maintaining a substation containing a FLCB, and technical performance of the FLCB and overall solution under real network conditions.	Following decision to extend project trial, Ofgem was notified of this non-material change in July 2021

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Project Deliverable	Deadline	Evidence	Progress
9.2.4 Demonstration of solution at a customer's premises (Method 2)	30 June 2021	Publish Final Learning Report – Demonstration of a FLCB for customers, which will include results and learning from operating and maintaining a FLCB at a customer's premises, and technical performance of the FLCB and overall solution under real network conditions.	Removed from project
9.3 Assess the suitability of the solutions against customers' needs			
9.3.1 Review the customer needs for these two FLCBs technologies on behalf of DNOs and DG stakeholders	31 October 2017	Publish Learning report – Understanding customers' requirements , which will describe our findings from customer dialogue sessions, i.e. understanding their requirements and concerns about FLCBs, and customer feedback.	Complete on time
9.3.2 Assess the (commercial) business case based on the technical and customer findings, focusing on investment decision criteria and trade-offs, such as cost, time to connect, space and impact on security of supply	31 March 2020	Publish Learning report – Suitability of FLCBs, which will inform generation customers of the solutions, answer frequently asked questions, and provide enough information for customers to assess whether the solution meets their requirements (e.g. cost, time to connect, space required, operational impacts, etc.).	Removed from project
9.4 Share the learning throughout the project with the wider utility industry			
9.4.1 Share overall learning from the project with customers, regulators, other DNOs, other manufacturers, and academia via a stakeholder event	31 August 2022 <i>Changed from 31 January 2022</i>	Publish key materials from the stakeholder event (e.g. slides), and provide Ofgem with a list of invitees and attendees.	Following decision to extend project trial, Ofgem was notified of this non-material change in July 2021

8. Data access details

To view the full Innovation Data Sharing Policy, please visit UK Power Networks' website [here](#).

UK Power Networks recognises that innovation projects may produce network and consumption data, and that this data may be useful to others. This data may be shared with interested parties whenever it is practicable and legal to do so and it is in the interest of GB electricity customers. In accordance with the Innovation Data Sharing Policy, UK Power Networks aims to make available all non-personal, non-confidential/non-sensitive data on request, so that interested parties can benefit from this data.

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9. Learning outcomes

The project team recognises the importance of learning and dissemination. Specific lessons learned in each of the workstreams are captured in the workstream progress reports in Section 2 of this progress report.

During this reporting period, the project team hosted two external webinars and held a training session with operational staff, to share knowledge gained from the installation work, commissioning and operation of the FLCB to date and other project progress as highlighted in Section 2.6.

We also hosted a Q&A session on the project at the Energy Networks Innovation Conference in October 2021, sharing our learning and progress to date with DNOs and other interested parties attending the conference.

Previous learning reports highlighted in Section 7 are also available through [this](#) website. Additional documents such as specifications, commissioning reports and standards are available to other GB DNOs upon request.

10. Intellectual Property Rights (IPR)

This section lists any relevant IPR that has been generated or registered during the reporting period along with details of who owns the IPR and any royalties which have resulted, and any relevant IPR that is forecast to be registered in the next reporting period.

IPR generated this period (July – December 2021)

Table 6 Project IPR generated during this reporting period

IPR Description	Owner(s)	Type	Royalties
Data and performance of FLCB during network demonstration	ABB UK Power Networks	Relevant Foreground IPR	Nil
Webinar content	ABB UK Power Networks	Relevant Foreground IPR	Nil
Safety case documentation	ABB UK Power Networks	Relevant Foreground IPR	Nil

IPR forecast next period (January – June 2022)

Table 7 Project IPR forecast for next reporting period

IPR Description	Owner(s)	Type	Royalties
Publish SDRC 9.2.3 Final Learning Report – Demonstration of a FLCB for substations	ABB UK Power Networks	Relevant Foreground IPR	Nil

11. Risk management

This section lists the risks highlighted in the FSP plus any other risks that have arisen in the reporting period. We have described how we are managing the risks we have highlighted and what we have learned. Risks 1-36 are captured in the FSP although some have been updated. The remaining risks were identified during the progress of the project. The project continues to monitor risks and issues on a monthly basis where risk impacts and mitigation plans are updated.

Ref	WS	Status	Description	Mitigation/Planned Action	Current Status	RAG
R1	WS1	Closed	ABB's costs increase because of exchange rate movements due to Brexit developments.	ABB has agreed to hold their quoted price in GBP until the project commences. Once the project has commenced, we will agree the ABB contract price in GBP, or agree the price in EUR and take steps to hedge the exchange rate risk.	Now the contract has been agreed and signed in GBP, this risk is mitigated.	G
R2	WS3	Closed	Unable to find a suitable site/willing customer for customer trial.	We will engage with customers to understand their motivations for participating in the trial, so that we can design the trial and recruitment campaign to provide the right incentives and target the right customers. We will also consider relevant customer research and learning from ENWL's FCL Service trial.	We identified a potential customer and a location for trials.	G
R3	-	-	NOT USED.	NOT USED.	NOT USED.	-
R4	WS1	Closed	Delay and/or cost overrun – prototype development.	ABB and AMAT have agreed to take all risk of cost overruns within their control. UK Power Networks will use our existing change control procedures to minimise the risk of changes that cause additional costs for ABB and AMAT.	We have negotiated and signed the collaboration agreement with ABB to minimise the risk of cost overruns. The risk of delay in prototype development is still present. See risk R41 for more specific risk. FLCB was delivered to site 5 November 2019	G
R5	WS1	Closed	Delay and/or cost overrun – safety case (due to unforeseeable requirements).	We have allowed specific contingency for the safety case, based on FNC's experience of required effort in the event of unforeseen requirements.	FNC delivered the preliminary safety case within the given timescales. SDRC 9.1.3 and SDRC 9.1.4 are complete.	G
R6	WS1	Closed	Prototype as delivered is not fit for purpose.	UK Power Networks, ABB, AMAT, FNC to collaborate to develop the FLCB specifications; Safety consultant to develop safety case in parallel; engage with other HSE, ENA, and other DNOs.	Regular meetings and ad-hoc communications between ABB, FNC, and UK Power Networks technical experts has meant successful collaboration on the FLCB specification and safety case. The preliminary safety case is complete. The FLCB has undergone type testing and FATs	G
R7	WS1	Open	Solution does not deliver the necessary reliability and/or redundancy to be able to prove the safety case.	Safety case feasibility study completed before full submission. Safety case to be developed in close collaboration with FLCB designers and engineering standards.	All key stakeholders, including ABB and UK Power Networks technical experts, attended the safety case workshops. The preliminary safety case is complete. Phase 2 of safety case to be completed during demonstration period.	G

Ref	WS	Status	Description	Mitigation/Planned Action	Current Status	RAG
R8	WS1	Open	Solution is not suitable for general population of GB sites due to operational or physical space constraints.	We will engage with other DNOs to understand any operational or physical space constraints that are unique to their networks.	N/A this period.	G
R9	WS2	Open	Trial site does not experience enough HV network faults to prove that the solution is safe and reliable.	<p>We will use history of HV network faults as a criterion when selecting trial sites. We will use the safety case to determine how much data is required to prove that the FLCB is safe.</p> <p>Additionally a 24 month trial period will be completed.</p>	<p>We have used historic fault data when looking at potential sites – recognising that fault history is not necessarily an indicator of future faults.</p> <p>The trial period has been reduced due to various delays experienced during type testing and commissioning. This includes delays linked to COVID-19 preventing energisation and commencement of the trial period.</p> <p>This risk is linked to risk R47 where a project extension is being considered and is dependent on the number of network faults experienced</p>	G
R10	WS2	Open	Trial fails to capture the data necessary to prove that the solution is safe and reliable.	We will ensure that our data capture solution has adequate reliability and redundancy so that we don't miss any opportunities to capture data from real network faults.	Sufficient data was captured from network faults during this reporting period.	G
R11	WS2	Open	Solution fails to operate correctly during field trial (i.e. fails to limit fault current).	We will not allow fault levels to exceed equipment ratings until the FLCB has been proven safe and reliable. This minimises the risk of an unsafe situation if the FLCB fails to operate correctly.	FLCB correctly operated for two network faults in the previous reporting period so the risk is low.	G
R12	WS2	Closed	Customer trial has adverse impacts on customer.	We will identify the potential impacts on the customer and work with them to ensure the risks are well managed.	M2 (customer site trials) will no longer be pursued as part of this project.	G
R13	WS4	Open	ABB decides not to offer a commercial product.	ABB have confirmed that if they are unable to offer their foreground IPR to Licensees in the form of a commercial FLCB product, they are willing, in principle, to licence any relevant foreground/background IPR to a third party for the purpose of developing a commercial FLCB product.	N/A this period.	G
R14	WS4	Open	Solution is not accepted by other DNOs.	We will engage with other DNOs at key stages of the design and specification processes to ensure that their requirements and concerns are addressed.	N/A this period.	G
R15	WS1 and WS2	Closed	Project partners unable to deliver on commitments on time because of lack of resources and/or other commitments.	We will agree heads of terms and scopes for collaboration agreements with all project partners in advance of project kick-off.	Lead times of UPSs and resource availability saw a second site visit for commissioning take place in February	G
R16	PM	Open	UK Power Networks not able to deliver on commitments because project delivery team is under-resourced.	We will secure resources for the core project delivery team in advance of project kick-off and ensure adequate succession planning to manage the risk of staff movements.	N/A this period.	G
R17	PM	Open	UK Power Networks not able to deliver on commitments because other teams supporting the project have operational resource constraints.	We have engaged the relevant business units within UK Power Networks to confirm their support of the project and will confirm resourcing commitments during project mobilisation.	N/A this period.	G

Ref	WS	Status	Description	Mitigation/Planned Action	Current Status	RAG
R18	PM	Closed	Partner withdraws from project for financial, commercial, or technical reasons.	If one technology partner withdraws from the project, we will consider using the same technology at both substation and customer sites, or if this would not provide value for customers' money, we would de-scope the project to only trial one method. If FNC withdraw from the project, we will seek an alternative partner who can provide the necessary safety case expertise.	AMAT did not sign the collaboration agreement and have withdrawn from the project. Following this change, we engaged with the market to find an alternative partner for M2. However when no suitable replacement could be found, the project team decided to request a change from Ofgem to remove M2 from the project.	G
R19	WS2	Closed	Customer (trial participant) withdraws from the project because the trial is impacting their business activities.	To minimise probability, we will only consider customers where the risk of adverse impact on their business activities is minimal or can be managed.	Risk no longer valid. M2 (customer site trials) will no longer be pursued as part of this project. Change request submitted to remove M2 from the project.	G
R20	PM	Open	Breach of data protection regulations.	We will ensure that all customer's details are handled and stored in accordance with our data protection procedures.	N/A this period.	G
R21	WS2	Open	Solution has adverse impacts on protection grading, causing unacceptable fault clearance times.	We will complete a protection coordination study to ensure that the solution does not have any adverse effects on protection coordination.	We have engaged with the protection team and they have not indicated any initial issues.	G
R22	WS2	Open	Solution fails, causing unplanned outages.	We will install additional circuit breakers that enable the FLCB to be remotely bypassed and isolated to minimise the risk of unplanned outages in the event that it fails.	N/A this period.	G
R23	WS2	Open	Solution is not suitable for general population of UK Power Networks sites due to operational or physical space constraints.	We have already completed a preliminary feasibility study on a sample of LPN sites, and will complete a feasibility study on a sample of LPN, EPN, and SPN sites as part of the project.	N/A this period.	G
R24	WS3, WS4	Open	BAU method cost is higher than expected.	If we discover any issues that could increase the BAU method cost to the point where the project business case is no longer viable, we will assess whether the project should be halted or de-scoped.	N/A this period.	G
R25	WS1	Closed	Equipment fails to pass high power type tests.	ABB and AMAT have both allowed adequate contingency to build another prototype, in the event that the device intended for the field trials fails catastrophically during type testing and cannot be salvaged.	4 of 5 type tests passed. Internal arc withstand will be re-tested. Re-test of IAC test completed in July 2019	G
R26	WS2	Closed	Unable to find a suitable site for substation trial.	If we are unable to find a suitable site in LPN (e.g. there are sites that would be suitable for a BAU deployment but not suitable for a trial for business/commercial/safety reasons), we will also consider sites in SPN or EPN that have similar operational and/or physical constraints as typical LPN sites.	This risk is closed as a trial site has been selected within LPN.	G
R27	WS4	Open	Learning from the project is not disseminated effectively to the DNO community.	We will benchmark our knowledge dissemination strategy against other projects and other DNOs to ensure its effectiveness.	Two external webinars were held and Q&A session at ENIC 2021 to disseminate knowledge.	G
R28	WS4	Open	Solution is not approved by UK Power Networks.	We will involve key UK Power Networks stakeholders to champion the design and specification of the solution to ensure that it is accepted.	Key UK Power Networks stakeholders (i.e. technical experts) are forming an internal working group to discuss issues that may arise in the BAU adoption of FLCB technology.	G

Ref	WS	Status	Description	Mitigation/Planned Action	Current Status	RAG
R29	WS3	Closed	Solution is not accepted by customers.	We will engage with customers to understand their requirements and motivations, and ensure the solution is designed to meet their needs.	The customer based solution for M2 was removed from the scope of the project.	G
R30	WS2	Closed	Delay and/or cost overrun – civil works.	We will leverage the expertise of our in-house capital delivery teams to ensure that all site works are well managed.	Civil works completed this period	G
R31	WS2	Closed	Delay and/or cost overrun – electrical installation works.	We will leverage the expertise of our in-house capital delivery teams to ensure that all site works are well managed.	See R17 for the delay in electrical installation works	G
R32	WS1	Closed	Project kick-off delayed by negotiations with project partners.	We have agreed heads of terms and scopes for collaboration agreements with all project partners before full submission.	AMAT withdrew from the project and ABB have signed the collaboration agreement.	G
R33	WS1, WS2	Closed	Project delivery team lacks necessary technical expertise.	We have engaged technical experts within the business to serve as the project design authority. We will also engage an expert on power electronics to provide assurance on ABB designs and specifications.	We are working closely with any relevant business units where necessary.	G
R34	WS2	Closed	Delay and/or cost overrun – commissioning.	Costing exercise is under way to estimate remobilisation costs and forecast time required to complete remaining works to minimise the use of contingency costs	Additional site works to complete commissioning in February, R44 and R45 requiring time and cost in the future has impacted the budget planned for commissioning	G
R35	WS3	Closed	Delay and/or cost overrun – customer engagement/recruitment.	We will leverage the expertise of our in-house capital delivery teams to ensure that all site works are well managed.	WS3 was removed from scope of project as it was related to M2.	G
R36	WS2	Closed	ABB-provided (conventional) circuit breakers do not comply with UK Power Networks' requirements.	We have allowed adequate contingency for UK Power Networks to supply approved circuit breakers, which would be connected to the FLCB by joggle panels ² .	The CBs used in the project are retrofitted from existing ones and we have used the same supplier for the retrofit before.	G
R37	WS3	Closed	Delay in contract phase with the customer.	Shortlist a number of potential customers should the customer withdraw from the project. Engage with the customer and legal team early to allow sufficient time for contracts to be drawn up.	WS3 was removed from scope of project as it was related to M2.	G
R38	WS1	Closed	Unable to sign contract with Method 2 supplier.	Find an alternative supplier. Efforts were made to find an alternative supplier but were unsuccessful. The decision was made to remove Method 2 from the project and a change request was submitted to Ofgem. We are awaiting official response from Ofgem but has been agreed in principle.	Method 2 is removed from the project.	G
R39	WS2	Closed	Delay in delivery of retrofitted CBs.	We have allowed adequate time contingency for ABB UK to supply approved circuit breakers.	The CB retrofit is complete and ready to be delivered to site. The CB retrofit were delivered to site	G

² Joggling is a metalworking technique to attach two metal sheets together. It is an offset bending process in which the two opposite bends are each less than 90°, and are separated by a neutral web so that the offset (in the usual case where the opposite bends are equal in angle) is less than five work piece thicknesses. Often the offset will be one work piece thickness, in order to allow a lap joint, which is smooth on the 'show-face'.

Ref	WS	Status	Description	Mitigation/Planned Action	Current Status	RAG
R40	WS2	Closed	Delay in completion of electrical design (CPP).	Close support of the electrical design team from the project team. Monitoring of progress and assistance from the supplier.	Electrical design completed.	G
R41	WS1	Closed	Delay in testing and/or FAT of FLCB device.	Change order of type tests depending on what is causing the delay.	<p>This risk became an issue due to the original high power test laboratory having a fault with the generator required for the type testing. Due to the long lead time (3-4 months) for repair of the generator, an alternate high power test laboratory has been booked. This will minimise the impact on the readiness of the FLCB for delivery to site.</p> <p>The FLCB failed the first internal arc classification (IAC) test so an investigation and panel modification were made. The re-test was completed in July 2019 but this did impact the delivery to site</p>	G
R42	WS2	Closed	<p>Delay in energisation and commencement of trial period (due to defect identified in QF switchgear (retrofit circuit breakers)).</p> <p>A defect was discovered with a batch of retrofit VOR-M CBs of the same type as the ones being used for the trial site. The defect caused capacitor failures due to a defective batch and they form part of the magnetic actuator mechanism. Failure of the capacitor would prevent the CB from opening/tripping</p>	<p>Project team have identified that the retrofit CBs procured for the project are not part of the defective batch of capacitors so the risk of failure is low.</p> <p>UK Power Networks proposed that in the unlikely event of a DC power supply failure of the substation a portable power pack should be developed by ABB so that the CB can be operated.</p>	ABB designed and produced portable power pack for the retrofitted circuit breakers.	G
R43	WS2	Closed	<p>GT1 cable fault cannot be repaired until sinkhole near where excavation is required is fixed first.</p> <p>Trial site has three transformers in total and the impact of GT1 being out of service is that GT2 and GT3 cannot also be taken out of service as two must be in service. The result of this is that both the auto-close scheme and the fault recording relays cannot be fully commissioned.</p>	Return at a later date to commission auto-close scheme and fault recorders to mitigate delay in energisation. Auto-close scheme is required for running arrangement 3 and the FLCB has its own fault recording devices.	GT1 cable fault was repaired and GT1 put back into service.	G
R44	WS2	Closed	<p>Replacement of R43. Delay in GT1 cable fault repair.</p> <p>Trial site has three transformers in total and the impact of GT1 being out of service is that GT2 and GT3 cannot also be taken out of service as two must be in service. The result of this is that both the auto-close scheme and the fault recording relays cannot be fully commissioned.</p>	Return at a later date to commission auto-close scheme and fault recorders to mitigate delay in energisation. Auto-close scheme is required for running arrangement 3 and the FLCB has its own fault recording devices.	GT1 cable fault was repaired and GT1 put back into service.	G

Ref	WS	Status	Description	Mitigation/Planned Action	Current Status	RAG
R45	WS2	Closed	Delay modification of HV compartment door interlock on the FLCB due to COVID-19 restrictions. This impacts energisation of the FLCB.	<p>Currently no mitigation is possible until site works can safely recommence.</p> <p>Prior to the full lockdown measures implemented by UK Government on 23 March 2020, ABB were scheduled to complete site works 25-27 March 2020. ABB Germany were unable to travel due to aforementioned restrictions. To mitigate the uncertainty as to when ABB Germany could travel again, the project team arranged for ABB UK to carry out the modifications as directed by video for ABB Germany while maintaining safe distances between employees on site.</p>	The FLCB was energised 12 August 2020.	G
R46	WS2 and WS4	Closed	Delay in publication of learning report SDRC 9.2.1 – Interim Learning Report – Demonstration of a FLCB for substations.	To minimise the impact of delays the project team has already starting drafting SDRC 9.2.1 with our learnings to date from installation and commissioning.	SDRC 9.2.1 has been completed.	G
R47	WS2	Closed	Extension to project trial end date (also linked to R9).	The project team will monitor performance of the FLCB once the trial period has started. If a number of network faults are experienced, the team will assess whether or not an extension to the project trial is required.	<p>Delays encountered during type testing, approval to energise the retrofit circuit breakers due to the defect linked to R42 (outside the scope of the project), issues arising during commissioning and COVID-19 have impacted the trial start date.</p> <p>There were two network faults encountered during this reporting period. The FLCB performed as expected and generated valuable insights so the decision was made by the project team to extend the trial period to continue building confidence in the FLCB.</p>	G

12. Material change information

No material changes have been encountered during this reporting period and none are foreseen for the next reporting period.

13. Other information

Currently there is no other information to report to Ofgem.

14. Accuracy assurance statement

The project has implemented a project governance structure as outlined in our innovation policies and procedures that effectively and efficiently manages the project and all its products. All information produced and held by the project is reviewed and updated when required to ensure quality and accuracy. This report has gone through an internal project review and a further review within UK Power Networks to ensure the accuracy of information.

We hereby confirm that this report represents a true, complete and accurate statement on the progress of the Powerful-CB project in its tenth six-month reporting period and an accurate view of our understanding of the activities for the next reporting period.



Signed

Date7 December 2021.....

Suleman Ali
Director of Customer Service, Strategy, Regulation & IS
UK Power Networks