Powerful-CB

Project Progress Report – December 2020

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Contents

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
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)
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

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 11 kV 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 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 will develop 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 2020. The next reporting period will cover January to June 2021. Collectively, these PPRs form the annual progress report required by Ofgem's Network Innovation Competition Governance Document.

Overall, the project has made good progress during the reporting period, considering the challenges associated with COVID-19, focussing on completing final commissioning of the FLCB with associated interconnectors, energisation, commencing the trial period, commissioning the auto-close scheme and gathering trial data.

As explained in the June 2020 PPR, all project site works were suspended in March due to COVID-19 related restrictions. Our estimate at the time was that the project would be delayed by four months from the initiation of national lockdown on 23 March until the end of July. This estimate was correct and project site works recommenced in August. Based on these COVID-19 related delays, all future planned activities and deliverables for the project will be delayed by four months, and the project completion date by five months; this was communicated to Ofgem by a non-material change request letter on 8 July 2020. The second national lockdown which commenced in November 2020 has had no impact on project progress or future deliverables.

With the resumption of site works, the FLCB HV door interlock was repaired and the FLCB energised mid-August and the remaining site works to finish the auto-close scheme and fault recorders were completed at the start of November. Following energisation, for the first month of operation, the FLCB was trialled under Running Arrangement 1 without any issues. After the first month, the site configuration transitioned to Running Arrangement 2 as explained in the previous period's PPR, where the FLCB acts as a transformer incomer breaker. The project team has been monitoring and collecting data, analysing performance in collaboration with the supplier and project partner, ABB.

During this reporting period the project was nominated for two awards; Business Green Leaders Awards in the category for Green Infrastructure Project of the Year for 2020, where it was highly commended and the E&T Innovation Awards 2020 in the category of Outstanding Innovation in Future Power & Energy. Such recognition is not just great success for Powerful-CB project, but also for Network Innovation Competition funding mechanism.

Workstream 1 – Development of a FLCB Device

All Workstream 1 (WS1) activities for the development of the FLCB were completed in the previous period.

Workstream 2 – Network Demonstration

During this reporting period, Workstream 2 (WS2) focused on completing the remaining site works, which were interrupted in the previous reporting period due to COVID-19 restrictions, and commencing the trial period. The work completed as part of WS2 during this period includes:

- During the previous period an issue with the HV door interlock of the FLCB was identified. The changes needed to resolve this were minimal; however, could not be completed until COVID-19 restrictions were lifted. The issue was fully addressed and resolved on 6 August 2020;

Figure 1 FLCB HV door interlock being repaired

- Completed final commissioning checks and tests prior to energisation, with energisation of the FLCB taking place 12 August 2020;
- Completed wiring and commissioning of the fault recorders installed on site;
- Completed wiring and commissioning of the auto-close scheme;
- Following energisation, commenced trial of Running Arrangement 1 for one month as shown in Figure 2 below which is also known as a 'soak' test of the FLCB;

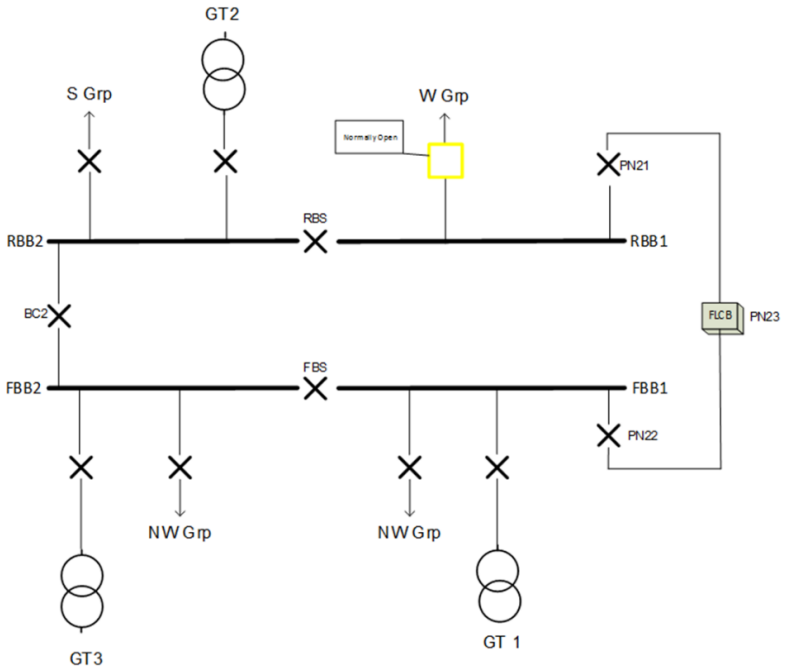

Figure 2 Running Arrangement 1. Note yellow indicates 'normally open'

- Transitioned to the second phase of trial by switching across to Running Arrangement 2 on 30 September 2020 as shown in Figure 3; and

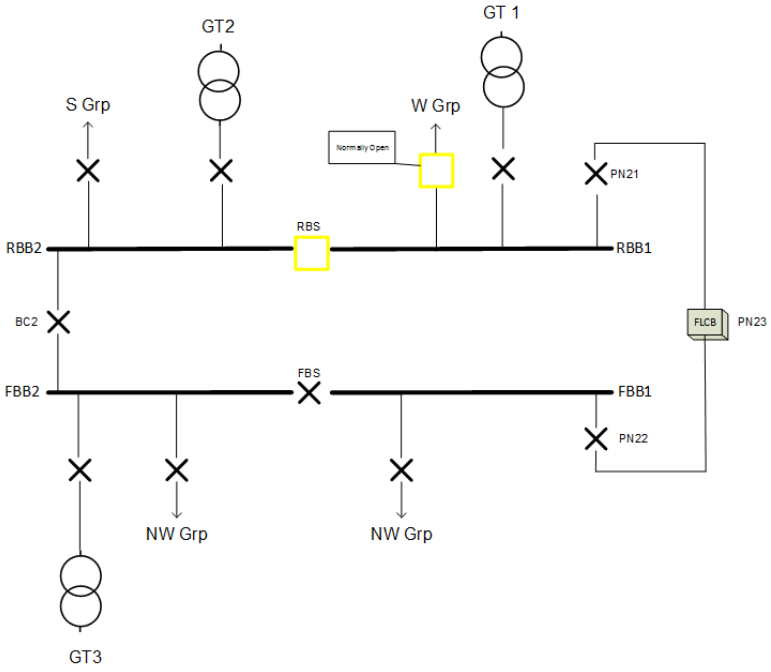

Figure 3 Running Arrangement 2. Note yellow indicates 'normally open'

- Ongoing data collection and analysis during trial period. The full dataset of operation to date of the FLCB since energisation is shown below in Figure 4.

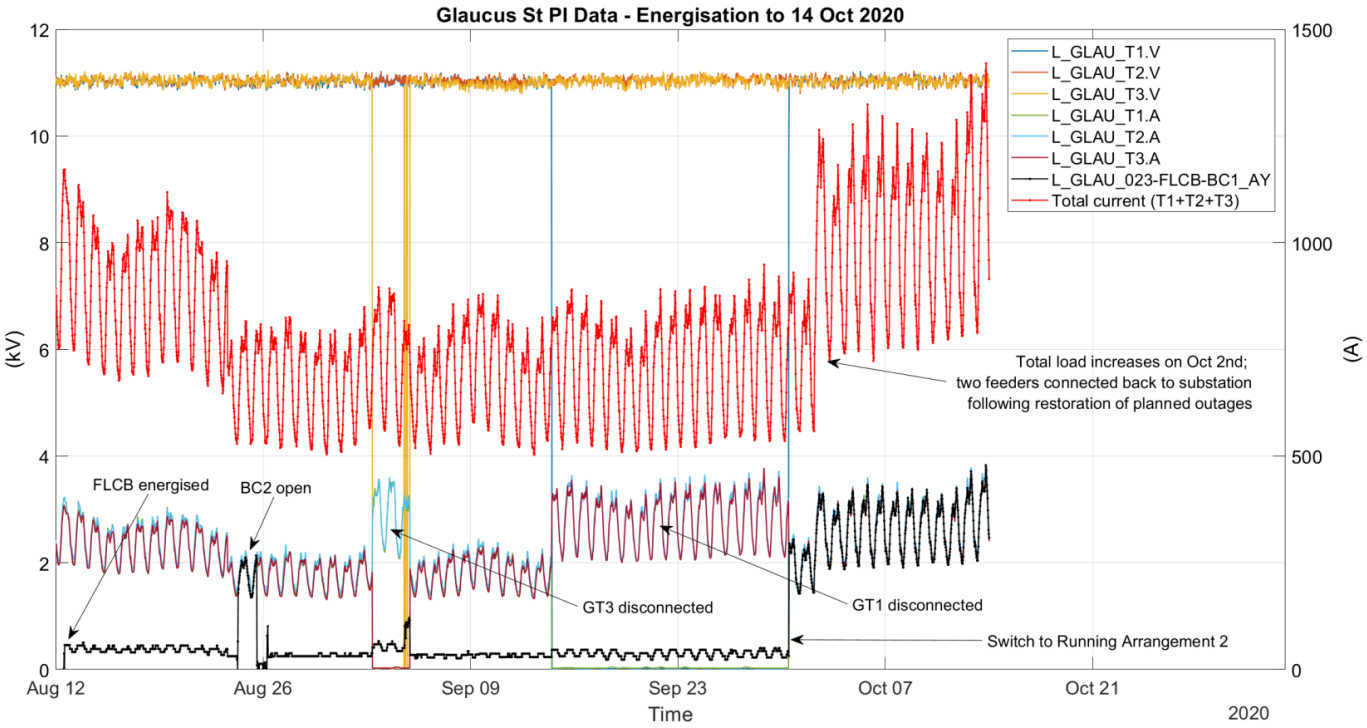

Figure 4 Operation to date of the FLCB through Running Arrangement 1 and Running Arrangement 2

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) focussed on preparing Successful Delivery Reward Criteria (SDRC), SDRC 9.2.1 – Install and commission solution at an 11kV substation. This was submitted to Ofgem on 18 November 2020 ahead of the revised delivery date of 30 November 2020 and published on UK Power Networks' Innovation website https://innovation.ukpowernetworks.co.uk/projects/powerful-cb/. This learning report includes results and learnings from the installation and commissioning of the FLCB as well as experience from operation to date of the FLCB. The document also explains the challenges faced and lessons learned from these.

We continued to keep our stakeholders informed of the project progress as well as sending an update newsletter to the project mailing list informing them of energisation of the FLCB and publication of SDRC 9.2.1. The project also featured in UK Power Networks Annual Review 2019/20 highlighting the great work and progress of the project team.

Internally three sessions were held with our Network Planning Teams from each of our licence areas where details of the project, more specifically technical details, were provided so that the FLCB can be taken into consideration for deployment into business as usual.

Further afield, in July 2020, the project was introduced and presented to experts from a distribution company in Australia, South Australia Power Networks (SAPN), as they expressed interest in the solution from a bushfire reduction perspective.

Unfortunately the planned site tours continue to be postponed due to COVID-19 restrictions.

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. Several risks have materialised in previous reporting periods that have impacted project activities during this reporting period so they are still shown in Table 1. The project team have taken 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
R34	Delay and/or cost overrun – commissioning	Additional visits to complete commissioning in February, and activities captured in R44 and R45 requiring additional time has had an impact on the budget planned for the completion of commissioning. Contingency funding was used.	Costing exercise completed to estimate remaining costs for commissioning and energisation. These include: • Multiple remobilisation and demobilisation costs due to site shutdown from COVID-19 and returning to complete remaining commissioning; • Time to complete HV door interlock repair; • Energisation; and

Ref	Issue	Impact	Mitigation
			• Commissioning of auto-close scheme and fault recorders. Work was planned in such a way that the number of site visits to complete remaining works would be minimised to drive efficiencies in use of project finances **Note:** This risk is now closed as all remaining commissioning works have been completed.
R45	Delay in modification/repair of HV compartment door interlock on the FLCB due to COVID-19 restrictions	Delay in energisation of the FLCB as the interlock is a critical safety mechanism.	Prior to the full lockdown measures implemented by UK Government on 23 March, ABB Germany were unable to travel due to their own COVID-19 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 from ABB Germany while maintaining safe distances between employees on site. Once UK Government lockdown commenced no mitigation was possible until site works could safely recommence. **Note:** This risk is now closed as the repair has been complete and the FLCB energised.
R46	Delay in publication of learning report SDRC 9.2.1 – Interim Learning Report – Demonstration of a FLCB for substations	To fulfil the requirements of SDRC 9.2.1 energisation of the FLCB needs to be complete. The delay of this SDRC is the same assumption as for R45 – anticipated four month delay.	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. **Note:** This risk is now closed as the SDRC has been published.

Ref	Issue	Impact	Mitigation
R47	Potential extension to project trial end date (also linked to R9)	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. This decision will be finalised in the next reporting period. 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.

Although risks R34, R45 and R46 were highlighted in the previous reporting period and have now been closed, they did impact the project during the current reporting period and so remain in Table 1 above. Namely the energisation of the FLCB, completion of the fault recorder and auto-close scheme works and the publication of SDRC 9.2.1 were affected.

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. Due to the possible continued restrictions from COVID-19 knowledge dissemination may be limited to virtual events and online publications.

The project will continue to trial the FLCB in two running arrangements as follows:

- The trial of Running Arrangement 2 will continue, where the FLCB operates as a transformer incomer circuit breaker for transformer GT1. The total trial time for this Running Arrangement will be three to four months; and
- Transition to the final running arrangement, Running Arrangement 3. This arrangement as shown in Figure 5, will see the FLCB operated as a bus coupler by opening the existing bus coupler BC2. And would require the FLCB to break the short circuit current fed from two transformers certain faults.

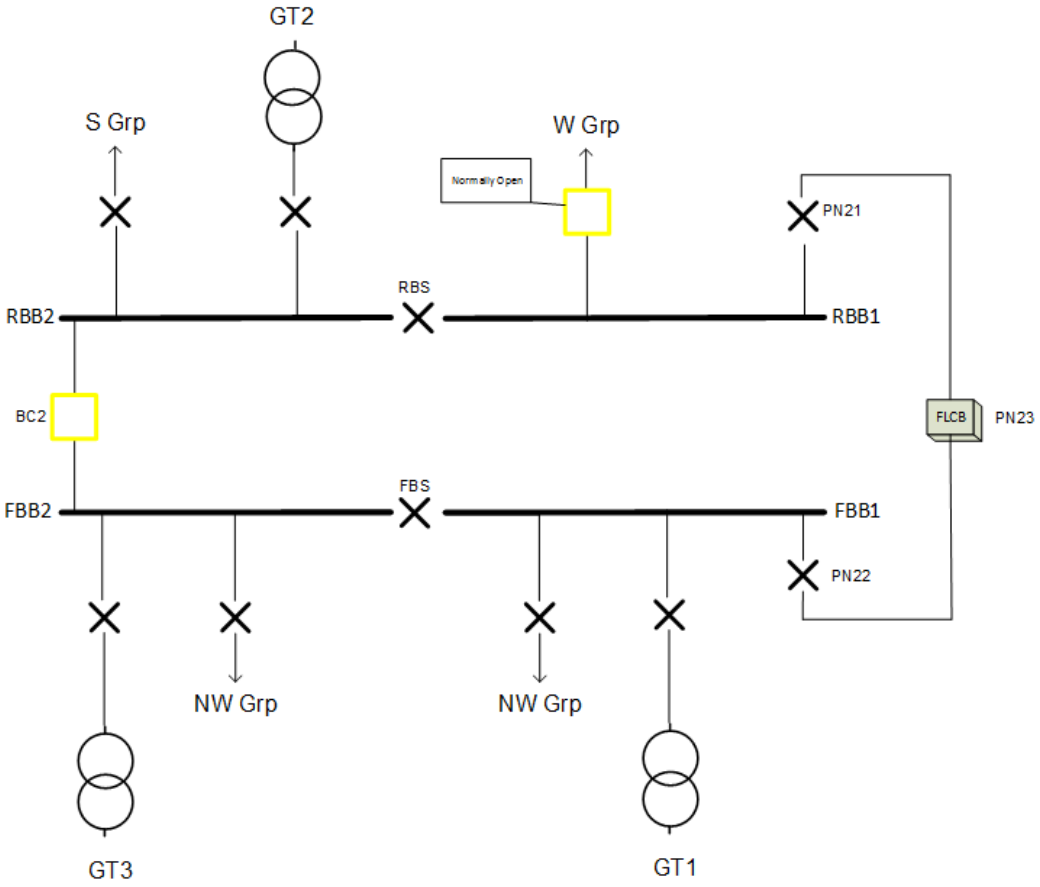

Figure 5 Running Arrangement 3. Note yellow indicates 'normally open'

The fifth SDRC of the project, SDRC 9.2.3, was originally planned for delivery at the end of the next reporting period however as previously highlighted will be delayed due to COVID-19 preventing energisation of the FLCB.

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.

The project team intends to keep recipients on the project mailing list, who are interested stakeholders, informed about how M1 is progressing as it transitions from the development phase to the network demonstration phase of the project.

Knowledge dissemination planned for the next reporting period includes engaging with internal and external stakeholders to share knowledge gained from the installation work, commissioning and operation to date of the FLCB.

2. Project Manager's report

The project made good progress during this reporting period (July-December 2020), while dealing with the impact of COVID-19, focusing on the following areas:

- Ongoing project planning;
- Modification/repair of the HV compartment door interlock and energisation;
- Finalising commissioning and energisation of the FLCB;
- Completing installation and commissioning of the fault recorders and auto-close scheme;
- Completing networking demonstration of Running Arrangement 1;
- Transitioning to network demonstration of Running Arrangement 2; and
- Data gathering and analysis.

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 remains unchanged and the core project team continues to comprise of three dedicated roles:

Role	Status	Start Date
Project Manager	Appointed	4 February 2019
Workstream 1&2 Lead	Appointed	23 March 2018
Workstream 3&4 Lead	Appointed	3 July 2017

The Workstream 1 (WS1) and Workstream 2 (WS2) Lead remains unchanged from the period however the role of the Workstream 3 (WS3) and Workstream 4 (WS4) Lead has been reduced to WS4 only. This is due to the change request submitted to Ofgem for the removal of M2 from the scope of the project.

2.2 Project Partners

As highlighted in the December 2018 Project Progress Report (PPR) our project partner ABB has signed onto a collaboration agreement and progressing with developing and trialling of the FLCB. The M2 proposed project partner, AMAT, did not sign onto a collaboration agreement and subsequently withdrew from the project. The change request which was submitted to Ofgem has been approved and M2 will be removed from the project. The removal of M2 impacts WS1, WS2 and WS3 and as such works relating to M2 will no longer be discussed in future PPRs.

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.

2.3 Workstream 1 – Development of a FLCB Device

WS1 is responsible for designing, building and testing prototype devices suitable for installation and trial and both a primary substation and customer site within London Power Networks (LPN). With 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 TRL4 (single-phase proof-of-concept prototype) to TRL7 (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 it 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 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 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;
- 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 Great Britain (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 and how to handle failure of the FLCB; 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, especially Electricity North West (ENWL) and Western Power Distribution (WPD) who have investigated similar issues with the Respond and FlexDGrid projects respectively. The learning from this phase will be captured in engineering policies, standards, and procedures and shared via learning dissemination activities.

Progress during this reporting period

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

- As highlighted in the previous PPR, during commissioning in February 2020, it was identified that the magnetic lock which forms part of the HV compartment door interlock was malfunctioning. It was observed that even when the electromechanical locking mechanism would be locked in place, the door could still be opened with brute force. As this is a vital safety feature, the energisation of the FLCB could take place until this issue was rectified. Following investigations by ABB, mechanical modifications to the interlock were required to resolve the issue.
    - The interlock of the FLCB panel works as described below in Figure 6 and Figure 7. The door handle moves a rail that runs the full height of the panel door. There are circular studs on the panel housing side which engage in the circular cut-outs of the rail, hence securing the door in place. The door handle pushes the rail downwards so that the smaller circular cut-outs are moved behind the studs. At the same time, the rectangular cut-out circled in red in Figure 6 below engages a lever on the opposite side of the panel housing. The rail in the door pushes it downwards when the door handle is operated;

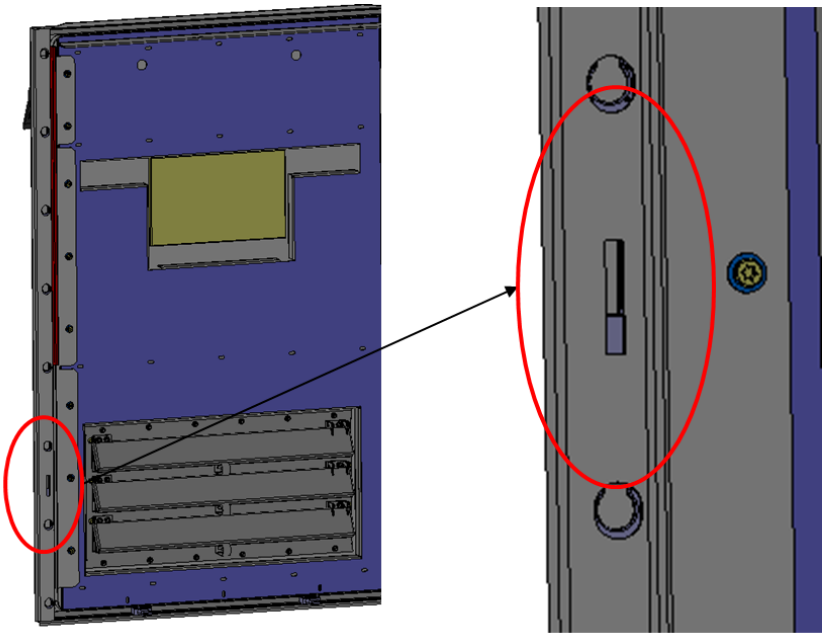

Figure 6 FLCB HV door detailing the rail running in the door which moves up and down as the door handle is engaged

- On the right side of the panel a lever (circled in red in Figure 7), is pushed down when the door is closed. The electromechanical locking mechanism is located behind the cover (circled in green in Figure 7). When the lever is pushed down from the outside, a stud moves into the locking mechanism. This prevents the lever from being pushed upwards when the door is locked, so that the handle on the door and thus the rail cannot be operated; and

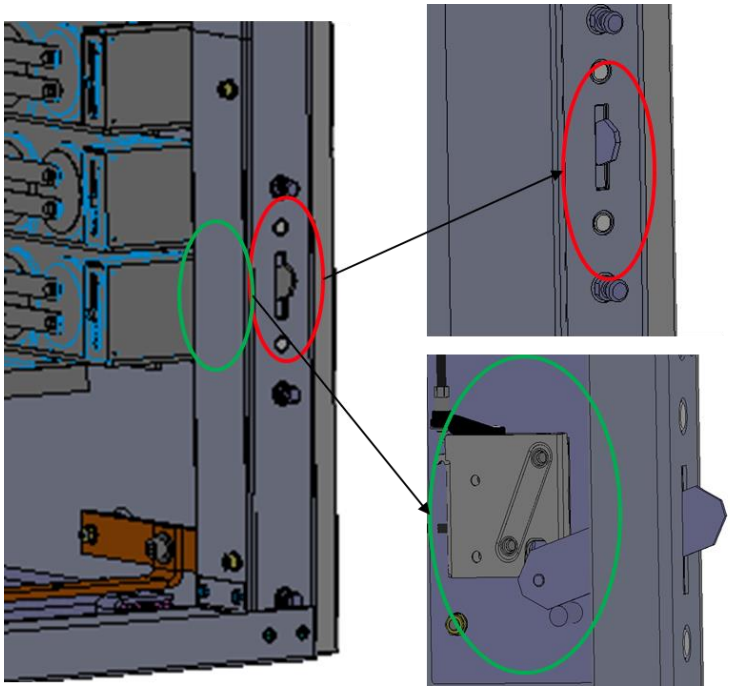

Figure 7 FLCB panel detailing electromechanical locking mechanism used to implement the interlock and prevent opening when conditions are unsafe

- ABB's investigation concluded that the rail in the door had most probably been bent in such a way that the rail could be pushed past the lever of the electromechanical locking mechanism and hence allowed the door to still be opened, albeit with strong force exerted, even though the lever was locked into position and should have prevented opening. Replacing the rail in the HV panel door (shown in Figure 8), the door handle and some other mechanical parts resolved the issue and the interlock performed as required, i.e. the HV door could not be opened when unsafe to do so.

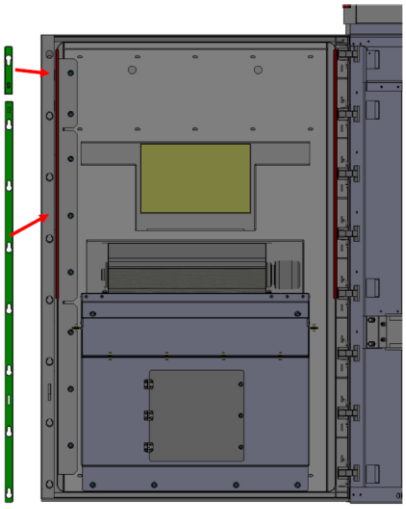

Figure 8 Rail replaced in FLCB HV panel door

- Completing the final commissioning of the FLCB with all associated interconnectors and energisation of the FLCB. The FLCB was commissioned in the previous reporting period but the final connection tests with the live network were not completed. Following the resumption of site works and the repair of HV door interlock, the HV cables connected to the adjacent circuit breakers were tested and energisation completed;
- The first month after energisation saw Running Arrangement 1 trialled where the FLCB underwent a 'soak' test to ensure there are no problems. There is no requirement for the FLCB to trip for a network fault under this running arrangement. A 'soak' test' is typical for all new equipment in order to avoid early failures. It is driven by reliability engineering and the Bathtub Curve of product failures shown in Figure 9 below. This approach allowed the project team to identify any early issues before the FLCB would be required to operate for a network fault;

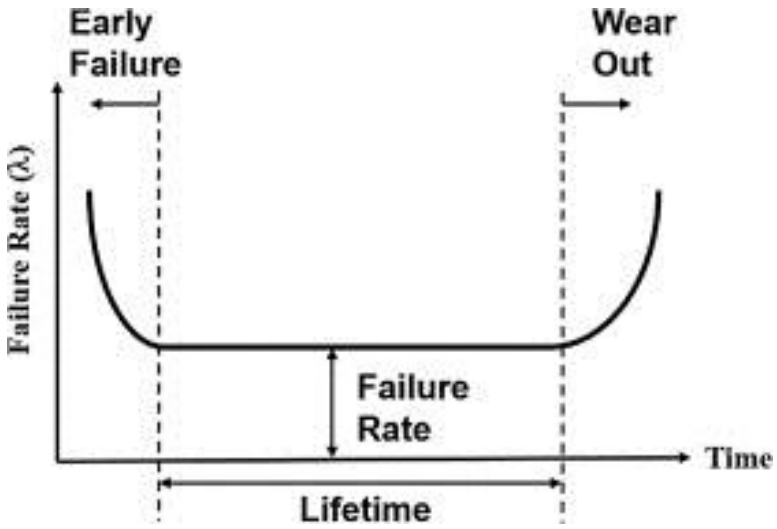

Figure 9 The bathtub curve highlighting failure rate vs lifetime of operation for equipment

- Completion of wiring and commissioning of the fault recorders and the auto-close scheme. As explained in the previously published SDRC 9.1.1[1] and 9.2.1[2], there was a need to install fault recorders and an auto-close scheme at Glaucus Street substation. The relays that compromise the auto-close schemes need to be wired to the Current Transformers (CTs) and Voltage Transformers (VTs) in the Grid Transformer bays. On the trial site, the Grid Transformer GT1 cable fault kept GT1 out of service. As such, the remaining GTs on site could not be taken out of service to maintain the reliability standards. This issue was discussed in the previous reporting period, and also recorded in the project risk register as risk R44. The GT1 cable fault was fixed and restored 9 July 2020 as part of works separate to the project and once site work resumed, the wiring was completed, the schemes tested and commissioned;
- Transitioning to Running Arrangement 2 following the successful 'soak' test of the FLCB. The project team worked with UK Power Networks' Outage Planning teams to transition to Running Arrangement 2 and the switchover was executed on 30 September 2020. This arrangement shown in Figure 3 simulates the scenario

[1] https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2019/11/Powerful-CB-SDRC-9.1.1-v1.0-DP.pdf
[2] https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2020/11/Powerful-CB-SDRC-9.2.1-v1.0.pdf

where the FLCB would be used as a circuit breaker for a specific transformer, also known as a transformer incomer, rather than a bus coupler. To change to this running arrangement, the circuit breaker RBS was opened and GT1 was shifted to the rear busbar RBB1. By switching over to this running arrangement, the current flowing through the FLCB increased when compared to Running Arrangement 1 as there is no parallel path. To illustrate this, indicative current paths can be found in Figure 10 and shows current flowing from GT1 through the FLCB to the load groups located on busbar FBB1-2;

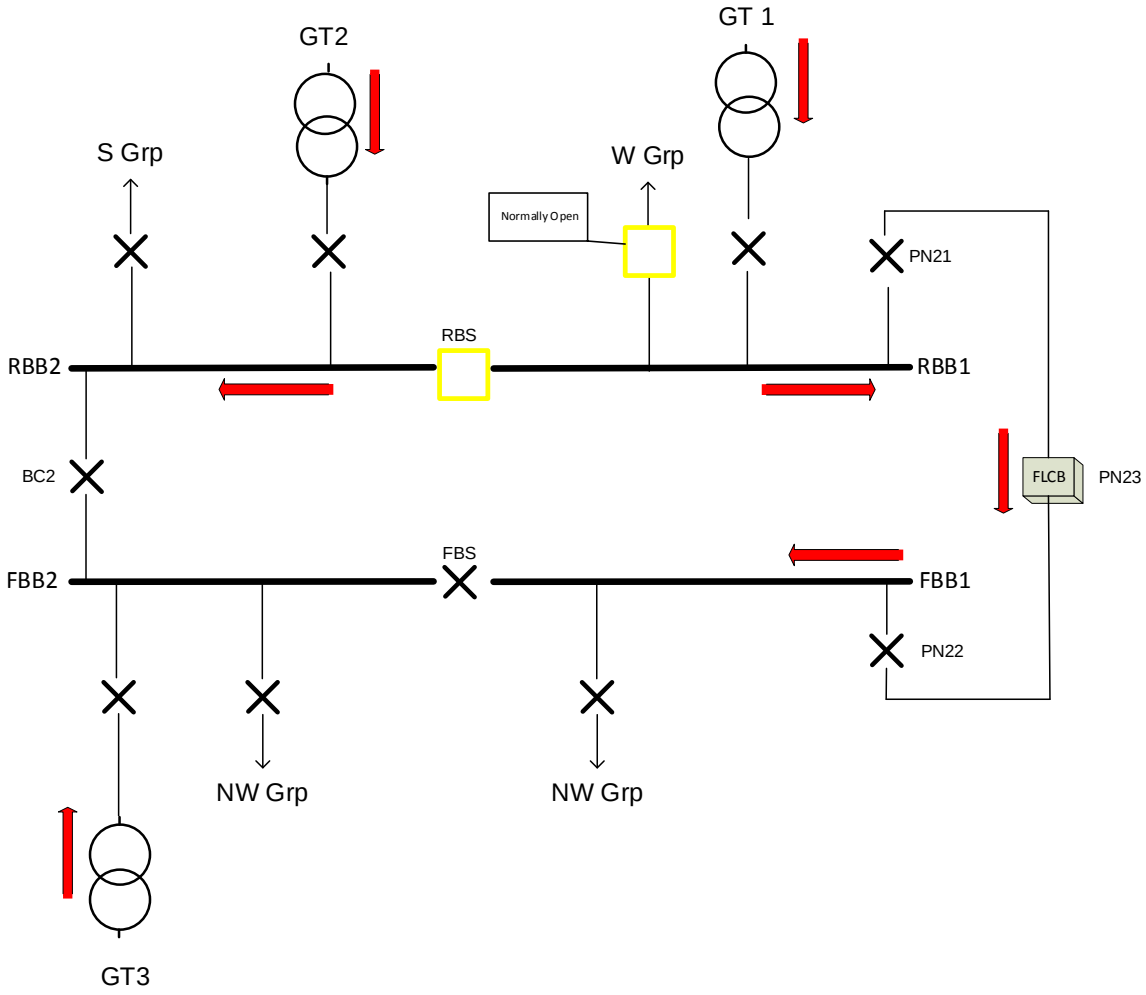

Figure 10 Running Arrangement 2 with indicative current flow direction shown with red arrows

- Data collection and analysis of the FLCB performance since commencing the trial period. This is done in collaboration with ABB and further details of our analysis can be found below; and
- Updating the safety case with FNC by collecting the commissioning reports which form part of the required evidence documents.

The full operational data to date of the FLCB for the period where Running Arrangement 1 was implemented is shown below in Figure 11. During this phase, the FLCB continued to report healthy with no issues including when confidence switching took place or when outages of transformers and circuit breakers were taken to complete wiring of the auto-

close scheme and external fault recorders. As can be seen in Figure 11 below, a relatively small amount of current has been flowing through the FLCB with the exception of when outages took place. The most interesting to note is that from 24-26 August 2020 there was an outage of circuit breakers BC2 and RBS to complete wiring for the auto-close scheme. Here we can see the current flowing through the FLCB has increased significantly as there is no parallel path for the current to flow.

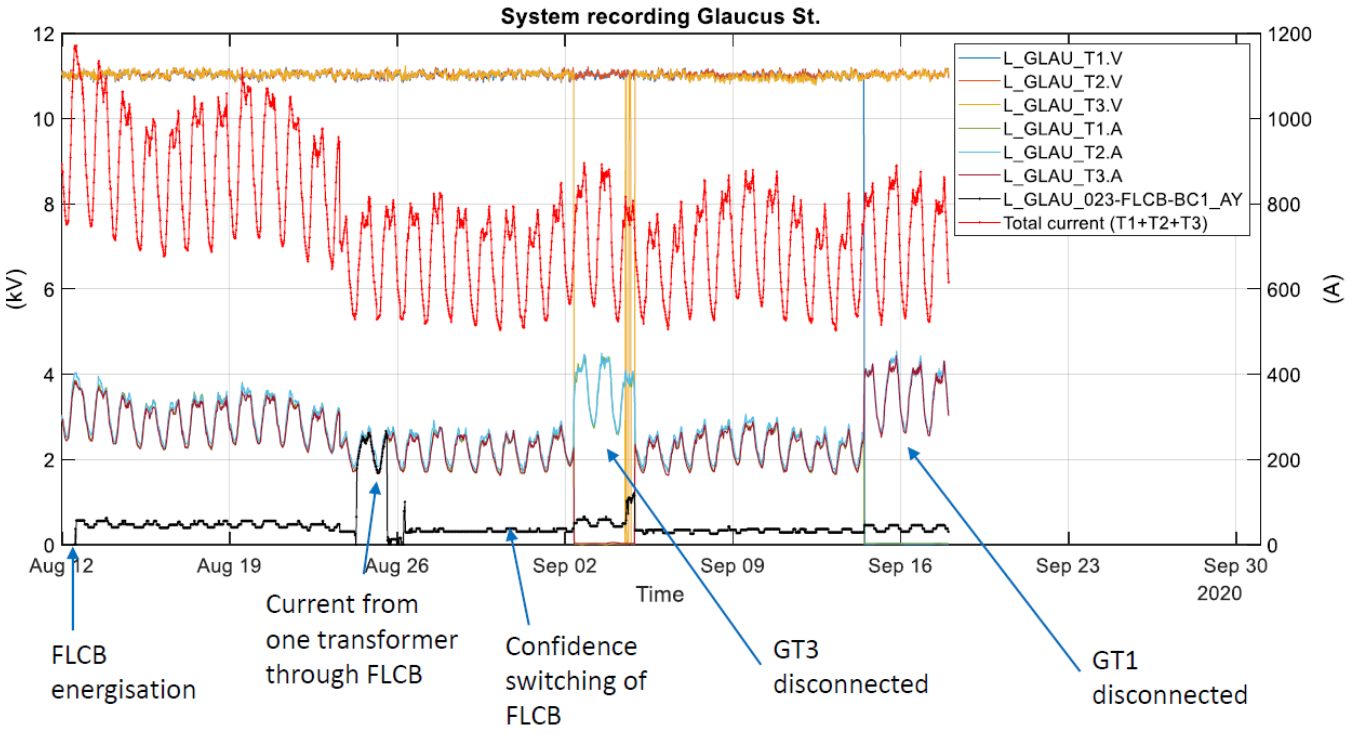

Figure 11 Operation to date in Running Arrangement 1 highlighting various outage events

Figure 12 below shows the data from the trial phase of Running Arrangement 2 until mid-October. It is also possible to see the step change in current flowing through the FLCB when the transition from Running Arrangement 1 to Running Arrangement 2 was completed at the end of September. The average current flowing through the FLCB in Running Arrangement 1 was 45 A whereas the average current to date in Running Arrangement 2 has increased to 327A.

On 2 October 2020 a step change can be seen in both the total current of the substation and the FLCB itself. The reason for this increase is the restoration of two feeders which were taken out of service as part of the outages arranged for the completion of auto-close scheme works. This is a typical approach to planned outages, whereby demand is transferred to reduce the single circuit risk under N-1 outage conditions. Following completion of works and the outage restoration, the total load of the substation was restored.

Although the FLCB passed type testing, the strategy the project team and ABB agreed was to gradually increase the potential fault current the FLCB would be required to interrupt. This is achieved as the magnitude of fault current the FLCB may see under Running Arrangement 2 is lower than the potential fault current under Running Arrangement 3.

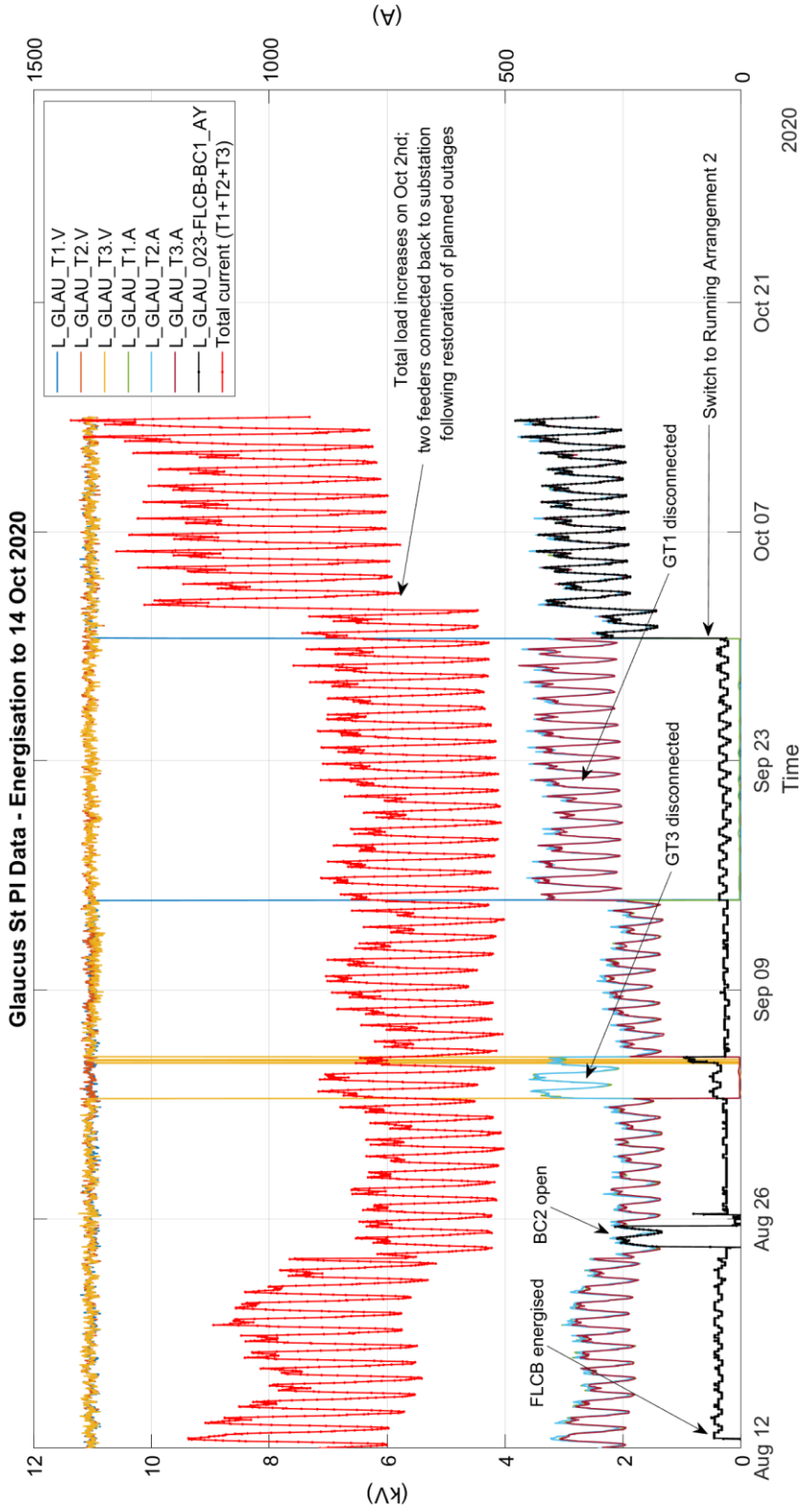

Figure 12 Operation to date of the FLCB through Running Arrangement 1 and Running Arrangement 2

Challenges and lessons learned

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

During energisation of the FLCB in August 2020, a seemingly unexpected set of behaviours was observed by UK Power Networks commissioners regarding the joint operation of the FLCB and the adjacent circuit breakers PN21 and PN22. The location of the adjacent circuit breakers can be seen in Figure 13 below.

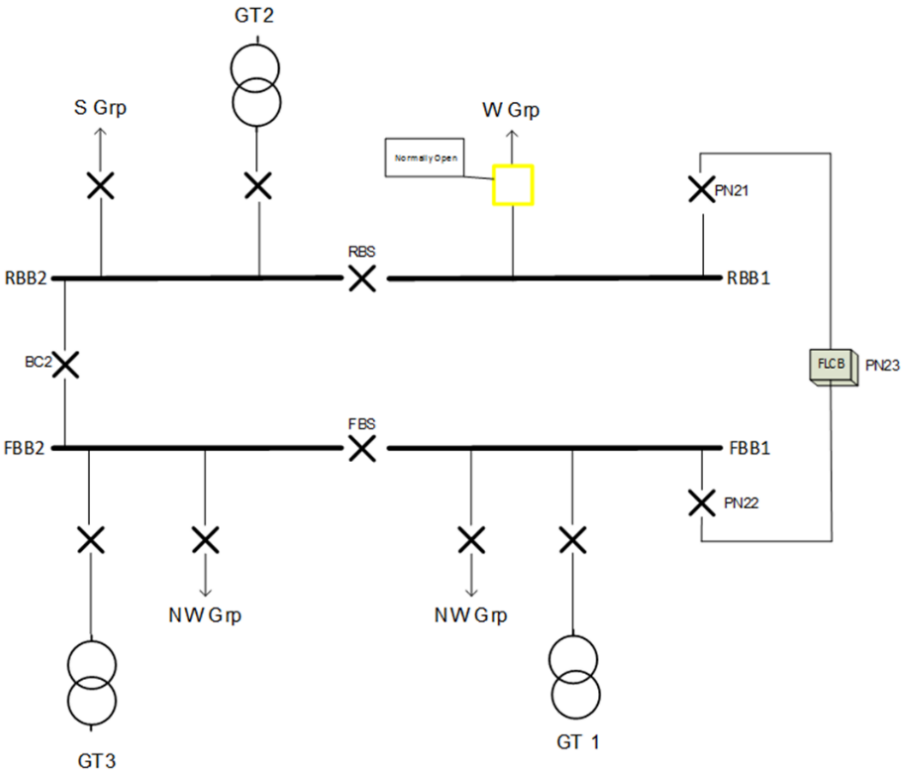

Figure 13 Running Arrangement 1. Note yellow indicates 'normally open'

As part of the final energisation commissioning process, it was required to operate the FLCB independently from PN21 and PN22. In particular, the intended energisation sequence was to:

1. Close PN21;
2. Close the FLCB;
3. Perform a phase control check at PN22; and
4. Finally close PN22 and hence energisation complete.

The FLCB controller relay is not programmed to perform any independent operation of the FLCB and adjacent circuit breakers, so therefore the independent operations had to be enabled by disconnecting the wires carrying the operation commands from the FLCB to PN21 and PN22 (these wires are referred to as “the links” in the following passage). The wires carrying the status signals from the circuit breakers to the FLCB were kept connected.

The following behaviour was then observed:

- When the FLCB, PN21 and PN22 are all closed, the FLCB refuses to open when the links are disconnected; and
- When the FLCB is open and either PN21 or PN22 is closed, the FLCB refuses to close.

The behaviour above can be explained by considering how the FLCB relay is programmed to operate the FLCB and PN21/PN22 jointly to achieve the agreed behaviour with all wiring connected in the following situations:

- At tripping of the FLCB due to overcurrent detection, the FLCB will open firstly to provide the desired fast current limitation, and subsequently PN21 and PN22 will open to disconnect the FLCB from the network;
- At opening of the FLCB (either by external command or via the relay button interface), the committed sequence is to first open PN21 and PN22, and subsequently open the FLCB when both PN21 and PN22 are confirmed open. In this way, the current in the circuit will be interrupted by the circuit breakers and not by the FLCB. With this logic in place, when the links are disconnected, PN21 and PN22 will then not operate and hence no change to the required open state will be observed. As the two adjacent circuit breakers will not be open, the FLCB will not operate as was experienced during the energisation process; and
- At closing of the FLCB, the committed sequence is to first close the FLCB and subsequently close the circuit breakers. In this way, the circuit breakers will close the circuit allowing current to flow, and not the FLCB. This requires that both PN21 and PN22 are initially in the open state, so if any either of the adjacent circuit breakers is closed at the time of the close command, the close operation of the FLCB will be blocked. This explains why the FLCB refuses to close if either PN21 or PN22 have been manually closed before the close command is sent to the FLCB.

The energisation commissioning steps required were accomplished by deploying a work-around: First, only the FLCB was closed while both PN21 and PN22 were open with the links disconnected. Subsequently, PN21 was closed manually to end up in the desired state with PN21 and FLCB closed and PN22 open. Subsequently, the phase control was performed at PN22 before finally closing PN22 and hence the FLCB energised.

In Engineering Operation Standard, EOS 03-0125, which the project team developed in the previous period, the following text is included, “In order to avoid problems in the sequence of operation, engineers (control or field) shall not directly operate the adjacent circuit breakers. They shall only operate the FLCB and it will send the appropriate command to the adjacent circuit breakers. Only if the FLCB device is faulty, shall the adjacent circuit breakers be operated directly.”

In summary, the switching steps required for energisation were not explicitly considered while defining the committed behaviour of the FLCB relay, which prompted for an ad-hoc solution at site. A lesson learned from this issue is therefore to also consider rare switching scenarios occurring e.g. at commissioning in the requirements, so that the manufacturer can provide this functionality in a more well-controlled manner.

Another solution for this issue could be a change in the closing sequence so that the adjacent circuit breakers close first and then the FLCB. Closing the FLCB in this manner would allow the full utilisation of the semiconductors within the FLCB. If for example, closing in this way onto a fault, the FLCB will interrupt the current in 10 microseconds after the fault current level is detected and hence minimises the stress on the system. It was decided early in the project

not to use this sequence for the trial to reduce the burden on the FLCB until it is approved for BAU. However this ability was proven during the type testing for future needs and possibilities.

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 for any possible network faults to occur. Additionally in the next period, the transition to Running Arrangement 3 as shown in Figure 5, will occur. In this running arrangement the device is likely to experience a fault fed from two transformers and it is under this running arrangement where the most benefits can be realised under BAU.

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 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 keep recipients on the project mailing list (which constitutes all interested stakeholders) informed about how M1 is progressing as it transitions from the development phase to the network demonstration phase of the project.

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 learning, 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

Key learning report, SDRC 9.2.1 – Install and commission solution at an 11kV substation was submitted to Ofgem on 18 November 2020 which was ahead of the revised COVID-19 impacted date 30 November 2020 and published on UK Power Networks' innovation website, https://innovation.ukpowernetworks.co.uk/projects/powerful-cb/. SDRC 9.2.1 is the fourth SDRC for Powerful-CB that has been submitted over the course of the project as described in the Project Direction.

This learning report includes results and learnings from the installation and commissioning of the FLCB as well as experience from the first two months of operation of the FLCB. The document also explains the challenges faced and lessons learned from these.

We continued to keep our stakeholders informed of the project progress as well as sending an update newsletter in December to the project mailing list informing them of energisation of the FLCB and publication of SDRC 9.2.1. The project also featured in UK Power Networks Annual Review 2019/20 highlighting the great work and progress of the project team and can be found here http://annualreview2020.ukpowernetworks.co.uk/annualreview2020/.

Internally three sessions were held with our Eastern Power Networks (EPN), London Power Networks (LPN) and South Eastern Power Networks (SPN) Network Planning Teams. In these sessions details of the project and more specifically technical details, were provided so that the FLCB can be taken into consideration for inclusion into our RIIO-ED2 business plans. The planners were given opportunities to ask questions such as how best to model the FLCB in our network models and if there are any implications to change parameters of the FLCB.

Further afield, in July 2020, the project was introduced and presented to experts from a distribution company in Australia, South Australia Power Networks (SAPN), as they expressed interest in the solution from a bushfire reduction perspective.

The project was highly commended in Business Green Leaders Awards in the category for Green Infrastructure project of the year for 2020 as seen in Figure 14 below where it was highly commended. It was also a candidate the Institution of Engineering and Technology E&T Innovation Awards in the category of Outstanding Innovation in Future Power and Energy Award. Such recognition is not just great success for Powerful-CB project, but also for Network Innovation Competition funding mechanism.

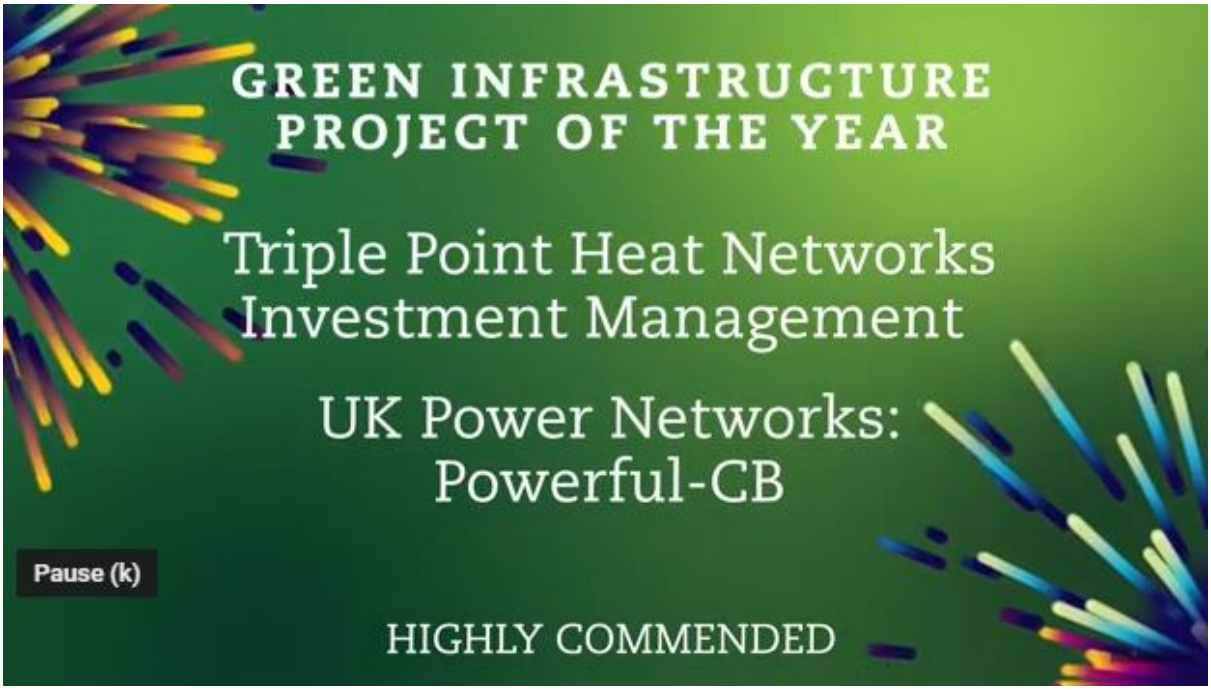

Figure 14 Business Green Leaders Awards - Green Infrastructure Project of the Year - high commendation received

Challenges and lessons learned

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

- The project team was planning to organise site tours to Glaucus St for internal and external stakeholders in order to showcase the FLCB and explain how the FLCB works, its components and connection to the network. However due to the COVID-19 restrictions these type of engagement activities did not take place;
- The project lead attends the ENIC (LCNI previously) conference annually and shares information about the project to all interested parties during collaborative sessions. COVID-19 restrictions mean the conference will be virtual this year which means opportunities to share information outside presentations, such as at stands and networking conversations are challenging; and
- With the uncertainty on gatherings still present for the next reporting period due to COVID-19 the project team will host a webinar or prepare a video log (vlog) to overcome the limitation.

Outlook for next reporting period

The following activities are planned for the next reporting period, subject to COVID-19 restrictions:

- The project is planning to feature in other UK Power Networks led external events or webinars;
- Complete tours to key internal stakeholders to showcase the FLCB;
- Inform project mailing list of key milestones such as the start of the trial period;
- Produce a vlog showing the installation on site; and
- Continued updating of the project website.

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 the change request submitted to request the removal of M2 from the project has been approved by Ofgem. Based on this, 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 2020. 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 15 below shows the key activities and changes to the project plan during the current reporting period. As previously forecast in the June 2020 PPR, the project fully returned to pre-COVID-19 lockdown status at the end of July; four months after the initiation of national lockdown on 23 March. Based on this all future planned activities and deliverables for the project will be delayed by four months and the project completion date by five months. Another national lockdown was introduced 5 November 2020 due to COVID-19 however there is no anticipated impact on the project plan. It must be noted that this is the best estimate at this point of time, as COVID-19 is a developing situation and we will continue to monitor and assess project progress.

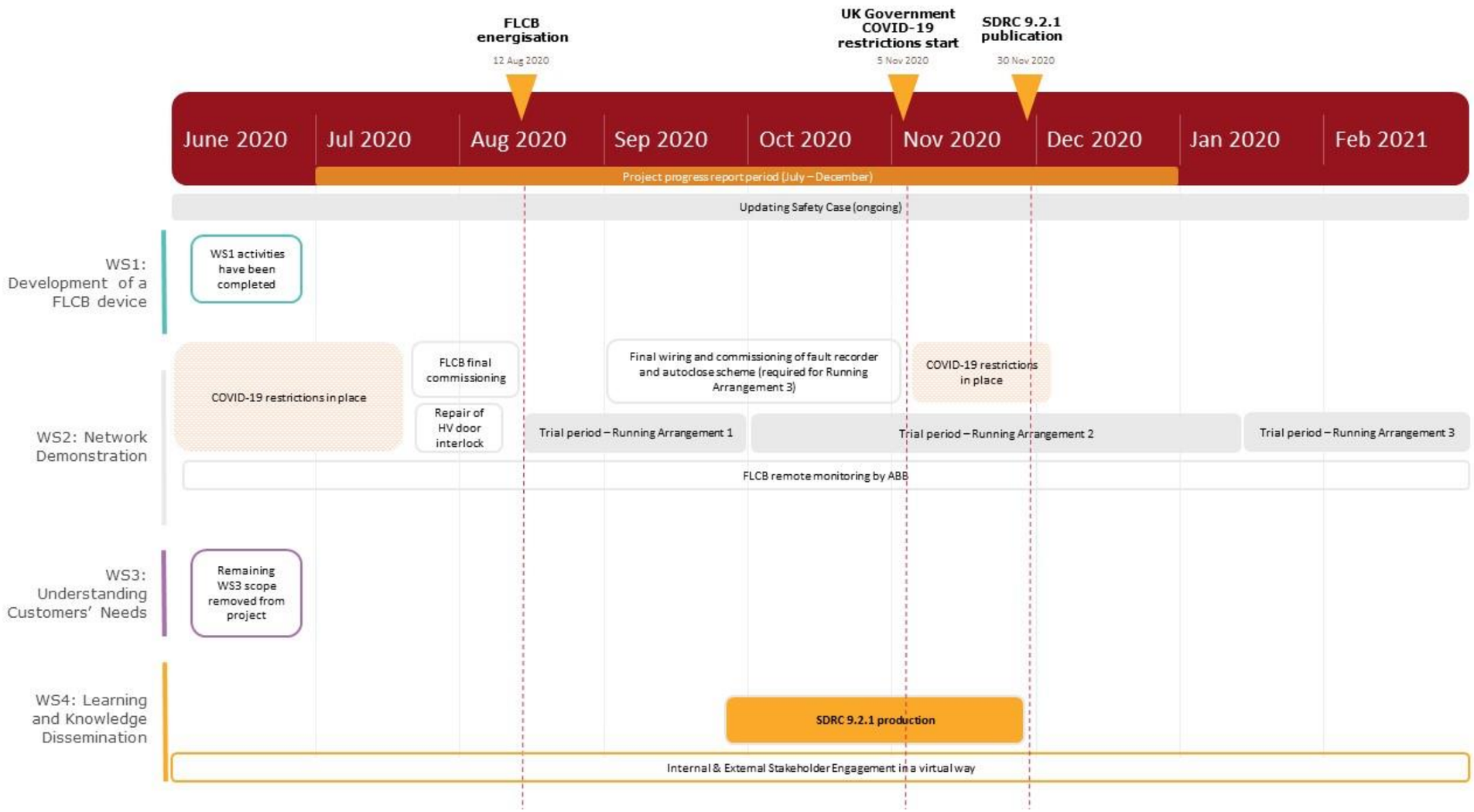

Figure 15 High level project plan highlighting changes during the current reporting period.

Since the previous reporting period, Ofgem was formally notified with a non-material change letter on 8 July 2020 detailing the impact of COVID-19 on project progress. All remaining SDRCs have been rescheduled to be delivered four months later and the project completion date by five months compared to the Project Direction. The revised dates of these SDRCs can be found in Section 7.

4.2 Detailed progress in the reporting period

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

Task description	Workstream	Status at start of period	Status at end of period
Modification of HV compartment door interlock of FLCB (postponed due to COVID-19)	2	In progress	Complete
Commissioning of auto-close scheme and fault recorders	2	In progress	Complete
Energisation (postponed due to COVID-19)	2	In progress	Complete
Trial – Running Arrangement 1 phase	2	Not started	Complete
Trial – Running Arrangement 2 phase	2	Not started	In progress
Data monitoring and analysis of performance of FLCB	2	In progress	In progress

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. However, during this period it can be reported that risks R34, R45, R46 and R47 have impacted the schedule of specific project activities as explained in the previous reporting period. Although risks R34, R45 and R46 were highlighted in the previous reporting period and have now been closed in Section 11, they did impact the project during the current reporting period and so remain in the table below.

The following issues have been recorded in the workstream reports and are also captured below. It is not anticipated that the issues above will result in a material change to the project.

Ref	Issue	Impact	Mitigation
R34	Delay and/or cost overrun – commissioning	Additional visits to complete commissioning in February, and activities captured in R44 and R45 requiring additional time has had an impact on the budget planned for the completion of commissioning.	Costing exercise completed to estimate remaining costs for commissioning and energisation. These include: • Multiple remobilisation and demobilisation costs due to site shutdown from COVID-19 and

Ref	Issue	Impact	Mitigation
		Contingency funding will be used.	returning to complete remaining commissioning; • Time to complete HV door interlock repair; • Energisation; and • Commissioning of auto-close scheme and fault recorders. Work was planned in such a way that the number of site visits to complete remaining works would be minimised to drive efficiencies in use of project finances.
R45	Delay in modification/repair of HV compartment door interlock on the FLCB due to COVID-19 restrictions	Delay in energisation of the FLCB as the interlock is a critical safety mechanism.	Prior to the full lockdown measures implemented by UK Government on 23 March, ABB Germany were unable to travel due to their own COVID-19 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 from ABB Germany while maintaining safe distances between employees on site. Once UK Government lockdown commenced no mitigation was possible until site works could safely recommence. Note: This risk is now closed as the repair has been complete and the FLCB energised.
R46	Delay in publication of learning report SDRC 9.2.1 – Interim Learning Report – Demonstration of a FLCB for substations	To fulfil the requirements of SDRC 9.2.1 energisation of the FLCB needs to be complete. The delay of this SDRC is the same assumption as for R45	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.

Ref	Issue	Impact	Mitigation
		– anticipated four month delay.	
R47	Potential extension to project trial end date (also linked to R9)	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. This decision will be finalised in the next reporting period. 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.

4.4 Key achievements and notable events

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

- Repair of FLCB HV door interlock;
- Energisation of the FLCB:
- Commence network demonstration period (WS2);
- Collection of network data to monitor performance of the FLCB; and
- Published learning report SDRC 9.2.1.

4.5 Look-ahead to next reporting period

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

- Transition to Running Arrangement 3 of the FLCB (WS2);
- Updating Phase 2 of the safety case (WS1 and WS2);
- Present at UK Power Networks hosted event (WS4); and
- Provide tours to key internal stakeholders if safe to do so based on the latest COVID-19 advice. Alternatively web events can be carried out.

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. We have struck-through the SDRCs that were removed as part of the change request to remove M2.

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.	Complete
~~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.	Complete
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	Complete

Project Deliverable	Deadline	Evidence	Progress
		BAU without the FLCBs being installed in series with a back-up circuit breaker.	
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 *changed from 31 July 2020*	**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.	Complete 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)	31 October 2021 *changed from 30 June 2021*	**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.	Delayed by four months due to COVID-19 as notified in the non-material change request letter to Ofgem on 8 July 2020
~~9.2.4 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	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

Project Deliverable	Deadline	Evidence	Progress
and DG stakeholders			
~~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 January 2021 *changed from 30 September 2021*	Publish key materials from the stakeholder event (e.g. slides), and provide Ofgem with a list of invitees and attendees.	Delayed by four months due to COVID-19 as notified in the non-material change request letter to Ofgem on 8 July 2020

8. Data access details

To view the full Innovation Data Sharing Policy, please visit UK Power Networks' website here: https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2019/11/UKPN-Innovation-Data-Sharing-Policy-7-Nov-19.pdf

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, published in 2019, 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.

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 published SDRC 9.2.1 and is available on the Powerful-CB website. Previous learning reports highlighted in Section 7 are also available through this website.

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 2020)

IPR Description	Owner(s)	Type	Royalties
Commissioning reports	UK Power Networks	Relevant Foreground IPR	Nil
FLCB and control system status snapshots (as necessary)	ABB	Relevant Foreground IPR	Nil
Data and performance of FLCB during network demonstration	ABB UK Power Networks	Relevant Foreground IPR	Nil
SDRC 9.2.1 – Install and commission solution at an 11kV substation	UK Power Networks	Relevant Foreground IPR	Nil

IPR forecast next period (January – June 2021)

IPR Description	Owner(s)	Type	Royalties
Data and performance of FLCB during network demonstration	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
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.	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. Additionally a 24 month trial period will be completed.	We have used historic fault data when looking at potential sites – recognising that fault history is not necessarily an indicator of future faults. 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.	A

Ref	WS	Status	Description	Mitigation/Planned Action	Current Status	RAG
					This risk is linked to risk R47 where a project extension is being considered and is dependent on the number of network faults experienced	
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.	N/A this 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.	N/A this period.	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
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

Ref	WS	Status	Description	Mitigation/Planned Action	Current Status	RAG
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.	COVID-19 impacted some knowledge dissemination activities.	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
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	Open	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 Network's 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[3].	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.	Method 2 is removed from the project.	G

[3] 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
				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.		
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
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 in this period. The risk remains open for any changes that might be identified during commissioning.	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.	This risk has become 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 be booked. This will minimise the impact on the readiness of the FLCB for delivery to site. 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	G
R42	WS2	Closed	Delay in energisation and commencement of trial period (due to defect identified in QF switchgear (retrofit circuit breakers)). 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	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. UKPN has 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.	ABB to design and produce portable power pack. Asset management have requested that the energisation of these CBs does not take place until this has been received.	G
R43	WS2	Closed	GT1 cable fault cannot be repaired until sinkhole near where excavation is required is fixed first. Trial site has three transformers in total and the impact of GT1 being out of service is that GT2 and GT3 cannot also been 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.	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.	Have been in contact with London Borough of Tower Hamlets to discuss when the sinkhole will be fixed.	G
R44	WS2	Closed	Replacement of R43. Delay in GT1 cable fault repair. Trial site has three transformers in total and the impact of GT1 being out of service is that GT2 and GT3 cannot also been taken out of service as two must be in service. The result of this is	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.	Delay in GT1 cable fault repair Due to the redundancy in our network, this cable fault is currently not affecting customers or security of supply. In May cable fault was found and repaired however a second fault has been identified.	G

Ref	WS	Status	Description	Mitigation/Planned Action	Current Status	RAG
			that both the auto-close scheme and the fault recording relays cannot be fully commissioned.			
R45	WS2	Closed	Delay modification of HV compartment door interlock on the FLCB due to COVID-19 restrictions. This impacts energisation of the FLCB.	Currently no mitigation is possible until site works can safely recommence. Prior to the full lockdown measures implemented by UK Government on March 23, ABB Germany were unable to travel due to 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.	This prevented energisation of the FLCB until site works safely recommenced.	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.	To fulfil the requirements of SDRC 9.2.1 energisation of the FLCB needs to be complete.	G
R47	WS2	Open	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.	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. The project team continue to monitor the performance of the FLCB and are awaiting for network faults before determining if a project extension is required.	A

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 eighth six-month reporting period and an accurate view of our understanding of the activities for the next reporting period.

Signed 

Date 9 December 2020

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