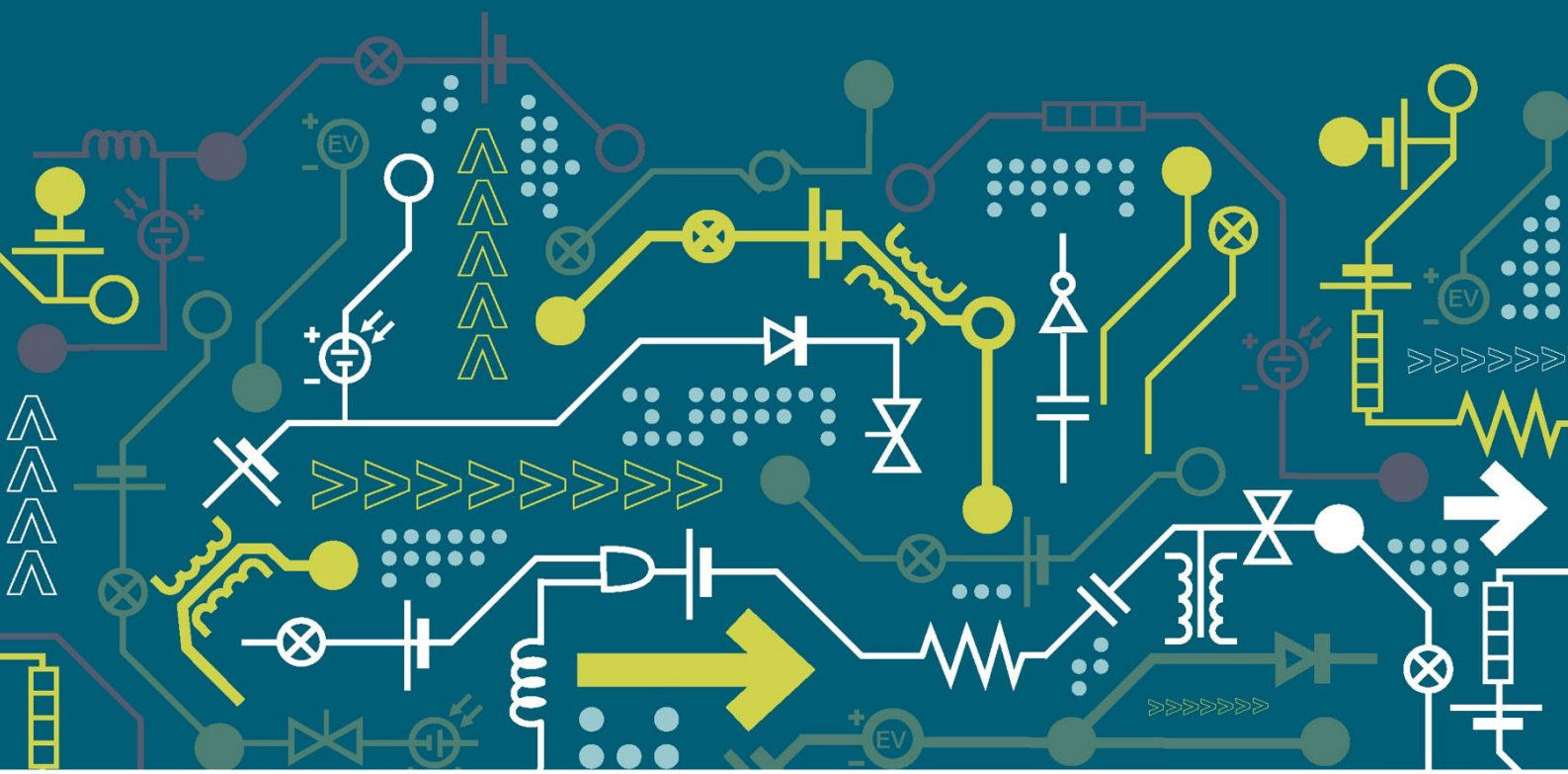
WPD INNOVATION

# EDGE-FCLi

## WPD_NIA_033

NIA Major Progress 6 Monthly Report

Reporting Period: October 2019 – March 2020



WESTERN POWER DISTRIBUTION

*Serving the Midlands, South West and Wales*

# Version Control

| Issue | Date |
|---|---|
| **1** | 17 April 2020 |

# Publication Control

| Name | Role |
|---|---|
| **Daniel Hardman** | Author |
| **Yiango Mavrocostanti** | Reviewer |
| **Jonathan Berry** | Approver |

# Contact Details


## Email
wpdinnovation@westernpower.co.uk

## Postal
Innovation Team
Western Power Distribution
Pegasus Business Park
Herald Way
Castle Donington
Derbyshire
DE74 2TU


## Disclaimer
Neither WPD, nor any person acting on its behalf, makes any warranty, express or implied, with respect to the use of any information, method or process disclosed in this document or that such use may not infringe the rights of any third party or assumes any liabilities with respect to the use of, or for damage resulting in any way from the use of, any information, apparatus, method or process disclosed in the document.

# Contents

# 1 Executive Summary

The EDGE-FCLi project is funded through Ofgem's Network Innovation Allowance (NIA). EDGE-FCLi was registered in September 2018 and is due for completion by March 2022. EDGE-FCLi aims to develop a prototype solid-state Fault Current Limiting Interrupter (FCLi) into a commercial scale device. The device is manufactured by GridON, Israel and has been designed to connect in series with Distributed Generators (DG) on the 11kV network with a maximum 5MW rated output. The device is able to quickly disconnect the generation from the network upon detection of a fault condition. The FCLi has the capability to limit the fault current contribution of DG and therefore overcome fault level issues that can limit network capacity and prevent future DG connections.

The project is being delivered collaboratively between WPD and UKPN to ensure that a device is developed that is safe to connect to the 11kV network and is also replicable so that it can be deployed throughout GB. Both WPD and UKPN plan to install and trial an FCLi device on their respective 11kV networks with significant coordination of the FCLi design, factory and laboratory testing to ensure that the devices are suitable for longer-term testing and trials in the field.

This report details project progress from October 2019 to March 2020.

## 1.1 Business Case

The growth of connected DG has caused an increase fault level across the 11kV network. This is particularly an issue in urban areas, where the fault level is more likely to exceed the capability of the switchgear to safely disconnect a network fault. The following section describes the business case for the FCLi device.

A typical 33/11kV urban primary substation can be assumed to contain 25 no. circuit breakers in total, with on average 20 no. 11kV feeders per substation. It has been assumed that there is eight Ring Main Units (RMUs) per 11kV feeder.

Within the GB distribution network the majority of the existing 11kV switchgear is rated at 13.1kA (250MVA). The typical reinforcement approach includes upgrading the switchgear to 25kA (476MVA) units. In addition, RMUs close to the primary would also need to be upgraded. The typical cost of replacing an 11kV circuit breaker and all peripheral equipment is £50k. Similarly, the typical cost of replacing an 11kV RMU is £20k. It is assumed that 25% of RMUs will need to be replaced if the fault level at the site increases above the existing limits. Therefore:
Base Case Cost= 11kV switchgear cost + 11kV RMU cost = (25 x £50k) + 0.25 x (20 x 8 x £20k) = £2,050k
The fault level headroom enabled by the 25kA switchgear is 226 MVA per site and this can accommodate approximately six no. 5MW synchronous generators. Due to other technical constraints it is reasonable to assume that there will be a 33% reduction in allowed DG connections, hence allowing only four additional 5MW DGs.
The business as usual cost of an 11kV, 5MW FCLi is expected to be £275k, hence:
Method Cost = 4 x £275k = £1,100k
There is therefore a saving of £950k per installation (Base Case Cost – Method Cost).

## 1.2 Project Progress

This progress report covers progress from October 2019 to March 2020.
During this reporting period there has been significant additions to the project scope to allow for greater collaboration with UKPN to ensure that the device is replicable and deployable throughout GB. The collaboration will consist of working jointly on the design of the FCLi device as well as factory and laboratory testing to ensure that it is suitable for the site trials. In addition, a Long Duration Performance Test (LDPT) (or 'soak test') has been included as an additional work package to test the FCLi for an extended period of time at rated current in a controlled laboratory environment. The purpose is to increase the confidence that this first-of-a-kind device is able to safely operate on the 11kV network.

In this reporting period, the WPD FCLi device has been fully manufactured and the preliminary testing has been successfully completed by GridON; however, significant design changes had to be made to pass the preliminary 28kV withstand test and 95kV lightning impulse test. The design changes mainly consisted of the inclusion of additional solid insulation in the device's phase compartment. UKPN's device is still in the early stages of manufacturing and has therefore not been affected by the changes.

GridON have submitted an updated design documentation pack to formally capture all design changes made during the build and preliminary testing phases. The updated design pack was subject to a thorough review by WPD and a significant number of comments and changes to the documentation have been communicated to GridON for their consideration.

This reporting period has seen significant effort expended to develop GridON's testing specification to a satisfactory level and a significant number of additional tests and checks had to be included in the document. The document is now approved after numerous revisions and provides the necessary confidence that the device will be tested rigorously in the Factory Acceptance Test (FAT) and short circuit testing.

The FAT and short circuit testing was due to be witnessed in Israel on 17-18 March 2020 and in KEMA, Prague on 23-24 April 2020 respectively. However, the testing was postponed in response to the escalating COVID-19 pandemic. The Israeli and Czech governments enforced a ban for all foreign nationals entering their countries on w/c 9 March and this had a direct impact on the planned witness testing. The decision to postpone the testing was taken to preserve the health and safety of WPD and GridON staff. The postponement of the FCLi FAT and short circuit testing has also had the knock-on effect of suspending the coordination activities for the LDPT since this was scheduled to follow-on from the short circuit tests.

UKPN's device is specified to be IAC compliant and the WPD project team was invited to observe the IAC type test carried out on a dummy of their FCLi at the KEMA's laboratory in Prague, Czech Republic on 16 December 2019. The witnessing of this test by WPD was for information and knowledge gathering purposes only.

## 1.3 Project Delivery Structure

The EDGE-FCLi Project Review Group meets on a bi-annual basis. The role of the Project Review Group is to:

- Ensure the project is aligned with organisational strategy;
- Ensure the project makes good use of assets;
- Assist with resolving strategic level issues and risks;
- Approve or reject changes to the project with a high impact on timelines and budget;
- Assess project progress and report on project to senior management and higher authorities;
- Provide advice and guidance on business issues facing the project;
- Use influence and authority to assist the project in achieving its outcomes;
- Review and approve final project deliverables; and
- Perform reviews at agreed stage boundaries.

## 1.4 Project Resource

Table 1-1 provides an overview of the project resources for the project.

**Table 1-1 Project Resources**

| Project Partner | Name | Role |
|---|---|---|
| WPD | Yiango Mavrocostanti | Project Manager |
| GHD | Daniel Hardman* | Project Manager |
| UKPN | Jack McKellar | Project Manager |
| GridON | Yoram Valent | CEO |
| | Uri Garbi | Project Manager |
| | Alex Oren | Senior Engineer |
| | Dvir Landwir | Senior Engineer |

## 1.5 Procurement

Table 1-2 provides a summary of the current status of the procurement activities for the project.

**Table 1-2 Procurement Status**

| Provider | Services/Goods | Project Area | Status/Due Date |
|---|---|---|---|
| GridON | Detailed Design | Design | Complete |
| GridON | FCLi | Build | Complete |
| GridON | FAT | Testing | TBD* |
| GridON | Short circuit testing | Testing | TBD* |
| EMS | Sub.net monitoring system | Trial | Delivered |
| Envico | GRP housing | Installation | TBD* |
| Control Engineering Ltd | HMI wall box panel | Installation | Delivered |
| Nexans | Surge Arrestors | Installation | Delivered |
| Nexans | T-connectors | Installation | TBD |

*Note – the milestone payments for successful FAT and short circuit testing have been delayed by the COVID-19 pandemic. Revised dates for these payment milestones are currently subject to ongoing review by the project team.

## 1.6 Project Risks

A proactive role has been taken to effectively manage risk in the delivery of the EDGE-FCLi project. Processes have been put in place to review the applicability of existing risks; identify and record new risks that have arisen; and update the impact, likelihood and proximity of risks that have developed.

A summary of the updates to the most significant risks identified in the previous six monthly reporting periods are provided in Section 7.2.

## 1.7 Project Learning and Dissemination

The project learning is captured throughout the project lifecycle by ongoing engagement with the project partners and stakeholders. The learning is regularly recorded and updated through our monthly reporting process and will be shared and disseminated through various media. Table 1-3 gives a brief summary of the dissemination activities that have already taken place. The project learning for the current reporting period is given in Section 5.

**Table 1-3 Project Dissemination**

| Event | Date | Location |
|---|---|---|
| Low Carbon Network Fund Conference | 16 October 2018 | Telford, UK |
| Electricity Innovation Forum on New Technology and Commercial Evolution, ENA | 28 September 2018 | London, UK |

# 2 Project Manager's Report

## 2.1 Project Background

The project aims to design, build, test, install and trial a solid state FCLi on the 11kV distribution network. The FCLi is designed to connect in series with DG and quickly disconnect the generation upon the detection of a network fault. The FCLi is therefore able to reduce the fault current contribution from generation fitted with the device, thus allowing the cost effective connection of DG to networks that are fault level constrained.

## 2.2 Project Progress in the Last Six Months

### 2.2.1 Project Re-Baseline

The FCLi project was re-baselined in December 2019 to allow for greater collaboration with UKPN to ensure that the device is replicable and deployable throughout GB. The collaboration will consist of working jointly on the design of the FCLi device, factory and laboratory testing to ensure that it is suitable for longer-term testing and site trials. A further addition has been the inclusion of a LDPT into the programme to understand how the device behaves in a controlled environment over a long period of rated current operation. This will give further assurances that the FCLi is safe to connect to the 11kV network.

The project work packages have been adjusted accordingly to meet the new project requirements. Table 2-1 gives the new work package structure along with an indication of the status of each of these work packages.

An updated NIA Project Registration and Project Eligibility Assessment (PEA) document was subsequently submitted to the ENA on 3 January 2020 after agreement was made with UKPN on their more integrated role in the project.

The installation and trial of our device at the selected trial site location is now dependent on successful completion of the LDPT and also successful operation of the UKPN device on their 11kV network for a period of six months. This approach allows the project to maximise the learning generated whilst also ensuring customers receive continuing value for money.

**Table 2-1 Adjusted Work Packages Following Project Re-Baseline**

| Work Package No. | Work Package Description | Status |
|---|---|---|
| 1 | Device specifications | Completed |
| 2 | Preliminary FCLi design and review | Completed |
| 3 | Detailed FCLi design and review | Completed |
| 4 | FCLi device manufacture | Completed |
| 5 | Performance testing (FAT & short circuit tests) | Not started |
| 6a* | LDPT (conditional on successful completion of WP 1-5) | Not started |
| 6b* | Installation and operation of the UKPN FCLi on their 11kV network | Not started |
| 7* | Trial of the WPD FCLi on 11kV network (conditional on | Not started |

| | | |
|---|---|---|
| | successful completion of WP 6a and 6b for six months) | |
| Asterisk (*) indicates the updated/new work packages | | |

### 2.2.2 GridON Delays

In this reporting period, the project has been subject to significant delays due to GridON not being able to manufacture and carry out the preliminary testing to their project programme. In addition, the testing specification for the FAT and short circuit tests was lacking overall quality and important tests were missing. This meant that WPD had to perform a significant detailed review of the testing activities to ensure the testing was representative and rigorous enough to give confidence the device could be connected to the network safely. A summary of the GridON delays is given in Table 2-2.

Fortunately, the delays did not affect the overall programme as they were able to be integrated into the re-baselined project programme through coordination with GridON. A detailed description of the re-baselining activities is given in Section 2.2.1.

**Table 2-2 Summary of GridON Delays**

| Activity | Original GridON Timescale | Delayed GridON Timescale |
|---|---|---|
| FCLi Manufacturing Complete | 19 September 2019 | 23 Jan 2020 |
| FCLi Preliminary Testing Complete | 4 November 2019 | 9 March 2020 |
| Factory Acceptance Testing | 5-7 November 2019 | 17-18 March 2020 |
| Short Circuit Testing | 3-4 December 2019 | 23-24 April 2020 |

### 2.2.3 Long Duration Performance Test

The LDPT is a new project work package incorporated into the updated Project Registration and PEA document that was submitted in this reporting period. The FCLi is a novel device that uses power electronics to quickly interrupt fault current; it is therefore a critical requirement that the device is tested robustly before connection to the operational 11kV network. After project team discussions during the re-baselining activities, it was decided to include the LDPT to give additional reassurance that the device can operate for longer time periods at its rated current before being connected to the operational 11kV network.

The LDPT is intended to be performed in a third party laboratory following successful completion of FAT and short-circuit testing of the device. An outline scope document was produced and issued to the Power Networks Demonstration Centre (PNDC) on 5 December 2019. The scope document set out the full requirements for the LDPT: namely, to verify the device can maintain full rated current, fault interrupting capability and cooling system/supervisory systems functionality over a period of at least one month and in both outdoor and indoor test conditions.

A series of negotiations were held with the PNDC in the subsequent months to refine and agree the scope of the LDPT taking into account the budget assigned for this work package in the re-baselined project. A number of concessions had to be made to the original scope presented in

the outline scope document to ensure the test stayed within the budget. PNDC submitted a detailed quotation for the LDPT on 7 Feb 2020. The scope that was agreed in principle was to:

- Operate the FCLi at the rated current (328A) from 11 May 2020 until 5 June 2020 i.e. three working weeks in total. This constitutes the bulk of the LDPT;
- Perform a simulated outage test after the rated current test – this would involve placing the device into its Idle mode for one working week and then performing an 8 hour rated current test to validate that the device is able to continue normal operation after a simulated prolonged outage;
- Perform the entire LDPT with the FCLi located outdoors in its GRP housing and with both air intake vents partially blocked (50% of surface area blocked) – this represents the most onerous environmental conditions for the test;
- Monitor the BIT functionality throughout the testing to ensure that the device is able to interrupt fault current under all scenarios; and
- Take insulation resistance measurements before and after each testing phase to ensure that there is no degradation of the device insulation.

Unfortunately the COVID-19 pandemic caused the postponement of the FAT and short circuit testing and therefore the final confirmation of the test scope and contractual terms and conditions were unable to be finalised. Further details of the impact the COVID-19 pandemic on the project are given in Section 2.2.9.

The final steps to reach contract signature are able to be completed prior to rescheduling of FAT and short circuit testing and will be addressed when the current travel and social distancing restrictions are relaxed.

### 2.2.4 FCLi Build and Preliminary Testing

GridON completed the build phase of the project in January 2020 and began a series of preliminary tests to validate the performance of the FCLi in advance of the FAT. Through our weekly design calls with GridON, we were informed on 23 January 2020 that the device had failed the initial 28kV withstand test and 95kV lightning impulse test carried out as part of the preliminary tests in the GridON factory. GridON investigated the root cause of the insulation breakdown and determined that additional solid insulation was required in the FCLi phase compartments. Furthermore, the low voltage dc supplies for the power electronic modules were required to be relocated in the phase cabinets.

GridON designed, built and installed the additional insulation, and subsequently retested the device in its new configuration on 8 March 2020. GridON confirmed that all preliminary tests had passed successfully on 9 March 2020. An image of the FCLi in its final configuration in the factory is shown in Figure 2-1.

The GridON investigation into the insulation failure and the subsequent device modifications were monitored closely via the weekly progress teleconferences with the manufacturer. From the outset, it was made clear to GridON that the modifications were to be permanent solutions, with all changes to be captured in an updated detailed design pack submitted to WPD for review and approval. GridON were asked to include specific design change documents to describe why the re-design was required, and to summarise the design process leading to the

chosen solution. Section 2.2.5 describes the progress that has been made to review this updated design pack.

Figure 2-1 FCLi Build Complete

### 2.2.5 FCLi Design Updates

The updated design pack was intended to formally capture the significant changes to the device following the build and preliminary testing activities. The project team had made it clear that the design pack was to be made available to WPD with sufficient time to allow the documentation to be reviewed prior to the FAT.

In the week preceding the FAT (w/c 9 March 2020), we had still not received the documentation from GridON and consequently this did not give the project team confidence that the FCLi was ready to pass the FAT. The project team was in discussions with GridON to possibly delay the FAT on this basis when travel restrictions were escalated in response to the COVID-19 pandemic, which meant the testing could no longer go ahead as scheduled in any case. Further details of the impact the COVID-19 pandemic on the project are given in Section 2.2.9. The updated detailed design pack was eventually submitted to WPD on 17 March 2020, the planned start date for the FAT in Israel.

Despite the uncertainty with the testing schedule due to COVID-19, the project team proceeded to review the design documentation so that this activity would not delay any subsequent test rescheduling. The project team performed an initial review of the updated design pack on 17 March 2020 and found that the quality of the submission was very poor. The document pack did not contain a design change document that was explicitly requested from GridON during the FCLi preliminary testing. In addition, there were documents containing errors and lacking reviewer/approver information indicating a lack of quality checks prior to submission.

GridON responded by submitting an updated design pack on 19 March 2020. A very thorough and robust review of the design pack was carried out in the subsequent weeks. The project team submitted detailed comments to GridON on 7 April 2020. The design documentation and the Installation and Operational Manual was found to be very poor. In particular, the comments from the first review of the manual had been ignored or not properly addressed by GridON; in some instances sections were completely deleted without efforts being made to comply with our direction in the comments. The design change documents lacked sufficient detail to justify the methods implemented to resolve the issues experienced in the preliminary testing.

At this current moment in time GridON have acknowledged receipt of WPD's comments and are working to update the documentation to the standard expected by WPD. The project team has instructed GridON to take sufficient time to reach this level of quality considering there are now significant delays associated with the COVID-19 situation.

### 2.2.6 Testing Specification

In this reporting period it was found that the testing specification covering the FAT and short circuit testing was inadequate to give the project team confidence that the device would be tested in a robust manner and in accordance with the technical specification. This reporting period has seen significant effort expended to develop the testing specification and increase confidence that the device is safe to connect to the 11kV network after it has undergone factory and type testing.

The issues that were apparent with the test specification and subsequent changes to the document in the review process are too numerous to list in this progress report. However, the following list summarises the main additions/changes that the project team have incorporated into the document to ensure that it is fit for purpose:

- The addition of a full suite of functional tests that were not originally proposed. These include:
    - Operational mode tests to check that the device behaves correctly on receipt of control commands i.e. On/Off/Fault Detection/Idle.
    - Failure mode tests to check that device behaves correctly for component, control system and auxiliary system failures i.e. simulating an IGBT failure to closed or open circuit, or simulating a loss of multiple cooling fans etc.
    - Interface system tests to check that the FCLi correctly activates the correct alarms, trips and indications to the WPD control system as per the agreed design.
- The inclusion of specific tests to validate the operation of the BIT functionality. This function is critical to ensuring that the device can detect IGBT failures and the disconnect the device from the network accordingly;
- The inclusion of a partial discharge test after the 28kV withstand test and 95kV lightning impulse test;
- Modifications to the temperature rise test to ensure the test validates the cooling system design point correctly:
    - Addition of temperature stickers at various locations across the device to ensure the temperature of critical components does not exceed their design point.
    - Addition of an acceptance criteria stating that the temperature variance between any two heatsinks in the device must not exceed 5°C. This is to ensure that the cooling system is operating effectively across all heatsinks.
    - Addition of an acceptance criteria stating that the measured heatsink temperatures are to be below expected heatsink temperature at the recorded ambient temperature in the laboratory. This ensures that the measured values are compared directly to the values calculated in the GridON models.
    - A thorough review of the GridON cooling system thermal models was performed to confirm that the temperature rise of the heatsinks that cool the IGBT modules behaved in a linear fashion, thus giving confidence that the heatsink temperature

at the cooling system design point (40°C) can be extrapolated from the directly measured heatsink temperature at the laboratory ambient temperature during the test.

- Significant additions to the short circuit testing requirements, namely:
    - DC insulation tests added before and after the short circuit tests to check if there has been any deterioration in the insulation due to the application of the short circuit current.
    - Short circuit current applied at two different fault detection settings to validate that the FCLi setting can be changed successfully and short circuit current is correctly interrupted at the new setting.
    - Expansion of the short circuit current application to 13 tests in total (originally only five tests were proposed) to take into account the change in detection threshold, but also important additional tests to validate that the device does not operate for simulated worst case remote faults and transformer magnetic inrush.
    - Inclusion of specific tolerances on the expected interruption time for each short circuit current test.

The final test specification (revision 8) was submitted and approved on 23 February 2020.

### 2.2.7 FAT and Short Circuit Test Witnessing

As alluded to in previous sections above, the FAT and short circuit testing was due to be witnessed in Israel on 17-18 March 2020 and in KEMA, Prague on 23-24 April 2020 respectively.

The FAT was eventually postponed in response to the escalating COVID-19 pandemic that was taking place at the same time as the modified design discussions detailed in Section 2.2.5. National governments across the globe (including Israel and the UK) were beginning to implement severe travel restrictions and public health measures to curb the spread of the disease. In particular, the Israeli and Czech governments enforced a ban for all foreign nationals aiming to enter their countries on w/c 9 March and this had a direct impact on the planned witness testing. Ultimately, the decision to postpone the testing was taken to preserve the health and safety of WPD and GridON staff.

Regardless of the COVID-19 situation, the FAT was likely to be delayed as the project team was not confident that the design changes and insulation modifications were fit for purpose. In addition, GridON had made no effort to properly capture the modifications to the device in updated design documentation and submit for WPD review and approval prior to the testing.

### 2.2.8 IAC Test Attendance

The WPD FCLi is not designed to be Internal Arc Test (IAC) compliant. Instead, interlocking measures are in place to ensure that maintenance and inspection work on the device is only carried out when the device is isolated from the 11kV supply. However, UKPN's device is specified to be IAC compliant and the WPD project team was invited to observe the IAC type test carried out on a dummy of their FCLi at the KEMA's laboratory in Prague, Czech Republic on 16 December 2019. The witnessing of this test by WPD was for information and knowledge gathering purposes only.

The test setup, method, findings and observations are documented in our IAC Test Report that was produced and submitted on 17 December 2019. To summarise, the unit passed the IAC tests, however, it was our opinion that the FCLi dummy device was not representative of either the UKPN production unit or the WPD production unit. The UKPN device is a top-entry cable design as it is being installed in a basement. However, the dummy unit had a bottom-entry cable box. Furthermore, the UKPN cable box and duct assembly had not yet been finalised at the time of the test. In our opinion, any changes to either the cable box or duct arrangement will require a further internal arc test, however, this will be subject to agreement between UKPN and GridON. In any case, the WPD production unit is significantly different and therefore any statement of compliance by GridON for the FCLi dummy unit in this test shall not be extended to the WPD production unit.

Figure 2-2 and Figure 2-3 show photographs of the dummy unit in the HV test bay prior to application of the short circuit current.

**Figure 2-2 Dummy FCLi in the HV Test Bay**

**Figure 2-3 Dummy FCLi in the HV Test Bay**

### 2.2.9 COVID-19 Impact

The COVID-19 pandemic has had a significant impact on the EDGE-FCLi project. Sections 0, 2.2.5 2.2.7 relating to the LDPT, the updated detailed design pack and the FAT/short circuit testing respectively, have all detailed the specific impact on the progress on these activities. The EDGE FCLi COVID-19 Report (dated 27 March 2020) was produced in response to the COVID-19 pandemic and gives a more detailed analysis of the impacts and WPD response in the short, medium and long term.

It is important to note that rescheduling for the FAT, short circuit testing and LDPT tasks will only be resumed once travel restrictions and social distancing measures have been relaxed, and any decision to proceed with these tasks will be subject to a thorough risk assessment. Table 2-3 presents a summary of the overall impact to the project and also a summary of the actions being taken in response to the event.

Table 2-3 Summary of COVID-19 Impact

| Work Package No. | Work Package Description | Affected? | Comment |
|---|---|---|---|
| 5 | FAT & short circuit tests | Yes | Postponed. Not able to physically witness the FAT in Israel, and also the short circuit tests in KEMA, Prague due to the H&S risks and severe travel restrictions |
| 6a | Long Duration Performance Test (LDPT) | Yes | This activity is carried out after FAT and short circuit tests. The postponement of the FCLi testing has meant that the contract negotiations are on hold pending further developments |
| 6b | Installation and operation of the UKPN FCLi on their 11kV network | Possibly | Could be delayed due to UKPN programme being adversely impacted. This situation is being monitored carefully through regular teleconferences with UKPN |
| 7 | Trial of the WPD FCLi on 11kV network | Possibly | This activity is dependent on successful completion of all the preceding work packages and is susceptible due to knock-on delays from the UKPN schedule. There may be the need to modify the project scope and timeline as a result of our communications with UKPN. |

# 3 Progress Against Budget

Table 3-1 summarises the details of the progress that has been made with respect to the project budget.

**Table 3-1 Project Finances**

| Budget Item No. | Budget Item | Budget (£k) | Expected Spend to Date (£k) | Actual Spend to date (£k) | Variance to Expected (£k) | Variance to Expected (%) |
|---|---|---|---|---|---|---|
| 1 | GridON EDGE-FCLi Unit | 1,250.0 | 840.0 | 787.5 | -52.5 | -6.3 |
| 2 | Contractor Costs | 367.6 | 360.5 | £360.5 | 0.0 | 0.0 |
| 3 | WPD Project Management | 122.1 | 67.8 | 67.2 | -0.6 | -0.9 |
| 4 | Equipment and Labour | 258.9 | 183.1 | 183.1 | 0.0 | 0.0 |
| 5 | Schneider Switchgear | 105.2 | 105.2 | 105.2 | 0.0 | 0.0 |
| 6 | Long Term Performance Test | 108.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **-** | **Totals** | **2,212.0** | **1,557.0** | **1,504.0** | **-53.0** | **-3.4** |

### *Comments around Variance*

The negative variance associated with budget item 1 is due to the expected spend being inclusive of the remaining FAT milestone payment that was prior to the end of March. However, due to the COVID-19 pandemic the FAT did not occur and is postponed, therefore, the actual spend is lower.

# 4 Progress Towards Success Criteria

Table 4-1 presents the progress towards the success criteria documented in the EDGE-FCLi Project Registration and PEA document.

**Table 4-1 Progress towards Success Criteria**

| Criterion No. | Success Criterion | Progress |
|---|---|---|
| 1 | The FCLi limits and reduces the fault current contribution of the generator to zero before the first current peak | The FCLi has now been fully manufactured and the preliminary testing of the device in the GridON factory is complete.<br><br>This criterion can only be assessed following the outcome of the short circuit testing to be held in KEMA, Prague. The testing was scheduled for 23-24 April 2020, however, the COVID-19 pandemic has meant that this activity is now postponed until further notice (Refer to Section 2.2.9 for more detail). |
| 2 | The FCLi introduces minimal disturbance to the network and the generator during normal operation | The final detailed design has been approved and the device has now been fully manufactured.<br><br>This criterion can only be assessed following the outcome of the LDPT. The LDPT was being organised with PNDC until contract negotiations were put on hold due to the COVID-19 pandemic (Refer to Sections 0 & 2.2.9 for more detail). |
| 3 | The FCLi remains in normal conduction mode for transient non-fault related events and for faults outside the 11kV network on to which it is connected. | The final detailed design has been approved and the device has now been fully manufactured.<br><br>This criterion can only be assessed following the outcome of the short circuit testing to be held in KEMA, Prague. The testing was scheduled for 23-24 April 2020, however, the COVID-19 pandemic has meant that this activity is now postponed until further notice (Refer to Section 2.2.9 for more detail). |

# 5 Learning Outcomes

The following learning outcomes resulted from activities during this reporting period:

## 5.1 Testing Specification

A thorough review of the GridON cooling system thermal models was performed as part of the activity to review the testing specification. This review confirmed that the temperature rise of the heatsinks that cool the IGBT modules behaved in a linear fashion, thus giving confidence that the heatsink temperature at the cooling system design point (40°C) can be extrapolated from the directly measured heatsink temperature at the laboratory ambient temperature during the test.

## 5.2 FCLi Build and Preliminary Testing

WPD was informed on 23 January 2020 that the device had failed the initial 28kV withstand test and 95kV lightning impulse test carried out as part of the preliminary tests in the GridON factory. GridON investigated the root cause of the insulation breakdown and determined that additional solid insulation was required in the FCLi phase compartments. Furthermore, the low voltage dc supplies for the power electronic modules were required to be relocated in the phase cabinets.

GridON designed, built and installed the additional insulation, and subsequently retested the device in its new configuration on 8 March 2020. GridON confirmed that all preliminary tests had passed successfully on 9 March 2020.

## 5.3 UKPN Coordination

The increased coordination with UKPN in this reporting period has been positive and is creating project efficiencies by removing duplication of effort. An important example is the testing specification that was reviewed and approved by our project team. The approved document formed the basis of the UKPN testing specification and only required minor modification by their policy engineers to adapt the testing procedures to their device. This saved a large duplication of review effort. In addition, WPD was invited to observe the IAC test of the UKPN device in KEMA, Prague on 16 December 2019. This allowed WPD to gain valuable knowledge of the behaviour of the device under internal arc fault conditions. A detailed description of the IAC test is given in Section 2.2.8.

# 6 Intellectual Property Rights

A complete list of all background IPR from all project partners has been compiled. The IP register is reviewed on a quarterly basis.

GridON entered this project with two relevant background IPR patent applications:

1. Patent application “DC Power Supply Arrangement” - filed on 24 January 2017
2. Patent application “AC Switching Arrangement” - filed on 21 March 2017

# 7 Risk Management

## 7.1 General

Our risk management objectives are to:

- Ensure that risk management is clearly and consistently integrated into the project management activities and evidenced through the project documentation;
- Comply with WPDs risk management processes and any governance requirements as specified by Ofgem; and
- Anticipate and respond to changing project requirements.

These objectives will be achieved by:

- Defining the roles, responsibilities and reporting lines within the project delivery;
- Team for risk management;
- Including risk management issues when writing reports and considering decisions;
- Maintaining a risk register;
- Communicating risks and ensuring suitable training and supervision is provided;
- Preparing mitigation action plans;
- Preparing contingency action plans; and
- Monitoring and updating of risks and the risk controls.

## 7.2 Current Risks

The EDGE-FCLi risk register is a live document and is updated regularly. There are currently 12 live project related risks, the number of risks has increased since the end of the design phase as insulation failures were reported in the preliminary testing and also the project has suffered delays due to the COVID-19 pandemic. The risk register includes mitigation action plans for each identified risk and appropriate steps then taken to ensure risks do not become issues wherever possible. The EDGE FCLi COVID-19 Report (dated 27 March 2020) was produced in response to the COVID-19 pandemic and gives a more detailed analysis of the impacts and WPD response in the short, medium and long term.

In Table 7-1 we give details of our top four current risks by category. For each of these risks, a mitigation action plan has been identified and the progress of these are tracked and reported.

**Table 7-1 Top five Current Project Risks (by rating)**

| Risk | Risk Rating | Mitigation Action Plan | Progress |
|---|---|---|---|
| Delays in high voltage/high power lab tests | Severe | Continual review of COVID-19 situation to ascertain when testing can be rescheduled. In the meantime, robust review of the updated design pack | The project team is continually reviewing the situation and also assessing the programme impact with UKPN |

| Risk | Risk Rating | Mitigation Action Plan | Progress |
|---|---|---|---|
| The COVID-19 pandemic continues for a long period of time creating extended delays to the NIA project programme | Major | The situation is beyond the control of WPD and UKPN. The action to be taken is to monitor the situation closely and restart planning for the FAT and short circuit testing as soon as safe to do so | COVID-19 report produced to identify actions and next steps for the project |
| Delays in UKPN's programme translate to delays in WPD's FCLi installation and energisation dates | Major | Regular progress calls with UKPN to discuss their test and install schedule. If their installation is delayed, WPD may have to reduce the 6 month trial period | Held teleconference with UKPN to understand COVID-19 impact |
| WPD unable to approve the changes to the device captured in the design pack submitted after preliminary testing | Major | Thorough review of the documentation and robust commenting to GridON | Design pack documentation has been reviewed and comments have been submitted to GridON for further action |
| Design upscale from single phase prototype to three phase fully operational device may not be realised as expected | Major | WPD are to thoroughly review the updated design pack prior to FAT. The FAT and short circuit tests are to be robustly monitored during witnessing | Design pack documentation has been reviewed and comments have been submitted to GridON for further action |

Figure 7-1 provides a graphical summary of the project risk register to give an ongoing understanding of the project risks.

| Likelihood = Probability x Proximity | | | | | | |
|---|---|---|---|---|---|---|
| | Certain/Imminent (21-25) | 0 | 0 | 0 | 0 | 0 |
| | More likely to occur than not/Likely to be near future (16-20) | 0 | 0 | 0 | 2 | 1 |
| | 50/50 chance of occuring/ Mid to short term (11-15) | 0 | 0 | 1 | 1 | 0 |
| | Less likely to occur/Mid to long term (6-10) | 0 | 0 | 0 | 4 | 0 |
| | Very unlikely to occur/Far in the future (1-5) | 0 | 1 | 2 | 0 | 0 |
| | | 1. Insignificant changes, re-planning may be required | 2. Small Delay, small increased cost but absorbable | 3. Delay, increased cost in excess of tolerance | 4. Substantial Delay, key deliverables not met, significant increase in time/cost | 5. Inability to deliver, business case/objective not viable |
| | | Impact | | | | |

| | Minor | Moderate | Major | Severe | |
|---|---|---|---|---|---|
| Legend | 3 | 0 | 6 | 3 | No of instances |
| Total | 12 | | | | No of live risks |

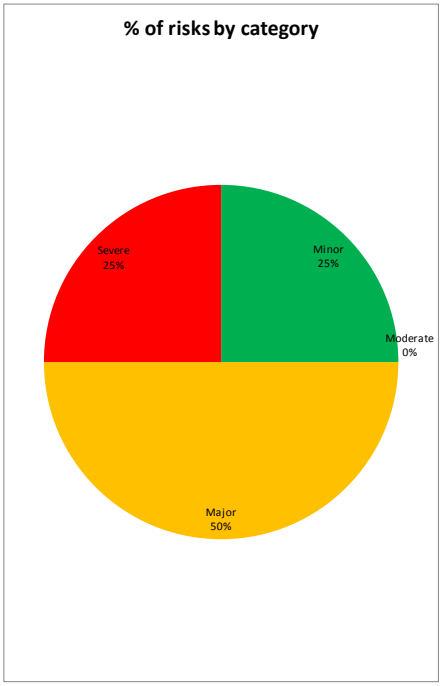



**Figure 7-1 Graphical View of Project Risks**

## 7.3 Update for Risks Previously Identified

Descriptions of the most significant risks, identified in the previous six monthly progress report are provided in Table 7-2 with updates on their current risk status.

**Table 7-2 Risks Identified in the Previous Reporting Period**

| Risk | Previous Risk Rating | Risk Rating | Mitigation Action Plan | Progress |
|---|---|---|---|---|
| Design upscale from single phase prototype to three phase fully operational device may not be realised as expected | Major | Major | WPD are to thoroughly review the updated design pack prior to FAT. The FAT and short circuit tests are to be robustly monitored during witnessing | Design pack documentation has been reviewed and comments have been submitted to GridON for further action |
| FCLi fails during high voltage/high power tests | Major | Major | The FAT and short circuit tests are to be robustly monitored during witnessing | Device initially failed 28kV withstand and 95kV LI in the preliminary testing and had to be fitted with additional insulation. The FAT and short circuit tests are to be robustly monitored during witnessing |

| | | | | |
|---|---|---|---|---|
| FCLi fails to interrupt faults during demonstration, resulting in damages to customer and/or DNO equipment | Major | Moderate | Include LDPT after type testing | FATs/short circuit testing will provide evidence. An LDPT has been included after the type testing to further mitigate the risk |
| Delays in FCLi manufacturing | Moderate | Closed | N/A | Device has been manufactured |
| Delays in high voltage/high power lab tests | Moderate | Severe | Continual review of COVID-19 situation to ascertain when testing can be rescheduled. In the meantime, robust review of the updated design pack | The project team is continually reviewing the situation and also assessing the programme impact with UKPN |

# 8 Consistency with Project Registration Document

During this reporting the period, the Project Registration and PEA document has been updated as part of a wider re-baselining process to integrate greater UKPN collaboration in the development, testing and trial of the FCLi device. The aim of the re-baseline is to increase the replicability of the technology across GB, ensure the device is safe to connect to the 11kV network and maintains continued value for money for network customers. The project re-baselining activities are described in detail in Section 2.2.1.

The changes made to project registration document have had an effect on the cost and timeframe of the project. The project duration has increased from 2.25 years to 3.5 years to cater for the inclusion of the LDPT and the subsequent trial of the FCLi at the UKPN device at their site prior to the WPD installation. The project budget has therefore increased from £2.1m to £3.0m as a result of the inclusion of the UKPN budget items.

A copy of the latest Project Registration and PEA document can be found here.
Unfortunately, the COVID-19 pandemic is causing delays to the WPD and UKPN project programmes. Although not the case at the moment, the registration document may need to be revisited in the future to adapt the project scope or timescales to take these delays into account. Further details of the impact the COVID-19 pandemic on the project are given in Section 2.2.9.

# 9 Accuracy Assurance Statement

This report has been prepared by the EDGE-FCLi Project Manager (Daniel Hardman), reviewed and approved by the Innovation Team Manager (Jonathan Berry).

All efforts have been made to ensure that the information contained within this report is accurate. WPD confirms that this report has been produced, reviewed and approved following our quality assurance process for external documents and reports.

# Glossary

| Acronym | Definition |
|---|---|
| AC | Alternating Current |
| BIT | Built In Test |
| CEO | Chief Executive Officer |
| COVID | Coronavirus disease 2019 |
| DC | Direct Current |
| DG | Distributed Generation |
| DNO | Distribution Network Operator |
| EDGE-FCLi | Embedded Distributed Generation Electronic Fault Current Limiting interrupter |
| ENA | Energy Networks Association |
| FAT | Factory Acceptance Testing |
| GB | Great Britain |
| GHD | Gutteridge, Haskins & Davey Limited |
| GRP | Glass Reinforced Plastic |
| HMI | Human Macine Interface |
| HV | High Voltage |
| IAC | Internal Arc Classification |
| IGBT | Insulated-gate Bipolar Transistor |
| IP | Intellectual Property |
| IPR | Intellectual Property Rights |
| KEMA | Keuring van Elektrotechnische Materialen te Arnhem |
| LDPT | Long Duration Performance Test |
| LI | Lightning Impulse |
| MVA | Mega Volt-Amperes |
| NIA | Network Innovation Allowance |
| PEA | Project Eligibility Assessment |
| PNDC | Power Networks Demonstration Centre |
| RMU | Ring Main Unit |
| UKPN | UK Power Networks |
| WP | Work Package |
| WPD | Western Power Distribution |

Page left intentionally blank

Western Power Distribution (East Midlands) plc, No2366923
Western Power Distribution (West Midlands) plc, No3600574
Western Power Distribution (South West) plc, No2366894
Western Power Distribution (South Wales) plc, No2366985
Registered in England and Wales
Registered Office: Avonbank, Feeder Road, Bristol BS2 0TB

wpdinnovation@westernpower.co.uk
www.westernpower.co.uk/innovation

@wpduk