WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

# EDGE-FCLi

**WPD_NIA_033**

## NIA MAJOR PROJECT PROGRESS REPORT

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## Glossary

| Term | Definition |
|---|---|
| BAU | Business as usual |
| CHP | Combined Heat and Power |
| DG | Distributed Generation |
| DNO | Distribution Network Operator |
| DSOF | Distribution System Operability Framework |
| EDGE | Embedded Distributed Generation Electronic |
| ED1 | Electricity Distribution 1 |
| FCLi | Fault Current Limiting interrupter |
| GB | Great Britain |
| GRP | Glass Reinforced Plastic |
| HMI | Human Machine Interface |
| HV | High Voltage |
| IPP | Independent Power Producers |
| IPR | Intellectual Property Register |
| LCT | Low Carbon Technologies |
| LV | Low Voltage |
| MW | Mega watt |
| NIA | Network Innovation Allowance |
| RIIO | Revenue, Incentive, Innovation, Output |
| RMU | Ring Main Units |
| UoW | University of Warwick |
| WPD | Western Power Distribution |

# 1 Executive Summary

EDGE-FCLi is funded through Ofgem's Network Innovation Allowance (NIA). EDGE-FCLi was registered in Sept 2018 and will be complete by November 2020.

EDGE-FCLi aims to upscale a newly developed solid-state Fault Current Limiting Interrupter (FCLi), targeted for cost effective connection of distributed generation, from prototype level to a commercial scale device, and trial it in one of WPD's generation customer's sites. GridON, the manufacturer, will be responsible for the FCLi design, build, testing, and installation and commissioning. The second project partner, RINA, will be responsible for the site design, project management, and data monitoring and technical consultancy.

This report details progress of the project, focusing on the progress since its commencement in September 2018 to March 2019.

## 1.1 Business Case

In our DSOF, WPD has identified fault level management as a commercial challenge within the network operations core-area (which are identified in WPD's RIIO-ED1 Business Plan).

Increased interconnection to achieve improved grid reliability has led to a substantial increase in fault levels in recent times. In addition, the shift in the generation mix in recent years led to the traditional radial structure of the network to change. Increased proliferation of distributed generators has increased the number of points of fault infeed, and also aided in increased fault levels on the distribution system. Network reinforcement which could at times be costly, resource-intensive and time-consuming has historically been the common approach of addressing the issues of rising fault levels. WPD has identified both short term and long term solutions to deal with the changing profile of fault currents. One of the solutions identified is the use of new fault level mitigation technologies that could limit the flow of excessive short circuit currents.

The problem is particularly severe in areas where fault level headroom is scarce or non-existent, but there are multiple generation connection opportunities. In order to enable a scalable and long term path for such connections, the fault current contribution from new generators needs to be reduced to near zero. While some generation sources contribute little fault current (inverter based generation like solar), others (such as CHP) contribute significant fault current.

The fault current limiting interrupter, that will be trialled in this project, will provide a scalable solution for such new connections. FCLi provides both the ability to reduce the fault current to near-zero, and be cost effective enough to be acceptable to IPPs. Furthermore, the FCLi will expedite IPPs' ability to export electricity to the grid while creating revenue.

The problem of high fault levels is more prominent in urban networks. An urban substation with 25 circuit breakers is assumed with 8 RMUs per 11kV feeder (20 in total). Within the GB distribution network the majority of the old 11kV switchgear is rated at 13.1kA

(250MVA). The typical reinforcement approach includes upgrading them to 25kA (476MVA). Close-up RMUs also need upgrading.

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, while it is assumed that 25% of them will need replacing.

Base Cost= 11kV switchgear cost+11kV RMUs cost= (25 x50) + (0.25 x20x8x20) = £2050k

The fault level headroom enabled by the 25kA switchgear is 226 MVA and this can accommodate approximately six 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 Distributed Generators.

The business as usual cost of an 11kV, 5MW FCLi is expected to be £275k, hence:
Method Cost= 4x275= £1100k
Saving= £950k

## 1.2 Project Progress

This is the first six monthly progress report. It covers progress from initial registration in September 2018 to the end of March 2019. Details of the work to date is summarised below.

- **Site identification**: UoW agreed in December 2018 to host the FCLi in series with their embedded CHP generators. A major milestone was achieved with this as finding a suitable site was perceived as a great challenge (and risk) to the project given the lack of financial incentive to the host participant.
- **FCLi Conceptual & Preliminary Design**: GridON produced the FCLi philosophy and overall concept in their conceptual design document that covered the power circuit and control system architecture. After a detailed review by both WPD and RINA, the conceptual design was approved on 01/11/2018. After the approval of the conceptual design, the preliminary design for the FCLi device commenced covering mechanical, thermal, electrical design and initial electrical performance simulations. The preliminary design pack was submitted in December 2018. A DigSilent representative 'network and FCLi' model was also developed to carry out a set of simulations to support design review. After a series of iterations WPD approved the preliminary design on 15.02.2019.
- **FCLi detailed design:** GridON are currently carrying out FCLi detailed design activities which include finalising the mechanical and thermal design, detailed electrical simulations, PCB design, failure analysis, etc. At the time of writing this report nearly 80% of the detailed design work has been completed. The current target submission date is 19.04.2019.
- **GRP design**: We have been engaged with Envico (WPD's chosen vendor for GRP container) since December 2018. The status at the time of writing this report is that the project team has requested WPD to confirm the GRP design (pending a few issues, which will have to be resolved) with Envico and raise a purchase order as soon as possible.

- **Demo site electrical and civil design:** We have received a preliminary version of the HMI wall-box from RINA based on an initial signal list from GridON. We are constantly working with RINA to update the drawings taking into account the detailed design being carried out by GridON. The final versions of the HMI wiring and signals will only be known once the detailed design is completed by GridON. We are also supporting the UoW's electrical team in the design of required changes to the university internal network. This includes doing cable route and size designs. Due to delays in GRP design the civil design has been impacted (but not perceived to pose any risk). Based on the preliminary GRP dimensions RINA has issued a preliminary drawing showing the FCLi positioning and interfacing cable ducts. The GRP design is still not finalised, however, based on the information received so far RINA is currently carrying out the plinth/foundation, cable ducting design for the FCLi and GRP container.

## 1.3 Project Delivery Structure

### 1.3.1 Project Resource

| Project Partner | Resource | Detail |
|---|---|---|
| Western Power Distribution | Faithful Chanda | Project Manager, WPD |
| GridON | Yoram Valent | CEO, GridON |
| | Uri Garbi | R&D Manager, GridON |
| | Alex Oren | Senior Engineer |
| | Dvir Landwir | Senior Engineer |
| RINA | Nagaraju Pogaku | Project Manager & Senior Technical Consultant, RINA |
| | Simon Ebdon | Head of Power Systems, RINA |
| | Sayyed Zulqarnain | Principal Consultant, electrical, RINA |
| | Enrico Rossi | Civil Engineering Manager, RINA |

Table 1: Procurement Details

## 1.4 Procurement

The following table details the current status of procurement for this project.

| Provider | Services/goods | Area of project applicable to | Anticipated Delivery Dates |
|---|---|---|---|
| Different suppliers | Components ordering | Device build | Long lead items have already been delivered |
| Ardan Electrical Engineering Ltd | Device manufacturer/ subcontractor | Device build and type test | In process. Build and factory test expected to finish by July 2019. |
| Authorized short circuit test lab | Short circuit testing | Device short circuit test | Currently assessing two qualified laboratories – KEMA and VEIKI-VNL |
| Power Standards Lab | PQube 3 Power Quality Monitor | FCLi data monitoring | Quotation received. Finalising specs. July 2019. |

Table 2: Procurement Details

## 1.5 Project Risks

A proactive role in ensuring effective risk management for EDGE-FCLi is taken. This ensures that processes have been put in place to review whether risks still exist, whether new risks have arisen, whether the likelihood and impact of risks have changed, reporting of significant changes that will affect risk priorities and deliver assurance of the effectiveness of control.

Contained within Section 7.1 of this report are the current top risks associated with successfully delivering EDGE-FCLi as captured in our Risk Register. Section 7.2 provides an update on the most prominent risks identified at the project bid phase.

## 1.6 Project Learning and Dissemination

Project lessons learned and what worked well are captured throughout the project lifecycle. These are captured through a series of on-going reviews with stakeholders and project team members, and will be shared in lessons learned workshops at the end of the project. To date no dissemination of the project has taken place but is planned for June at the Balancing Act.

# 2 Project Manager's Report

## 2.1 Project Background

WPD, GridON and RINA agreed on an innovation proposal to upscale a newly developed solid-state FCLi by GridON. This project will demonstrate the operation of a new solid state technology based fault current mitigation device in an 11kV network. Such a device has not yet been trialled in an 11kV network in the UK. GridON's FCLi utilises novel circuitry for controlling the voltage over the semiconductor devices during current interruption. Such circuitry has not been demonstrated to date. The FCLi enables cost effective connection of distributed generators to networks which are already fault level constrained.

The proposed project runs for 2 years and 3 months and is divided into six work packages:

1. Device specifications – Specifications were defined at the start of the project to cover all the device requirements.

2. Preliminary FCLi design and review - This includes the identification of key components, high level electrical, thermal and control design and detailed test plan preparation.

3. Detailed FCLi design and review - This involves full design of all parts including power modules, insulation, control system and operator interface, fault detection system, enclosures, thermal and ventilation detailed design. Long lead time components will be ordered.

4. Site design, review and preparation - Civil and electrical site design, and design review, followed by site preparation works to accommodate the integration of the FCLi.

5. FCLi manufacturing and testing - the FCLi will be manufactured and undergo factory and external lab testing.

6. Installation, commissioning energisation and field operation - The FCLi will be installed, commissioned, and energised. Subsequently it will be operated in the network, its behaviour will be monitored and its performance will be analysed for a 9-month period.

## 2.2 Project Progress

### 2.2.1 Device Specification

Technical requirements for the FCLi were debated in length and a detailed technical specification document was produced.

### 2.2.2 Site Identification

A major milestone in the project was site identification as finding a suitable site was perceived as a great challenge (and risk) given there is no financial incentive to the host participant. We explored multiple sites to host the FCLi. UoW and Cardiff University had expressed interest in hosting the trial. However, the generators at Cardiff University were not suitable for the trial due to small generator size and capacity. The UoW was identified

as the best candidate site for hosting the FCLi. After a series of meetings and network operational proposals, the UoW agreed in December 2018 to host the FCLi in series with their embedded CHP generators.

### 2.2.3 FCLi conceptual & preliminary design

GridON produced the FCLi overall concept in their conceptual design document that covered the power circuit and control system architecture. We reviewed the document and ensured GridON addressed all the comments/questions raised during the review. The conceptual design was approved on 01/11/2018. Following this GridON carried out preliminary design activities and presented the preliminary design pack in December 2018, covering mechanical, thermal, electrical design and initial electrical performance simulations. A DigSilent representative 'network and FCLi' model was also developed and a set of simulations to support design review were carried out. The preliminary design was reviewed in detail we ensured that all issues were addressed including any additional information that was required. Any remaining issues were logged with a view to address them during the detailed design phase. The preliminary design was approved on the 15.02.2019.


Figure 1: FCLi will look like this

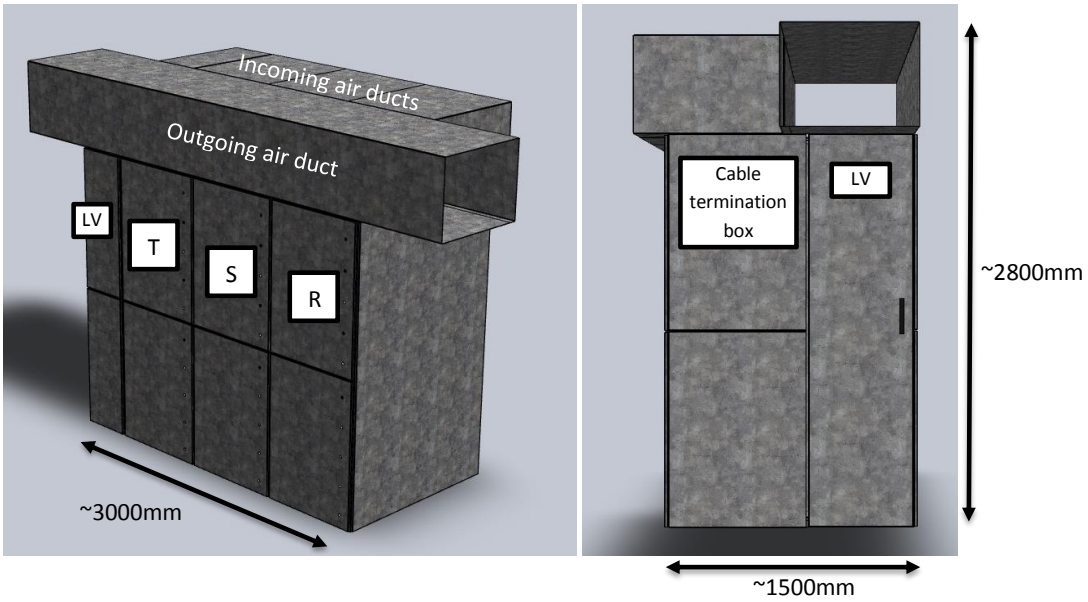


Figure 2: FCLi dimensions (preliminary)

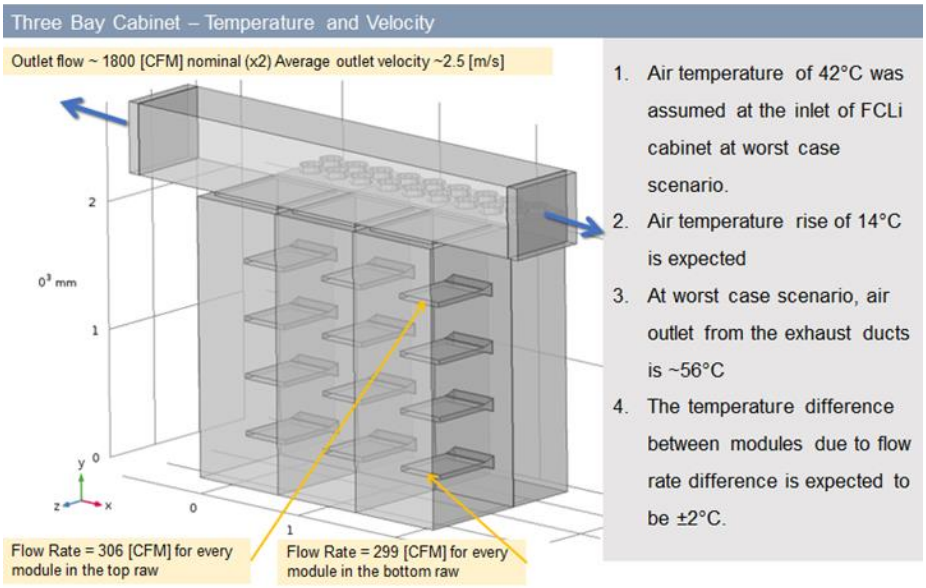


Figure 3: FCLi thermal analysis (preliminary)

**FCLi detailed design:** GridON are currently carrying out FCLi detailed design activities which include finalising the mechanical and thermal design, detailed electrical simulations, PCB design, failure analysis, etc. At the time of writing this report nearly 80% of the design work has been completed. The current target submission date is 19.04.2019.

**GRP design**: We have been engaged with Envico (WPD's chosen vendor for GRP container) since December 2018. There were some delays in Envico's response, however, lately they have been more active and have provided a sales drawing to work with. The status at the time of writing this report is that the project team has requested WPD to confirm the GRP design (pending a few issues, which will have to be resolved) with Envico and raise a purchase order as soon as possible.

**Demo site electrical and civil design:** We have visited the UoW primary substations multiple times, taken the required measurements, and met the site engineers and University electrical team.

- It has been agreed that RINA will develop the detailed schematic for interfacing FCLi with WPD network. For this, RINA has been designing a HMI wall-box panel. As the detailed design is still in progress, the final version of the HMI has not been completed.
- We are also supporting the UoW's electrical team in the design of required changes to the University's internal network. We are currently doing cable route and size designs.
- As far civil design is concerned, due to delays in GRP design the civil design has also been impacted (but not perceived to pose any risk). Based on the preliminary GRP dimensions we have developed a preliminary drawing showing the FCLi positioning and interfacing cable ducts. The GRP design is still not finalised, however, based on the information received so far we are carrying out the plinth/foundation design for the FCLi & GRP container.

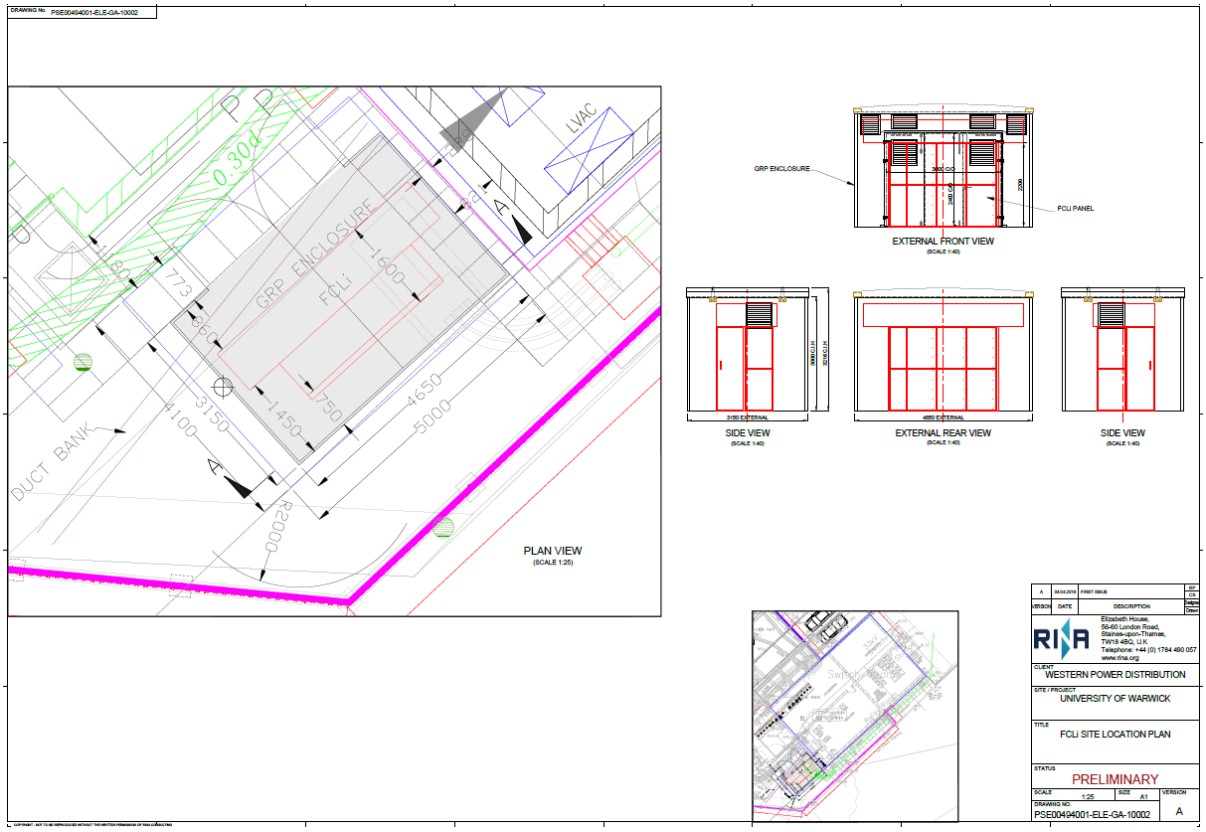


Figure 4: FCLi positioning at the UoW site (draft sketch)

## Next steps

- FCLi detailed design submission, review and approval
- Site detailed design submission , review and approval
- Site preparation
- FCLi manufacturing

# 3 Progress against Budget

| Spend Area | Budget (£k) | Expected Spend to Date (£k) | Actual Spend to Date (£k) | Variance to expected (£k) | Variance to expected % |
|---|---|---|---|---|---|
| WPD Project Management | 74.147 | 19.886 | 19.886 | 54.261 | -73 |
| Project Partner Project Management | 340.4 | 102.12 | 102.12 | 238.28 | -70 |
| GRIDON FCLi UNIT | 1250 | 472.5 | 472.5 | 777.5 | -62.2 |
| WPD TELECOMS COSTS | 5.096 | 0 | 0 | 5.096 | 100 |
| SCHNEIDER SWITCHGEAR | 105.220 | 0 | 0 | 105.220 | 100 |
| **TOTAL** | **1,774.863** | **594.506** | **594.506** | **1180.357** | |

Table 3: Procurement Details

### Comments around variance

Spend is below the expected value as the project is delivering in accordance to the project plan - on time and on budget. We have not yet spent on the Schneider switchgear but have raised the purchase order, project partner costs are paid in line with the agreed schedule, and so are the project management fees.

# 4 Progress towards Success Criteria

| Expected success | How this is being achieved |
|---|---|
| The FCLi limits and reduces down to zero before the first peak the fault current contribution of the generator during a network fault | This is the fundamental aspect of the FCLi design. The FCLi is made of IGBT switches. These switches open within a few milliseconds (before first peak) when the fault current exceeds a pre-set threshold. There are surge arrestors in parallel and clamping circuit. The surge arrester absorbs the vast majority of the grid stored energy during current interruption. It is selected such that it has a significant energy margin over the maximum anticipated grid energy. The clamping circuit provides reduction of transient voltage originating from parasitic inductances in the FCLi circuit.<br><br>Preliminary electrical simulations have been conducted on a preliminary model of the all components of the FCLi system which demonstrated successful interruption of fault current before first week. Detailed simulation are currently underway as part of detailed design work. |
| The FCLi introduces minimal disturbance to the network and the generator during normal operation | The FCLi is specified and being designed such that there is minimum disturbance to the network. High performance components were chosen along with appropriate redundancy. Preliminary simulation results showed 0.23% voltage drop at rated current whereas the specification is <0.5%. Similarly, an almost negligible harmonic content (0.06%) was observed in the grid voltage at rated current. |
| 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 | Fault detection thresholds are chosen such that FCLi is insensitive to spurious and remote faults. |
| Any device failures are minor and do not render the plant unavailable for more than a few hours | Sufficient design margins are maintained in the design to minimise the risks. |

Table 4: Procurement Details

# 5 Learning Outcomes

An integral aspect of innovation projects is the inclusion of those outside of the typical business, to support the project and to introduce new methodologies and ideas to the project. However there are inherent risks in working with different industries and businesses that may approach the project in a different manner, and have different priorities or systems for tackling a large-scale project. Coordination between different teams is therefore vital to realise success. Also, it is important to be clear about job roles and tasks, in projects such as these as it is likely that new, and unexpected, tasks will emerge during the project. It is important that all partners have a certain amount of flexibility in their contracts to respond to these new tasks and be open to working above and beyond their initial job description.

In terms of the technology, we are beginning to understand that it is quite a process to up-scale from a single phase prototype to a full 3 phase product; from conceptual and preliminary design, to detailed final design. In addition, a suite of electrical interface (trips/alarms) signals will need to be developed between the FCLi and the distribution network.

# 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:

a. Patent application “DC Power Supply Arrangement” - filed on 24-Jan-2017
b. Patent application “AC Switching Arrangement” - filed on 21-Mar-2017

# 7 Risk Management

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.

## 7.1 Current Risks

The EDGE-FCLi risk register is a live document and is updated regularly. There are currently 22 live project related risks. Mitigation action plans are identified when raising a risk and the appropriate steps then taken to ensure risks do not become issues wherever possible. In Table 7-1**Error! Reference source not found.**, we give details of our top five 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.

| Details of the Risk | Risk Rating | Mitigation Action Plan | Progress |
|---|---|---|---|
| Design upscale from single phase prototype to three phase fully operational device may not be realised as expected | 45 | Preliminary design simulations showed positive results. Detailed design simulations are currently being conducted and once completed the outputs should give a more precise indication on whether the design is capable of meeting the specification or not. | In progress |
| FCLi fails to interrupt faults during demonstration, resulting in damages to customer and/or DNO equipment | 30 | Following successful prototype testing, the design of the full FCLi will be carefully verified through simulations and testing. Preliminary design simulations showed positive results. Detailed design simulations are currently being conducted and once completed the outputs should give a more precise indication on whether the design is capable of meeting the specification or not. Moreover, at the chosen demonstration site (University of Warwick) fault levels do not exceed the switchgear ratings even if FCLi fails to interrupt the fault current. | In progress |
| Delays in demonstration site design and preparation | 27 | Early site selection, early ordering of long-lead items, efficient site design. Preliminary site designs have already been done and detailed designs are progressing as per the project plan. | In progress |
| Delays in FCLi design | 27 | Appropriate resources will be identified early in the project and made available as per the project plan. Parallel activities will be identified and executed. Preliminary design is already approved by WPD and detailed design is currently progressing as per the plan. | In progress |
| Delays in FCLi manufacturing (component lead times) | 27 | Appropriate resources will be identified early in the project and made available as per the project plan. Long-lead items have been ordered early. Has been engaged with the manufacturer since very early stages of the project. Parallel activities will continued to be identified and executed | In progress |

Table 7-1: Top five current risks (by rating)

Table  provides a snapshot of the risk register, detailed graphically, to provide an on-going understanding of the projects' 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** | **0** | **0** |
| | 50/50 chance of occuring/ Mid to short term (11-15) | **0** | **0** | **0** | **0** | **0** |
| | Less likely to occur/Mid to long term (6-10) | **0** | **2** | **5** | **2** | **2** |
| | Very unlikely to occur/Far in the future (1-5) | **0** | **0** | **6** | **3** | **2** |
| | | 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** | **8** | **10** | **4** | **0** | **No of instances** | |
| **Total** | **22** | | | | No of live risks | |

Table 7-2: Graphical view of Risk Register

Table 7-1 provides an overview of the risks by category, minor, moderate, major and severe. This information is used to understand the complete risk level of the project

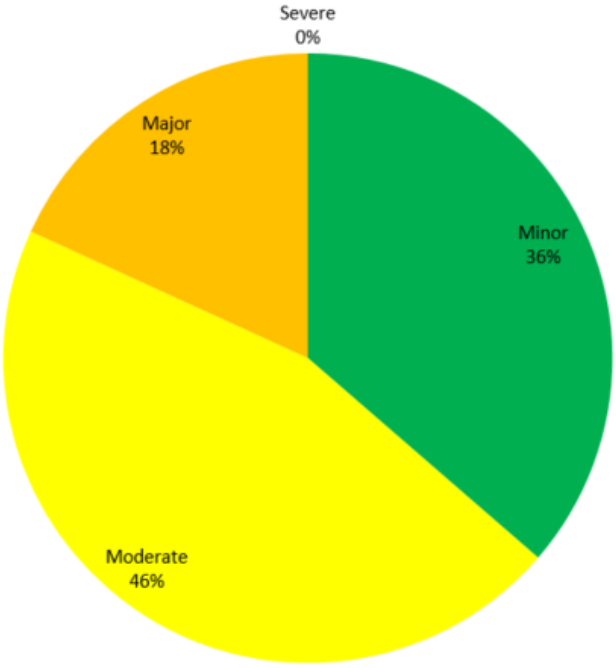


Table 7-1: Percentage of Risk by category

## 7.2 Update for risks previously identified

**[This section is not applicable as this is the first 6 monthly report of EDGE-FCLi project]**

# 8 Consistency with Project Registration Document

The scale, cost and timeframe of the project has remained consistent with the registration document, a copy of which can be found here: https://www.westernpower.co.uk/projects/edge-fcli

However, the schedule of some activities have been brought forward to meet the generator customer requirement (University of Warwick) to conduct the site preparations works in summer vacation period (July 2019-Sept 2019) instead of originally planned Sept 2019 to Nov-2019 period. Although this puts a bit of pressure, the project team is working hard and believes the new schedule can be achieved. The positive aspect of this accelerated plan is that the trial period increases by nearly three months and hence the network can potentially present more network faults to FCLi to interrupt and hence prove its functionality.

# 9 Accuracy Assurance Statement

This report has been prepared by the EDGE-FCLi Project Manager Dr Raju Pogaku reviewed by Faithful Chanda and approved by the Innovation Team Manager, Jon 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.