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FLEXDGRID

HEAT AND POWER FOR BIRMINGHAM

PROJECT PROGRESS REPORT
REPORTING PERIOD:
DECEMBER 2014 – MAY 2015

LCN Fund Low Carbon Networks

THE UNIVERSITY OF WARWICK

PARSONS BRINCKERHOFF

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Glossary

Term	Definition
AC	Alternating Current
AFD	Active Fault Decoupler
BaU	Business as Usual
BCC	Birmingham City Council
CBD	Central Business District
CHP	Combined Heat and Power
DC	Direct Current
DG	Distributed Generation
DNO	Distribution Network Operator
DPCR5	Distribution Price Control Review 5
ER G74	Engineering Recommendation G74
EU	European Union
FCL	Fault Current Limiter
FLM	Fault Level Monitor
FLMT	Fault Level Mitigation Technology
GT	Grid Transformer
HV	High Voltage - 6.6kV or 11kV
IEC	International Electrotechnical Commission
KPI	Key Performance Indicator
LCNI	Low Carbon Networks & Innovation
PEFCL	Power Electronic Fault Current Limiter
PSFCL	Pre-saturated Core Fault Current Limiter
PSS/E	Power System Simulator for Engineering
RAMs	Risk Assessment Method statement
RII0-ED1	DNO Price Control from 1 April 2015 to 31 March 2023
RSFCL	Resistive Superconducting Fault Current Limiter
SDRC	Successful Delivery Reward Criteria
SoW	Scope of Work
ST	Standard Technique
TCA	Testing and Certification Australia
UoW	University of Warwick
WPD	Western Power Distribution
X/R ratio	The X/R ratio is the ratio of the system reactance to the system resistance looking back towards the power source from any point in the network

1 Executive Summary

FlexDGrid is funded through Ofgem's Low Carbon Networks Second Tier funding mechanism. FlexDGrid was approved to commence in January 2013 and will be complete by 31st March 2017. FlexDGrid aims to develop and trial an Advanced Fault Level Management Solution to improve the utilisation of Distribution Network Operators' (DNO) 11kV (HV) electricity networks while facilitating the cost-effective and early integration of customers' generation and demand connections.

This report details progress of FlexDGrid, focusing on the last six months, December 2014 to May 2015.

1.1 Business Case

The business case for FlexDGrid remains unchanged. Birmingham City Council (BCC) continue to have a policy in place for the inclusion of combined heat and power (CHP) plants in new domestic and commercial construction sites.

1.2 Project Progress

During this report period FlexDGrid has continued to be in the construction phase. Significant works have included the installation, commissioning and energisation of a further four fault level monitors (FLM), taking the total commissioned FLMs to six. Also in this period the installation, commissioning and energisation of the first fault level mitigation technology (FLMT) at Castle Bromwich substation took place, on the 8th April 2015.

Significant data is now being provided from the six energised FLMs in the form of Peak and RMS fault level data. This data is being used to support Method Alpha to determine the differences between the monitored and modelled data. Through detailed analysis key learning is being generated about how fault level changes throughout the day and how it varies for substations with different load types connected.

During this reporting period (December 2014 – May 2015) FlexDGrid has made significant progress in working towards the delivery of other project SDRCs, specifically SDRCs 7 - 11.

1.3 Project Delivery Structure

1.3.1 Project Review Group

The FlexDGrid Project Review Group met once during this reporting period. The main focus of this meeting was the construction activities to integrate both the fault level monitors (FLM) and fault level mitigation technologies (FLMT) along with a Gateway Review following the commissioning and energisation of the first FCL.

1.3.2 Resourcing

There have been no significant resourcing changes during this reporting period.

Contracted construction staff continues to be employed on a site by site basis to support WPD with the delivery of the technology installation activities.

1.4 Procurement

The procurement activity for the technologies (FLMs and FLMTs) is now complete, where all contracts are in place. An overview of these technologies and their expected installation dates is provided below in Table 1-1.

Table 1-1 - FlexDGrid Technology Contracts

Manufacturer	Technology	Applicable Substations	Anticipated Delivery Dates
S&C Electric	Fault Level Monitors	10 Sites	Phased throughout 2014 and 2015
GridON	Fault Current Limiter – Pre-saturated Core	Castle Bromwich	April 2015 **(Complete)**
Nexans	Fault Current Limiter - Resistive Superconducting	Chester Street Bournville	July 2015 September 2015
Alstom	Fault Current Limiter - Power Electronic	Kitts Green Sparkbrook	January 2016 April 2016

1.5 Installation

Four FLMs have been installed and commissioned during this reporting period taking the total live FLMs to six. The remaining four FLMs will be commissioned and energised in the next reporting period.

The first FLMT is now commissioned and energised, 8th April 2015. The second FLMT is now scheduled for energisation in October 2015.

1.6 Project Risks

A proactive role in ensuring effective risk management for FlexDGrid 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 8.1 of this report are the current top risks associated with successfully delivering FlexDGrid as captured in our Risk Register along with an update on the risks captured in our last six monthly project report. Section 8.2 provides an update on the most prominent risks identified at the project bid phase.

1.7 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. These are reported in Section 6 of this report.

A key aim of FlexDGrid is to ensure that significant elements of the work carried out for network modelling, monitoring, design and installation are captured and shared within WPD and the wider DNO community. During this period the main focus has been to capture learning in the form of WPD policy documents.

During this reporting period significant internal WPD dissemination took place. Following the issuing of the policies, relating to the Inspection and Maintenance and Operation and Control of the FLMs and the Pre-Saturated Core FCL, practical training on site of these were carried out with operational staff.

In addition to this we have shared our learning (where applicable), through discussions and networking at a number of knowledge sharing events hosted by other organisations.

2 Project Manager's Report

2.1 Project Background

The FlexDGrid Low Carbon Networks Fund project aims to develop and trial an Advanced Fault Level Management Solution to improve the utilisation of Distribution Network Operators' (DNO) 11kV (HV) electricity networks while facilitating the cost-effective and early integration of customers' generation and demand connections. The FlexDGrid project was awarded funding through Ofgem's Low Carbon Networks Second Tier funding mechanism and commenced on the 7th January 2013.

The Carbon Plan aims to deliver carbon emission cuts of 34% on 1990 levels by 2020. This national target is devolved, in part, through local government carbon emission reduction targets as set out in their strategy planning documents. The Carbon Plan sets out ways to generate 30% of the UK's electricity from renewable sources by 2020 in order to meet the legally binding European Union (EU) target to source 15% of the UK's energy renewable sources by 2020. The UK Government has identified distributed generation (DG) as a major low carbon energy enabler and an important part of the future electricity generation mix.

Fault level is a measure of electrical stress when faults occur within networks. It is a growing issue in the connection of Distributed Generation (DG), especially in urban networks, as the majority of DG increases the system fault level. Conventional solutions to manage Fault Level often entail significant capital costs and long lead times.

In order to address the Fault Level Management Problem, three methods will be trialled and evaluated within the Central Business District (CBD) of Birmingham. The findings from these three methods will be extrapolated in order to understand the wider applicability to GB urban networks.

These Methods are:

Method Alpha (α)	-	Enhanced Fault Level Assessment;
Method Beta (β)	-	Real-time Management; and
Method Gamma (γ)	-	Fault Level Mitigation Technologies.

These three methods aim to defer or avoid significant capital investment and create a wider choice of connection options for customers who can accept a flexible connection to the network. These benefits will be provided to customers through advanced and modified generation connection agreements. Each method on its own will help customers to connect DG more flexibly. The three methods used together will aim to create greater customer choice and opportunities for connection.

2.2 Project Progress

This is the fifth project report. The period covered in this report is focussed on the construction and data analysis activities. Within this reporting period the construction activities have continued. The energisation of the first FLMT has been achieved. The second FLMT is now in the build phase. Substantial progress has also been made on Method Beta relating to the detailed understanding of Fault Levels at individual substations. These studies are specifically focussed on the quantity and type of load and/or generation connected.

2.3 Project Reporting Progress

Table 2-1: Project Reporting Dates

Due Date	Type	Description	Status
11.05.2015	KPI	Commence Second FLMT Install	Complete
31.05.2015	KPI	Successfully complete FLM Re-Testing	Complete
30.06.2015	KPI	Successfully test Second FLMT	Complete
31.07.2015	KPI	First FLMT Energised	Complete

2.4 Substation Selection Update

The design phase for FlexDGrid selected 10 and 5 sites for the installation of FLMs and FLMTs respectively, from 18 sites originally identified as part of the detailed design phase of the project.

As discussed in the previous reporting period Perry Barry substation has been replaced by Nechells West substation for the inclusion of an FLM. Sparkbrook substation has now been replaced by Bartley Green substation.

Following further detailed design of the Alstom AFD a revised study of the substations identified for inclusion at the detailed design stage was carried out. It became apparent due to existing equipment at the respective sites that Sparkbrook substation was now less suitable than other previously investigated substations.

2.5 Fault Level Monitors - Method Beta

The total number of FLMs now installed is six. Following the installation of these units and successful device re-testing in May 2015 (where the device was tested to be accurate for both Peak and Break fault levels to within 5%) a key focus is now analysis of the FLM data being provided to understand the differences between the enhanced network models, created as part of Method Alpha.

2.5.1 Testing

As detailed in the previous reporting period, the issues that caused the FLM to fail during laboratory testing, in May 2014, have been successfully rectified. In May the re-testing of the FLM device was successfully completed, where the device for both Peak (10ms) and Break (90ms) fault level provided results within 5% of the bolted fault level value. Some issues with the Break values were experienced and this is being investigated. Figure 2-1 shows the arrangement of the testing laboratory.

Figure 2-1 - FLM Testing laboratory

Two key learning points were identified during testing the testing. The first was that the mechanical nature of the device (Pad-Mounted Intellirupter) created variances in the performance of the device. This was due to the pole mechanisms varying in their opening and closing times, which affected the quality of the artificial disturbance and therefore the fault level results. Therefore, the maintenance requirement of the device will be investigated and revised, if necessary, to ensure they are performing as required. The second is that in some instances the 50Ω impedance didn't create a voltage disturbance great enough to produce a valid fault level reading; therefore these readings were discounted from the results.

An overview of the testing results is provided in Table 2-2.

				Fault Level		*Percentage Error*	
Test	**Impedance (Ω)**	**X/R Ratio**	**Voltage (kV)**	**Peak (kA)**	**Break (kA)**	**Peak (%)**	**Break (%)**
Bolted Fault		8	11.53	7.08	2.94		
PulseClose	20	8	11.46	6.99	2.96	-1.27%	0.79%
PulseClose	30	8	11.47	6.93	2.99	-2.12%	1.82%
PulseClose	20	8	11.47	6.93	2.93	-2.12%	-0.23%
PulseClose	30	8	11.57	7.07	3.05	-0.14%	3.86%
PulseClose	20	8	11.57	6.87	2.96	-2.97%	0.79%
PulseClose	30	8	11.57	6.99	3.00	-1.27%	2.16%
Bolted Fault		25	11.44	34.66	12.73		
PulseClose	20	25	11.59	32.46	13.30	-6.35%	4.48%
PulseClose	30	25	11.59	34.69	13.84	0.09%	8.72%
PulseClose	20	25	11.59	33.72	13.54	-2.71%	6.36%
PulseClose	30	25	11.59	33.71	14.02	-2.74%	10.13%
PulseClose	20	25	11.59	34.52	13.57	-0.40%	6.60%
PulseClose	30	25	11.59	36.03	14.07	3.95%	10.53%
Bolted Fault		29	11.56	22.42	8.24		
PulseClose	20	29	11.56	21.95	8.68	-2.10%	5.38%
PulseClose	30	29	11.57	23.18	9.03	3.39%	9.63%
PulseClose	20	29	11.57	22.07	8.27	-1.56%	0.40%
PulseClose	30	29	11.57	22.71	8.35	1.29%	1.38%
PulseClose	20	29	11.53	21.87	8.17	-2.45%	-0.81%
PulseClose	30	29	11.57	22.69	8.90	1.20%	8.05%

Table 2-2 - FLM Test Results

The overall success of the testing now enables the project to move forwards in understanding the effects of differing loads and generation at specific times of the day. This will now enable a greater understanding of the available fault level headroom to be exploited.

2.5.2 Installation

The previous progress report for the period May 2014 to November 2014 gave a summary of the construction work that has been completed (two FLM sites) and the installation start dates for eight of the ten substations selected for installation of FLMs.

During this reporting period a further four site have been energised, taking the number of energised FLMs to six. The remaining four sites are planned for energisation in June and September.

Table 2-3 below lists the sites and the FLM energisation date or the forecast date.

Table 2-3 - Energisation dates for FLM sites

Substation	Status	Energisation Date
Elmdon	Energised	14/10/2014
Chad Valley	Energised	02/12/2014
Castle Bromwich	Energised	12/02/2015
Kitts Green	Energised	04/03/2015
Shirley	Energised	04/03/2015
Hall Green	Energised	01/04/2015
Chester Street	Under construction	June 2015*
Nechells West	Under construction	June 2015*
Bournville	Under construction	September 2015*
Bartley Green	Under Design	September 2015*

*Forecast energisation dates

2.5.3 FLM Data Analysis

Data analysis has taken place in this reporting period to understand the FLM's performance connected to the six substations currently energised. Below is an overview of three of the devices connected.

For clarification the natural disturbance data gathered by the FLM provides the fault level contribution from upstream of the location it is connected. This means that when connected on the 11kV busbar at a primary substation the fault level data is for the system above this location, i.e. WPD's EHV and National Grid's network. Artificial disturbance fault level data combines both the upstream and downstream contributions to fault level.

Chad Valley

Chad Valley substation's load is made up of mainly domestic connections. Typically this would mean that there is minimal rotating load or generation on either the 11kV or LV network, which contributes significantly to downstream fault levels.

The graph below in Figure 2-2 shows the natural and artificial disturbance Make (Peak at 10ms) data. The natural disturbance is the green line and the artificial the orange points, split by FLM resistor value. It can be seen that the artificial and natural disturbance data overlap. This suggests, as detailed above, that the load is dominated by domestic installations and that minimal fault level infeed is generated from downstream of the substation's 11kV busbars.

Another key feature of Figure 2-2 is the difference between the FLM fault level data and the modelled (original data not that generated from Method Alpha). The modelled value is about 4kA higher than the monitored. This suggests the G74 value for LV connected load infeed of 1MVA/MVA is greater than the infeed value of domestic dominated load. During the next reporting period this work will be investigated further.

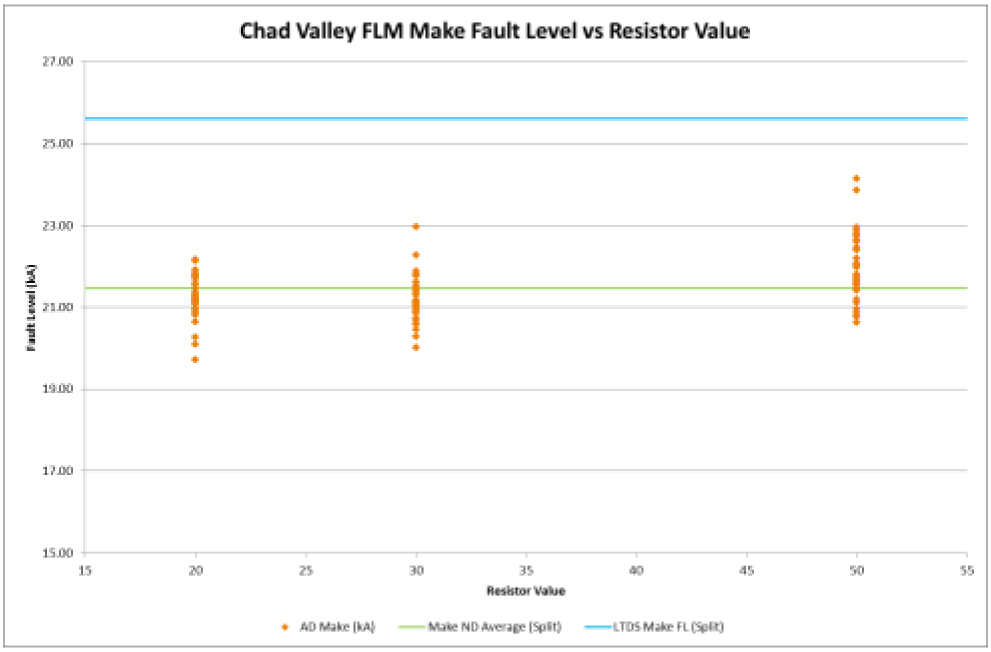


Figure 2-2 - Chad Valley Make FL Vs. Resistor Value

Figure 2-3 shows the variation in fault level (Make – Peak at 10ms) for the four artificial disturbances produced a day. It can be seen that for 06:00, 12:00 and 18:00 the line is relatively flat and at 00:00 is reduced. In the next reporting period detailed analysis of this effect will take place to understand if it is due to a reduced amount of centralised generating plant or another phenomenon.

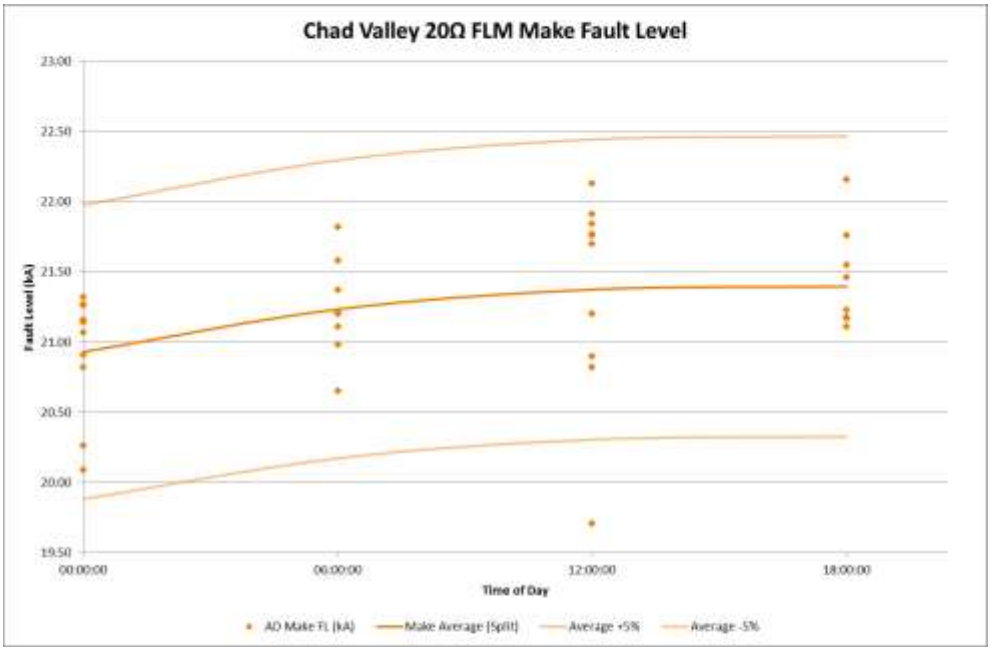


Figure 2-3 - Chad Valley Make FL Vs. Time of Day

Elmdon

The load connected at Elmdon substation is a mix of domestic, commercial and industrial (7.18%, 7.30% and 85.52%). Key loads connected at Elmdon are Birmingham Airport and the NEC; these loads would be expected to have a significant amount of rotating plant (whether load or generation) that would contribute to downstream fault infeed. This is clear in Figure 2-4 by the difference between the natural disturbance data (green line) and the artificial disturbance data (orange points). Only the artificial disturbance values take in to account the downstream fault level contribution.

It can also be seen in Figure 2-4 that the artificial FLM values are greater, in general, than the original modelled fault levels. This indicates that as expected and learnt through the detailed modelling and network analysis as part of Method Alpha that not all generation connected to the network is modelled comprehensively. It also suggests that for a substation with significant commercial and industrial connections that the G74 value of 1MVA/MVA fault level infeed is lower than actual.

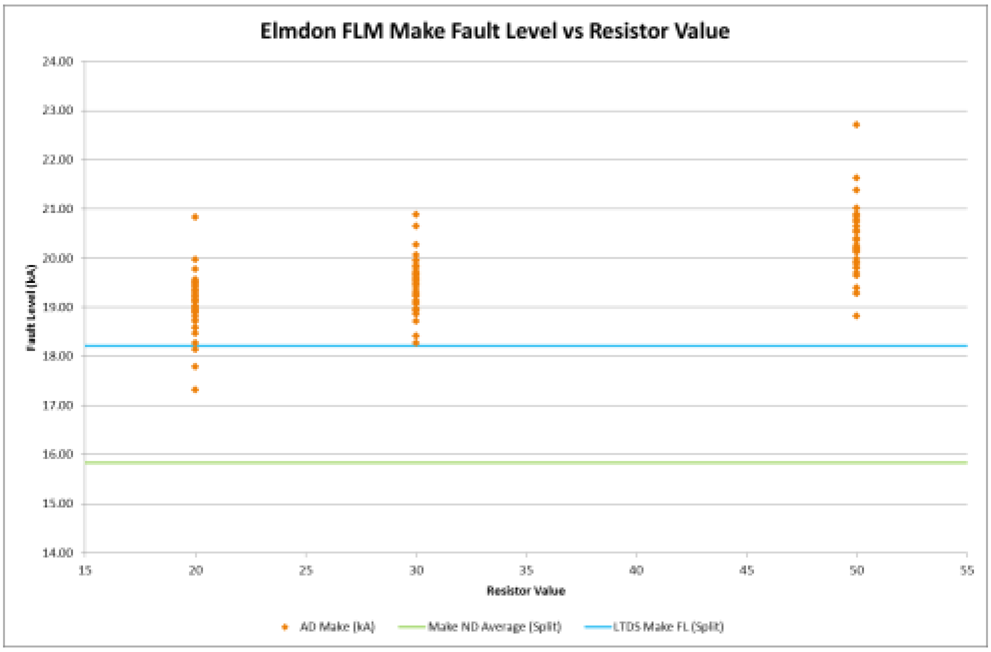


Figure 2-4 - Elmdon Make FL Vs. Resistor Value

Figure 2-5 shows the change in fault level provided by the artificial disturbance for different times of day. It can be seen that whilst the average value of fault level remains relatively flat there is a slight increase at 12:00. This could be explained by the greater level of rotating load connected and operational in the middle of the day.

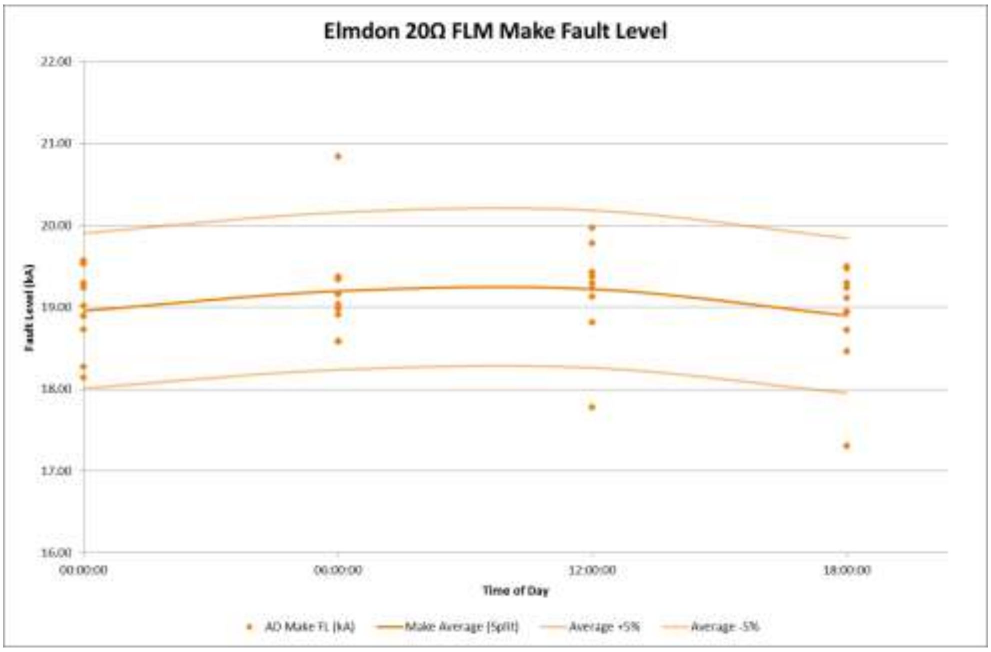


Figure 2-5 – Elmdon Make FL Vs. Time of Day

Castle Bromwich

The graph in Figure 2-6 shows the make fault levels at Castle Bromwich substation. On the 8th April the FLMT was commissioned, which involved the paralleling of two previously distinct networks. The graph below illustrates that the FLM can correctly identify and calculate the fault level when the network is connected in parallel. It is to be noted that the fault level values do not take in to account the limiting effects of the fault current limiter. How this is being managed is explained in Section 2.7.2.

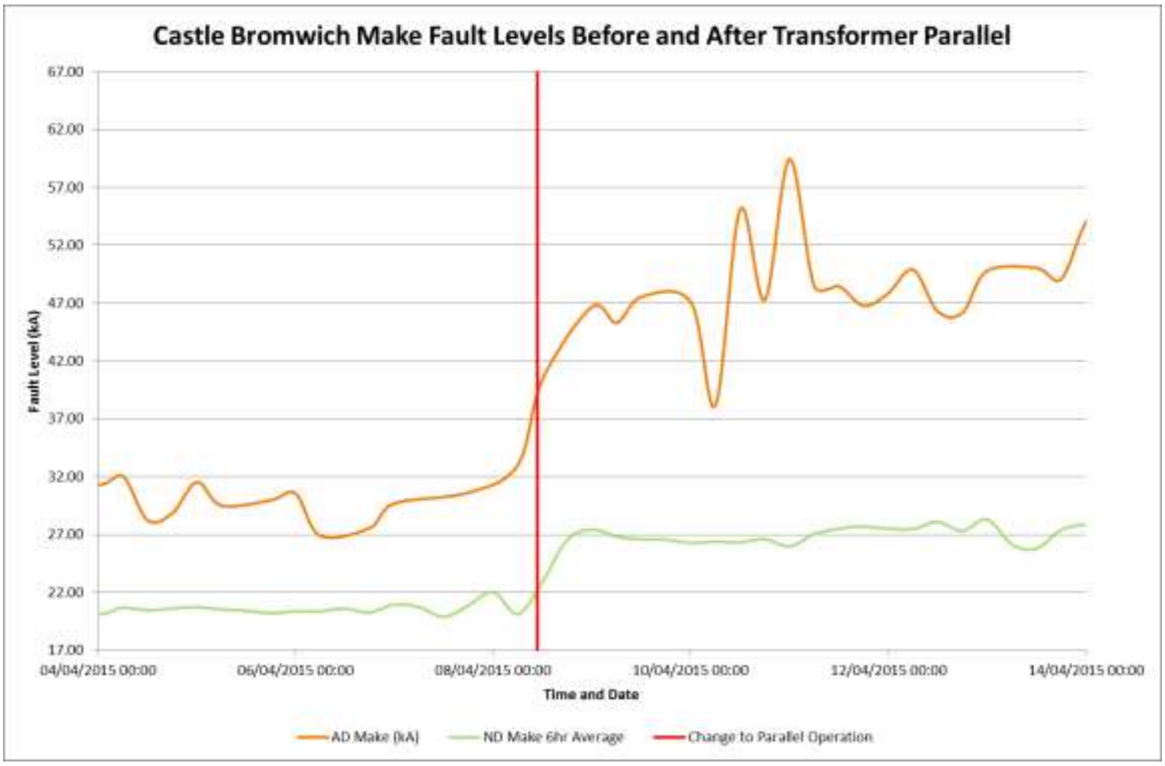


Figure 2-6 – Castle Bromwich Parallel Detection – FLMT Commissioning

2.6 Fault Level Mitigation Technologies – Method Gamma

During the current reporting period a significant Method Gamma milestone has been achieved. The first FLMT was commissioned and energised at Castle Bromwich substation on the 8th April 2015.

The second FLMT is planned for commissioning and energisation in October 2015 at Chester Street substation. This is the first of two Nexans Resistive Superconducting Fault Current Limiters. During this reporting period the device was subjected to current and voltage testing at Nexans Factory, Hannover.

Significant progress for the final two devices, Active Fault Decoupler (AFD) produced by Alstom, has been made. The final design of the device is now complete and initial testing of the performance of the fault current detection and circuit interruption has taken place. Full laboratory and type testing have been scheduled for early September 2015.

2.6.1 GridON Pre-Saturated Core FCL

Delivery

The GridON FCL device was delivered to site on the 9th December 2014. Due to the device being installed indoors significant civil work, post the delivery of the device was required. Therefore further works to commission the device commenced in the New Year. These works involved the installation of the magnetic shield, which is required due to the significant DC field emanating from the device during both load and fault current operation.

The magnetic shield installation involved the installation of several layers of silicon steel to the interior walls of the FCL room, which is designed to ensure that the magnetic field is no greater than 500µT (5G) [this value is the field limit for operational working]. However, on testing of the magnetic shielding, there were significant areas outside of the FCL room that had a field greater than 500µT. This led to a delay in the device being ready for energisation, as the field needs to be limited to less than 500µT within the FCL room for operational safety. It transpired that the shielding had not been built as per the original design; once the shielding was remedied to be as per the design the field was limited as required.

Figure 2-7 and Figure 2-8 show the FCL installed within the FCL room and the magnetic shielding.

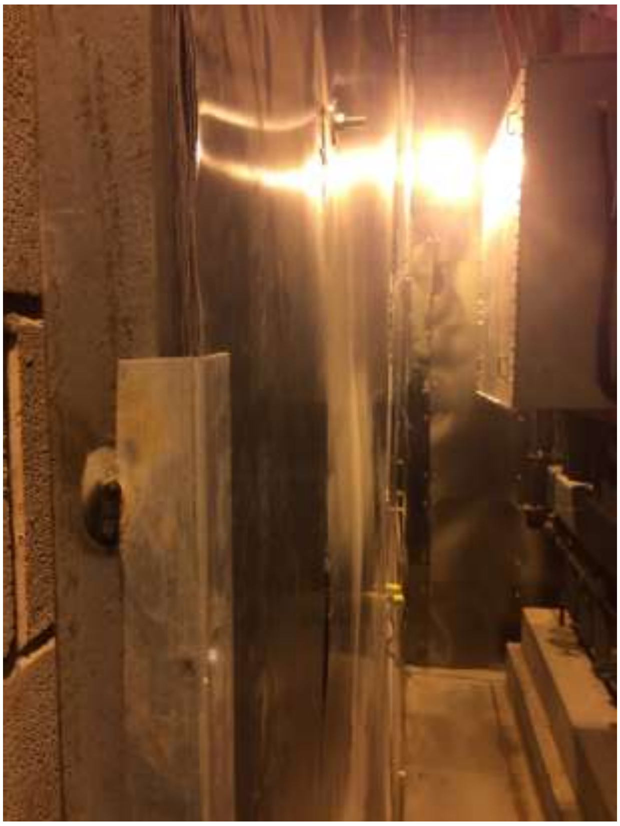


Figure 2-7 - FCL and Shieling side view

Figure 2-8 - FCL Control Cubicles and Shielding

Commissioning and Energisation

Rigorous factory testing took place, which meant the commissioning work on site was minimised. The site work was limited to making final interface connections and proving all elements were operating as expected. In order to transfer device learning key WPD operational staff attended the cold commissioning activities, where GridON staff explained and demonstrated the operation of the device.

Following successful commissioning of the device it was energised on the 8th April 2015.

Figure 2-9 shows the FCL in circuit on the WPD Network Management System (NMS).

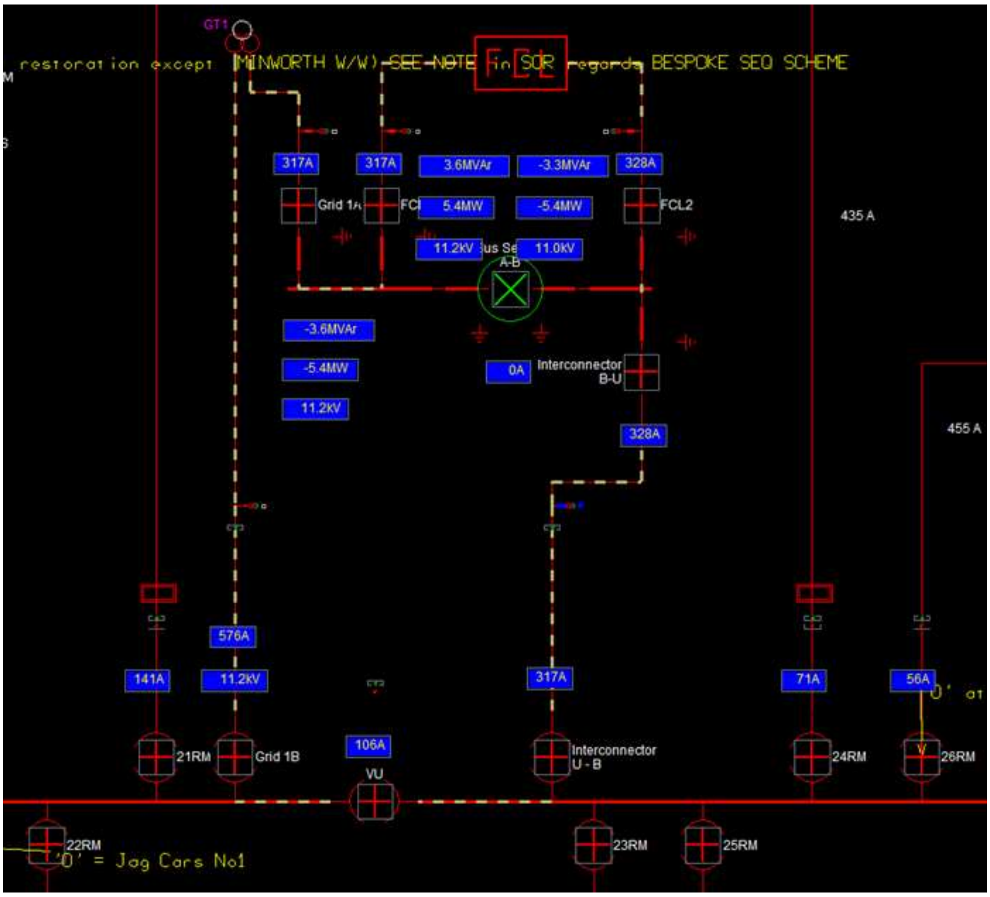


Figure 2-9 - FCL represented on WPD's NMS

Initial Learning

Following energisation, the GridON FCL has successfully been carrying load current without interruption. To date there has been no fault on the network, to which the FCL is connected.

The key areas of learning, relating to design and commissioning are detailed below.

Magnetic field created from FCL

The magnetic shielding did not perform as required until significant remedial work took place. Another key learning point was the visual appearance of the shielding, as seen in Figure 2-7 and Figure 2-8. A solution is currently being designed that will suitably cover and protect the shielding.

Another key learning point regarding the magnetic field is the strength of the field when the device is operating. As this installation was a fully indoor installation, the control procedure for limiting the field on the wider substation area, for the purpose of minimising the restriction of access, for people with pacemakers etc., was controllable through magnetic shielding installation. However, for these devices to be installed in a more outdoor type environment a shielding option would not be suitable. An exclusion zone in the region of up to 10 metres would be required on all sides of the device. This type of device could pose potential difficulties, specifically in dense city centre environments with limited space.

High impedance under normal load

During the tender and procurement process the request had been for the voltage drop under maximum load conditions.

During the detailed device design and testing it was identified that the impedance of the device in steady state operation was greater than WPD had expected. Due to the larger than anticipated impedance under load there is significant unbalance between the now paralleled transformers, to a ratio of 1:1.8. This has meant that the firm capacity of the substation, in this instance, has had to be slightly reduced from 78MVA to 62MVA.

Moving forwards a more accurate and useful piece of information, for this type of device, would be the impedance (resistance and reactance) under maximum steady state current. A key learning point is to include this information in any future tenders.

2.6.2 Nexans Resistive Superconducting FCL

Since the last reporting period significant progress has been made in the design and manufacture of Nexans' resistive superconducting FCLs for both Chester Street and Bournville substations.

During the testing of the Chester Street device an issue was highlighted. This issue relates to the device's ability to ensure that it is kept in superconducting operation at full load current, 1600A. This is where the critical temperate of the superconducting operation, 78.5K, was breached. During the next reporting phase detailed investigation as to the cause of the issue and a solution, which is likely to involve increasing the cooling capability of the device, will take place.

Due to the failure of the device under load testing and the necessary changes required to re-test at full load conditions a significant delay in the installation and commissioning of the device will happen. This will also mean a delay for the Bournville device as it is likely to have the same issue at full load current. Table 2-4 below shows the reforecast projected key milestone dates for the Nexans FCL devices.

Table 2-4 - Key milestones for Resistive Superconducting FCL

Activity	Forecast Date	
	Chester Street	Bournville
Device Build	August 2015	September 2015
Successful Testing	September 2015	October 2015
Delivery to Site	October 2015	November 2015
Energisation	October 2015	November 2015

Chester Street Device

During this reporting period the construction of the Chester Street Nexans device has been completed ready for testing. Figure 2-10 shows one of the three FCL cryostats being lowered in to the FCL concrete enclosure.

Figure 2-10 - Cryostat being installed in the FCL enclosure

Between the 18th and 22nd May a series of tests were completed and witnessed by WPD at Nexans' factory in Hannover. The tests included:

- Insulation Resistance;
- Auxiliary Equipment and Wiring;
- Power Consumption;
- Temp Rise;
- Voltage Withstand; and
- Current Withstand;

As described above the temperature rise test was unsuccessful. However, all other tests relating to voltage withstand and performance was successful. Figure 2-11 and Figure 2-12 show the FCL during testing.

Figure 2-11 -Cryostats during current testing

Figure 2-12 - FCL Display during testing

The construction activities for the inclusion of the FCL and also the FLM at Chester Street have made progress. Following confirmation of all the scheduled dates for build and testing, early in this reporting period, the construction activity work was tendered, with Morrison Utility Services (MUS) successful. Work began on site on the 20th April 2015 and was scheduled for completion on the 10th July 2015. Due to the failure of the device, during testing, this completion date is likely to be extended to October 2015.

Below is a selection of photos from the construction work to date.

Figure 2-13 - Switchgear installed containing equipment for FlexDGrid

Figure 2-14 - FCL and FLM area with new palisade fencing

Figure 2-15 - Concrete casting of FCL pressure relief bund

Bournville Device

Following confirmation of the final build and testing schedule from Nexans the tender for the civil and electrical works to include the device in to the substation is currently being completed. Work was due to commence in July 2015, however, due to the testing failure of the Chester Street device this date is likely to be pushed back to October 2015.

In preparation of the device being delivered to site, a 5-panel 11kV switchboard has already been installed at site. This was ordered early, due to the lead time associated with the equipment to ensure that no delays were caused in installing the device on to the network.

Figure 2-16 - New 5-panel Schneider switchboard

Below is the final GA and 3D model for the Bournville installation.

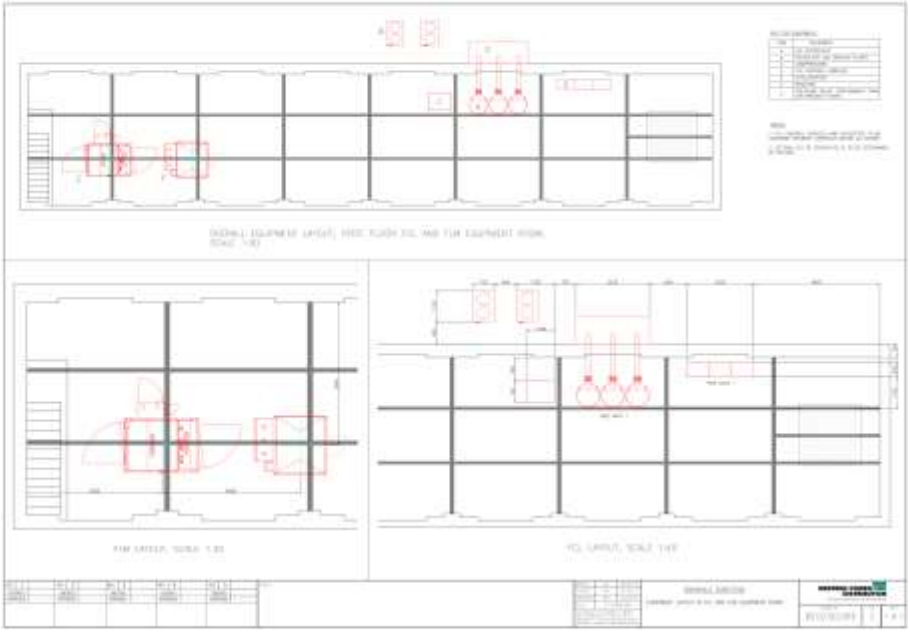


Figure 2-17 - Bournville first floor GA

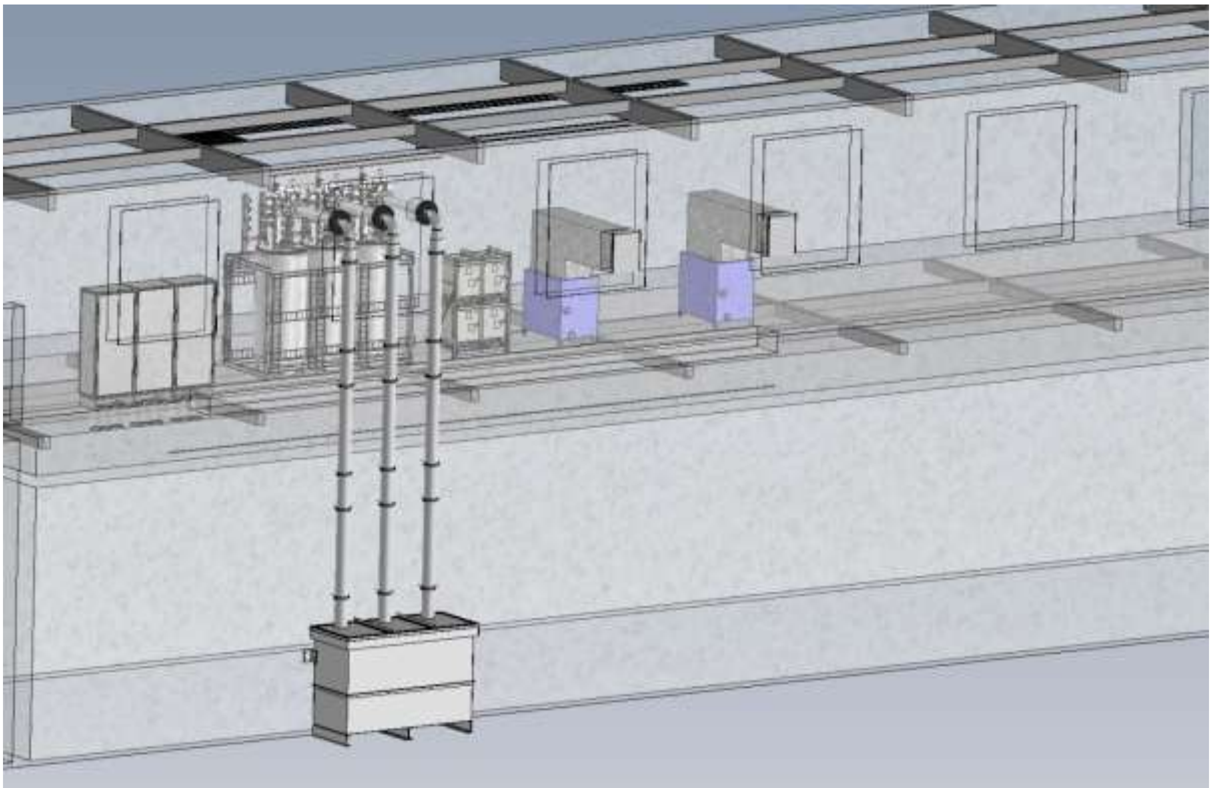


Figure 2-18 - 3D Model of FCL installed at Bournville

2.6.3 Alstom Power Electronic FCL

During this reporting period a design modification of the Alstom Power Electronic Active Fault De-Coupler (AFD) FCL has been made to include an additional circuit breaker and cable end box. By implementing this change it has allowed the site installation requirements to be simplified. It now becomes a standalone device that doesn't require additional switchgear to protect and disconnect the device from the network. This development will increase the number of suitable installation locations as well as reducing future installation costs. Figure 2-19 provides an overview of the latest GA of the AFD.

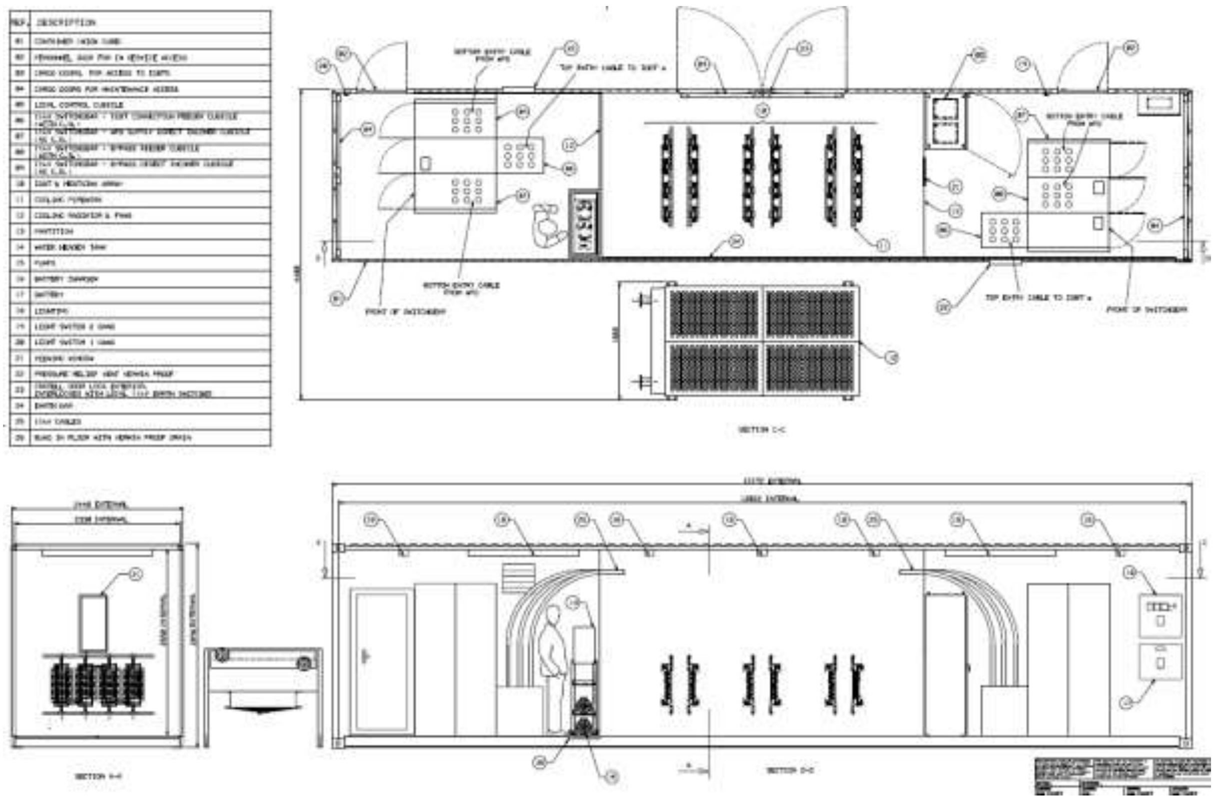


Figure 2-19 - Latest GA for Alstom AFD

The Alstom AFD will use IGBT technology in order to disconnect the fault current in less than 10ms, a technology that is being adapted from its extensive use in the HVDC environment. Figure 2-20 shows the physical construction of the IGBTs, of which there will be 196.

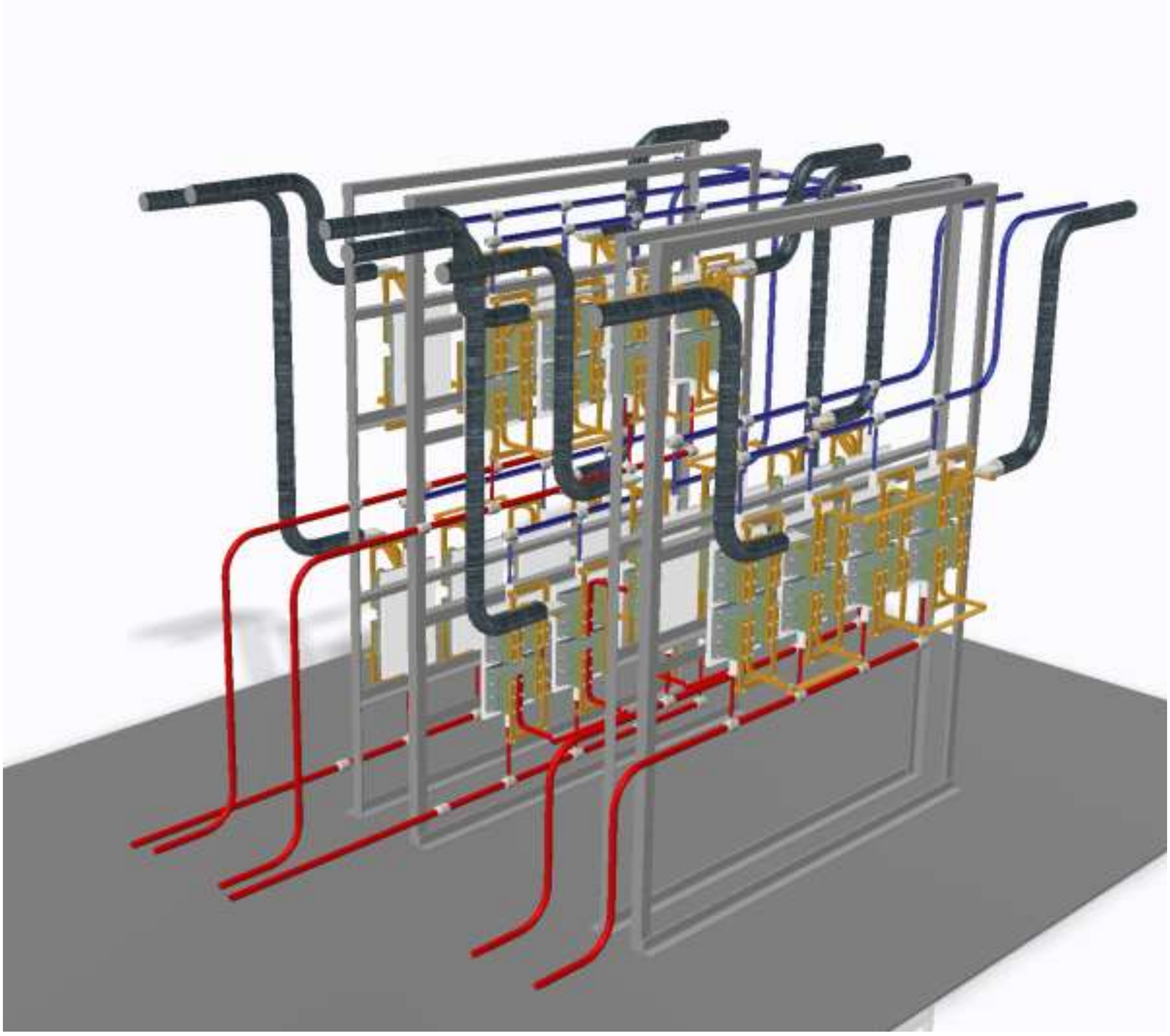


Figure 2-20 - 3D model of IGBT arrays

As discussed in Section 2.4 Sparkbrook substation has been replaced by Bartley Green. Table 2-5 below shows the key milestone dates for the Alstom Devices, which have not changed since the previous reporting period.

Table 2-5- Key milestones for Power Electronic FCL

Activity	Forecast Date	
	Kitts Green	Bartley Green
Device Build	October 2015	January 2016
Successful Testing	November 2015	February 2016
Delivery to Site	November 2015	February 2016
Energisation	January 2015	March 2016

In March 2015 Alstom demonstrated the development of the AFD by running a series of tests, which involved full rated current (1000A as it was a half bridge version of the device) and setting a current trip level mimicking the operation of the device in a fault scenario. This is a significant step in a new technology to demonstrate the required performance is achievable.

2.7 Policy Documents – All Methods

2.7.1 Device

Four engineering policy documents relating to the connection and specification of FLMs and FLMTs went “live” as WPD policies in the previous reporting period:

EE201 – Fault Level Monitor (FLM) Devices for use on the 11kV Network (FlexDGrid);
EE202 – Fault Current Limiter (FCL) Devices for use on the 11kV Network (FlexDGrid);
SD4R – Application and Connection of 11kV Fault Level Monitors (FLM) devices for FlexDGrid; and
SD4S – Application and Connection of 11kV Fault Current Limiters (FCLs) for FlexDGrid.

During this reporting period, a further four policies have been produced. These policies relate to the Operation and Control (O&C) and Inspection and Maintenance (I&M) of the FLMs and GridON FCL:

OC1V – Operation and Control of 11kV FLMs;
SP2CAB – Inspection and Maintenance of 11kV FLMS;
OC1W – Operation and Control of GridON FCL; and
SP2CAA – Inspection and Maintenance of GridON FCL.

All these policies are available to the other DNOs upon request.

During this reporting period significant progress has also been made in the production of the I&M and O&C policies for the Nexans Superconducting FCL. These policies will be in place prior to the energisation of the first device, at Chester Street, in July 2015.

2.7.2 Modelling

As documented previously a draft modelling policy, as part of Method Alpha, has been produced. This draft policy is now being trialled and an update on the progress is provided below.

Fault Level Mitigation Technology Modelling

Following the connection of the GridON FCL at Castle Bromwich the WPD Primary System Design (PSD) team are now utilising the model created to study the device’s effect on the network. This is being utilised for studying new load or generation connections, at Castle Bromwich, as well as for asset reinforcement studies.

11kV Network Modelling

In order to more accurately model the effects of a new generation connection on to the 11kV network a Distribution Fault Level Report has been produced. This is to be trialled to understand the potential benefits to customers from increased granularity of network studies. A tool for studying the effect of a specific generation connection at an existing substation is also to be trialled. Benefits expected are to be a reduction in time to provide a quote, as highlighted as an original aim in the Project’s bid.

2.8 Socio-Economic Update

The socio-economic analysis of the district heating survey of residential consumers in Birmingham has made significant progress in the past 6 months by completing the general descriptive analysis of the survey data and also completing the statistical analysis regarding the current and future sources of information about district heating among Birmingham residents. After the completion of these activities the researchers at the University of Warwick have started the investigation of the main drivers of the decision to connect to a district heating scheme, which has generated some interesting initial results. The progress and main findings in these three parts of the socio-economic research work are discussed below.

The analysis of the descriptive statistics regarding the attitudes of Birmingham's consumers towards energy efficient technologies has revealed that the main drivers of the decision to connect to district heating was the opportunity to make savings, although many respondents did not require substantial savings on their current bills to be persuaded to join the scheme, which leads to the expectation that many would chose to participate to an extended district heating scheme and that they will be able to take advantage of higher than expected savings, alongside the social and environmental benefits for the local community. Furthermore, considerations for environmental and local community benefits were also mentioned as important factors in the decision to connect to district heating. On the other hand the participants to our survey had not been engaged in the energy market by switching supplier, which could originate from limited trust in the market or in traditional energy suppliers.

The analysis of the energy use of vulnerable consumers revealed that households living in social housing and prepayment meters users tend to have higher energy bills than average, which implies that their participation in a district heating scheme would allow them to benefit from financial savings on their energy bills and would therefore contribute to address fuel poverty issues in the city area. Furthermore when considering subjective measures of fuel poverty it appears that more households than those officially identified as fuel poor are unable to afford their desired level of warmth in their home.

The analysis of the sources of information investigated the level of knowledge about district heating among residents in the Birmingham city area who responded to our survey as well as the main sources of information about district heating among different groups of respondents. It also analysed the methods of information delivery which respondents would prefer if they were to receive further information about district heating, with the aim of identifying some of key characteristics which explain different preferences about how to receive the relevant information but also, in some cases, factors related to a complete lack of interest in finding out more. This latter category is particularly important as it identifies the households who will be most difficult to target and engage in the process of developing a city-wide district heating system. The key findings of this analysis can be summarised as follows:

- The majority of respondents to our survey had very limited information about district heating at the time of the survey. Using different heating fuels, rather than exclusively using gas, and being in fuel poverty have been identified as some of the key factors associated with relatively high levels of previous knowledge about district heating.

- Those who had some prior knowledge about district heating obtained it mainly through the internet or word of mouth, so that the quality of information previously received about this technology might not have been very reliable.

- Despite the widespread lack of previous knowledge among our respondents the majority of them expressed an interest in finding out more about this technology, with a general preference for information being provided by post.

- Age and education factors play an important role in the choice of media for the delivery of information about district heating. These key characteristics can be used to inform the deployment of a set of diversified methods for targeting different socio-demographic groups.

- A minority of respondents showed no interest in connecting to district heating or in receiving any information about it in the future, regardless of its format. This minority might need to be targeted more effectively than others, as it includes some of the social categories which are traditionally considered to be vulnerable, such as low income households, or those in fuel poverty, who might benefit more than others from the advantages of district heating schemes.

The next phase of statistical analysis of the survey data will address the factors affecting the consumer's decision to participate in a local district heating scheme. This analysis will be followed by a more detailed investigation of patterns of energy consumption among different socio-economic groups of consumers in order to assess the potential benefits accruing to them as a result of participation in a local scheme, and to evaluate the potential aggregate savings that can be obtained by expanding to district heating beyond public buildings more widely.

The initial statistical investigation of the decision process leading to the participation in a scheme, for given levels of current and expected costs, reveals that when considering whether to replace the current heating system with a system compatible with district heating most consumers expect to be able to repay the initial investment in a period of up to 8 years; for longer repayment periods the probability of participating declines rather rapidly. The expected repayment period however varies for consumers with different levels of income. Male and highly educated consumers are more likely to participate in such a scheme, while in general single people are less interested. Consumers with inefficient housing condition, such as with dampness problems in their accommodation and those with financial concerns about their energy bills are also more likely to connect.

Overall significant progress has been made in finding out the information requirements of potential participants in future schemes and some initial progress has been made in identifying the key financial drivers of the decision to connect to district heating. The work to be developed in the next six months will be important to assess the potential economic benefits of district heating and to produce some policy recommendation about targeting consumers and providing them with the necessary support in order to allow them to make well informed and profitable investment decisions.

3 Business Case Update

There is no change to the business case. The business case was to facilitate the increased connection of DG, specifically combined heat and power (CHP), in urban HV networks. This is still applicable.

4 Progress against Budget

Table 4-1 - Progress against budget

	Total Budget	Expected Spend to Date May 2015	Actual Expenditure to date	Variance £	Variance %
Labour	**1809.49**	**1160.92**	**693.23**	**-467.69**	**-40%**[1]
WPD Project management	320.00	179.33	163.38	-15.95	-9%
Detailed Investigation of Substation for Technology Inclusion	71.26	71.26	29.44	-41.82	-59%
Detailed Investigation of Technologies	71.14	71.14	29.43	-41.71	-59%
Detailed design of substation modifications for Technology Inclusion	72.43	72.43	0.00	-72.43	-100%
Determine Enhanced Assessment Processes	71.88	71.91	0.00	-71.91	-100%
Create Advanced Network Model	72.32	72.48	0.00	-72.48	-100%
Installation of Fault Level Measurement Technology	5.75	3.73	0.00	-3.73	-100%
Installation of Fault Level Monitoring Technology	296.65	190.81	192.71	1.90	1%
Installation of Fault Level Mitigation Technology	445.10	248.79	256.51	7.72	3%
Installation of VCU Technology	148.11	76.83	0.00	-76.83	-100%
Capture, Analyse Data and performance	234.85	102.22	21.77	-80.45	-79%
Equipment	**9779.63**	**6829.51**	**5243.28**	**-1586.22**	**-23%**
Procurement of Fault Level Measurement Technology	117.01	117.01	128.96	11.95	10%[2]
Installation of Fault Level Measurement Technology	9.58	8.26	8.52	0.26	3%
Procurement of Fault Level Monitoring Technology	1554.99	1554.99	983.21	-571.78	-37%[3]

Installation of Fault Level Monitoring Technology	494.52	494.52	451.25	-43.27	-9%
Implementation of Real Time Modelling	3.76	1.98	1.80	-0.18	-9%
Procurement of Fault Level Mitigation Technology	5830.14	3351.56	3158.04	-193.52	-6%
Installation of Fault Level Mitigation Technology	741.84	523.56	510.01	-13.55	-3%
Procurement of VCU technologies	777.86	647.99	0.00	-647.99	-100%[4]
Installation of VCU Technology	246.85	128.04	0.00	-128.04	-100%[4]
Equipment to enable modelling and technology installation	3.08	1.59	1.50	-0.09	-6%
Contractors	**1927.36**	**1316.23**	**1344.10**	**27.88**	**2%**
PB Project Support	340.94	213.09	201.56	-11.53	-5%
Detailed Investigation of Substation for Technology Inclusion	96.14	96.14	103.60	7.46	8%
Detailed Investigation of Technologies	102.89	102.89	107.98	5.09	5%
Detailed Design of Substation Modifications for Technology Inclusion	48.85	48.85	51.04	2.19	4%
Determine Enhanced Assessment Processes	64.85	64.81	65.88	1.07	2%
Create Advanced Network Model	51.38	51.38	52.00	0.62	1%
Implementation of Real Time Modelling	350.94	255.91	262.63	6.72	3%
Capture Monitored & Measured Data	49.61	26.63	27.96	1.33	5%
Analyse Monitored and Measured Data	157.49	79.99	85.68	5.69	7%
Verify and Modify Advanced Network Models	253.89	178.65	175.39	-3.26	-2%
Gather Performance of Mitigation Technologies	50.07	26.87	25.50	-1.37	-5%
Knowledge Capture and Learning Dissemination	281.62	131.37	142.20	10.83	8%
Procurement & Installation Support	78.69	39.64	42.68	3.04	8%
IT	**57.73**	**54.29**	**31.95**	**-22.34**	**-41%**
IT Costs	57.73	54.29	31.95	-22.34	-41%[5]
IPR Costs	**3.29**	**1.50**	**1.44**	**-0.06**	**-4%**
IPR Costs	3.29	1.50	1.44	-0.06	-4%

Travel & Expenses	**465.62**	**293.83**	**303.98**	**10.15**	**3%**
Travel & Expenses	465.62	293.83	303.98	10.15	3%
Contingency	**1407.05**	**1102.29**	**42.19**	**-1060.10**	**-96%**
Contingency	1407.05	1102.29	42.19	-1060.10	-96%
Other	**27.21**	**13.52**	**12.83**	**-0.69**	**-5%**
Other	27.21	13.52	12.83	-0.69	-5%
TOTAL	**15477.38**	**10772.07**	**7673.00**	**-3099.07**	**-29%**

Note 1 - *All Labour costs to date are underspent due to previously documented change in split of activities between WPD internal staff and Parsons Brinckerhoff*

Note 2 – *Additional features were provided with the technology to ensure they were transferrable between substation sites*

Note 3 – *Procurement of FLMs delayed due to re-testing requirements*

Note 4 – *Due to the FLMT designs VCUs are not currently required*

Note 5 – *Existing WPD IT has been used to date – as technologies are installed additional IT will be required*

5 Successful Delivery Reward Criteria (SDRC)

During this fifth reporting period there have been no additional SDRCs completed (none were planned).

The six previously completed SDRCs are available on WPD's Innovation website.

5.1 Future SDRCs

Table 5-1 captures the remaining SDRCs for completion during the project life cycle.

Table 5-1 - SDRCs to be completed

SDRC	Status	Due Date	Comments
SDRC-7 Open-loop test of FLMs	Green	31/12/2015	On track
SDRC-8 Open-loop test of FLMTs	Green	31/12/2016	On track
SDRC-9 Closed-loop test of FLMs & FLMTs	Green	31/12/2016	On track
SDRC-10 Analysis & Benefits	Green	31/12/2016	On track
SDRC-11 Novel commercial aggs	Green	31/03/2017	On track

Status Key:	
Red	Major issues – unlikely to be completed by due date
Amber	Minor issues – expected to be completed by due date
Green	On track – expected to be completed by due date

6 Learning Outcomes

Learning outcomes have been detailed in all six SDRCs submitted and approved to date (SDRC1-6).

The production and internal WPD publication of the policies as described in Section 2.7 has generated a significant amount of learning. This learning, which is available to other DNOs, upon request, centres on the specification requirements of both FLM and FLMTs and the process for connecting and applying these technologies on to a DNOs' 11kV network.

The learning generated and reported in the previous period relating to FLMT modelling is now being used by relevant network design teams. Following the energisation of the FCL at Castle Bromwich, the dynamic FLMT model is now being used to assess the revised network condition.

In this reporting period learning has been shared both formally and informally at several other DNO led events; ENW's Transformer life extention oil regeneration project at their Blackburn training school (05.12.14), SSE's GnoSys project at the IET in Birmingham (29.01.15) and ENW's CLASS dissemination event, London (10.04.15).

7 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.

No relevant foreground IP has been identified and recorded in this reporting period.

8 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
- ✓ Monitoring and updating of risks and the risk controls.

8.1 Current Risks

The FlexDGrid risk register is a live document and is updated regularly. There are currently 61 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 8-1, 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.

Table 8-1 - Top five current risks (by rating)

Risk	Risk Rating	Mitigation Action Plan	Progress
Suppliers can't meet agreed functional specifications	Severe	Early engagement and rigorous tendering process	FLMs have now been successfully tested. Nexans FCL has failed testing and needs to be updated.
UoW - understanding of the agreed workpackage tasks is incomplete or inaccurate	Severe	UoW have put a process in place to ensure their understanding of WPD expectations for each deliverable up front and an ongoing process throughout each deliverable to continuously check they are meeting with the agreed deliverables	Discussions between WPD and the UoW are on-going to establish UoW's role in FlexDGrid going forwards.
Changes to Key Personnel	Severe	Rigorous and robust documentation of work.	All work continues to be fully documented to ensure learning is captured.
Using external construction resource results in a higher build price	Major	Cost of using external resources has been factored into costing at outset	Costs are being closely monitored and regularly reviewed.
Third parties interfere with site works	Major	Ensure that expensive items are not stored on site. Consider installing CCTV or employing other security measures during construction work.	All programmes for site works include security as required to mitigate this risk.

Table 8-2 provides a snapshot of the risk register, detailed graphically, to provide an on-going understanding of the projects' risks.

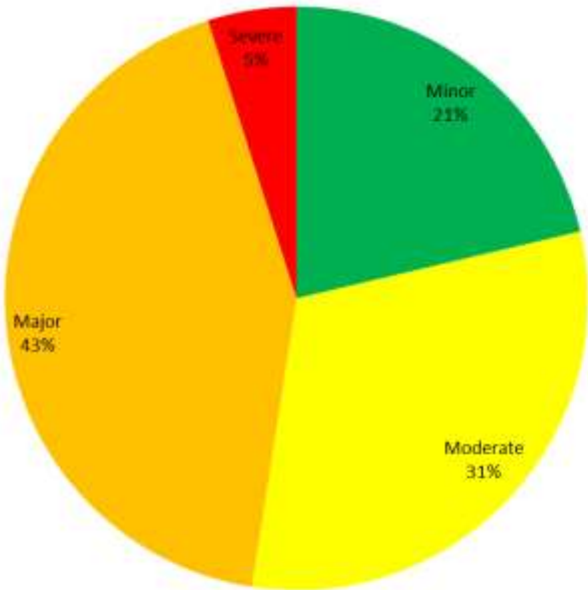
Table 8-2 - Graphical view of Risk Register

Likelihood = Probability x Proximity						
	Certain/Imminent (21-25)	0	2	1	1	0
	More likely to occur than not/Likely to be near future (16-20)	0	0	5	1	0
	50/50 chance of occuring/ Mid to short term (11-15)	0	0	0	7	0
	Less likely to occur/Mid to long term (6-10)	0	1	6	11	1
	Very unlikely to occur/Far in the future (1-5)	1	1	10	12	1
		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	13	19	26	3	**No of instances**
Total	61				No of live risks

Table 8-3 provides an overview of the risks by category, minor, moderate, major and severe. This information is used to understand the complete risk level of FlexDGrid.

Table 8-3 - Percentage of Risk by category



8.2 Update for risks previously identified

Descriptions of the most significant risks, identified in the previous six monthly progress report are provided in Table 8-4 with updates on their current risk status.

Table 8-4 - Top five risks identified in previous six monthly report

Risk	Previous Risk Rating	Current Risk Rating	Comments
Suppliers can't meet agreed functional specifications	Severe	Severe	Nexans FCL failed load testing and now is to be re-designed and re-tested.
Using external construction resource results in a higher build price	Severe	Major	The construction activities associated with installing the new technologies are better understood and costs going forwards are reduced.
Third parties interfere with site works	Severe	Major	To date no third party interference has taken place, therefore risk has been reduced to major as the security requirements are better understood.
PB may be sold by BB	Severe	Minor	PB has now been sold to WSP and the integration has been completed with no transfer of staff.
University of Warwick - understanding of the agreed work package tasks is incomplete or inaccurate	Severe	Severe	The situation is being actively monitored and an appropriate solution is being explored.

Descriptions of the most prominent risks, identified at the project bid phase, are provided in Table 8-5 with updates on their current risk status.

Table 8-5 - Top five risks identified at the project bid phase

Risk	Previous Risk Rating	Current Risk Rating	Comments
Insufficient WPD resource for project delivery	Minor	Minor	Specific WPD staff have been assigned to manage and deliver the construction aspects of the project
Partners and supporter perception of the project changes	Minor	Major	Detailed schedule of works have been produced for the Engineering element of the UoW contract, however, the perception of what is to be achieved is yet to be fully understood.
Cost of high costs items are significantly higher than expected	Closed	Closed	Closed as per previous 6 monthly reports
No suitable FLMTs will be available	Closed	Closed	Closed as per previous 6 monthly report
No suitable FLMs will be available	Closed	Closed	Closed as per previous 6 monthly report
The overall project scope and costs could creep	Minor	Minor	The scope of the project has been well defined in the initial delivery phase of FlexDGrid, which has been represented and documented in the SoWs with each party. This has significantly controlled this risk and therefore the cost of delivery. All potential scope creep is managed at project management level, where a decision is made as to the viability of inclusion and/or recommendation for future work
A partner may withdraw from the project or have oversold their solution	Moderate	Moderate	Whilst six SDRCs have been delivered on time and to the specification set out in the Project Direction the UoW Engineering department have, to date, not delivered fully their requirements
The project delivery team does not have the knowledge required to deliver the project	Minor	Minor	Project partners have provided personnel with significant experience in all project areas. A review of individual's CVs takes place prior to their engagement with the project. Construction also have significant experience in the activities to be undertaken as part of the project

9 Consistency with Full Submission

During this reporting period the same core team from both WPD and PB have been used, which has ensured that there has been consistency and robust capturing of learning from the previous reporting period. This has ensured that the information provided at the full submission stage is still consistent with the work being undertaken in the project phase.

The scale of the project has remained consistent for all three methods:

- **Alpha** – Build advanced network model of FlexDGrid network;
- **Beta** – Install ten Fault Level Monitors at Birmingham Primary Substations; and
- **Gamma** – Install five Fault Level Mitigation Technologies at Birmingham Primary Substations.

Each of the six completed SDRCs to date has been completed on, or before, schedule, ensuring that the proposed delivery plan at the full submission stage is still applicable in project delivery.

10 Accuracy Assurance Statement

This report has been prepared by the FlexDGrid Project Manager (Jonathan Berry), reviewed by the Future Networks Team Manager (Roger Hey), recommended by the Policy Manager (Paul Jewell) and approved by the Operations Director (Philip Swift).

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.

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