WESTERN POWER DISTRIBUTION

FLEXDGRID

HEAT AND POWER FOR BIRMINGHAM

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
RIIO-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, June 2015 to November 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 the final four fault level monitors (FLM), taking the total commissioned FLMs to 10, which completes the number of FLM installations. Also in this period the installation, commissioning and energisation of the second fault level mitigation technology (FLMT) at Chester Street substation took place, on the 25th November 2015.

Following the completion of the 10 FLM installations the data provided, both artificial and natural disturbance data is now being gathered with the purpose of understanding the variation on fault levels throughout days, weeks, months and seasons. This data is now being used to understand the contribution of general load to the fault level of the 11kV system to enable increased accuracy of models, as part of Method Alpha to be created.

During this reporting period (June 2015 – November 2015) FlexDGrid has made significant progress in working towards the delivery of other project SDRCs, specifically the submission of SDRC 7 on the 25th November 2015 to Ofgem.

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 progress of the installation of the next FLMTs, in terms of successful Nexans testing and issues needing resolution of the Alstom devices. Also, a gateway review meeting was held following the completion of the construction phase of the FLMs and move in to the analysis phase.

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 **(Complete)**
GridON	Fault Current Limiter – Pre-saturated Core	Castle Bromwich	April 2015 **(Complete)**
Nexans	Fault Current Limiter - Resistive Superconducting	Chester Street Bournville	October 2015 **(Complete)** December 2015
Alstom	Fault Current Limiter - Power Electronic	Kitts Green Bartley Green	March 2016 April 2016

1.5 Installation

Four FLMs have been installed and commissioned during this reporting period taking the total live FLMs to 10. This has completed the FLM commissioning.

The first FLMT is now commissioned and energised, 8th April 2015. The second FLMT is now on site, after delivery in October 2015, and was energised on the 25th November 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 continued to capturing learning in the form of WPD policy documents.

Building on the policies produced previously, the Inspection and Maintenance and Operation and Control policies for the Resistive Superconducting FCL have now been review and approved and on-site training has also been provided to key 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 sixth project report. The period covered in this report is focussed on construction, data analysis and model updating activities. Within this reporting period the construction activities have continued. The energisation of the second FLMT has been achieved. The third FLMT has been build and is planned for both factory and laboratory type test testing in December. Following the successful energisation of all 10 FLMs a significant amount of data has been analysed to understand the variable nature of fault levels and to enable updates to modelling practices to be applied.

2.3 Project Reporting Progress

Table 2-1: Project Reporting Dates

Due Date	Type	Description	Status
31/12/2015	KPI	FL Monitors installed	Complete
31/12/2015	SDRC	Submit SDRC-7 Report to Ofgem	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 previously Perry Barr substation has been replaced with Nechells West and Sparkbrook with Bartley Green. No further substation alterations are expected.

2.5 Fault Level Monitors - Method Beta

In this reporting period the final four FLMs have been installed, commissioned and energised. Following this Method Beta has concentrated on gathering the data for both natural and artificial disturbances at each substation. This data has then been used to calculate the MVA/MVA fault level infeed at each substation.

2.5.1 Installation

All 10 FLMs are now energised and providing fault level data as required. Below is a selection of photographs of the different elements of the FLMs at various sites.

Figure 2-1 - External view of FLM Control Cubicle

Figure 2-2 - Internal view of FLM Control Cubicle

Figure 2-3 – Rear view of 11kV FLM

Figure 2-4 - Front view of 11kV FLM

Table 2-2 below lists the sites and the FLM energisation dates.

Table 2-2 - 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
Nechells West	Energised	29/07/2015
Chester Street	Energised	13/08/2015
Bartley Green	Energised	03/09/2015
Bournville	Energised	27/10/2015

2.5.2 FLM Data Analysis

A key element of the FLM installations as part of Method Beta is to provide updated information in relation to network fault levels and enable feedback to Method Alpha to further increase the accuracy of 11kV fault level modelling.

Make (peak @ 10ms) and Break (RMS @ 90ms) fault levels are now being obtained every six hours, 00:00, 06:00, 12:00 and 18:00 for each FLM. Also, all natural disturbance data, where a network event, not driven by the FLM, has caused a variation on both the current and voltage significant enough to enable fault level values to be calculated. This data is then being used to generate updated MVA/MVA fault level infeed values, which are currently set to 1MVA/MVA, as per G74 requirements in the absence of monitored or measured values.

Below is an overview of analysis produced from fault level gathered from Elmdon Substation in July 2015.

Artificial Disturbance Data

Figure 2-5 and Figure 2-6 show the 7 day week averages for the Peak (Make) and RMS (Break) fault levels respectively for the four weeks of July 2015 as well as an average. It can be seen that both the Peak and RMS values follow a trend, where the maximum value is observed at 12:00. When the type of load at Elmdon Substation was analysed, it was found to be dominated by industrial and commercial loads, where the maximum energy utilisation is expected to be in the daytime.

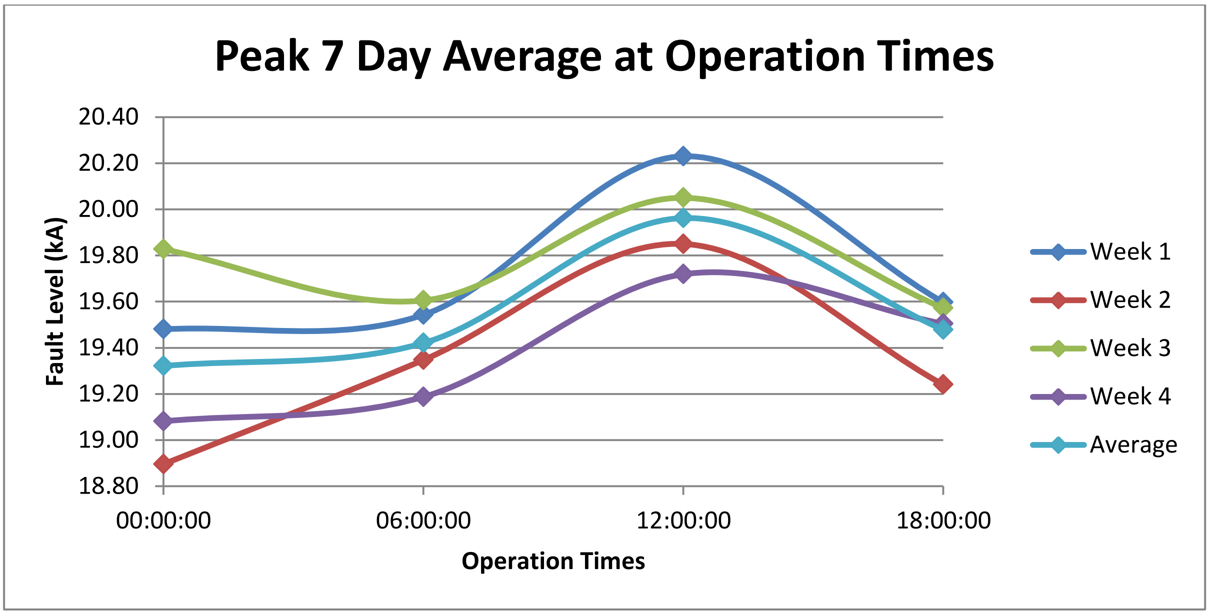


Figure 2-5: Peak 7 Day Average for the Month

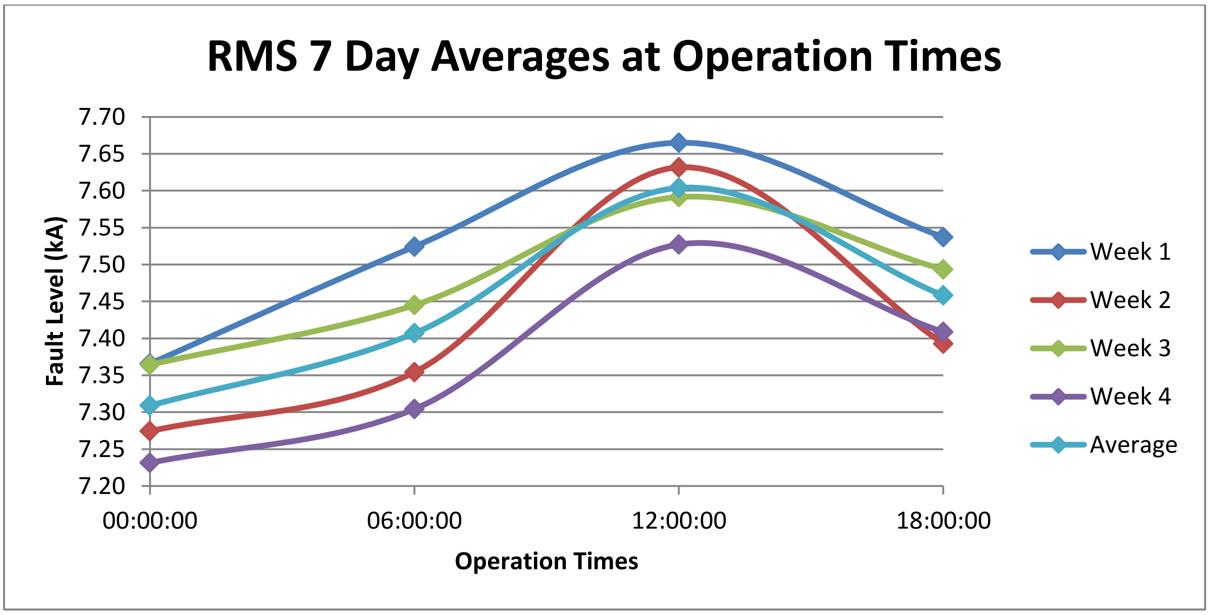


Figure 2-6: RMS 7 Day Averages for the Month

Figure 2-7 and Figure 2-8 further break down the information detailed in Figure 2-5 and Figure 2-6. The data is now split by traditional working day (Monday – Friday) and weekend (Saturday – Sunday). It can be seen that for both Peak and RMS the weekday value (blue line) is greater than the weekend value. As previously discussed the demand on the substation is dominated by industrial and commercial load and is therefore expected to be greater on business days.

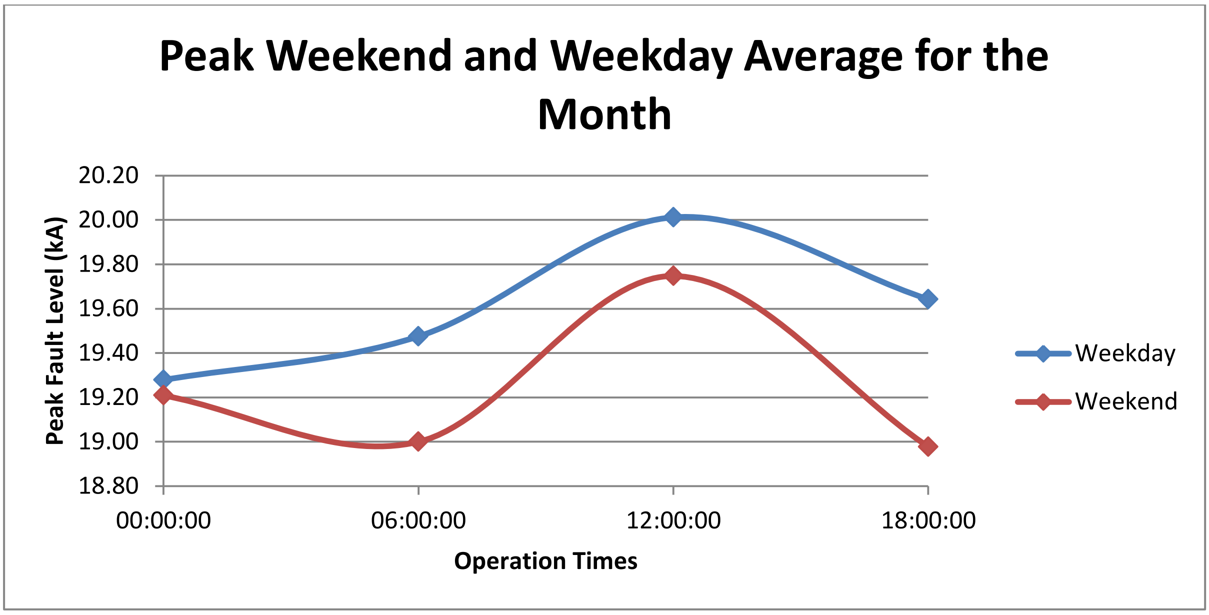


Figure 2-7: Peak Weekend and Weekday Averages

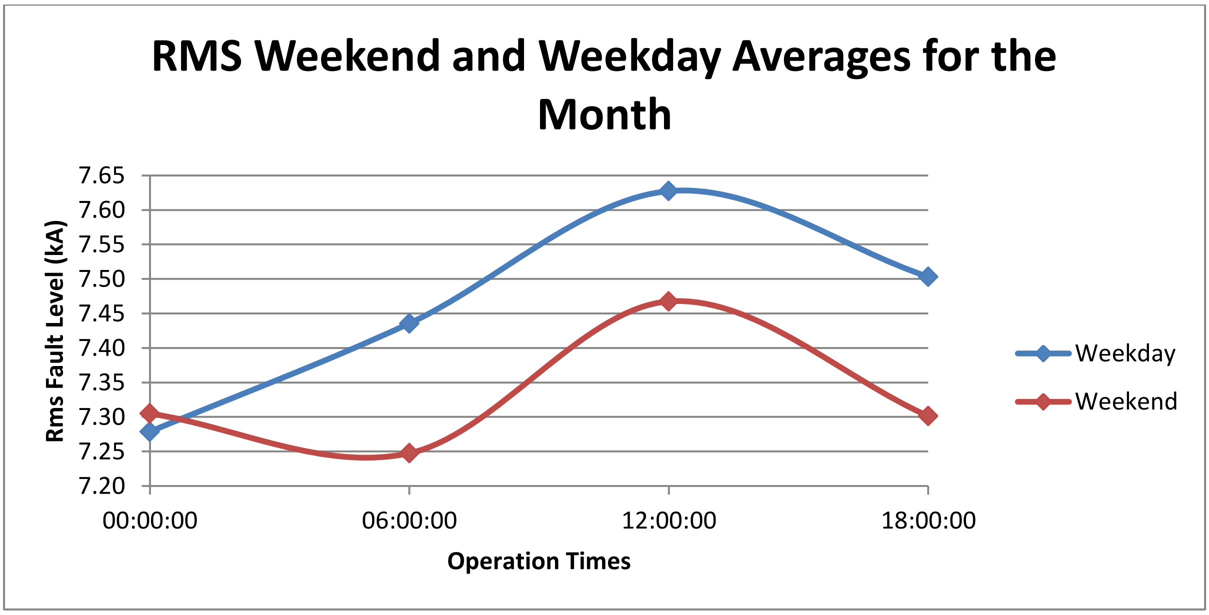


Figure 2-8 RMS Weekend and Weekday Averages

Natural Disturbance Data

Natural disturbance data, for the connection configuration as part of FlexDGrid, considers only the upstream contribution to fault level, i.e. the contribution from National Grid, through WPD's EHV network to the 11kV busbars. Therefore, the values are lower than in the artificial disturbance data, which considers both upstream and downstream fault level contributions.

Considering Figure 2-9 and Figure 2-10 it can be seen that bar a few exceptions, week on week the upstream fault level follows a specific trend.

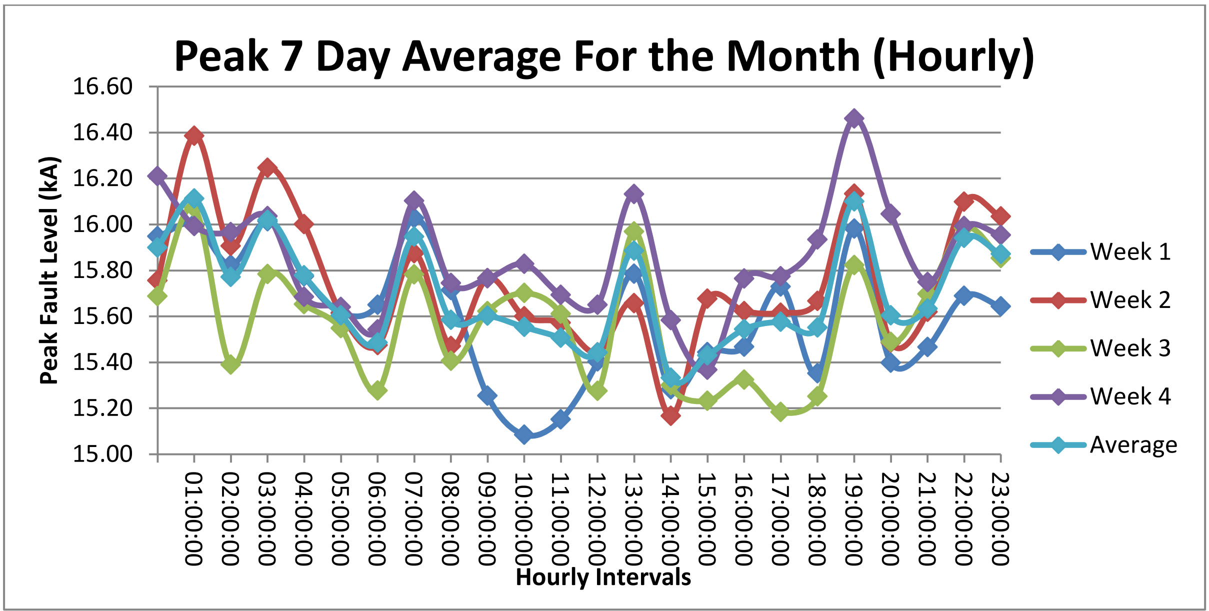


Figure 2-9: Peak 7 Day Averages for the Month for Hourly Intervals

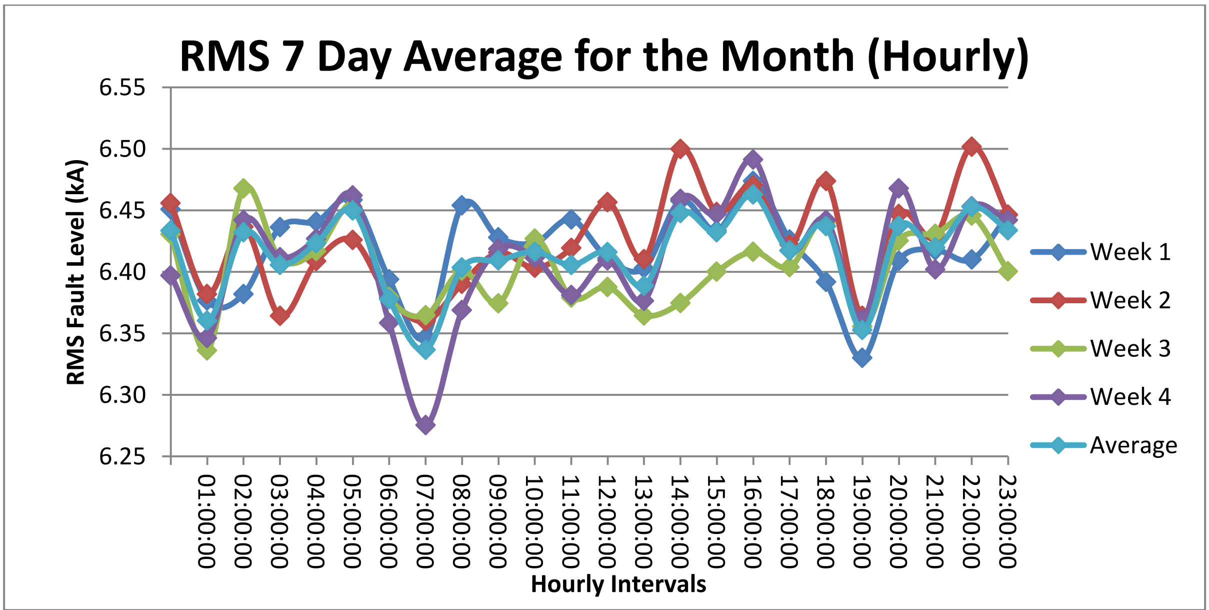


Figure 2-10: RMS 7 Days Average for the Month at Hourly Intervals

Fault Level Infeeds

The artificial fault level data has been used to understand the MVA/MVA fault level based on the models created as part of Method Alpha. A script was created to automatically derive the MVA/MVA infeed value, which provides a fault level contribution in MVA compared to 1MVA of connected load. Figure 2-11 details the fault level infeeds based on the analysis provided above. It can be seen that for the month of July at Elmdon Substation the fault infeed should be anywhere between 2.7 and 3.3MVA/MVA.

MVA/MVA per	00:00	06:00	12:00	18:00	Average
1 month	2.6	2.6	2.9	2.8	2.7
weekdays of 1 month	2.6	2.8	2.9	3.0	2.8
weekends of 1 month	2.6	2.7	3.5	2.2	2.8
week 1	2.9	2.9	3.2	2.9	3.0
week 2	2.0	3.1	2.8	2.5	2.6
week 3	3.6	3.0	3.1	3.0	3.2
week 4	2.3	2.9	2.7	3.0	2.7
weekdays of week 1	3.1	3.8	2.8	2.4	3.0
weekdays of week 2	2.2	2.9	2.9	2.8	2.7
weekdays of week 3	3.4	3.3	3.2	3.4	3.3
weekdays of week 4	2.3	3.2	2.6	3.3	2.9
Average	2.7	3.0	3.0	2.8	

Figure 2-11 - Elmdon July 2015 - MVA/MVA Infeed

As all networks considered as part of FlexDGrid have no fault level issues in their normal operating condition, non-parallel, this learning will increase the system fault level but not to a level of concern.

2.5.3 Next Steps

Throughout the next reporting period all 10 FLMs data will be analysed and extensively investigated. Key considerations will be the relationship between fault level and load on the system, which more broadly will be used to understand the implication on fault level based time of day, day, week, month and season.

As well as analysing individual sites a cohesive approach will be taken to understand the relationship of fault level between substations. The aim is to produce a methodology for the updating of substations MVA/MVA fault level based infeed based on load mix, split by domestic, industrial and commercial loads, to produce an 11kV MVA/MVA fault level infeed template.

2.6 Fault Level Mitigation Technologies – Method Gamma

During this reporting period the second FLMT has been successfully tested and then delivered, commissioned and energised at Chester Street substation. This is the first of two Nexans Resistive Superconducting Fault Current Limiters. The second device planned for installation at Bournville substation is to undergo factory and type testing in December.

Originally the plan for the final two devices, produced by Alstom, was to test the first at the factory and external laboratory in December. However, following the completion of the build of the first device it was identified that a significant amount of re-design was required before it could successfully pass all required tests prior to installation on site.

2.6.1 GridON Pre-Saturated Core FCL

Overview

Following on from the successful energisation of the GridON FCL device on 8th April 2015, further works have taken place to complete the installation including a new cover for the magnetic shield which is detailed below.

After successfully operating for five months the FCL has seen no 11kV network faults and hence the fault limiting performance of the FCL could not be analysed. However, an issue with the DC sensing circuit was identified in September 2015 which required the FCL to be disconnected from the network until it could be resolved. Further details of the issue are detailed below.

Magnetic Shield

In the previous reporting period, it was noted that the visual appearance of the magnetic shield was not acceptable and could be prone to being damaged. Several options were considered to provide a protective cover over the shield. After evaluating the options it was decided that the shield should be covered using wooden particleboard as it would be the most cost effective and safest method for installation within the congested FCL bay. Figure 2-12 and Figure 2-13 below show the installation of the particleboard cover for the shield.

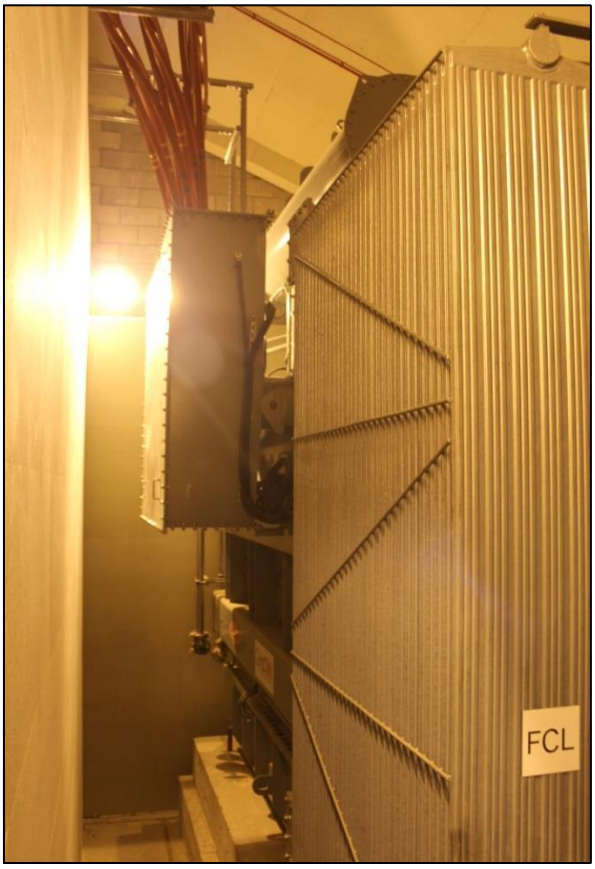


Figure 2-12: FCL with covered magnetic shield

Figure 2-13: Covered magnetic shield around control cabinets

The cover has significantly improved the appearance of the FCL room and will ensure that the shield is adequately protected.

DC Power Supply Sensor

The GridON FCL uses DC Bias current to limit the impedance of the device during normal operation. Figure 2-14 below shows how the DC current is controlled in steps as the AC current varies during operation. It can be seen that the DC current only switched between the two lowest levels of bias (130A and 220A) during operation between 8th April and 22nd June.

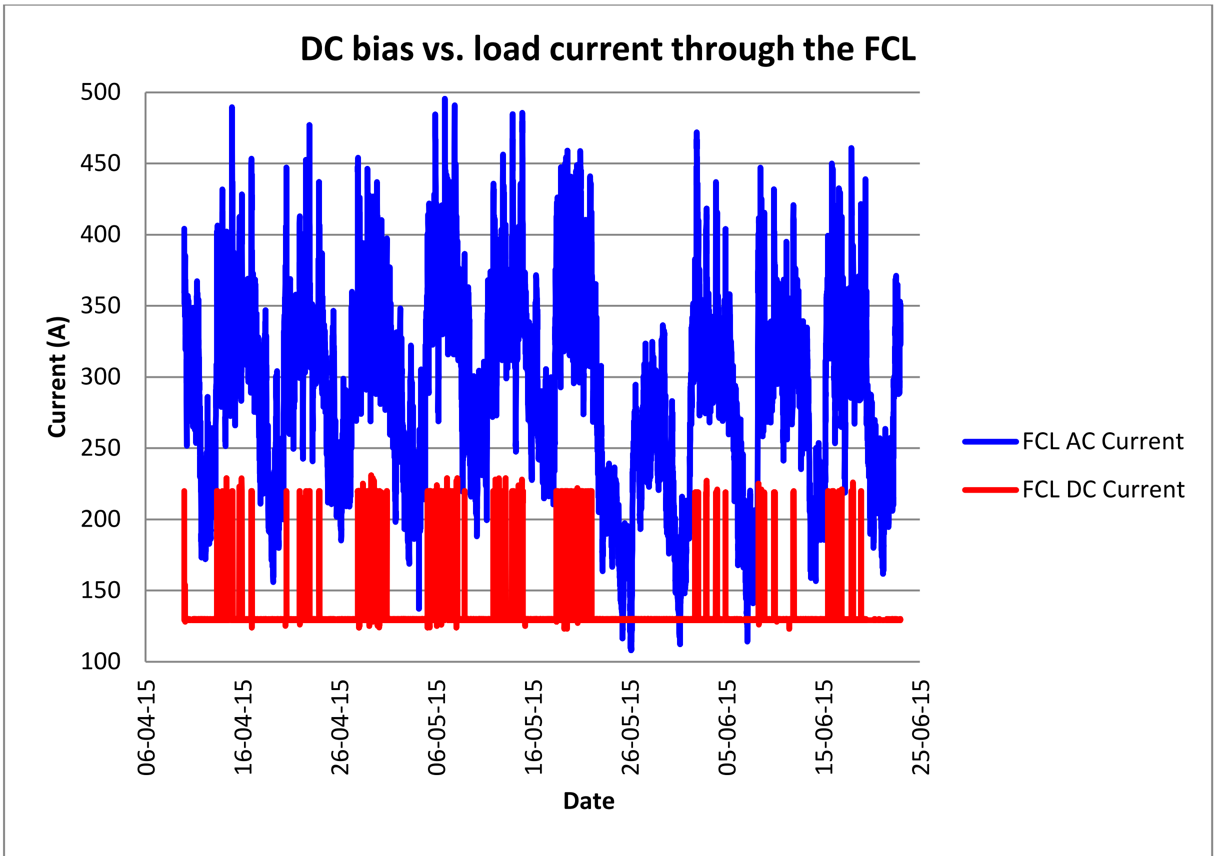


Figure 2-14: Graph of AC and DC current in FCL

If the DC current drops to zero this would require the FCL to be tripped as the impedance would rise causing a significant voltage drop across it. Due to this, the DC current is monitored using a "DC sensor" mounted in the AC Marshalling Kiosk in addition to individual monitors on each power supply unit.

On 13th September 2015 at 23:51hrs the FCL Protection Panel received a trip signal from the FCL causing the two FCL 11kV circuit breakers to open and isolate the device. No customers were lost during the event as the network was configured in parallel. Figure 2-15 and Figure 2-16 below show the operation of the alarm flag and trip relay associated with the DC supply failure respectively.

Figure 2-15: Alarm Flag Operation

Figure 2-16: Trip Relay Operation

GridON instructed their UK representative (Wilson Transformers) to visit site to obtain alarm and information logs from the device so further investigations could be conducted. During the investigation a minor fault was identified in the UPS system which supplies the FCL. The manufacturer of the UPS, Eaton Holec, attended site to resolve the issue by replacing the software in the controller.

The initial solution for the DC sensor issue was to replace the DC sensor, check the connections and confirm the logic. However, despite performing various tests and checks, the FCL tripped shortly after re-energisation when the DC sensing circuit reported 0A.

Presently GridON are undertaking a thorough investigation of the entire DC sensing circuit to establish the root cause of the failure.

2.6.2 Nexans Resistive Superconducting FCL

Chester Street

The Chester Street FCL failed its Factory Acceptance Testing during the last reporting period. When operating at its rated current of 1600A the cooling system was unable to regulate the temperature of the cryogenic material to the required set-point. The temperature was seen to rise slowly and would have eventually led to a quench event. The device was therefore unable to run continuously at its rated current of 1600A.

The manufacturer, Nexans, carried out a series of investigations to understand the behaviour of the FCL. Nexans discovered that the device had higher current dependent losses than expected. Further investigation led to the conclusion that the additional losses were attributed to eddy currents present in the various electrical contacts in the device. During the investigation it was also found that air was able to leak into the cryostat vessels via a pressure relief safety valve when the pressure inside the vessel was reduced to below atmospheric pressure (1000mbar). The water vapour present in the air condensed and froze on the cold head causing reduced heat transfer from the cryogenic material.

The air leakage issue was remedied by replacing the three pressure relief safety valves with a single electronic valve rated for sub-atmospheric pressures. The valve assembly on top of the vessel was redesigned with flexible pipework to accommodate the new valve and ensure a tight seal to the valve.

A solution to resolve the eddy current losses could not be found without a fundamental redesign of the internal components of the FCL which would have incurred significant delays to the programme. After consultation with the Network Asset Manager a decision was made to accept the de-rated device. The Chester Street device is now rated for 1300A continuous operation with an overload capability of 1600A for a maximum of five hours.
The Chester Street device went through a second Factory Acceptance Test on 21-23rd September 2015. The device successfully passed all functional and HV tests. The tests performed were as follows:

- Insulation resistance measurement (before and after each test sequence);
- Temperature rise test;
- Acoustic sound level test;
- Withstand voltage test;
- Lightning impulse voltage test; and
- Partial discharge measurement test.

Figure 2-17 shows the Chester Street FCL undergoing current testing during the second Factory Acceptance Test.

Figure 2-17 - Chester Street FCL undergoing current testing during FAT

Following the successful completion of the Factory Acceptance Testing the FCL went through a ‘warm-up’ process and was then transported to the KEMA test laboratory in Arnhem, Netherlands for the short circuit testing. The FCL was tested on 5th October 2015 in test bay 5 in the high current laboratory. The test set-up was adjusted from the original test specification to more closely follow the actual site layout. This was required to ensure the correct operation of the quench detection system. Refer to Figure 2-18 for a connection diagram of the test set-up.

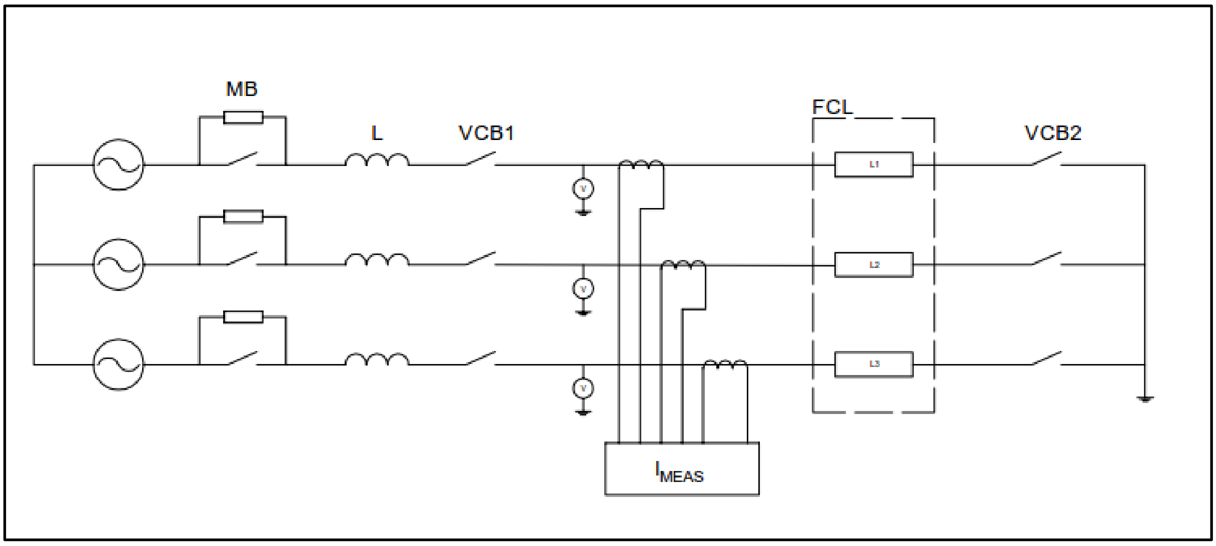


Figure 2-18 – Connection diagram showing the KEMA short circuit test set-up for Chester Street FCL.

Voltage was applied to the FCL by closing the Main Breaker (MB) and VCB1 before application of the short circuit. The short circuit was applied by closing VCB2. The short circuit duration was set to 100ms to avoid damage to the superconducting tape inside the cryostats. This is the maximum time that a fault current is allowed to flow through the FCL. The KEMA test engineers carried out several shots of short circuit current without the FCL in the circuit. Measurements were taken and circuit parameters adjusted to ensure that the prospective peak current and RMS break current was as close as possible to the contractually specified values (19.76kA, 7.03kA respectively).

The FCL was then placed in the circuit and the short circuit limitation test was performed. The FCL successfully passed the test, limiting the peak prospective current to 9.1kA and the RMS break current to <3kA, well below the contractual values of 9.90kA and 3.68kA respectively.

The next test to be performed was the short circuit current withstand test. The KEMA test engineers removed the FCL from the test circuit and carried out further test shots. Measurements were taken and circuit parameters adjusted to ensure that the prospective peak current as close as possible to the contractually specified value of 33.4kA.

The FCL was then placed in the test circuit and the short circuit withstand current applied. The FCL successfully passed the test, limiting the peak prospective current to 9.55kA.

The FCL quench detection system was tested in parallel to the short circuit limitation tests and short circuit withstand test. The quench detector system was required to send a signal to the KEMA test equipment a maximum of 20ms after the applied short circuit. Initial tests revealed that the signal was being received after 25ms and suffered from contact bounce. This was rectified by mimicking site conditions by increasing the supply to the auxiliary contact from 5V to 110V and removing an unnecessary repeat relay in the quench detector panel. After these changes the signal was present 15ms after the short circuit inception and the test was successfully passed.

Refer to Figure 2-19 and Figure 2-20 for photographs of the Chester Street FCL in the KEMA high current laboratory.

Figure 2-19 - Chester Street FCL in the KEMA high current laboratory

Figure 2-20 - Connections to Chester Street FCL in the KEMA high current laboratory

After the tests at KEMA the FCL was transported to the United Kingdom. The device was successfully delivered and offloaded onto its concrete plinth on Sunday 11th October 2015. The 11kV cables have been installed and terminated to the device. The installation and commissioning works were completed to enable energisation on the 25th November 2015.

Bournville

During this reporting period it was found that the Bournville device suffered from the same higher than expected electrical losses consistent with the phenomenon found in the Chester Street device. Nexans conducted internal testing to confirm that the device would not be able to maintain the continuous rated current of 1050A.

Unlike the Chester Street device, the Bournville cryostat vessels had space available on the lid for an additional two cold heads which would provide the additional cooling power to ensure the 1050A continuous operation. The decision was taken to install the additional cold heads. This also required a further two compressors units and one recooler unit for their correct operation. The additional cooling system equipment required to maintain the continuous rating of the Bournville device has delayed the installation and commissioning of the device. Table 3 shows the reforecast projected key milestone dates for the Nexans FCL devices.

Table 3 - Key milestones for Resistive Superconducting FCL

Activity	Forecast Date	
	Chester Street	Bournville
Device Build	Complete	November 2015
Successful Testing	Complete	December 2015
Delivery to Site	Complete	December 2015
Energisation	25th November 2015	February 2015

The FCL is to be installed on the first floor at Bournville and due to the age of the building an intensive inspection and survey of the structure is currently being carried as previous inspections were found to be substandard. This work will be carried out and remedied, if required, prior to the installation of the device in December.

2.6.3 Alstom Power Electronic FCL

In November Alstom completed the build of the first of two AFDs in preparation for testing in December. However, when the build was inspected it was identified that several elements were not build to the design specification. An example of this is the 11kV braiding proximity to the light fitting and external container as illustrated in Figure 2-21. A further picture of the internal elements of the AFD is provided in Figure 2-22.

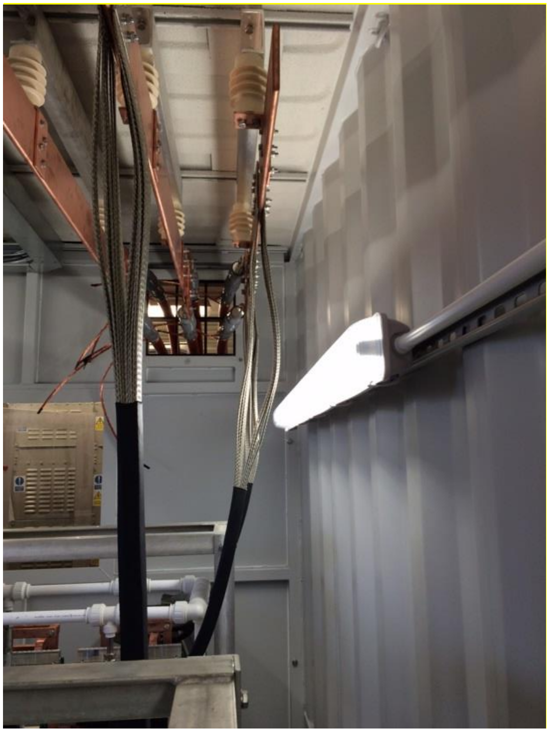


Figure 2-21 - Alstom AFD 11kV Braiding

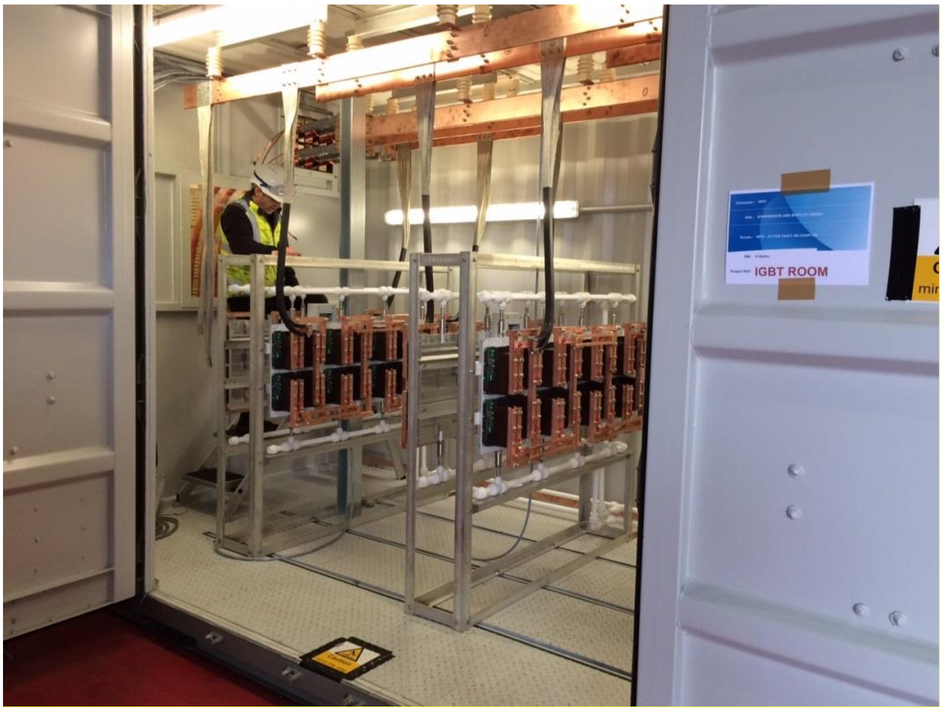


Figure 2-22 - Internal view of Alstom AFD

It was also identified, during a meeting with the external laboratory test engineers, that the surge arrestors installed were not suitable to protect the IGBTs from excessive switching voltage that would occur during testing.

Currently the resolution to these issues is being thoroughly investigated by Alstom to understand the actions and timescales required to be able successfully test the device. A test slot was booked in February 2016, for the second AFD device, this is now considered a sensible target for the first device to be tested.

Table 2-4- Key milestones for Power Electronic FCL

Activity	Forecast Date	
	Kitts Green	Bartley Green
Device Build	March 2016	April 2016
Successful Testing	April 2016	May 2016
Delivery to Site	May 2016	June 2016
Energisation	May 2016	June 2016

2.7 Policy Documents – All Methods

2.7.1 Devices

During this reporting period, a further two 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:

OC1W – Operation and Control of Nexans RSFCL; and
SP2CAA – Inspection and Maintenance of Nexans RSFCL.

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 Alstom Power Electronic FCL. These policies will be in place prior to the energisation of the first device, at Kitts Green in 2016.

2.8 Socio-Economic Update

In the six months from June 2015 the socio-economic component of the FlexDGrid project involved continuing the analysis of the survey data, with a focus on estimating consumer expenditure and the potential savings from the decision to connect to district heating. The work also involved the econometric analysis of the factors affecting the decision to connect.

The first phase of the analysis of energy expenditure data involved some extensive data manipulation and statistical analysis, which was aimed at producing an estimate of annual gas expenditure in order to calculate how much a household could expect to save by connecting to a local district heating system in Birmingham. Due to the wide variety of energy bill payment methods, tariffs, housing and other characteristics, a series of data transformations were required in order obtain a reliable measure of annual gas expenditure for each household.

Estimates of annual gas expenditure for consumers with the same supplier for gas and electricity required a different treatment from the calculations applied to the information provided by consumers with different suppliers. We used econometric techniques to estimate the gas expenditure for households paying for gas and electricity with a dual fuel tariff by calculating the proportion of total energy expenditure dedicated to gas for those respondents who provided separate amounts for gas and electricity expenditure and using this as a dependent variable while controlling for socio-economic, housing and behavioural characteristics in order to estimate the proportion of total expenditure dedicated to gas for dual fuel consumers. We then used the estimated proportion to calculate the total gas expenditure for dual fuel consumers.

Different data treatments were also required for consumers who do not pay constant amounts over the year but rather pay quarterly on receipt of their bill. Since the survey took place in May-June 2014, the last energy bill likely to have been paid for or the expenditure recalled by households who did not have their bills at hand would have been their winter energy bill (January-March). For this reason we estimate a seasonally adjusted annual gas expenditure for each household by weighting their gas bill on the basis of the seasonal variation in expenditure in England.

One noticeable feature of the distribution of gas expenditure obtained from the survey is the long right tail of gas bills exceeding £1500 per year. Large gas bills could be due to household characteristics, such as high income and a large number of residents consuming energy, or to the household overestimating their energy costs. However the presence of unusual observations (or outliers) in the data, which differ significantly from the bulk of other observations, limits the applicability of statistical methods required for our analysis. For this reason we used different methods, such as "winsoring" and logarithmic transformations, to obtain a more statistically sound distribution, while reducing the impact of any abnormal observations.

After estimating and cleaning the annual gas expenditure for all respondents to our survey we calculated the savings which could potentially be obtained by all households in the sample, should they decide to connect to a local district heating scheme.

The sample was separated into three groups - low, medium and high gas consumers – based on the Consumer Focus (2014) price comparison report for January 2014. Based on the chosen cut-off points we find that a low-user would lose £84 on average, a medium-user saves £25 on average and a high-user saves £400 on average. As expected, high-usage consumers (with heating bills in excess of £1000) appear to have the greatest opportunity to save. Overall, the average yearly gas expenditure for households in our sample would decrease by £35, without considering potential saving in installation and maintenance costs compared to traditional heating systems such as a combination boiler.

As the final step in our analysis to date, we estimated the probability that a household in our sample would connect to district heating using a Probit model. This involved estimating how the probability of connecting to district heating is affected by the size of the potential monetary savings and the time horizon required to recover the initial investment costs. This analysis relies on the calculation, for each of the respondent who provided sufficient financial information, of the lifetime-cost of the investment in district heating and the number of years required to pay it back. The estimated probabilities were obtained using a 2-stage Heckman Probit model. The empirical findings suggest that the households in our sample tend to discount the annual costs quite heavily and that the probability of connecting to district heating decreases with the time it would take to break even, as would be expected.

In terms of socio-economic characteristics of the households most reluctant to adopt the district heating technology, we find that non-homeowners, single individuals, the elderly (over 60 years) and households with at least one unemployed resident are less likely to participate in district heating scheme. This implies that households with these characteristics may need to be targeted with financial support or information programmes to encourage participation in a district-heating scheme.

Finally, we find evidence indicating that income is the main driver of the decision to connect, followed by the size of the energy bill. Furthermore, our subjective measure of financial vulnerability in the energy market suggests that financial concerns over the size of the winter energy bills increase the probability of connecting to a district-heating scheme.

In the next report, which will focus on fuel poverty and rationing behaviour, we intend to investigate the potential financial benefits from connecting to district heating for those households in our sample who can be defined as fuel poor according to the official Low-Income-High-Cost (LIHC) indicator. An initial analysis of this group of households indicates that the mean fuel poverty gap in our sample is around £500, implying that a fuel poor household would need a reduction in their annual energy bills of over £500 in order to move out of fuel poverty. This compares with a value of £386 for the whole of England (DECC, 2015). In the next phase of the analysis we plan to extend these findings to assess how many consumers could potentially be taken out of fuel poverty as a result of savings made on their annual gas expenditure.

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**	**1452.70**	**921.80**	**-530.90**	**-37%**[1]
WPD Project management	320.00	206.73	189.66	-17.07	-8%
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	4.95	0.00	-4.95	-100%
Installation of Fault Level Monitoring Technology	296.65	296.65	323.35	26.70	9%
Installation of Fault Level Mitigation Technology	445.10	309.23	317.19	7.96	3%
Installation of VCU Technology	148.11	109.72	0.00	-109.72	-100%
Capture, Analyse Data and performance	234.85	166.20	32.73	-133.48	-80%
Equipment	**9779.63**	**8136.61**	**7030.53**	**-1106.08**	**-14%**
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	1306.84	-248.15	-16%[3]

Installation of Fault Level Monitoring Technology	494.52	494.52	539.03	44.51	9%
Implementation of Real Time Modelling	3.76	1.98	1.80	-0.18	-9%
Procurement of Fault Level Mitigation Technology	5830.14	4500.00	4472.76	-27.24	-1%
Installation of Fault Level Mitigation Technology	741.84	549.52	571.13	21.61	4%
Procurement of VCU technologies	777.86	725.88	0.00	-725.88	-100%[4]
Installation of VCU Technology	246.85	182.86	0.00	-182.86	-100%[4]
Equipment to enable modelling and technology installation	3.08	1.59	1.50	-0.09	-6%
Contractors	**1927.36**	**1516.63**	**1511.33**	**-5.31**	**0%**
PB Project Support	340.94	255.71	235.17	-20.54	-8%
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	64.85	65.88	1.03	2%
Create Advanced Network Model	51.38	51.38	52.00	0.62	1%
Implementation of Real Time Modelling	350.94	298.00	301.20	3.20	1%
Capture Monitored & Measured Data	49.61	36.08	36.98	0.90	2%
Analyse Monitored and Measured Data	157.49	107.34	109.35	2.01	2%
Verify and Modify Advanced Network Models	253.89	178.65	175.39	-3.26	-2%
Gather Performance of Mitigation Technologies	50.07	36.42	33.98	-2.44	-7%
Knowledge Capture and Learning Dissemination	281.62	182.89	180.56	-2.33	-1%
Procurement & Installation Support	78.69	57.43	58.20	0.77	1%
IT	**57.73**	**56.15**	**35.23**	**-20.91**	**-37%**
IT Costs	57.73	56.15	35.23	-20.91	-37%[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**	**369.66**	**342.01**	**-27.65**	**-7%**
Travel & Expenses	465.62	369.66	342.01	-27.65	-7%
Contingency	**1407.05**	**1250.15**	**42.19**	**-1207.96**	**-97%**
Contingency	1407.05	1250.15	42.19	-1207.96	-97%
Other	**27.21**	**13.52**	**12.83**	**-0.69**	**-5%**
Other	27.21	13.52	12.83	-0.69	-5%
TOTAL	**15477.38**	**12796.92**	**9897.36**	**-2899.56**	**-23%**

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 – *Invoicing delay following the completion of all FLMs*

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 sixth reporting period there has been one additional SDRC completed, SDRC-7 10 FLMs Connected.

All seven 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-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 seven SDRCs submitted and approved to date (SDRC1-7).

Learning continues to be generated and disseminated through the production of WPD policies in relation to the Inspection and Maintenance and Operation and Control of all devices connected as part of the project. These are detailed in Section 2.7.

Significant learning is being generated now all 10 FLMs are providing real-time fault level values. This data will be used to further inform the future modelling of 11kV fault level and how the availability of real-time data can increase the flexibility of connections to customers.

In this reporting period learning has been shared both formally and informally at several events: CIRED 2015, Lyon – Paper Presentation on the Standardised Connection of FCLs (17.06.2015); ENA LNO Day, London – Policies in to Practice (15.09.15); NextGen 2015, Warwick – FlexDGrid learning to date (07.10.15) and LCNI Conference 2015, Liverpool – Fault Level Workshop (25.11.2015).

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 57 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	Alstom device is currently not suitable for testing or installation on site
Alstom AFD is not ready for KEMA type testing	Severe	Proactive design and build required from Alstom	Device has been delayed due to inappropriate internal Alstom review process
FCL fails and needs attention at one or more sites	Severe	Robust design and testing prior to the installation	GridON device is currently disconnected due to DC sensing error – remedial action in progress
Unforeseen issues relating to Bournville FCL and FLM installation being on the 1st Floor	Major	Detailed design of installation	Significant survey and investigation is currently being carried out to confirm any additional support installation requirements
Changes to Key Personnel	Major	Rigorous and robust documentation of work. Induction Package to aid new starters.	All work and learning is robustly captured to ensure changes to personnel would cause minimal disruption

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

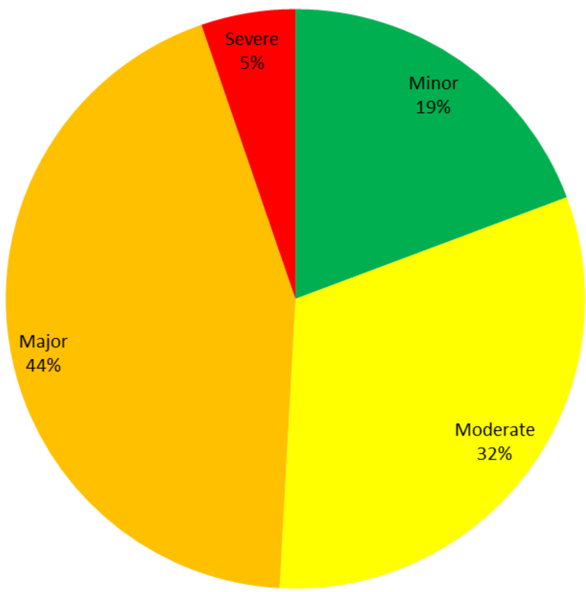
Table 8-2 - Graphical view of Risk Register

Likelihood = Probability x Proximity						
	Certain/Imminent (21-25)	0	1	0	2	1
	More likely to occur than not/Likely to be near future (16-20)	0	1	6	0	0
	50/50 chance of occuring/ Mid to short term (11-15)	0	0	2	6	0
	Less likely to occur/Mid to long term (6-10)	0	1	5	8	1
	Very unlikely to occur/Far in the future (1-5)	1	1	8	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	11	18	25	3	**No of instances**
Total	57				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	Alstom device is not suitable for test or installation to site
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	Moderate	University of Warwick's worked has been scaled down in order for them to focus on a specific element to produce useful output
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 seven 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.