WESTERN POWER DISTRIBUTION

FLEXDGRID

HEAT AND POWER FOR BIRMINGHAM

PROJECT PROGRESS REPORT
REPORTING PERIOD:
JUNE 2013 TO NOVEMBER 2013

LCN Fund Low Carbon Networks | THE UNIVERSITY OF WARWICK | PARSONS BRINCKERHOFF

Report Title	:	Six Monthly Progress Report Reporting Period: June 2013 to November 2013
Report Status	:	Final
Project Ref	:	FlexDGrid
Date	:	10.12.2013

Document Control

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Revision History

Date	Issue	Status
23.10.2013	D001	Draft for internal review
28.10.2013	D002	Revisions after RH/PJ review
28.11.2013	D003	For final review
10.12.2013	V001	Financial information added – Final

Contents

Executive Summary

The FlexDGrid project is funded through Ofgem's Low Carbon Networks Second Tier funding mechanism. FlexDGrid was approved to commence on the 7th 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.

Progress to date

During this reporting period (June – November 2013) the project has completed a further three Successful Delivery Reward Criteria (SDRC) deliverables:

- SDRC-3 – Fault Level Mitigation Technologies DNO Workshop – delivered early;
- SDRC-4 - Implementation of Enhanced Fault Level Assessment Process – on time; and
- SDRC-6 – Evidencing Method Gamma Will Provide Outlined Learning – delivered early.

All three SDRC documents have been made available on Western Power Distribution's (WPD) innovation website[1], along with the three SDRCs (1, 2 and 5) completed in the previous reporting period.

In this reporting period significant progress has also been made in working towards the delivery of other project SDRCs, specifically SDRCs 7 and 8.

Contracts

FlexDGrid's two project partners are Parsons Brinckerhoff (PB) and the University of Warwick (UoW). A collaboration agreement between WPD and each project partner is now signed and complete.

Resourcing

As stated in the previous six monthly progress report due to a better operational fit the team structure has adapted to be formed of PB engineers supported by WPD engineers. This team structure has been fully functional for this reporting period. The transfer of knowledge in to WPD has not been affected by this change.

UoW staff is now included in FlexDGrid's delivery team, where they are fully integrated within the current engineering structure.

Project Delivery Structure

The central operating location remains as WPD's Tipton Office. Following the signing of the UoW collaboration agreement all members of the project team from WPD, PB and UoW have full access to WPD systems.

The project steering committee has met twice in this reporting period, where the second committee meeting included a project gateway which was successful.

Financial Highlights

[1] www.westernpowerinnovation.co.uk/FlexDGrid

There are no significant financial highlights at this stage of the project. FlexDGrid is within its budget and ahead of target in terms of delivery.

Risks

Contained within the Risk Management section of this report is the current top risks associated with successfully delivering FlexDGrid as logged in the risk register along with an update on the risks captured in the last six monthly progress report.

Recruitment

In this reporting period there have been productive meetings with both project supporters Cofely District Energy and Birmingham City Council (BCC). These meetings have centred on the requirements of a combined heat and power (CHP) developer and operator to connect a CHP unit to the existing energy network and to understand BCC's energy strategy moving forwards.

Now the UoW have signed the collaboration agreement the socio-economic element of this work is progressing and has de-risked the recruitment of customers' element of FlexDGrid. They are currently working on the FlexDGrid Customer Communications Plan to allow customer surveys to be completed in Q2 2014.

Procurement

Using the procurement process outlined in SDRC-5 (Fault Level Mitigation Technology Procurement Procedure Report) we have now made the selection of which Fault Level Mitigation Technologies (FLMT) are to be installed in the five Primary Substations.

The Fault Level Monitoring (FLM) procurement process is also now completed, where the FLMs for inclusion in to ten Primary Substations is now complete.

Installation

Following the completion of the new technology procurement process and continuing work on the detailed design to include these technologies, in to the ten Primary Substations, the risk of not being able to install the required technologies on to the 11kV network has significantly decreased. This is centred on the detailed understanding of the technologies, such as their electrical connection requirements and the mass and size of each unit.

Learning

During this reporting period of FlexDGrid (June - November 2013) the key learning outcomes have centred on the working and outputs of SDRC-4 and the procurement of the technologies and detailed design requirements of their connection to the network.

Approach to learning capture

WPD employs a consistent approach to the process of capturing learning. This is formed and centred on the robust capturing of information, such as ensuring that all meetings are appropriately recorded, and that all options and possible methods to provide a solution are recorded to understand the learning in deriving an output.

Summary of Key Learning

Having developed a framework for the integration of Fault Level Monitoring and Mitigation technologies in to existing electrical network systems (SDRC-2) in the previous reporting period, this framework has now been used to design the confirmed technologies in to the ten chosen Primary Substations. Key lessons have been learnt in the requirements of site specific installations of these technologies that have been robustly captured and will be used to develop project specific policy documents for each technology prior to energisation on the network.

External Dissemination

The main focus of external dissemination in this reporting period has been two DNO workshops, the first to disseminate the learning to date on Method Alpha and Beta and the methodology of Method Gamma. The second was to provide an update on the implementation of an enhanced fault level assessment process and to gain DNOs' feedback on the process to date. All the presentation material is made available on the FlexDGrid section of the WPD innovation website.

An external FlexDGrid newsletter has also been produced, which contains up to date information on the progress of project activities and upcoming events for registration. This newsletter was disseminated to over 450 project stakeholders. This newsletter is to be disseminated on a quarterly basis.

The LCNF Conference which took place on the 13th and 14th November was also used as an opportunity to externally disseminate FlexDGrid's learning to date and plan moving forwards.

Internal Dissemination

In this reporting period companywide dissemination has centred on the distribution of a project leaflet, which provides a complete overview of the project, its aims and objectives. The FlexDGrid newsletter has also been disseminated internally, providing an update on the progress of specific areas of the project.

1 Project Managers Report

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.

In the previous and first reporting period the focus of the project was to ensure that an appropriate delivery team structure was created, along with appropriate governance and controls to allow the successful completion of SDRCs 1, 2 and 5. Now the team, process and controls are in place the focus has been on transitioning from the project concept and initial detailed design through to project trials and construction delivery.

The complete EHV and HV electricity network in the FlexDGrid area has now been modelled, using PSS/E (WPD's business as usual modelling tool) from the interface point with National Grid (NG) to the remote ends of the 11kV, which has been completed for the ten FlexDGrid Primary Substations and two supporting Primary Substations. These models were created by members of the FlexDGrid project team with guidance from WPD's team responsible for the creation and management of WPD's BaU models and have approved these models for use. This has now allowed the Enhanced Fault Level Assessment Process to be trialled, which has been reported and delivered in SDRC-4.

The process for modelling the complete electricity network has been developed in a way in which it is fully automated, as far as is practicable, which will allow the process to be transferred in to WPD's business as usual modelling activities at an appropriate point in time. These models are also now being utilised by UoW's members of the team to carry out time-domain modelling and understand the effects of varying loads and generation on the system, how this has changed and the effects of this on system fault level and the ability to maximise the connection of distributed generation on to the existing network.

SDRC-1 documented the proposed processes to be used for the Enhanced Fault Level Assessment and in this reporting period these processes have been trialled. The findings and next steps have been presented in SDRC-4.

In the previous reporting period SDRC-2 (Confirmation of Project Detailed Design) was completed, which detailed the engineering requirements to include ten Fault Level Monitors and five Fault Level Mitigation Technologies on to the existing Birmingham 11kV network. This document along with the additional information provided from manufacturers through the procurement process and afterwards has now been used to develop construction designs for the ten Fault Level Monitor sites and the five Fault Level Mitigation Technology sites. The design team are now working closely with the manufacturers to finalise the specific construction requirements for each of the technologies to be installed on to the 11kV network, which include physical dimensions, protection and electrical connection requirements. To ensure that all the sites are suitable for the integration of the technologies extensive survey work has been carried out, including trial holes, radar and topographical and structural.

The procurement process for the ten Fault Level Monitors and five Fault Level Mitigation Technologies has now been completed. A single supplier has been selected for the FLMs and 3 suppliers for the FLMTs. These selections were made following the specified procurement process (detailed in SDRC-5).

Following the collaboration agreement being finalised with the University of Warwick both their aspects of project involvement have been mobilised; engineering and socio-economic. In line with all engineering personnel working on FlexDGrid, the UoW staff has full access to WPD's systems and databases. This is allowing them to use the FlexDGrid models and other information to carry out their initial deliverables of determining, in a time-domain, the effect of varying loads and generation on the network to affect system fault level.

1.1 Construction Design Phase – All Methods

The previous progress report for the period December 2012 to May 2013 provided an overview of the work that had been completed to produce the "Confirmation of the Project Detailed Design" (SDRC-2). This document encapsulated the design for Fault Level Monitoring equipment at ten substations and Fault Level Mitigation Technologies at five substations.

During the period between July 2013 and November 2013, work has been progressing to finalise the design documentation and drawings required for progressing towards the construction phase of FlexDGrid. As detailed in the sections below, information gathered through intrusive surveys and discussions with manufacturers has been used to produce documentation and drawings to a level which can be used for construction purposes.

1.1.1 Design Team – All Methods

Moving towards the next phase of FlexDGrid, further engineering design support was required to complement the existing design team. Engineers specialising in civil, electrical and protection design from both WPD and PB have been integrated into the team to assist in the production, assurance and approval of designs.

1.1.2 Site Investigation Work – All Methods

Work carried out for SDRC-2 provided the basis for moving towards the provision of documentation and drawings for construction at the ten substations.

To obtain a greater level of detail in the designs and to mitigate design risk due to unknown conditions, a variety of site investigations were considered for each substation. Using the information produced in SDRC-2, detailed substation site assessments were carried out by electrical and civil engineers in the FlexDGrid design team. From these assessments it was identified that the following specialist surveys and investigations should be carried at a number of substations: ground penetrating radar, structural investigation, earthing / Rise of Earth Potential (ROEP) survey, geotechnical investigation (see Figure 1 as an example) and trial hole / trench. Survey and investigation work is now complete and the information gathered has been used to tailor the designs and mitigate risks associated with the site construction works.

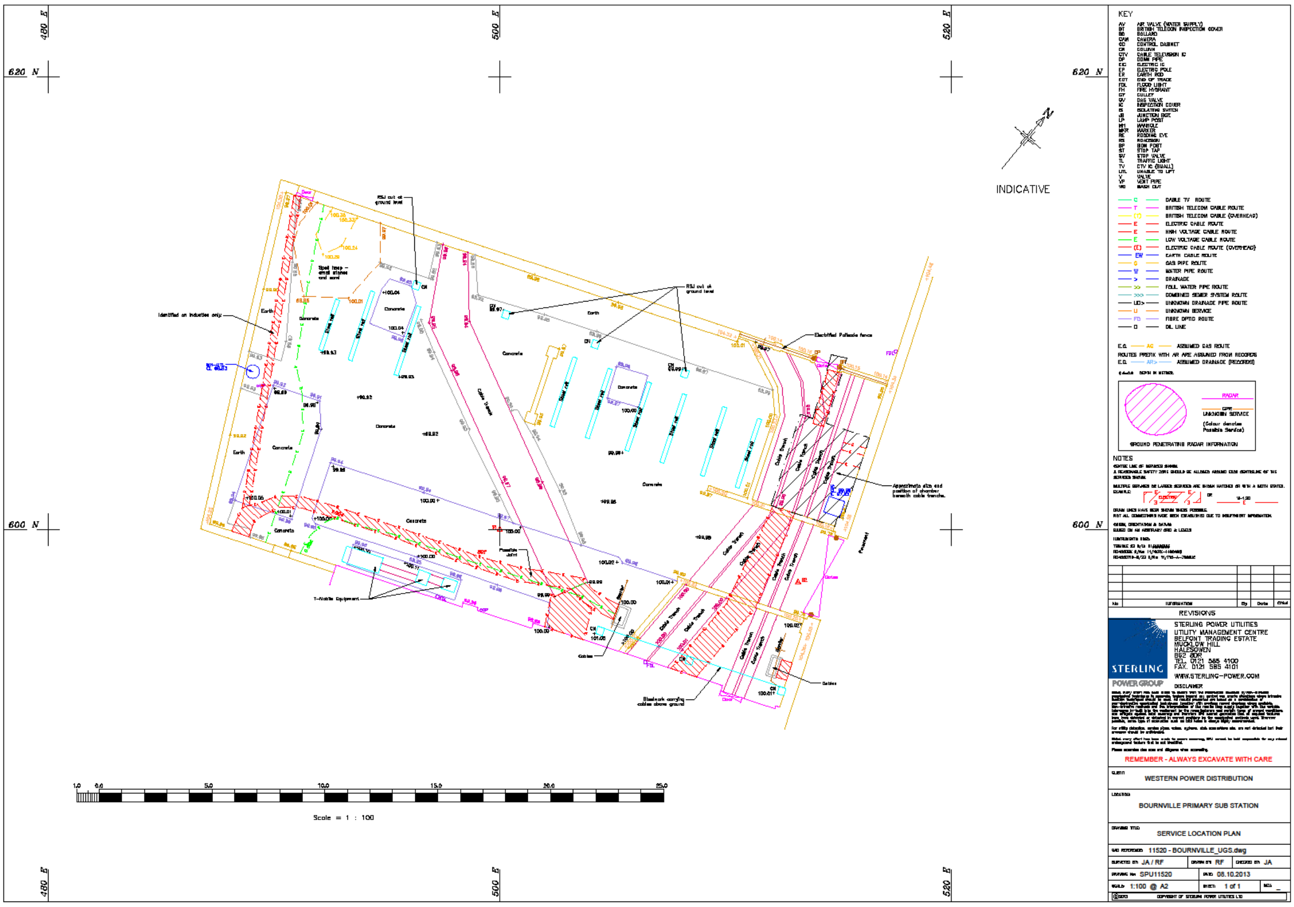

Figure 1 - Bournville Geotechnical investigation report

1.2 Procurement – Methods Beta and Gamma

Following the delivery of SDRC-5, which comprised a report detailing WPD's procedures and methodology for the procurement of Fault Level Mitigation Technologies, ITTs were released during the last reporting period for:

- Fault Level Monitors;
- Voltage Conditioning Units; and
- Fault Level Mitigation Technologies.

The following sections of this report provide an overview of the progress to date on the procurement of the items listed above.

1.2.1 Fault Level Monitors – Method Beta

Four manufacturers replied with solutions to the ITT that was issued for the procurement of Fault Level Monitors for ten substations. Evaluation of the these tenders during June and July 2013 resulted in three of the four manufacturers being invited to post tender negotiations at WPD's offices in August 2013.

Following the post tender negotiations, the tenders were evaluated and scored using the predetermined weightings defined within the ITT. The chosen Fault Level Monitor technology was Manufacturer S&C Electric's IntelliRupter FLM. This technology was selected as it was able to provide a perspective network fault level value at any instant in time, meaning that a real-time fault level value can be generated, which was a fundamental requirement of the product.

1.2.2 Fault Level Mitigation Technologies – Method Gamma

Six manufacturers replied to the ITT for Fault Level Mitigation Technologies for five substations, offering a total of ten different solutions. The same tender evaluation process for the Fault Level Monitors was used for the Fault Level Mitigation Technologies. The initial evaluation resulted in three technologies being down selected due to technical scores below the required pass level. This resulted in four manufacturers being invited for post tender negotiations.

Prior to the post tender negotiations, manufacturers were requested to complete questionnaires relating to the specific design of Fault Level Mitigation Technologies for the five substations. These questionnaires and the information provided with general tender information formed the basis of the post tender negotiations in August 2013.

Following the post tender negotiations, technologies were selected for each substation using the score and weightings outlined in the ITT documentation. In some instances technologies were not suitable for particular substations due to their performance and had to be rejected. For instance, a technology which disconnects or requires a time to reset / recover after fault inception would not be suitable if it compromised existing security of supply levels (e.g. installed at the point of a transformer incomer).

The report entitled "Evidencing Method Gamma will provide outlined learning" (SDRC-6) provides further details of the technology selection process.

The final outcome of the fault level mitigation technology tender resulted in the successful appointment of three manufacturers offering different three solutions:

- Power Electronic Active Fault De-coupler by Alstom (2 off);
- Pre-Saturated Core Fault Current Limiter by GridON; and
- Resistive Superconducting Fault Current Limiter by Nexans (2 off).

Discussions and detailed product design are currently on-going with these manufacturers to finalise the proposed solutions and to integrate these into the existing substations.

1.2.3 Voltage Conditioning Units – Method Gamma

The FlexDGrid Full Submission Pro-forma identified that there may be a need to install Voltage Conditioning Units to support system voltage following the installation and operation of Fault Level Mitigation Technologies. As such an ITT was issued for devices that could perform this duty.

However, following the selection of the chosen technologies for each substation it was determined through detailed system studies that voltages at all substations could be sustained during normal and contingency operation. Therefore, the requirement for Voltage Conditioning Units is no longer valid and the tenders were not progressed.

1.3 HV network modelling

A methodology for modelling HV networks in PSS/E was developed and trialled during the first six months of FlexDGrid (from 7th January until 31st June 2013) and reported in SDRC-1. The scope of work within the SDRC-1 work package was to develop the Birmingham HV electricity network in order to create the test bed for trialling the enhanced fault level assessment processes. The 11kV network model is currently fit-for-purpose. However, a more detailed electricity network model allows the future complexities associated with the integration of low carbon technologies to be more fully understood. The process and data sources used in the methodology deployed are shown in Figure 2. This methodology was successfully trailed for modelling the HV networks of three Primary Substations namely, Winson Green, Ladywood and Summer Lane.

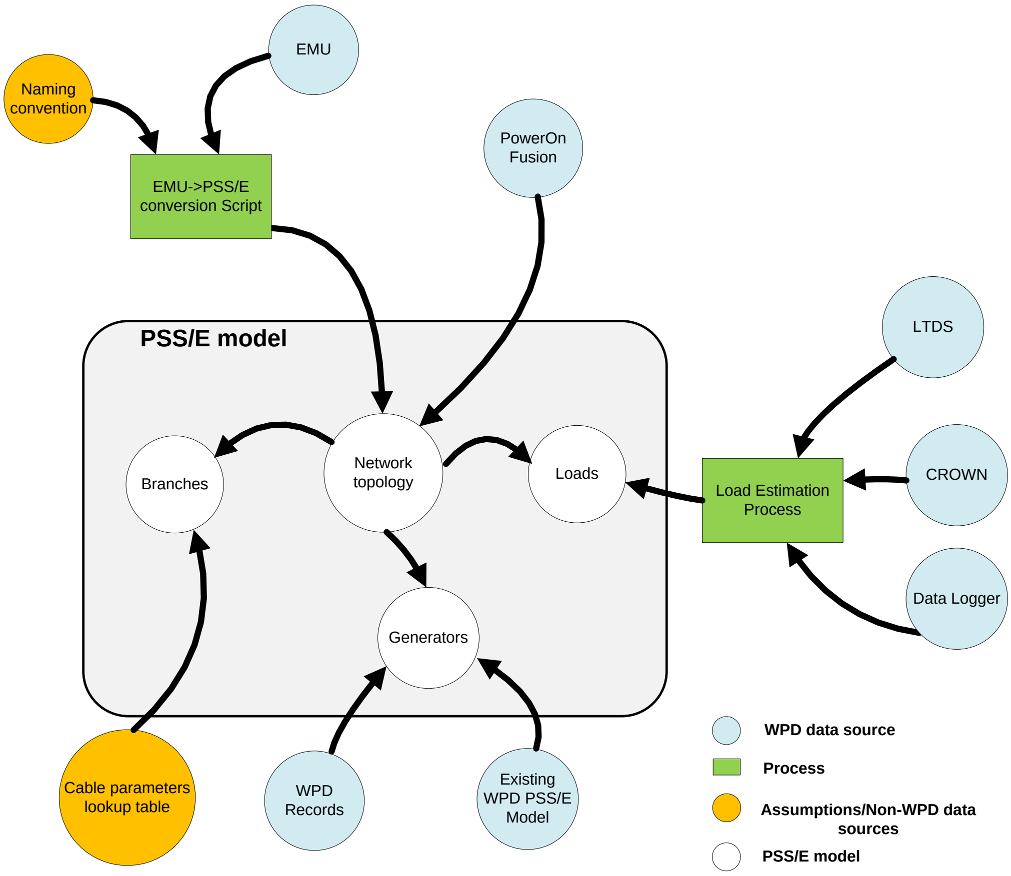

Figure 2 - Methodology for HV networks modelling in PSS/E

Based on the knowledge learnt and the methodology developed during the first six months, a user-friendly excel-based tool was developed to automate the modelling process by converting EMU[2] data to a PSS/E model. Figure 3 shows the user-interface of the developed EMU-to-PSS/E tool. This tool was then used to create PSS/E models of an additional nine Primary Substations in Birmingham's Central Business District, see Figure 4 as an example. In total the PSS/E model of HV networks of the following Primary Substations (12 Primary Substations in total) have been developed within FlexDGrid:

- Kitts Green;
- Castle Bromwich;
- Chester Street;
- Bournville;
- Sparkbrook;
- Hall Green;
- Elmdon;
- Chad Valley;
- Perry Barr;
- Winson Green;
- Ladywood; and
- Summer Lane.

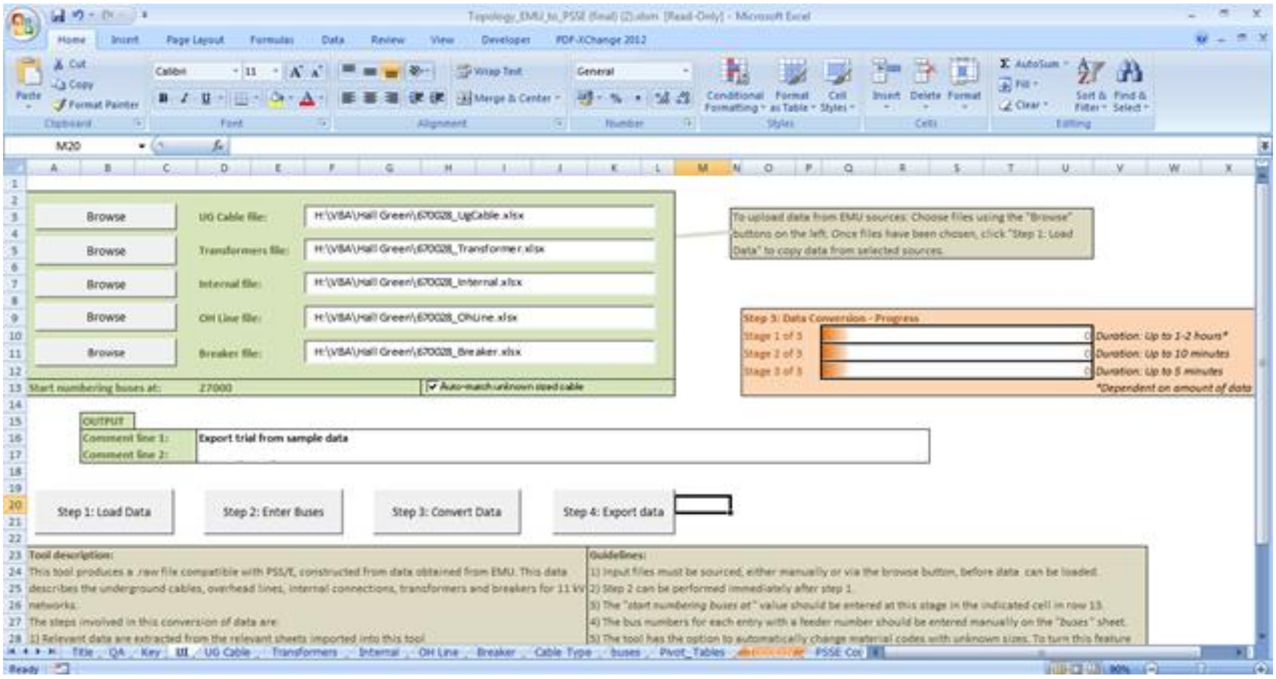

Figure 3 - Excel-based tool to convert EMU data to PSS/E model

[2] EMU – WPD's Geographical Interface System

The developed HV network models can be integrated with the existing WPD EHV PSS/E model. Therefore, a detailed model of the electricity network representing the network from National Grid's Supply Points (GSPs) to LV substations is now available to allow a more complex and detailed network analysis. Some of the benefits of the developed models are as follows:

- The network topology, cable types and overhead line (OHL) conductors are verified with EMU data and PowerOn Fusion[3] schematic diagrams;

- All normally open points (NOPs) and interconnections between different HV networks supplied by different Primary Substations are modelled. This allows detailed power system studies to be carried out where different HV network configurations are envisaged;

- The distributed generators are modelled as connected to the actual connection point on the 11 kV network. This allows a more accurate fault level calculation compared to the existing WPD EHV model which models the distributed generator connection with an equivalent circuit; and

- The developed models embody a full representation of the HV busbars at primary substations. The front and rear busbars as well as circuit breakers and busbar couplers are modelled. This allows power system studies for different substation configurations.

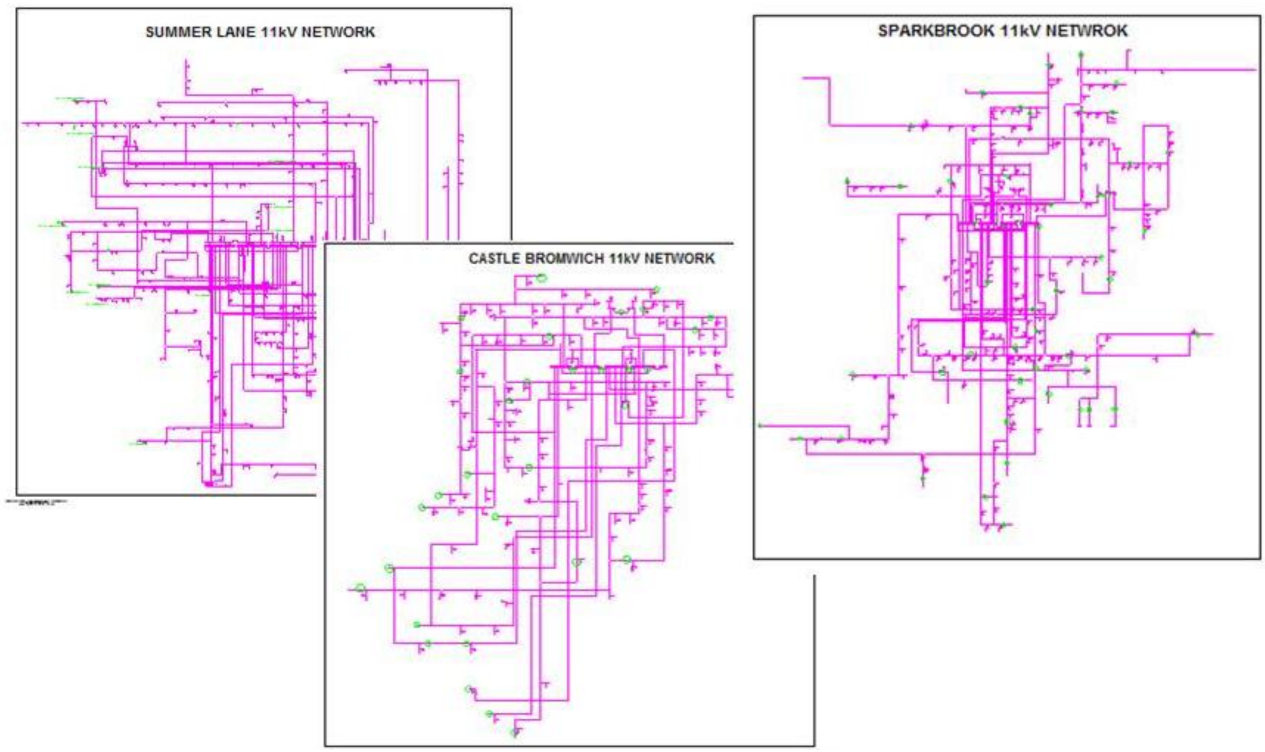

Figure 4 – Example of the networks developed

[3] PowerOn Fusion – WPD's Network Management System

1.4 Enhanced Fault Level Assessment Process – Method Alpha

1.4.1 Base-line fault level assessment processes

Two DNO workshops have taken place to discuss the development and implementation of enhanced fault level assessment processes, giving other DNOs the opportunity to provide feedback on the processes and endorse the planned trialling approach.

As part of FlexDGrid, a questionnaire was sent to each GB DNO to understand their present approach to the calculation and analysis of HV fault levels. Questionnaire responses were received by licence areas representing all UK DNOs. Previous work carried out by others in this area has only represented a selection of licence areas whereas the results reported in FlexDGrid (SDRC-4) represent a formal response from all of the UK DNOs.

The following points emerged from the analysis of the questionnaire responses:

1. Clarifications on the application of Engineering Recommendation (ER) G74[4] to HV electricity networks would be beneficial to the DNO community;
2. A comprehensive sensitivity analysis of HV electricity network fault levels to input parameters would provide further useful learning for DNOs;
3. A generic database of generator and motor plant types could introduce time savings for planning engineers particularly when dealing with missing or inconsistent data from customers;
4. The development of open source fault level mitigation technology models would be of benefit for planning engineers and allow the capacity to accommodate future customers' connections to be readily assessed;
5. The increase in frequency of fault level assessments would be useful for assessing the potential gains from real-time fault level management. However, the gains would need to outweigh the increased modelling effort for this option to be attractive to other DNOs;
6. A move to probabilistic fault level assessments was not deemed to be feasible at this point in time due to the health and safety aspects contained within the Electricity Safety, Quality and Continuity Regulations (ESQCR); and
7. The need was identified for the training processes within DNOs to be more robustly documented so that planning engineers make consistent decisions regarding the assessment of fault levels.

The application of ER G74 to HV networks varies significantly between DNOs and even between different licence areas of the same DNO. For example, based on the initial questionnaire responses, the safety margin applied to fault level assessments can vary from 0 – 10%.

[4] Energy Networks Association, 1992, *Engineering Recommendation G74: Procedure to meet the requirements on IEC 909 for the calculation of short circuit currents*, ENA, London, UK.

1.4.2 Sensitivity analysis

A sensitivity analysis was conducted to determine the variation of fault level values to different input parameters, using calculations in ER G74 as the basis. In this analysis the following input parameters were studied:

- Generation power factor (PF);
- Tap position at primary substation;
- Demand;
- General load fault infeed; and
- Cable length.

The results of the sensitivity analysis are summarised in Figure 5 and Table 1 for a representative section of WPD's 11kV electricity in Birmingham. The sensitivity analysis results are discussed in detail in SRDC-4 (Implementation of Enhanced Fault Level Assessment Processes). The results demonstrate that fault level is particularly sensitive to power factor at which generation operates. Follow up work is planned as part of the trialling of Method Alpha to explore how connection offers could be developed for customers that are able to manage their fault level infeed through the power factor control of the generation.

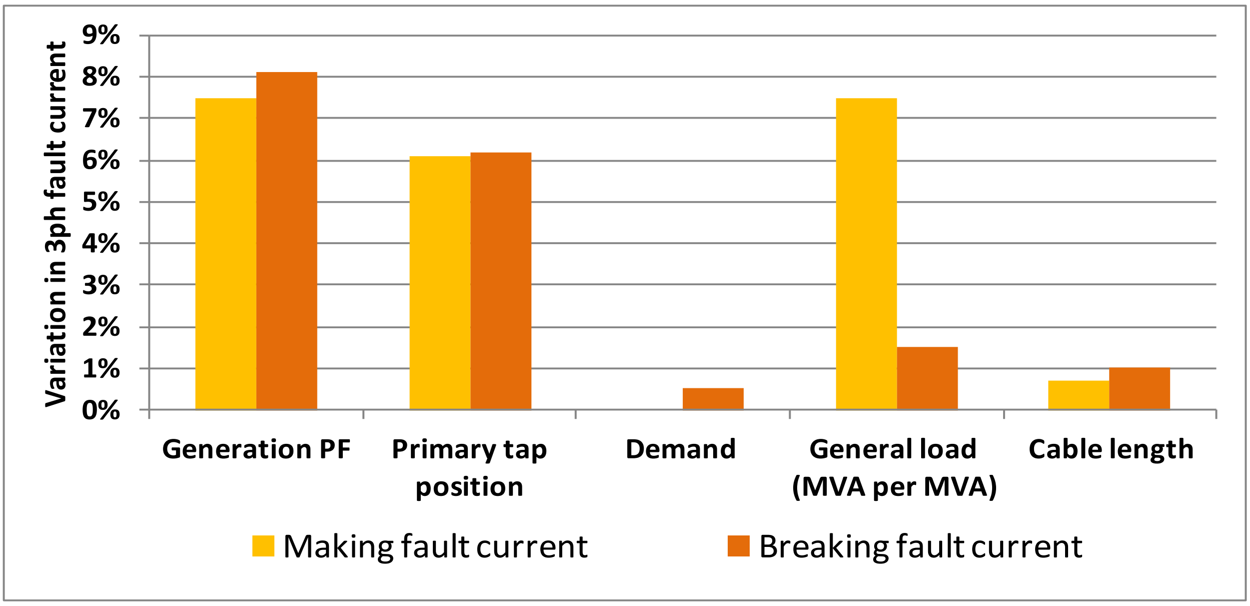

Figure 5 - Percentage variation of calculated break and make fault level due to variation in input parameters

Parameter	Variation Range	
Generation power factor (PF)	Unity, 0.95 leading, 0.95 lagging, Voltage control mode (1 per unit)	
Tap position at primary substation	0.95 per unit to 1.03 per unit	
Demand	- 10%	+ 10%
General load fault infeed	0 MVA per MVA load	2 MVA per MVA load
Cable length	- 5%	+ 5%

Table 1 - Variation of parameters for calculated break fault

1.4.3 Fault level decrement

The HV network models developed within FlexDGrid were used to calculate the fault level at the ten Primary Substation sites and associated 11kV electricity network. This information can enhance HV planners' knowledge about fault level at different points in the HV networks and how fault level reduces with distance from the Primary Substations. By modelling the 11kV network and determining the fault level at distribution substations (11kV / 0.415 kV) the accuracy of fault level calculations could be improved by up to 5% and a time saving of ½ day per modelled feeder has been introduced for future connection studies.

1.4.4 Heat Maps

The calculated fault level along the HV networks can be represented in the form of heat maps which give a large-scale overview of the fault level in the 11kV network. The heat map technique has been used to demonstrate the effect of a fault current limiter (FCL) on the fault level across the HV network of Kitts Green Primary Substation. Three network arrangements were considered:

- **Existing arrangement (split operation):** The interconnectors between the three Kitts Green "double-bubble" 132/11/11kV transformers are open;
- **Parallel operation:** The 11kV interconnector between GT1 and GT3 132/11kV transformer is close and these two transformers are operating in parallel; and
- **Parallel operation with FCL installed:** A FCL is installed within the 11kV GT1-GT3 interconnector. Figure 1 shows this arrangement (see Figure 6).

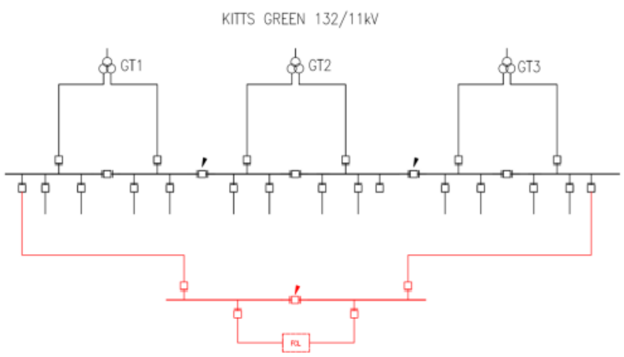

Figure 6 - Parallel operation with FCL installed within interconnector between GT1 and GT3

Existing arrangement (split operation)

Figure 7 shows the Break fault level heat map for the HV/LV substations which are supplied by Kitts Green Primary Substation with the, present, existing arrangement. The maximum and minimum calculated break fault level on the11kV network is 8.2kA and 3.5kA, respectively.

Parallel operation

Figure 8 shows the Break fault level heat map for the HV/LV substations supplied by Kitts Green Primary Substation when GT1 and GT3 are operating in parallel. The maximum and minimum calculated break fault level on the11kV network is 15.7kA and 3.5kA, respectively.

Parallel operation with FCL installed

Figure 9 shows the break fault level heat map for the HV/LV substations supplied by Kitts Green Primary Substation when GT1 and GT3 are operating in parallel and a FCL is installed within GT1-GT3 interconnector. The maximum and minimum calculated Break fault level on the11kV network is 9.0kA and 3.5kA, respectively.

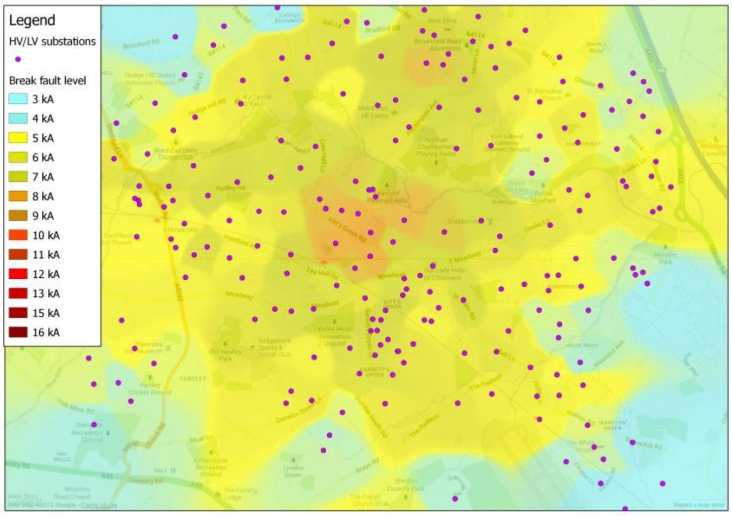

Figure 7 - Fault level heat map on Kitts Green HV network

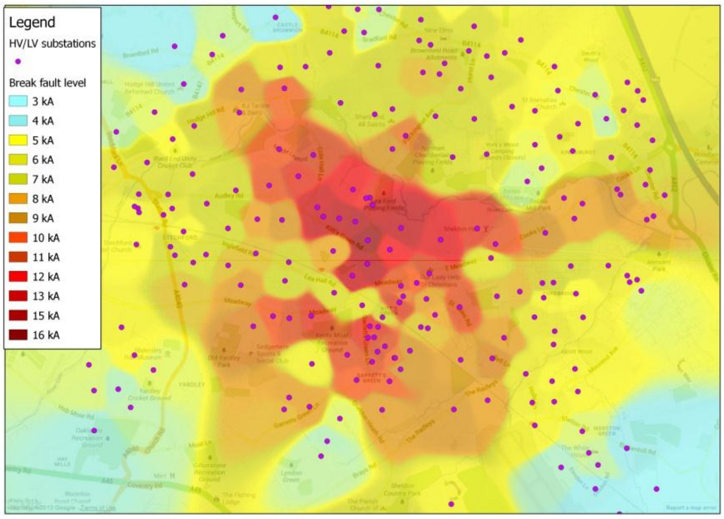

Figure 8 - Fault level heat map on Kitts Green HV paralleled network

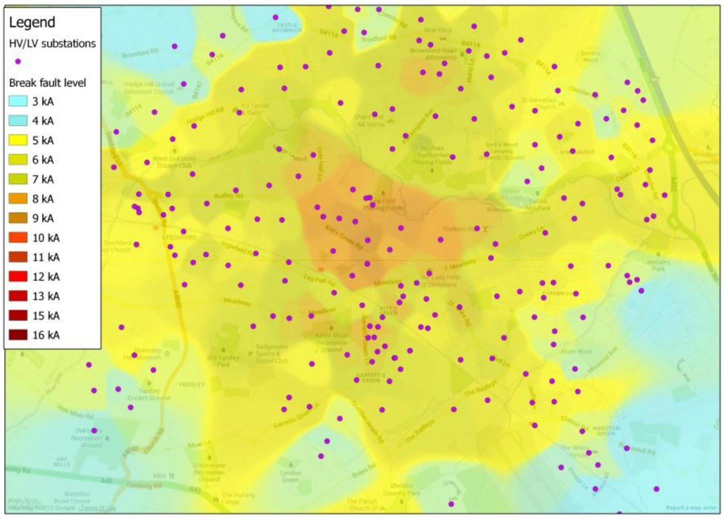

Figure 9 - Fault level heat map on Kitts Green HV paralleled network with FCL installed

1.4.5 Fault level variation with time

The increased fault level granularity introduced by the 11kV network model has allowed a detailed analysis of the variation of fault level with time to be conducted for the ten Primary Substation sites which have been selected for FlexDGrid.

This information has been used to quantify the frequency and duration of parallel operations and the headroom for accommodating customers' connections through a "connect and manage" agreement. This work has been reported in SRDC-4 and will underpin further analysis in the project (comparing modelled and monitored fault level values).

A time-series analysis graph is given in Figure 10 and a corresponding fault level duration curve is given in Figure 11 for a Primary Substation selected as the test site for fault level monitoring equipment.

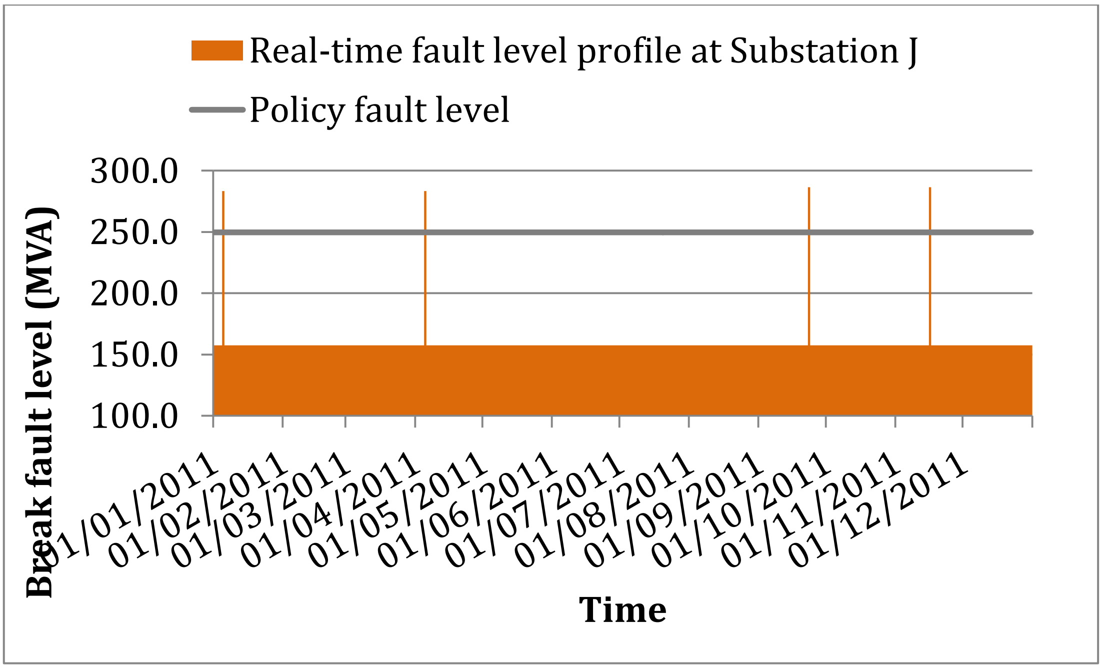

Figure 10 - A time series analysis of the real-time fault level profile at Substation J

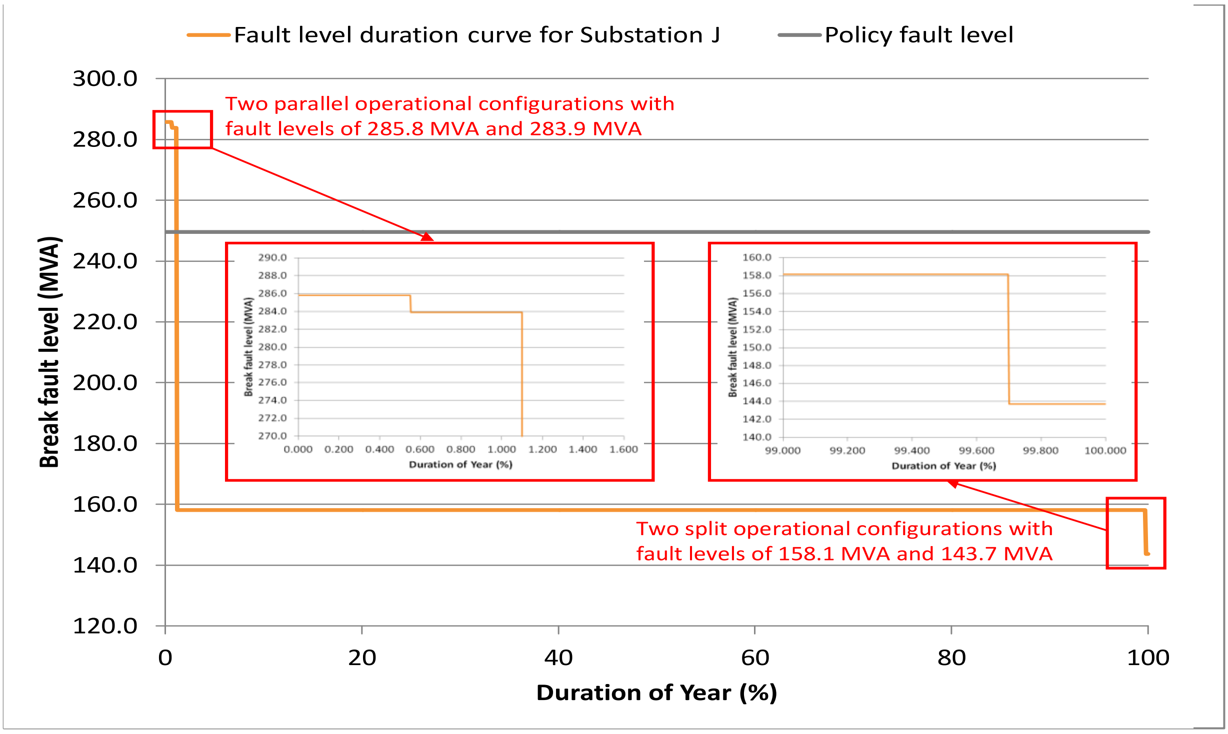

Figure 11 - Fault level duration curve for Substation J for the 2011 calendar year

Considering Figure 10 and an assumed fault infeed value of 4.5 MVA per MW of installed generation[5], this particular substation could accommodate an addition 14.9 MW of generation if a flexible 'connect and manage' approach is adopted and the fault level in Figure 11 is managed appropriately.

Method Alpha has identified the potential headroom for accommodating generation connections and Method Beta will be trialled to put the systems in place to exploit the headroom if a flexible 'connect and manage' approach is adopted.

1.4.6 Functional specification and development of fault current limiter models

A functional specification has been developed together with an excel tool for the planning of fault current limiter installations. This tool supports WPD's Primary System Design team with planning the integration of future customers' connections by allowing the team to establish which technologies are suitable for deployment in particular substations. The tool also allows the design parameters of fault current limiter to be determined (for example, the target fault level reduction and the required impedance characteristic of the fault current limiter).

Building on the output of SDRC-4, the excel model will be further refined to provide a cost-benefit analysis tool for DNOs to evaluate the merits of FCL deployments when compared to network reinforcement. Moreover, through collaboration with FCL suppliers and now that the fault level mitigation technologies have been selected, component-specific fault current limiter models will be developed and integrated into WPD's power system analysis package (PSS/E).

[5] KEMA Ltd, 2005, *The contribution to distribution network fault levels from the connection of distributed generation*, Crown, London, UK

1.4.7 Development of connection options for customers based on novel commercial frameworks

Data has been gathered to characterise the Primary Substations in terms of historic connection applications (number of applications and prospective installed capacity) and reliability data (customer interruptions and customer minutes lost). This will act as the datum by which the benefits of Method Alpha, Beta and Gamma can be measured.

Building on learning from WPD's Tier-2 Project "Lincolnshire Low Carbon Hub", connection options have been initially scoped out for customers who are flexible in terms of their connection to the distribution network. As part of Method Beta, a 'Connect and Manage' commercial framework is being developed, building on the technical analysis in section 1.4.3 to quantify indicative energy yield constraints. This information will be used in a cost-benefit analysis tool to evaluate the merits offering 'Connect and Manage' solutions alongside network reinforcement options.

2 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.

3 Progress against Budget

	Total Budget	Expected Spend to Date Nov 2013	Actual Spend to date Nov 2013	Variance £	Variance %
Labour	**1809.49**	**437.47**	**65.25**	**372.22**	**-85%**
WPD Project management	**320**	78.37	54.38	23.99	-31%
Detailed Investigation of Substation for Technology Inclusion	**71.26**	63.35	10.19	53.16	-84%
Detailed Investigation of Technologies	**71.14**	63.24	0.00	63.24	-100%
Detailed design of substation modifications for Technology Inclusion	**72.43**	64.38	0.00	64.38	-100%
Determine Enhanced Assessment Processes	**71.88**	63.97	0.00	63.97	-100%
Create Advanced Network Model	**72.32**	64.54	0.00	64.54	-100%
Installation of Fault Level Measurement Technology	**5.75**	-	0.00	0.00	0%
Installation of Fault Level Monitoring Technology	**296.65**	-	0.00	0.00	0%
Installation of Fault Level Mitigation Technology	**445.1**	-	0.00	0.00	0%
Installation of VCU Technology	**148.11**	-	0.00	0.00	0%
Capture, Analyse Data and performance	**234.85**	39.62	0.69	38.94	-98%

	Total Budget	Expected Spend to Date Nov 2013	Actual Spend to date Nov 2013	Variance £	Variance %
Equipment	**9779.63**	**121.17**	**129.38**	**-8.20**	**7%**
Procurement of Fault Level Measurement Technology	**117.01**	117.01	128.96	-11.95	10%
Installation of Fault Level Measurement Technology	**9.58**	3.66	0.00	3.66	-100%
Procurement of Fault Level Monitoring Technology	**1554.99**	-	0.00	0.00	0%
Installation of Fault Level Monitoring Technology	**494.52**	-	0.00	0.00	0%
Implementation of Real Time Modelling	**3.76**	0.20	0.17	0.03	-13%
Procurement of Fault Level Mitigation Technology	**5830.14**	-	0.00	0.00	0%
Installation of Fault Level Mitigation Technology	**741.84**	-	0.00	0.00	0%
Procurement of VCU technologies	**777.86**	-	0.00	0.00	0%
Installation of VCU Technology	**246.85**	-	0.00	0.00	0%
Equipment to enable modelling and technology installation	**3.08**	0.30	0.25	0.05	-18%
Contractors	**1927.36**	**547.57**	**421.69**	**125.88**	**-23%**
PB Project Support	**340.94**	85.24	56.34	28.90	-34%
Detailed Investigation of Substation for Technology Inclusion	**96.14**	85.46	85.15	0.31	0%
Detailed Investigation of Technologies	**102.89**	91.40	79.75	11.65	-13%
Detailed Design of Substation Modifications for Technology Inclusion	**48.85**	43.43	36.96	6.47	-15%
Determine Enhanced Assessment Processes	**64.85**	55.45	44.89	10.56	-19%
Create Advanced Network Model	**51.38**	41.35	36.91	4.45	-11%
Implementation of Real Time Modelling	**350.94**	81.65	34.99	46.66	-57%
Capture Monitored & Measured Data	**49.61**	-	0.00	0.00	0%
Analyse Monitored and Measured Data	**157.49**	-	0.00	0.00	0%
Verify and Modify Advanced Network Models	**253.89**	27.98	27.81	0.17	-1%
Gather Performance of Mitigation Technologies	**50.07**	-	0.00	0.00	0%
Knowledge Capture and Learning Dissemination	**281.62**	27.35	11.16	16.20	-59%
Procurement & Installation Support	**78.69**	8.27	7.74	0.53	-6%

	Total Budget	Expected Spend to Date Nov 2013	Actual Spend to date Nov 2013	Variance £	Variance %
IT	**57.73**	**50.44**	**8.43**	**42.01**	**-83%**
IT Costs	**57.73**	50.44	8.43	42.01	-83%
IPR Costs	**3.29**	**0.00**	**0.05**	**-0.05**	**0%**
IPR Costs	**3.29**	-	0.05	-0.05	0%
Travel & Expenses	**465.62**	**90.92**	**65.41**	**25.52**	**-28%**
Travel & Expenses	**465.62**	90.92	65.41	25.52	-28%
Contingency	**1407.05**	**246.60**	**-**	**246.60**	**-100%**
Project Contingency	**1407.05**	246.60	0	246.60	-100%
Other	**27.21**	**6.08**	**1.62**	**4.46**	**-73%**
Other	**27.21**	6.08	1.62	4.46	-73%
TOTAL	**15,477.38**	**1,500.26**	**691.83**	**808.43**	**-54%**

Table 2 - Progress against budget

4 Bank Account

A bank account was set up in the first reporting period and all monies have been paid in on time.

5 Successful Delivery Reward Criteria (SDRC)

During this second reporting period three planned SDRCs were completed and submitted to Ofgem in a timely manner. Two of these SDRCs (4 and 6) were delivered when planned and another (SDRC-3) has been delivered earlier than planned.

SDRC Milestone	RAG	Planned Date	Submitted Date	Comments
SDRC-1 EFLA Process	Green	1st June 2013	31st May 2013	Complete on time
SDRC-2 Detailed Design complete	Green	1st June 2013	31st May 2013	Complete on time
SDRC-5 Procurement Report	Green	31st Dec 2013	24th April 2013	Early Completion
SDRC-3 DNO Workshop (Gamma)	Green	31st Oct 2013	11th Oct 2013 W/shop on 4th Sept 2013	Early Completion
SDRC-4 EFLA Implementation	Green	1st Dec 2013	29th Oct 2013	Complete on time
SDRC-6 Evidence Gamma learning	Green	31st Dec 2013	21st November 2013	Early Completion

Table 3 - SDRCs delivered in reporting period

5.1 SDRC-3 (Fault Level Mitigation Technologies DNO Workshop)

The purpose of this report was to provide a summary of the Fault Level Mitigation Technologies Distribution Network Operator (DNO) Workshop held in Birmingham on Wednesday 4th September 2013, fulfilling the Fault Level Mitigation Technologies Successful Delivery Reward Criterion (SDRC-3). This is summarised below.

Hold a workshop, inviting all GB DNOs and other interested parties by 31 October 2013. At the workshop, the implementing DNO will:

a) provide details of the emerging learning of Method Alpha (Enhanced Fault Level Assessment) and Method Beta (Real-time Management) and the proposed methodology for Method Gamma (Fault Level Mitigation Technologies); and

b) provide GB DNOs and other interested parties the opportunity to provide feedback on the proposed methodology for Method Gamma (Fault Level Mitigation Technologies), based on the emerging learning of Method Alpha (Enhanced Fault Level Assessment) and Method Beta (Real-time Management).

The SDRC-3 document captures the information presented to the GB DNOs, where at least one representative from each DNO was present, in a presentation format and records of the workshop attendees.

5.2 SDRC-4 (Implementation of Enhanced Fault Level Assessment Process)

The specific deliverable of SDRC-4 was to have implemented the Enhanced Fault Level Assessment Process. This document was submitted to Ofgem on 28th November 2013. It documents the sensitivity of fault level calculations based on the accuracy of the input parameters, described in section 1.4.2, and comparisons of current methods and techniques employed by UK DNOs and an enhanced method proposed as part of FlexDGrid.

This document outlines the sensitivity of fault level calculations to the specific input network parameters based on current, DNO standard, methods and techniques. With endorsement from WPD's planning engineers, the SDRC-4 document also demonstrates what can potentially be achieved with customers' connections through an increased frequency of fault level assessments and by developing an integrated network model for power system analysis (described in section 1.3). Through a workshop with other DNOs (held at the IET in Birmingham on 23rd October 2013) the implementation of the enhanced fault level assessment process has been peer reviewed, challenged and approved.

5.3 SRDC-6 (Evidencing Method Gamma Will Provide Outlined Learning)

This required of the sixth Successful Delivery Reward Criterion of FlexDGrid was to evidence that Method Gamma will provide the outlined learning as documented in the Full Submission Pro-forma. The purpose of this document is to detail that the requirements specified in Section A of the Project Direction document, provided by Ofgem, have been satisfied.

A detailed design document, providing site specific information on the five Primary Substations and the inclusion of the Fault Level Mitigation Technologies along with a functional description of the technologies proposed by manufacturers during the technology procurement process, was made available to all GB DNOs. The information within this design document, as well as update on the learning to date of Methods Alpha and Beta, was presented in a DNO workshop on the 4th September 2013 (as detailed in SDRC-3, section 5.1) and following this written responses from all DNOs was provided and documented within SDRC-6.

5.4 Next Steps

Table 4 captures the remaining SDRCs for completion during the project life cycle.

SDRC Milestone	RAG	Planned Date	Forecast Date	Comments
SDRC-7 Open-loop test of FLMs	Green	31st Dec 2015	31st Dec 2015	On track
SDRC-8 Open-loop test of FLMTs	Green	31st Dec 2016	31st Dec 2016	On track
SDRC-9 Closed-loop test of FLMs & FLMTs	Green	31st Dec 2016	31st Dec 2016	On track
SDRC-10 Analysis & Benefits	Green	31st Dec 2016	31st Dec 2016	On track
SDRC-11 Novel commercial aggs	Green	31st March 2017	31st March 2017	On track

Table 4 - SDRCs to be completed

At this stage in the project all future SDRCs are on track. As all SDRCs have some degree of interdependency the importance of ensuring that FlexDGrid remains on track with all SDRCs is critical to delivering the proposed learning.

6 Learning Outcomes

Learning outcomes have been detailed in all six SDRCs submitted and approved to date (SDRC 1-6).

Specific learning on the Enhanced Fault Level Assessment (EFLA) Process is documented in SDRCs 1 and 4. Learning outcomes for the EFLA Process centre on the information captured within Figure 5, which details the important factors affecting the variation in modelled fault level dependent upon their distinct values. This learning has allowed the focus of the next phase of the EFLA Process to be determined based on the factors with the most significant effect on fault level based on their value accuracy.

Learning on the methodology for the installation of FLMs and FLMTs on to an existing 11kV distribution network with Primary Substations has also been developed. This learning will continue to be developed through to the final installation of the technologies, where an open source ‘how to connect’ guide will be produced. This will build on learning presented in SDRCs 2, 3 and 6.

In this reporting period learning has been shared in two FlexDGrid organised DNO workshops (4th September and 23rd October) along with the LCNF Conference (13th and 14th November).

7 Intellectual Property Rights

A complete list of background IPR from all project partners has been compiled. Relevant foreground IP for Methods Alpha, Beta and Gamma has been identified and recorded in this reporting period. The IP register is reviewed on a quarterly basis.

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 WPD’s risk management processes and the governance requirements; and
- anticipate and respond to changing project requirements.

These objectives are achieved by:

- ✓ defining the roles, responsibilities and reporting lines within the team for risk management;
- ✓ including risk management issues when writing reports and considering decisions;
- ✓ maintaining a risk register, through the project RAID log;
- ✓ communicating risks and ensuring suitable training and supervision is provided;
- ✓ preparing mitigation action plans;
- ✓ preparing contingency action plans; and
- ✓ regular monitoring and updating of risks and the risk management strategy.

8.1 Top five current risks (by rating)

Risk	Risk Rating	Mitigation Action Plan	Progress
We do not meet the deadline for gaining Ofgem approval for the 'Customer Communications Plan'.	Major	To create the 'Customer Communications Plan' early in case revisions are required from Ofgem prior to being able to commence surveys.	The 'Customer Communications Plan' is in progress with a provisional completion date for submission to Ofgem set for the end of December 2013.
The operation of FL Mitigation Technologies cannot be validated.	Major	Rigorous Factory Acceptance Testing (FAT).	FAT requirements are actively being developed with the product manufacturers.
Outage conflicts with network services to install equipment arise	Moderate	Thorough engagement with network services to understand their programme of works and timescales.	Detailed work carried out with Major Projects to minimise this risk. Project Engineer leading the construction work for the 10 sites who fully understands the network services programme.
Fault level calculations produce a fault level value that is significantly different than the monitored value.	Moderate	Accurate recording of monitoring equipment tolerances, factory acceptance test of equipment, validation of monitored value against actual fault current (if this occurs during the course of project).	Detailed investigation of the FLM was undertaken during the procurement tender process. Detailed design work and site characterisation is currently on-going with the FLM manufacturer.
We are unable to evidence a quicker response to customers' connection applications.	Moderate	Early interaction with HV planners who currently prove customers' connection applications in the FlexDGrid and wider WPD network regions.	Actively documenting the time taken to respond to customers' connections in the FlexDGrid region and providing iterative updates on time to connect through detailed FlexDGrid network model analysis.

8.2 Graphical Representation of Risk Register

The FlexDGrid risk register is a live document updated on a weekly basis in formal project meetings. Below is a snapshot of the risk register, detailed graphically, to provide an on-going understanding of the projects' risks. There are currently 53 live project related risks.

Likelihood = Probability x Proximity						
	Certain/Imminent (21-25)	1	0	0	0	0
	More likely to occur than not/Likely to be near future (16-20)	0	0	1	0	0
	50/50 chance of occuring/Mid to short term (11-15)	0	3	1	0	0
	Less likely to occur/Far to Mid to long term (6-10)	1	1	8	9	1
	Very unlikely to occur/Far in the future (1-5)	2	2	9	12	2
		1. Insignificant changes, re-planning may be required	2. Small Delay, small increased cost but absorbable	3. Delay, increased cost in excess of tolerance	4. Substantial Delay, key deliverables not met, significant increase in time/cost	5. Inability to deliver, business case/objective not viable
		Impact				

	Minor	Moderate	Major	Severe	
Legend	15	26	12	0	No of instances
Total	53				No of live risks

Table 5 - Graphical view of Risk Register

8.3 Percentage of risks by category

The chart below 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. There are currently no severe project risks.

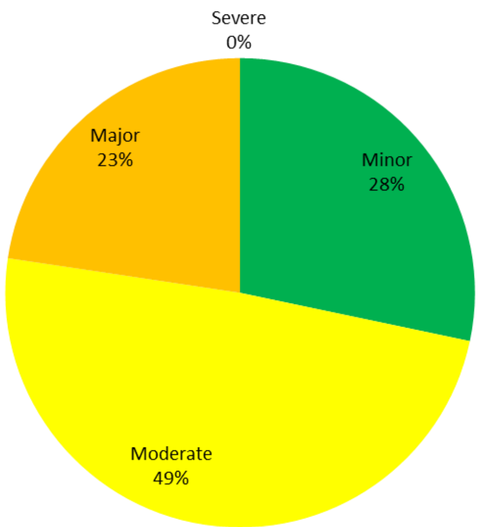

Table 6 - Percentage of risks by category

8.4 Project phase risks (Previous Six Monthly Progress Report)

Descriptions of the most significant risks provided in the previous six monthly progress report are provided below with updates on their current risk status.

Risk 1 – equipment procurement / delivery is delayed by supply chain
Status – Major to Moderate

Following completion of the procurement tender process we now have a greater understanding of the manufacturers' availability to build and deliver the technologies. As expected different technologies and manufacturers have different timescales to supply equipment, which is useful for the programme of delivery.

Risk 2 – 10 substations in Birmingham cannot accommodate FLM
Status – Minor to Closed

The procurement activities for the FLM are now complete. Each of the ten Primary Substations identified for the inclusion of FLMs has been designed to the stage that a FLM has been proven to be able to be installed successfully.

Risk 3 – Evidence feedback from other GB DNOs to proceed to the method Gamma is unsatisfactory
Status – Moderate to Closed

A workshop has been held a part of providing evidence that other GB DNOs are satisfied that proceeding to Method Gamma is appropriate (SDRC-3). The representatives from each DNO were then asked to write a letter in response to the information they had been provided. All the DNOs have written within their letters that the information provided allowed them to consider that the original learning set out in FlexDGrid's Full Submission Pro-Forma can be met and that there is merit in proceeding with the procurement of the Fault Level Mitigation Technologies (SDRC-6).

Risk 4 – The operation of FL Mitigation Technologies cannot be validated
Status – Major

Fault Level Mitigation Technologies can only be validated by operating successfully under a fault condition. As part of the manufacture and installation process of all FLMTs there will be a laboratory test to confirm its performance under a fault condition. Work has been undertaken to understand the fault frequency, at each of the five Primary Substations chosen for FLMT inclusion.

Risk 5 – University of Warwick does not sign a contract with WPD
Status – Severe to Closed

The collaboration agreement is now signed and UoW team members are now actively working on FlexDGrid.

8.5 Bid Phase Risks

Descriptions of the most prominent risks, identified at the project bid phase, are reported below.

Risk 1 – Insufficient WPD resource for project delivery
Status – Major to Minor

Significant interaction with the WPD delivery teams has taken place. The site specific detail has been presented and a delivery engineer has taken ownership of the site construction activity.

Risk 2 – Partners and supporter perception of the project changes
Status – Major to Minor

Detailed schedules of work (SoW) have been produced for the complete project activities with both PB and UoW. These SoWs are the basis of the contractual collaboration agreements between each party.

Risk 3 – Cost of high cost items are significantly higher than expected
Status – Major to Closed

Procurement activities for the high cost items have now been successfully completed within originally identified budget.

Risk 4 – No suitable Fault Level Mitigation Technologies will be available
Status – Major to Closed

Procurement activities for the high cost items have now been successfully completed and meet the site requirements.

Risk 5 – No suitable Fault Level monitors will be available
Status – Major to Closed

FLMs for each site have been procured.

Risk 6 – The overall project scope and cost could creep
Status – Major to 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.

Risk 7 – A partner may withdraw from the project or have oversold their solution
Status – Major to Moderate

A contractual collaboration agreement is in place with both PB and UoW for the project. Delivery of six SDRCs to date has delivered confidence that project partners can provide the required solution.

Risk 8 – The project delivery team does not have the knowledge required to deliver the project
Status – Major to 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.

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 have been completed on, or before, schedule, ensuring that the proposed delivery plan at the full submission state is still applicable in project delivery.

10 Accuracy Assurance Statement

This report has been produced by the FlexDGrid Project Manager (Jonathan Berry), recommended by the Future Networks Manager (Roger Hey) and approved for release by the Operations Director (Philip Swift).