Flexible Plug and Play Low Carbon Networks

Project Progress Report December 2013

UTILITY INDUSTRY ACHIEVEMENT AWARDS 2012

UTILITY OF THE YEAR

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Contents

1 Executive Summary

The Flexible Plug and Play (FPP) Low Carbon Networks project aims to demonstrate how, through the integration of innovative technological and commercial solutions, a cost effective connection of Distributed Generation (DG) to constrained parts of the distribution network can be achieved.

The FPP project was awarded funding of £6.7million by Ofgem, under the Low Carbon Networks Fund (LCNF) scheme, on 19 December 2011 and the project started on 1 January 2012.

The main focus of the second year of the project has been the design and construction of the FPP technical platform and finalising and offering FPP interruptible connection offers. The main outcomes have been the completion of the FPP technical platform which is now fully operational and the acceptance by DG customers of five FPP connection. As such, and as seen throughout the report and especially in Sections 2 (Project Managers report) and 7 (Learning outcomes, significant knowledge has been generated and disseminated through various channels for use by other Distribution Network Operators (DNOs).

This six monthly reporting period (July 2013 – December 2013) is the fourth for the project and saw the successful completion of the fourth and fifth Successful Reward Criterion (SDRC) deliverables (SDRC 9.8 – Deployment of Quadrature-booster within the trial area and SDRC 9.4 – Demonstrate FPP technical characteristics of FPP solution). These SDRC marked the completion of the FPP technical platform.

The Quadrature-booster delivered in July 2013 under SDRC 9.8, to our knowledge it is the first in the world to be deployed on a 33kV distribution network to balance two parallel overhead lines to provide additional capacity without the need for additional network reinforcement. The delivery of SDRC 9.4 has pushed the boundaries of technical innovation demonstrating the interoperability between technologies, such as Active Network Management (ANM), Dynamic Line Rating and Remote Terminal Units to manage distribution network constraints utilising the IEC 61850 protocol.

Through extensive customer engagement, the project has successfully signed up five customers that will connect onto the distribution network using the FPP methods. The five customers represent a total of 19.25MW with three wind projects (10MW, 8MW, 0.5MW), one solar Photovoltaic (PV) project (0.25MW) and one Anaerobic Digester (AD) project (0.5MW). Due to their size, the projects will be connected to different voltages levels on the distribution network (33kV, 11kV and LV). The technical diversity of the connections for this portfolio of projects is expected to provide UK Power Networks' teams with extensive experience and rich knowledge that will be invaluable for the business-as-usual roll out of this approach.

The first of the energisation is planned for January 2014 with the rest to follow later in 2014.

Moreover, due to the geographic location of each project, we have been able to offer two different 'principles of access' (the Capacity Quota mechanism and Last-In-First-Out), which follow on from the extensive work completed throughout 2012 within the commercial arrangements workstream. This places us ahead of schedule for delivery of SDRC 9.7 and proves that our connection agreements reflect an attractive offer to customers.

The FPP project continues to make customer recruitment a priority of the project. As of 6 December 2013 eighteen connection offers have been issued, five of which have been accepted. It is anticipated that more will come through as accepted offers in due course. A more detail is provided in section 2.1.1

The final year of the project (2014) will see extensive technical trials of the FPP technical platform in accordance with the FPP bid Use Cases. These will comprise of a combination of data gathering and analysis, simulated events and real operations in the case of the connected customers. The FPP trials will be simulated with defined limits before the operational phase to ensure the connected customer are not exposed to technical risks arising from the trials carried out.

In addition, 2014 will see the completion of the Strategic Investment Model (SIM) which will be used to assess different scenarios and network investment strategies in networks with increased penetration of DG. Finally, further work will be carried out on the commercial workstream to conclude on the most suitable principle of access for the business-as-usual roll out planned by UK Power Networks by 2015 and to further explore the cost allocation of reinforcement in actively managed networks.

Risks

Recruitment risks

The FPP project recognised from the bid stage that a key risk to demonstrating the technical and commercial innovation developed by the project is the lack of customer participation to its trials (Bid risk R004). This has been successfully managed with excellent stakeholder engagement from the start of the project and mitigated by signing up five customers for the FPP 'interruptible' connections, most of which will be live by summer 2014. However, the FPP project continues to engage and recruit customers to ensure the project is a success and to have a deep understanding to how multiple customers react to the proposed commercial arrangements.

Learning outcomes

The key areas where the project has seen significant learning outcomes relate to the FPP systems integration, the installation of the Quadrature-booster and the on-going engagement with customers.

The project has learnt that multi-vendor technical solutions can be integrated on a single platform by using open standard IEC 61850 standard.

We designed and installed the first 33kV Quadrature-booster and we have learnt that it does create more capacity on parallel overhead lines of the network.

We have been able to understand the key drivers of DG customers and consequently, the process for offering 'interruptible' connections are been optimised. We have also learnt that customers are willing to accept curtailment levels ranging between 3-5.3% in a reduction of their expected annual output, and appear to still be able to finance schemes with this level of curtailment

Please refer to sections 2.1.1 and 7.1 for further learning and more detail.

Knowledge Dissemination

The FPP project team puts particularly emphasis on external learning dissemination and that can be evidenced by the five SDRC learning reports available in the public domain and the number of presentations and papers presented in various industry events. In addition, we have engaged in bilateral discussions with other DNOs, for example with Western Power Distribution's Low Carbon Hub project on connection agreements, to ensure that the value of the learning generated by the FPP project can be maximised by being used by other DNOs who are working on similar topic areas.

In addition, dissemination internally is happening both by design as the project team works very closely with an extensive number of business teams and stakeholders, but also by attending and presenting the work carried out to wider company audiences.

Full details of the learning dissemination activities can be found in section 7.2.

2. Project Manager's report

2.1 Progress in current reporting period

2.1.1 Customer engagement

Flexible Plug Play connection offer

The commercial workstream has focused on continuous engagement with customers who have been offered the FPP option to support their decision-making, identify new potential opportunities and offering FPP connections. In parallel we have developed our thinking further on the Capacity Quota smart commercial framework as originally developed by the FPP project in 2012.

We have seen an increased number of FPP offer acceptances and applications for connection in this reporting period, as a result, we have now offered the full Capacity Quota of 33.5 MW in the March Grid constraint under a pro-rata principle.

Customer Recruitment

Table 1 below summarises the DG developers with which the FPP project has engaged so far and the status of their FPP offers. For the purpose of clarity, we have redesigned the table with the customers to which connections have been offered and have not yet expired, indicating the current status of their offer.

Table 1: The status of the FPP 'interruptible' connection offers

Generator	MVA	Tech	Status
Generator 01	**8.00**	**Wind (33kV)**	**ACCEPTED**
Generator 02	0.50	Wind (11kV)	Re-requested – Offer valid until Jan14*
Generator 03	**10.00**	**Wind (33kV)**	**ACCEPTED**
Generator 04	5.00	Wind (33kV)	Expired
Generator 05	1.50	Wind (11kV)	Re-requested – Offer valid until Jan/14*
Generator 06	1.00	Wind (11kV)	Expired
Generator 07	10.25	Wind (33kV)	Offer valid until Jan/14
Generator 08	**0.50**	**CHP (11kV)**	**ACCEPTED**
Generator 09	2.40	PV (33kV)	Offer valid until Feb/14
Generator 10	0.50	CHP (11kV)	Expired
Generator 11	6.60	PV (33kV)	Offer valid until Oct/14
Generator 12	**0.50**	**Wind (LV)**	**ACCEPTED**
Generator 13	7.00	PV (33kV)	Offer valid until Feb/14
Generator 14	4.00	PV (33kV)	Offer valid until Jan/14
Generator 15	**0.25**	**PV (11kV)**	**ACCEPTED**
Generator 16	1.50	CHP (33kV)	Offer valid until Feb/14
Generator 17	6.93	PV (33kV)	Offer valid until March/14
Generator 18	0.50	PV (33kV)	Offer valid until Feb/14
Generator 19	11.84	PV (33kV)	Have requested offer, due February/13

* Initial offers sent on 1 March 2013, expired by 1 June, 2013.

As of 18 December 2013, there are five connection offers accepted that add up to 19.25MW. Two of them connect to Peterborough Central Grid substation and three of them are part of the March Grid quota.

We have now issued enough offers to fill the quota at March Grid. This requires us to monitor and manage the status of the quota so we can report to customers if there is any change in the position of the LIFO queue based on the date of connection request, which is reflected in an improvement of their estimated curtailment figures.

Table 1 also presents the variation in generation technology of the projects that have applied connection to the distribution system in the FPP trial area and they have ranged from wind and solar to Combined Heat and Power (CHP) plants. Each technology and size of project make each customer specific and this is reflected in diverse challenges and particular queries around each type of technology. For example:

WIND: Specific turbines might not suitable for operation with an ANM system. One of the turbines considered by a project participant can be curtailed by up to 30% of its actual output at a time. Further analysis was done to quantify when curtailment would be greater than 30% of generation as measured at the turbine (i.e. not net export). This way the developer would make an informed view on how appropriate that specific turbine would be for an interruptible connection.

SOLAR: Since the FPP project started, there has been significant growth in FPP connection applications from developers of solar PV plants (initially the list or pipeline of projects was formed primary of wind projects). Our curtailment estimates explain the assumptions behind the 11% assumed capacity factor and customers in the area have had to evaluate the potential of 2.7% curtailment. However, understanding the curtailment control signals and evaluating the interface between the ANM system and the solar installation has been a critical element for understanding how to connect an interruptible PV customer.

CHP: Additional analysis has been done on understanding the potential for CHP plants to be actively managed. Renewable energy projects, such as wind and solar, are accustomed to uncertainties regarding intermittent generation. However, CHP plants such as AD, or "always-on" technology, are designed to have 100% capacity factor, which means that they are designed to operate all of the time. One of the key questions that arises is what to do with the gas or heat in the occurrences that the plant is not allowed to generate and if there is an alternative solution to store them. We have issued four connection offers to CHP plants and have received one acceptance. We are looking forward to working closely with them to understand the technicalities of connecting a CHP generator to the ANM system.

Some of the most interesting results on curtailment analysis have been to understand the impact of applying pro-rata curtailment over LIFO. Figure 1 highlights the expected curtailment levels for the projects in the current pipeline of the March Grid constraint for the two different approaches:

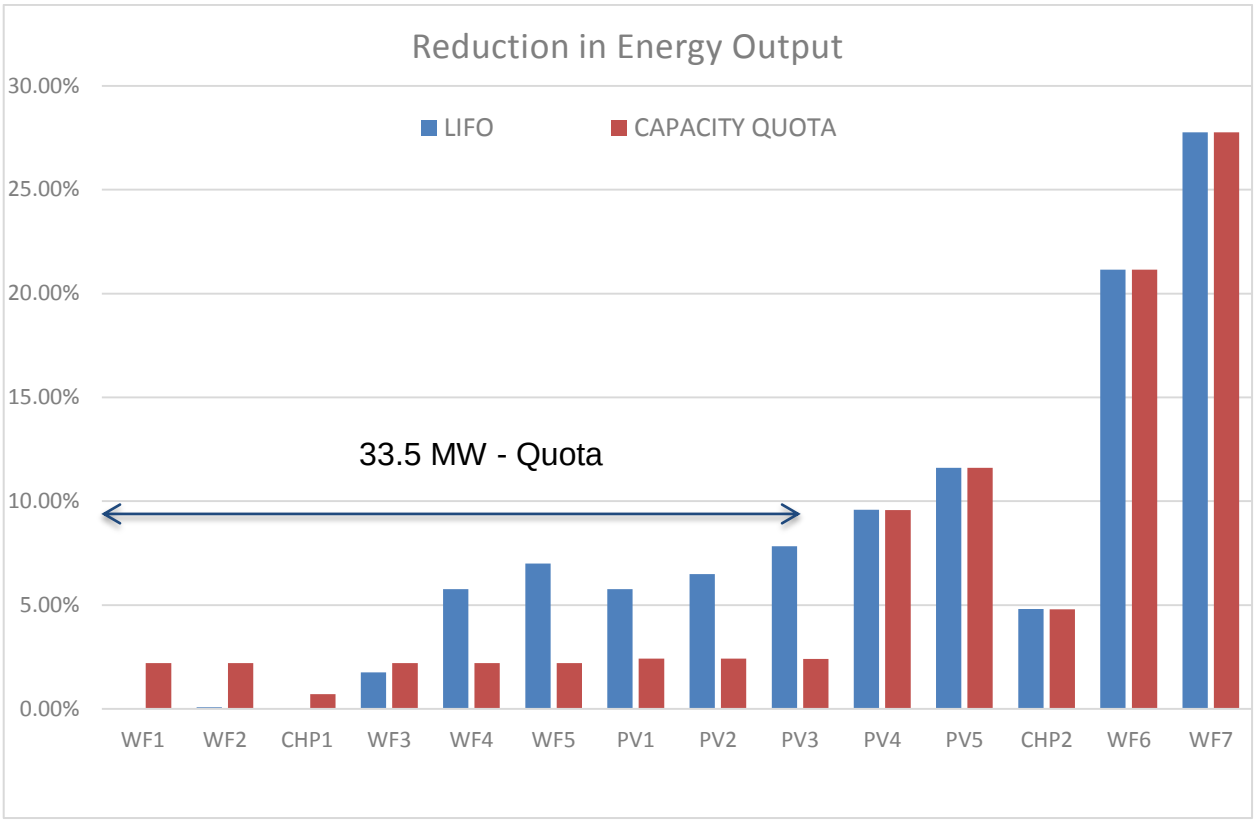


Figure 1 Principles of Access Assessment – Pro-Rata versus LIFO

* Please note that this analysis reflects the order of the connections that were valid at the point of assessment and its purpose is to signal the difference in levels of curtailment from implementing pro-rata versus LIFO in a specific case study.

** WF refers to wind farms, PV refers to photo voltaic installations and CHP refers to always on technology such as anaerobic digesters.

There are five key interesting points associated with Figure 1:

1. **Pro-rata allows more generation to be connected at reasonable levels of curtailment.** When modelling the actual order of the projects in the pipeline under a LIFO principle, results are extremely favourable to the first four projects in the pipeline, but less favourable for the projects after. If a "tolerable" level of curtailment was indeed 5.3%, all projects after the fourth application, in this case WF4, would not accept the FPP alternative.

2. **A balanced generation mix has a positive impact on curtailment.** One of the key design assumptions for the quota scheme is the generation mix. For the FPP project a 100% of wind mix was chosen at the beginning of the project, as it represented the pipeline at that point in time. It also provided a realistic "worst case" scenario for the projects and gave the greatest test on financeability. This worst case represented a value of 5.3% curtailment for wind farms and 2.7% for

solar projects. However, since then significant amounts of solar PV have emerged and now that the portfolio seems more balanced with 33% of the quota covered by PV requests, curtailment has dropped to less than 2.2% for both technologies.

3. **Estimating the capacity quota adequately is relevant for optimising the available interruptible capacity.** The FPP offer for the March Grid constraint is based on a pro-rata principle up to the quota capacity limit. Once the limit is reached, the customers are guaranteed that curtailment will be applied on a LIFO principle. When setting the quota, several assumptions are made, including the energy mix or composition of the generation that will connect. Often the offers that are requested deviate from the original assumption, altering the expected levels of curtailment. Based on Figure 1, PV4 will be curtailed down to zero before any of the other customers within the quota experience any curtailment. As seen in the chart, levels of curtailment for anyone connecting under LIFO are extremely high (10%). However, assuming a "tolerable" level of curtailment is 5.3%, if we had considered a more balanced generation mix, the quota would have been greater than 33.5MW and we would have connected more projects within a reasonable curtailment levels.

4. **Both Last-in-First-Out and Quota approach can be complex to manage at increased volumes.** Administrative complexity becomes evident when more and more projects request connections. Connection offer curtailment estimates for the projects in the LIFO queue become dependent on previous customers accepting or rejecting their FPP offers. This has shown to us that once a quota is defined, offering connections for projects within the limit is relatively simple, as all receive the same "worst case scenario" curtailment estimate. However, the LIFO principle, although it may appear to be the simple option for its natural first come first serve nature, is not as simple when determining specific curtailment estimates for a project in the last position.

5. **Pro-rata curtailment shares the impact of the constraint and therefore provides a better scenario for discussing with customers the possibility of sharing reinforcement costs.** In a pro-rata scenario, the participating generators share the burden of constraint which might incentivise discussions of sharing reinforcement costs. It brings forward generation, that might have otherwise not connected, in a pool of customers under the same terms and conditions.

A further piece of analysis has looked at the detail of how interruptions are forecasted. This means understanding when or how many times curtailment occurs, how long interruptions last, and how much energy is expected to be curtailed for each interruption. Although all of these results are only forecasts, they are still useful for developers and turbine or engine providers to understand if their products are suitable and how these might perform under a system such as ANM as shown in Figure 2 below.

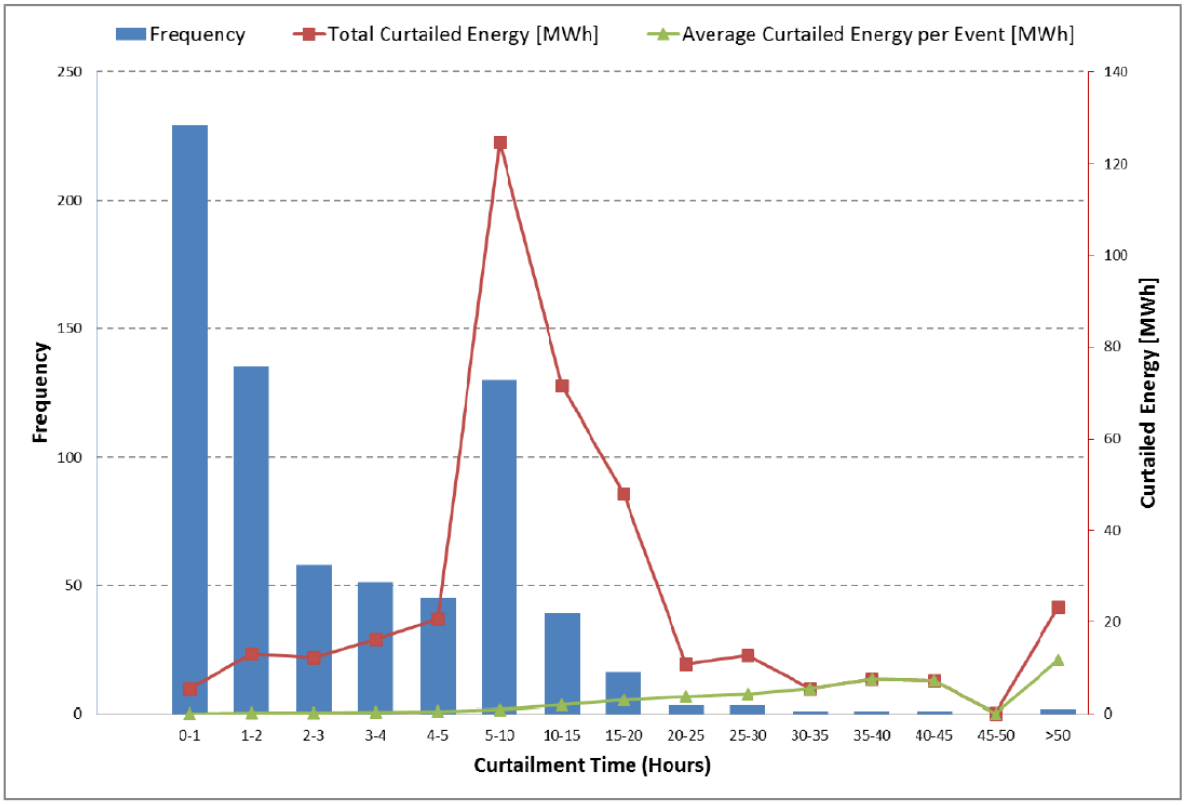


Figure 2 Frequency distribution of curtailment time and energy curtailed over five years of a 1.5MW CHP plant

Figure 2 shows we can provide customers with the analysis that shows the number of curtailment events in according to the length and their loss of energy. For example, out of the total of 714 events in the 5 years of analysis, 229 events (left axis) last for 1 hour or less, the total curtailed energy associated with those events is 5.37 MWh (right axis), and the average curtailed energy of those short events is 0.0235 MWh.

Progress of delivery of accepted connection offers

For the customers who have accepted their FPP connection offers, progress has been made in defining the technical requirements to deliver these connections. Kick-off meetings with UK Power Networks' Capital Programme and Connections departments have been held with the customers to initiate the plans to connect them over the summer 2014 or earlier in some instances.

Technical support in dealing with connection offers and customer queries continues to be provided. The design for the integration of the ANM system to the developers' DG control systems is currently in progress with the accepted DG customers. In parallel to all these activities, the team is also engaging with the business to ensure for an effective handover of the FPP infrastructure to the business-as-usual operations and maintenance teams. This will involve identifying and developing additional technical and process documentation, organising training, workshops and open days for the relevant parties.

Specifically, the customers that have accepted their offers are currently in different stages which are summarised in Table 2 below:

Table 2: Status of accepted connection offers

Generator	MVA	Expected energisation date*	Expected date to commence operation*
Generator 01	8	May 2014	June 2014
Generator 03	10	July 2014	January 2015
Generator 08	0.50	TBC 2014	TBC 2014
Generator 12	0.5	TBC 2014	TBC 2014
Generator 15	0.25	December 2013	January 2014

*Connection dates and commencement of operation dates as provided by the customers, these may change as the projects evolve.

2.1.2 Communications Platform (SDRC 9.3)

The FPP project team continues to oversee the operation, optimisation and upgrade of the Radio-Frequency (RF) mesh network. Since installation, the RF mesh network has been upgraded from generation-2 hardware to generation-4 hardware which offers considerable improvement in data capacity and radio performance. The communications network maintenance responsibilities have been handed over to business-as-usual operational team.

During the last reporting period, there was a failure of one of two RF mesh Access Points at one of the backhaul communication sites in Peterborough Central. The fault was managed and resolved by the business-as-usual process with no involvement from the FPP project team highlighting the successful handover to the business. During this event, the operation of the RF mesh network was not affected as all the associated RF mesh equipment swapped over to the second Access Point maintaining network monitoring from the Gridscape application. The resilient performance of the communications network during the reported fault scenario further verified that the network does behave in accordance with the intended original design. It appears that the failure of a piece of equipment was triggered by an issue with the local AC power supply and we are carrying further investigation on exact causes and how to mitigate this in the future.

2.1.3 Smart Devices

In line with the project Use Case as included in the bid document, with the exception of the frequent use switches, which have been covered as part of change request (Ref:CR0014), all smart devices were successfully deployed across the trial area as part of the SDRC 9.8 and 9.4, which were achieved in August 2013 and September 2013 respectively. The following activities were completed in the reporting period:

Quadrature-booster

The Quadrature-booster was successfully installed and commissioned in July 2013 and has been designed to shift real power flows from an overloaded circuit to a circuit that is less loaded to achieve improved load sharing and increased network capacity headroom. The Quadrature-booster is equipped with an automatic control system that drives an on-load tap changer to control the power flows in discrete steps.

The next stages of the trial will focus on identifying the additional headroom which has been created as a result of the integration of the Quadrature-booster. The initial analysis following the commissioning of the system indicated that additional headroom of approximately 10MW will be created. To validate this, monitoring equipment has been installed on the three feeder circuits which will be used to capture data over a period of a year to understand the seasonal variations in the headroom that has been created and to confirm the fixed headroom that is available.

Following the successful deployment of the Quadrature-booster, power quality monitors were installed for continued monitoring and analysis of its performance, and marking the beginning of the structured trial phase of the Quadrature-booster. Two Engineering Operating Standards (one for the Quadrature-booster, and the other for the Quadrature-booster Control System) were prepared and approved, providing UK Power Networks' control operations and Wissington British Sugar's technical teams with crucial guidance in on the operation and control of the Quadrature-booster.

Dynamic Line Rating

Four dynamic line rating systems were successfully deployed across the trial area. These systems each calculate a real-time ampacity value for a section of 33kV overhead-line based on local measurements of the weather conditions which, in favourable weather conditions i.e. windy, will enable the maximum capacity of the conductor to be managed in real-time. This is a development on the existing approach to calculating the capacity for the overhead lines which is based on conservative assumptions for the base case weather conditions. This additional capacity can be released to enable the connection of additional generation to the distribution network.

These systems are currently in operation and will be used to collect data for the ampacity, wind speed, wind direction and ambient temperature, which will be used to evaluate the system further and, ultimately, enable it to be developed such that it is suitable for adoption within business-as-usual activities. The objectives and detailed description of this evaluation have been created to structure and define a set of suitable outcomes for the trial. The focus of these trials is to validate the approach and to gain confidence in the end-to-end system operation. The system also forms part of the flexible connection that has been offered, which will provide an opportunity to test the end-to-end system in a live situation and understand the requirements, as well as any potential issues, from doing so.

Novel Protection Relay

To investigate alternative means of providing suitable back-up protection for the 132kV network, two novel protection relay systems have been successfully deployed at two grid substations within the trial area. The novel protection relays installed have a multitude of functions that can be configured as a replacement to the directional overcurrent philosophy and forms one of the major benefits of using these relays. The relays have been programmed to generate alarms resulting from directional negative phase sequence, which are

generated during unbalanced faults, and voltage dependant overcurrent, which can detect and clear balanced faults. These systems are currently in operation and will be evaluated over the trial period to determine their suitability as a back-up protection system for the 132kV network.

An alternative approach currently under consideration is the introduction of load blinding and voltage drop functions within the existing directional overcurrent system, which would be combined with the directional overcurrent functionality and enable it to react to reverse power flows only in the event of a change in circuit impedance or as a result of a significant voltage drop, both of which could occur during fault conditions. This approach can be implemented and trialled as part of the existing set up and the FPP team is planning its implementation.

Automatic Voltage Control

Two advanced automatic voltage control systems have been deployed at a grid and a primary substation that supports a large capacity of DG. These systems are configured to consider the influence from DG when managing the voltage levels on the network and incorporate the IEC 61850 protocol. The trials associated with these systems will focus on the interoperability enabled through IEC 61850, which includes the ability to remotely change the target voltage, which will be determined and configured by the ANM system.

Frequent Use Switches

Ring Main Units (RMUs), which are being installed as part of business as usual activities, are being used instead of Frequent Use Switches, and has resulted in a refund of the funding back to Ofgem's LCN fund associated with the supply/design/installation and commissioning costs for the Frequent Use Switches.

Remote Terminal Unit (RTU) Deployment

To enable the integration of these smart devices into the Flexible Plug and Play trials, as well as the wider UK Power Networks' Supervisory Control and Data Acquisition (SCADA) system, the existing remote telemetry units were replaced, as the existing RTUs did not have necessary functionality to support these interfaces. The new RTUs, which were installed in the twelve substations in the trial area, have the necessary functionality to support these interfaces including the IEC 61850 server functionality, which is being trialled as part of the project.

2.1.4 Smart Applications

In this reporting period the project's main focus was the commissioning of the ANM production platform which is the operational system that will control the DG participants for the trial and it is located in the UK Power Networks' control centre.

The production platform is a full scale version of the ANM system which will be used during the trial compared to the pre-production platform specifically used for the integration. The platform consists of two pairs of redundant servers similar to what is required for SCADA system. Each pair of servers is divided into a communication front end server and an application server. The communication front-end server performs all data handling via a range of standard protocols. The application server is an execution environment upon

which the Smarter Grid Solutions smart applications (i.e. Power Flow Management Application, Voltage Management Application and Dynamic Ratings Application) are deployed.

The production platform successfully passed the final Site Acceptance Tests in good time for meeting the completion of SDRC 9.4 in September. The process for testing and commissioning the ANM platform is described in detail in technical report for SDRC 9.4 that can be found on the FPP website (www.flexibleplugandplay.co.uk)

The integration with other UK Power Networks' information systems such as PI (Data historian) and ENMAC (SCADA) has been also completed in preparation of the trial.

As described in section 2.1.5, all the smart devices have integrated and tested with the ANM production platform during the field commissioning process to ensure the effective communication and data transmission from end-to-end.

Following the successful completion of SDRC 9.4, the project has been defining the ANM trial approach describing the general methodology to deliver the key learning outcomes described in the bid Use Cases on active power and voltage management of distribution networks.

2.1.5 System Integration

The system integration activities, in parallel to the field commissioning process, have been the core activities of the reporting period aiming to demonstrate the technical characteristics of the FPP solution and the completion of SDRC 9.4.

The FPP technical solution implemented smart devices from various vendors to address and manage specific existing or anticipated network constraints and operational limitations of the network that either restrict DG connections or are introduced by the connection of DG. The smart devices were connected to the FPP solution using a Local Area Network deployed the substation level. This scheme provided connectivity to the devices located in the same substations and also to interface with Radio Frequency (RF) mesh linking to the FPP Wide Area Network. Ultimately it segregates physically the FPP solution from the existing SCADA communication for security reasons.

Further to the design activities for the IEC 61850 standard, as highlighted in the last reporting period, the project has been closely involved in the implementation of the agreed design. This has included exchanging technical information among vendors, internal stakeholders, consultants and workstream managers to ensure all testing and commissioning of the solutions comply with the functional and non-functional requirement set out at design stage.

The IEC 61850 standard was adopted to ease the integration process and take advantage of the interoperability features provided by conformance devices. All the smart devices involved into the FPP solution have been conformed to the standard as required by the SDRC 9.4. As part of the RTU upgrade, substations were updated to embedded IEC 61850 server functionalities which were developed specifically for the project to provide connectivity between the substation and the ANM production platform. This new implementation has been successfully certified by consultancy DNV KEMA.

The FPP approach to commissioning of the smart devices followed several stages starting with interoperability tests using the pre-production platform and terminating with end to end tests with the devices connected to the RF mesh infrastructure. These various tests involved also simulation tools in order to proceed data integration and functional tests in the lab as described into the System Integration Test Specification document. The results of these tests have been captured into the site commissioning report to provide the necessary evidence of the successful integration of each device into the FPP technical solution.

The project has focused on the IEC 61850 data traffic optimisation over RF mesh network. This activity involved collaborative work with internal stakeholders, DNV KEMA and project partners Silver Spring Networks and Smarter Grid Solutions involving multiple development workshops and lab testing. This process identified some key enhancements, which have been subsequently tested and implemented. One of the key enhancements is the implementation of exception based reporting by smart devices instead of one second polling mechanism from ANM. This has considerably reduced the generation of ANM data traffic. Other enhancements focus on improving the behaviour and handling of IEC 61850 data traffic by application and communications network. Further test cases are being undertaken on the real network conditions with both actual and simulated devices as part of the FPP trial phase. This will also help in identifying the tipping point of the existing FPP communications infrastructure, which means identification of potential scenarios that will require certain upgrade or modification of existing equipment generating valuable learning from the project.

Subsequent to the previous activities involving FPP cyber security design reviews, risk assessments and risk mitigation action planning, the identified actions are being allocated to relevant parties for implementation and testing before the integration of a DG customer. Based on this process, FPP team is currently working with consultants to produce a smart grid cyber security framework as a product of this project that can be used as a template for future smart grid projects were completed.

2.1.6 Strategic Investment Model (SIM)

The second half of 2013 has been fundamental for delivering the SIM. As the model has commenced its build phase, Imperial College London have completed the Requirements and Design documents and approved the Test Work Program. Imperial College London is now working on finishing the building phase of the project.

The list of studies that have been carried out so far includes the evaluation of various solution options for thermal and voltage constraints considering the use of smart grid technologies. Specifically, the following technologies have now been modelled:

- Quadrature-booster;
- Static Var Compensator (SVC);
- Advanced protection schemes to improve the reverse power flow capability of the substation transformer;
- Dynamic Line Rating; and
- ANM as a smart application.

The tool will include various options for managing the curtailment (pro-rata, priority, and cost optimisation). The objective is that the tool allows a multi-year strategic investment in comparison with incremental

reinforcement, maximising the amount of DG that can be accommodated by the current assets considering the use of smart technologies.

So far, the following tasks have been completed:

- Development of optimisation models for circuit, Quadrature-booster, SVC, tap changers and DLR; and
- Initial tests and preliminary studies.

The next phase includes review and validation of the all the input data and models through running case studies and development of the key scenarios that will be used for evaluating the alternative investment strategies in networks with increased penetration of DG.

2.1.7 Trials

Utilising the output from system integration and commissioning, the project has embarked on trial design activities for seven trial cases – ANM, dynamic line rating, novel protection relay, Automatic Voltage Control (AVC), Quadrature-booster, Telecommunications and System Integration. These trial cases will be run over three separate phases:

- Baseline monitoring phase – this is the initial phase of each trial where the settings and configuration of each trial component are finalised in order to maintain consistency throughout the trial phase and provide a reference against which the results can be compared.

- Simulation phase – the second phase utilises real FPP components and simulated components to trial a fully functional FPP network. The results of this phase will be compared with the baseline to ensure that the systems operate as expected or to enable any modifications necessary for it to do so. Any enhancements identified are applied before the next phase.

- Operational phase – this is the third and final stage of the trial which includes customer connections. The results of this phase will be carefully compared against the former two phases to ensure expected operational condition.

Trial Design documents have been produced to define the structure, tests and analyses as well as providing a summary, guide and completeness check for each of the trials. These trial design documents are supported by trial plans, which provide an overview of the tasks, dependencies and resources necessary to deliver the trials.

2.2 Key challenges during this reporting period

The key challenge the project has faced during this reporting period has been focused on the commissioning of a large number of smart devices, as part of the overall FPP technical solution, into a large trial area and also the completion of the relevant technical developments and tests as required by the project. This has involved a number of project workstreams, the majority of the project partners, as well as

resources from a number of different directorates within UK Power Networks, including Network Operations, Capital Programme and IT.

The project plan initiated at an early stage of the project has been extensively used and detailed to ensure the tracking of all the activities to match the SDRC 9.8 and 9.4 deadlines, whilst all the risks and issues identified to affect the delivery of the SDRCs, were recorded and managed the in the project risk register. To support the effective delivery of the SDRCs, weekly plan and risk review meetings with the key Workstream Managers and Design Authority in attendance were held to identify, review and manage the risk and issues and review the project plan to track and monitor the dependencies between all the parallel activities to deliver the technical solutions involving three distinct work packages:

1. Workstream 2 : Delivery of the Smart Devices
2. Workstream 4 : Delivery of the ANM system
3. Workstream 8 : Systems Integration

One of the key aims of the project is to roll-out a multi-vendor independent solution, based on the IEC 61850 standard. For this purpose a key challenge the project faced during this reporting period was to have IEC 61850 certification for all smart devices, as not all of these had the required certification. The certification was to be achieved before the end of September 2013 to meet the SDRC 9.4 criteria. This required the project to work with and manage the smart device suppliers to identify and implement the required functional modifications to meet the IEC 61850 standard. Unlike the other protocols used in the industry, IEC 61850 required independent certification. All of the FPP smart devices had to be certified by an independent test house. The certification process started in August 2013 after the necessary modification were completed. This process lasted until late September 2013 in order to ensure that all the necessary remedial works were finalised to meet the conformance test requirements. It added another layer of technical complexity and project dependencies that the FPP project was exposed, however with the support of all parties involved it was managed effectively and to a successful conclusion.

2.3 Outlook for next reporting period

The project will focus on two key activities during the next reporting period, which will be the energisation of the FPP ‘interruptible’ connections and delivery of the trials. As with all previous reporting periods, the project continues to disseminate the valuable learning generated and actively transfer knowledge to UK Power Networks’ business-as-usual teams.

2.4 Key challenges for next reporting period

To deliver the final three SDRC and learning outcomes, the project will overcome a number of key challenges.

The project has entered the trials phase which will demonstrate and assess the capability of the overall FPP solution. This will be done through the seven trial approaches that have been designed to answer a number of key hypotheses. The challenge the project faces is to design and deliver comprehensive trials that will

fully test all of the hypotheses in parallel to delivering the FPP 'interruptible' connections without any impacting upon the connected FPP DG customers.

In order to do that, we will ensure that any potential impact on the DG customers that could arise from carrying out experiments on the FPP technical platform (and particularly the ANM component) will be removed through designing alternative methods for capturing all of the necessary data required for the verification of the trial hypothesis.

The project has installed and commissioned a number of smart devices and created an overall technical architecture to enable the FPP 'interruptible' connections. A key challenge, as with any other project, is the transferring of knowledge developed from a complex solution and designing effective processes suitable for integration into current business processes. The project has already started transferring activities into business as usual and has been working closely with numerous part of the business to enable a smooth transition.

3. Business case update

We have been able to offer 'interruptible' connections to a number of customers. The key benefit of the project is that those who would otherwise be required to connect at a higher voltage level or very far from their project sites. This is shown in Table 3:

Table 3: The comparison between a business-as-usual connection offer and FPP 'interruptible' connection offer

Generator	MVA	Tech	BAU offer	FPP offer	Savings
Generator 01	8.00	Wind	£3,508,930	£881,611	74.9%
Generator 02	0.50	Wind	£1,891,200	£234,779	87.6%
Generator 03	10	Wind	£4,827,000	£590,818	87.8%
Generator 04	5	Wind	£1,185,000	£649,788	45.2%
Generator 05	1.50	Wind	£1,950,000	£157,137	91.9%
Generator 06	1	Wind	£2,050,000	£384,711	81.2%
Generator 07	10.25	Wind	£5,244,247	£1,584,000	69.8%
Generator 08	0.5	CHP / AD	£1,900,000	£350,000	81.6%
Generator 09	2.4	PV	>£2,000,000	>£ 200,000	90.0%
Generator 10	0.5	CHP / AD	£2,500,000	£117,474	95.3%
Generator 11	6.6	PV	£9,000,000	£1,734,877	80.7%
Generator 12	0.5	Wind	£830,000	£61,293	92.6%
Generator 13	7	PV	>£5,000,000	£997,903	91.3%
Generator 14	4	PV	£2,000,000*	£800.00**	99%
Generator 15	0.25	PV	£57,596*	£750.00**	98.7%
Generator 16	1.50	CHP	>£4,000,000	£127,683	96.8%
Generator 17	6.93	PV	£4,000,000	£390,780	90.2%
Generator 18	0.50	PV	£9,000,000	£385,147	95.7%

Please note that the costs shown in the above table for the FPP offer do not take into consideration the infrastructure costs incurred under the project. i.e. ANM and communications platform.

* The business-as-usual connection offers for Generators 14 and 15 are expensive compared to the FPP offers is a result of there being no more capacity available on that section of the network. Therefore, these projects require different points of connection for having the additional firm export capacity requested.
** Generators 14 and 15 FPP offers are not comparable to the other projects and equivalent savings as they are existing connections that only require additional capacity. This means that there are minimal works required on the site and will therefore reflect minimal connection costs on their interruptible connection.

Consistent with the initial assumptions, the savings presented in the business case are significant and attractive for DG customers.

During this reporting period the University of Cambridge has published one paper addressing some of the key questions that the FPP project has raised:

Paper 2: Finding the optimal approach for allocating and realising distribution system capacity: Deciding between interruptible connections and firm DG connections

Aim: To evaluate different approaches that DNOs exercise for realising capacity and connecting more DG in a cost effective way. To estimate the trade-off of offering interruptible connections versus firm connections with a focus on UK Power Networks' recent proposal for connecting more DG under the FPP trial.

Conclusions: (1) In general small wind generators will always have advantage over the larger generators (higher Net Present Value /MW). Solar PV generators would struggle to get a positive NPV over the project lifetime and AD CHP generators will connect without any concerns. **(2)** Lower curtailment levels tend to reduce the value of firmness, being AD CHP generators the ones that are less affected. **(3)** Suppliers are those with the largest proportion of embedded benefits and generators with the lowest. This may allow generators to negotiate cheaper connection costs.

Status: Paper published as EPRG Working Paper (No 1320). See: http://www.eprg.group.cam.ac.uk/wp-content/uploads/2013/10/1320-PDF-v21.pdf. A short version will be submitted to the Applied Energy Journal.

4. Progress against budget

This section is provided as a confidential appendix.

5. Bank account

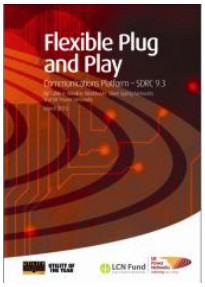
This section is provided as a confidential appendix.

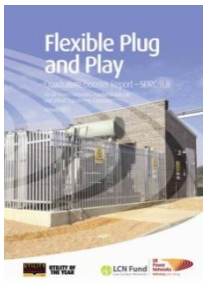
6. Successful delivery reward criteria (SDRC)

Table 4: Delivery required in 2012

SDRC			Progress/Status
9.1	**Stakeholder Engagement Report 1** 	***Evidence*** • *Publication of a stakeholder engagement report ("Stakeholder Engagement report I").*	**Completed**. Stakeholder engagement report submitted to Ofgem on 28 September 2012. The report was written in collaboration with DVN GL (formerly GL Garrad Hassan) on behalf of the FPP project and it includes a foreword by Renewable UK. The report has been shared with GB DNOs and other key stakeholders. It is available in the learning zone of the FPP website, www.flexibleplugandplay.co.uk
9.2	**Development of smart commercial arrangements** 	***Criterion*** *Development of smart commercial arrangements, which will provide a number of options that can be tested and implemented in new types of connection agreements with generation developers. These will be established in conjunction with key stakeholders. The development of smart commercial arrangements will be completed by the end of December 2012 in accordance with agreed specifications.* ***Evidence*** • *Publication of a report on Principles of Access, which will determine the Principles of Access for smart commercial arrangements.* • *Connection agreements templates (new model forms) for actively managed generator connections, to be established in conjunction with key stakeholders.*	**Completed**. Principle of Access report submitted to Ofgem on 28 December 2012. The report was written in collaboration UK Power Networks and Baringa Partners. The deliverable to Ofgem included: • Report on smart commercial arrangements for generators connecting under the FPP project, including a regulatory analysis on underwriting curtailment risk. The Principles of Access report has been shared and published and can be found in the learning zone on the FPP website: www.flexibleplugandplay.co.uk • UK Power Networks Connection Offer and Connection Agreement templates for implementing non-firm generation connections. • Report on international experience of the use of smarter connection arrangements for DG by the University of Cambridge.

Table 5: Delivery Required in 2013

SDRC			Progress/Status
9.3	**IP (Internet protocol) Communications Platform – Go Live** 	***Criterion*** *Full deployment of an Internet Protocol (IP) communications platform across the FPP trial area to support open standards communication protocols. This will be completed by the end of March 2013.* ***Evidence*** • *Installation and commissioning documentation of Vodafone Multi-Service Platform (MSP) network and Silver Spring Networks Radio Frequency mesh network in the FPP trial area and in accordance with the specification included in the contracts with the relevant partners.* • *Recorded results of IEC 61850 communication trials using IEC 61850 simulators at installed locations in the FPP trial area.*	**Completed**. The project successfully installed and commissioned an IP-based communications solution across the FPP trial area by end of March 2013. It also demonstrated through IEC 61850 trials that the end-to-end communications solution was and is capable of acting as a bearer for IEC 61850 traffic. The Communications Platform SDRC 9.3 Report was delivered to Ofgem on 28 March 2013. The report was written in conjunction with Vodafone *(formally Cable & Wireless Worldwide)*, Silver Spring Networks and UK Power Networks. The report has been shared with GB DNOs and other key stakeholders. It is available in the learning zone of the FPP website: www.flexibleplugandplay.co.uk

SDRC			Progress/Status
9.8	**Deployment of Quadrature-Booster within trial area** 	***Criterion*** *Successful deployment of a Quadrature-booster within the FPP trial area. This will be completed by 9 August*[1] *2013.* ***Evidence*** • *Installation and commissioning of a Quadrature-booster and in accordance with the specification included in the contracts with the relevant partners.* • *Demonstration of improved balance between the circuits allowing increased power flow headroom of approximately 10MW*	**Completed.** The Quadrature-booster was successfully installed and commissioned in July 2013. The Quadrature-booster SDRC 9.8 Report was delivered to Ofgem on 9 August 2013. The report was written in conjunction with Fundamentals Ltd, Wilsons Transformer Company and UK Power Networks. The report provides an overview of the deployment phase of the project from concept through to commissioning and includes initial analysis demonstrating the improved balancing between the circuits. The report has been shared with GB DNOs and other key stakeholders. It is available in the learning zone of the FPP website, at: www.flexibleplugandplay.co.uk

[1] This was agreed under change request https://www.ofgem.gov.uk/ofgem-publications/83108/sdrc9.4and9.8changesdecisionletter150813.pdf

SDRC			Progress/Status
9.4	**Demonstrate FPP technical characteristics of FPP solution** 	***Criterion*** *Demonstration of Flexible Plug and Play capabilities of the overall FPP technical solution following completion of the FPP installation phase. This will be completed by the end of September 2013.* ***Evidence*** • *IEC 61850 certification for all relevant Remote Terminal Units (RTUs), Intelligent Electronic Devices (IEDs) and other IEC 61850 field devices.* • *Installation and commissioning documentation of IEDs and other field devices necessary to support the trials and in accordance with the specification included in the contracts with the relevant partners.* • *Installation and commissioning documentation of production of Smart Applications in accordance with the specification included in the contracts with the relevant partners.* • *Pre-production interoperability test results for FPP's Smart Devices and Smart Applications.*	**Completed.** The FPP solution was successfully installed and commissioned in September 2013. The SDRC 9.4 Report was delivered to Ofgem on 30 September 2013. The report has been shared with GB DNOs and other key stakeholders. It is available in the learning zone of the FPP website, at: www.flexibleplugandplay.co.uk This milestone has seen the delivery of the following key outcomes : • The IEC 61850 conformance of the overall components. • The commissioning and the acceptance of the ANM production platform. The integration of the Smart devices including the Dynamic Line Rating system, the Quadrature-booster Control system, the Automatic Voltage Control units and the upgraded RTUs into the ANM production platform. • The field commissioning of the smart devices to the ANM production platform via the RF mesh infrastructure.

Table 6: Delivery Required in 2014

SDRC			Progress/Status
9.5	**Strategic Investment Model**	***Criterion*** *Delivery of the FPP strategic investment model including validation and testing of the model utilising data captured within the FPP trials. This will be completed by the end of December 2014.* ***Evidence*** • *Completion documentation for the strategic investment model development and build phase.* • *Recorded validation and test results.* • *Delivery of the strategic network investment model in a fully usable and external issue format.*	Activities associated with SDRC 9.5 are progressing according to plan for successful delivery by the end of December 2014. The project is now finalising the build phase and has started to present results that indicate that the approach and algorithm work accordingly. The validation and testing phase started in November 2013 as planned.
9.6	**Implementation of active power flow and voltage management within FPP trial area**	***Criterion*** *Deployment of active power flow management and active voltage management within the FPP trial area. This will be completed by the end of December 2014.* ***Evidence*** • *Pre-production functional test results for active power flow management and active voltage management applications.* • *Installation and commissioning documentation of production active power flow management and active voltage management applications in accordance with the specification included in the contracts with the relevant partners.* • *Suitable agreements with generators in place (if required).* • *Trial results for the active power flow management and active voltage management trials*	This is on schedule to be completed by the end of December 2014. Following the completion of the acceptance tests in July 2013, the commissioning of the production platform for the ANM was finalised in September 2013 as part of the SDRC 9.4. An ANM trial design has been developed to demonstrate how the ANM system will be used to control the generators output and prove the concept of active power flow management in accordance with SDRC 9.6.

SDRC			Progress/Status
9.7	**Facilitation of faster and cheaper connection of DG to the distribution network, as compared to timescales and costs of connection utilising traditional approaches.**	***Criterion*** *Facilitation of faster and cheaper connection of* DG *to the distribution network, as compared to timescales and costs of connection utilising traditional approaches. To be completed by end of December 2014.* ***Evidence*** ▪ *Demonstration that* DG *connection offers are: 1 - Cheaper; and 2 - Offer faster project connection timescales, than offers based traditional reinforcement. The evidence for this criterion will be met through the provision of one connection offer to generators using the FPP methods. If during the duration of the FPP project other generators are in a position to accept a connection offer, then we will use that as evidence supporting this criterion.*	SDRC 9.7 is on schedule to be completed by the end of December 2014. Since 1 March 2013 eighteen offers have been delivered to different DG customers. These offers have all been less expensive than the original firm connections, representing significant savings. Five of these offers have been accepted. The offers are not only cheaper but requiring less complex construction works can be delivered faster than the traditional solution with full reinforcement works.

7. Learning outcomes and knowledge dissemination

This section will focus on the specialised learning that has been captured, provide information on the internal and external knowledge dissemination activities, as well as provide a summary of formal published materials that are available relating to each of our key topic areas.

As the project approaches the end of its second year, we have provided some statistics to demonstrate our knowledge dissemination activities since the start of the project; most of these activities/materials are available at www.flexibleplugandplay.co.uk.

Activity	Statistics since 2011
FPP learning reports generated and published	5
FPP learning events	2
Published papers	9
National and international speaking slots	49
Internal dissemination/training activities	29
PR activity (press releases, articles, features)	26

7.1 Main Learning Outcomes from this reporting period

We have divided this section into core topics.

7.1.1 Commercial Arrangements

Since 1 March 2013 the project issued new 'interruptible' commercial contracts to 18 generation developers wanting to connect within the FPP trial area. These new commercial contracts, which are compliant with the current regulatory framework, have generated two significant learning points for the project.

1. **FPP has developed a smart commercial framework (or 'interruptible' connections)**: We have now engaged with more than twenty individuals in the business from Infrastructure Planners, Connections Managers, Regulation Managers, Solicitors, Programme Delivery Managers, amongst others. This has lead us to conclude that there are several processes that will need to be modified to include the capability of offering interruptible connections as a business-as-usual procedure:

    a. **Technical design:** our Infrastructure Planning department must be able to assess the alternative options when designing a connection. They must be able to identify the viable Point of Connection (POC) that would benefit the customer in terms of costs and that would be feasible by connecting ANM. They must also understand the implications of ANM and the measurement data required from each network location (depending on the specific constraint) to be able to deploy an interruptible connection.
    b. **Curtailment assessment:** for the time being, curtailment assessments are carried out by the ANM system supplier, however, the capability of conducting these studies in-house is critical for offering interruptible connections as business-as-usual.

c. **Customer engagement:** Connection Managers are the main point of contact with the DG customers. It is essential that Connection Managers understand the commercial implications of interruptible connections and are able to explain them to customers. In some instances, connections customers use consultants, ICP or other third parties to start the grid connection process. It is important that the end-customer is fully aware of the terms and conditions associated with the interruptible connections.

2. **Connection agreements**: The interruptible connection agreement includes a number of supplementary information documents such as the connection offer, the curtailment estimates and an overall briefing document of the Flexible Plug and Play project. Although the final offers have been delivered by the Connection Managers, the FPP team supported by the legal team has had considerable input into the end documents. This is one of the key knowledge and skill transfer areas necessary for the business as usual roll out of such offers.

3. **We must conduct further analysis on how interruptible connections can lead to reinforcement:** One of the key potential benefits of applying pro-rata curtailment is that by sharing the cost of curtailment customers are incentivised to eventually share the cost of reinforcement or upgrade of the network to alleviate the constraint. However, to date there have been a number of practical issues in developing a sound approach for linking reinforcement and interruptible connections. The cost allocation of future network reinforcement is a key area for ensuring a complete commercial framework for interruptible connections and this is consistent with stakeholders view on this area.

7.1.2 Customer Engagement

There are three key learning outcomes taken from our engagement with customers:

1. **Flexible connections are a viable alternative for DG customers.**
   Customers that have engaged with the FPP project are willing to accept curtailment levels ranging within 3%-5.3% in a reduction in expected annual output. The evidence to support this statement is the four accepted connection offers so far. However, it will be interesting to understand the response from customers that have been issued connection offers with higher curtailment levels due to being outside of the Quota and falling in to the last position of the LIFO queue. Also, the DG community has expressed their interest in all DNOs deploying interruptible connections. One example was at the last DG Fora organised by the ENA in October.

2. **Different role of stakeholders throughout the lifetime of the project.**
   One interesting finding has been to understand the role of the developer versus the owner of the project. One example is a project being developed by a company that looks to sell their projects. This specific customer has been focused on obtaining the most accurate curtailment figures that make financing more accessible. This means that if they can finance their projects on lower curtailment figures the better the project financial outcomes may look. However, when discussing curtailment with the owners of the projects, most of the time they are very keen on understanding the maximum curtailment they will experience in an extreme worst case scenario.

3. **New ways of working with DG customers**

   Technical and commercial audience: When dealing with customers in charge of both commercial as well as technical assessment of the FPP proposal, the need to engage both audiences is a constant challenge. As mentioned in the deliverables section, each offer received a briefing document describing the technical characteristics of the proposed connection. Finding the balance of a simplified and easily understandable technical description and an overall comprehensive outline of the technology has proven to be a challenge. These documents are subject to due diligence that has proven to raise more technical queries on how, for example, dynamic line rating will address constraints in the network.

   - **Information provision:** The novelty of the FPP offers has presented the need to provide more information and support than would be required for 'current connection offers. For example, as some of the customers have contracted third party experts to assess the curtailment estimates, UK Power Networks has been asked to share detailed network configuration information for consultants to replicate the relevant modelling.

   - **Level of interaction:** These offers have also involved much more interaction with the customers in order to follow through all their queries around the technical as well as commercial aspects of the offers.

7.1.3 Quadrature-booster (SDRC 9.8)

FPP has learnt how to design, install and protect the first 33kV Quadrature-booster. A Quadrature-booster can be used on the 33kV network; previously Quadrature-boosters were only used on the transmission network. The FPP Quadrature-booster is small (30MVA) with the two component transformers installed in one tank, and based on automatic control system to effect load balancing. The existing Quadrature-booster on transmission networks are typically large (750MVA – 2750MVA), and generally are made of two transformers installed in separate tanks, and the on-load tap changing is manually controlled because of the power shifted at each tap change is significantly larger than on a distribution network.

It has been shown that the Quadrature-booster is potentially an attractive technology to increase network capacity compared to Overhead/Underground network reinforcement. Initial tests on the case study at Wissington Quadrature-booster effectively balances power flow achieving optimal loading on two parallel 33kV lines, where previously one of the lines would be normally loaded twice as much load on the other. Through achieving optimal load sharing on the lines the Quadrature-booster has created approximately 10MW of capacity headroom on the Wissington 33kV network boundary.

7.1.4 System Integration (SDRC 9.4)

There are three key learning outcomes generated from integrating the FPP technical solution:

1. **A multi-vendor approach is achievable to build the FPP technical solution, which is integrated on a single platform by using the IEC 61850 open standard.**

   The use of the IEC 61850 standard required the development of an integration process that focused on the:

   a) assessment of interoperability in a lab environment and extensive testing before field deployment; and
   b) use of devices compliant with the conformance requirements of the IEC 61850 standard.

   The integration process started with lab testing in March 2013, and ended successfully with the field commissioning of 20 devices in September 2013. The twenty smart devices came from six different suppliers demonstrating the interoperability of IEC 61850. The integration process appears fast and efficient when compared with similar attempts using more traditional methods. It is also important to highlight that the time spent on site to carry out final end-to-end testing has been minimised demonstrating the potential benefits of this approach.

2. **The Manufacturing Messaging Specification (MMS) protocol can be used on the RF mesh infrastructure to send information to the Active Network Management system.**

   The current practice of using the IEC 61850 standard and the MMS protocol are at the substation level. The FPP project aimed to deploy this protocol to exchange data outside the substation and between the local smart devices and the ANM system that is situated at the control centre. The benefit of this approach is to facilitate the integration of devices and has been successfully illustrated during the commissioning of the FPP technical solution.

   The FPP project was the first project to use the IEC 61850 standard with MMS mapping at UK Power Networks and involved operational units to get more familiar with this standard.

   Nevertheless the use of MMS over a communication link like RF mesh was a real challenge because usually this protocol is deployed over media with higher bandwidth. Various optimisation strategies have been successfully implemented in collaboration with multiple project partners to mitigate the challenges presented by the bandwidth constraints over the radio mesh network.

3. **The integration and the commissioning of an interoperable solution require a strong commitment to new skills and processes. FPP has defined this governance under 'system integration'.**

   Since the beginning of the project the integration stage has always been identified as a strategic activity requiring a dedicated workstream. The role of the system integrator has been to implement the processes and to drive the integration of the various the smart devices and applications. More precisely, the system integrator has been responsible for the design, the testing and integration approach via sequential stages of lab and field testing.

Furthermore, the nature of this activity is new as well as transferable and needs to be allocated with an identified resource. The skills required are a combination of traditional power systems engineering and ICT knowledge. This evolution of skills and processes is an important step change when delivering smart grid projects and when transferring those concepts in business-as-usual activities.

7.2 Internal communications and knowledge dissemination activities

A number of internal dissemination activities have taken place over the past six months, mainly comprising of internal learning and training workshops relating to the commercial arrangements, the installation of the Quadrature-booster and the integration of FPP technical solution. These workshops provide the vital incremental steps that will contribute to a deeper understanding of the project, which is core to the process of embedding any new knowledge. FPP is essentially 'passing the baton' as the project shares knowledge with colleagues, increases the engagement and develops the tacit knowledge.

Quadrature-booster (SDRC 9.8)

As a result of having a new technology, the project held an internal Quadrature-booster training session in July 2013 to ensure employees understood what a Quadrature-booster is, what it can and cannot do, and how the Quadrature-booster control system works. The session included case studies of how the transmission network uses Quadrature-boosters and where they are used. A core element of the training session included a practical overview of the installation, commissioning, operation, control and maintenance of the device.

As part of the deployment of the Quadrature-booster and internal training, the following UK Power Networks' Engineering Standards and Manuals have been created by UK Power Networks and its project partners ready for business as usual integration:

- Engineering Development Standards 04-8002 Quadrature-boosters;
- Engineering Operation Standards 04-0042 Wissington Quadrature-booster 33kV;
- Engineering Operation Standards 04-8003 Quadrature-booster – Control System 33kV;
- 6330-1238U10 Quadrature-booster – Installation, Operating & Maintenance Manual; and
- 3334188/00EN Active Power Regulator TAPCON260 Operating Instructions.

The project has also attended internal directorate 'roadshows' for Network Operations (October 2013), Asset Management (November 2013) and Capital Programme (December 2013). Attending directorate roadshows provides all employees of all backgrounds and technical understanding a good overview of how UK Power Networks is making the transition to a low carbon future and developing and upgrading its network fit for smart technologies. Furthermore, it is important to share with our colleagues how innovation will play a key role in RIIO-ED1 price control period and that the progress and success of FPP is making 'interruptible' connection offers a reality.

7.3 External communications and knowledge dissemination activities

FPP continues raising the profile of the project through conferences and PR:

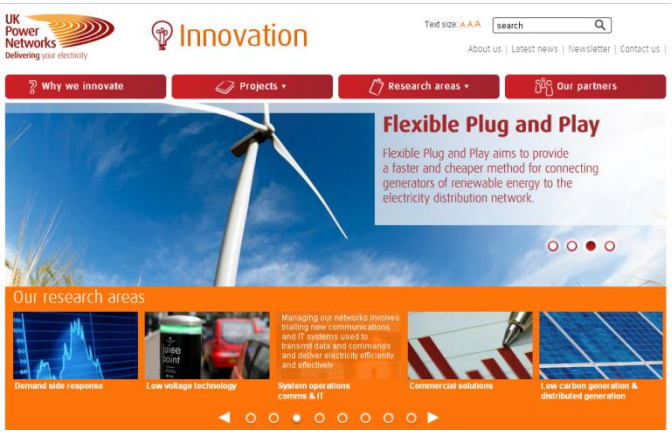
Conferences and formal dissemination activities	Main Messages/presentation title	Date
Western Power Distribution bilateral knowledge sharing regarding Commercial Arrangements	To discuss the Flexible Plug and Play connection agreement. The Low Carbon Hub project is looking at how to offer interruptible connections and we are pleased to know that they have taken our Flexible Plug and Play template and adopted most of the terms.	July 2013
Smart Grid Mission – Canada – (P.0302)	Flexible Plug and Play Low Carbon Networks: Smart Solutions of Connecting DG – presentation on our progress and challenges faced so far, specifically focused on customer engagement and interruptible connection offers.	September 2013
Telecoms for Smart Grids (SMi) (P.0357)	Implementation of smart solutions for connecting Distributed Generation	September 2013
Power in Unity: A whole system approach (IET) (P.0347)	Smart Solutions for connecting Distribution Generation: The Flexible Plug and Play method'	October 2013
The 12th International Workshop on Large-Scale Integration of Wind Power into Power Systems (P.0072)	Active Network Management for integrating renewable energy to the distribution network: a Commercial Perspective'	October 2013
European Utility Telecommunications Conference 2013: JRC radio workshop (P.0348)	Flexible Plug and Play - Implementation of smart solutions for connecting Distributed Generation	October 2013
Renewable 2013: (35th annual conference) (P.0349)	Participation in the round table on 'Innovation and Developments in Grid Connection'	November 2013
Low Carbon Network Fund 2013 (P.0030)	Interruptible Connections for DG Customers: A new commercial framework for integrating DG Smart Solutions for connecting DG: The Flexible Plug and Play approach	November 2013
20TechCon Euro (P.0004)	Flexible Plug and Play: Design and Deployment of 33kV Quadrature-booster	November 2013

Adriana Laguna (Workstream Lead) and Sotiris Georgiopoulos (Project Director) at the Low Carbon Network Fund 2013 conference, Brighton

PR and communications activities

The following PR and communications activities have been completed over this reporting period.

- **Flexible Plug and Play website refresh (October 2013).** As UK Power Networks' innovation portfolio develops and grows, it made sense to have one website to host all projects. This co-ordinated approach is effective use of the Low Carbon Network funds as it avoids duplication of resources, time and money. Visitors can now watch the FPP learning events on the website and see more images of the project's technologies, making our knowledge sharing more tacit.



- **Innovation newsletter** – Issue 3 (November 2013) – P.0288. This is available on the project website to read.

During the week of the Low Carbon Network conference (12-14 November 2013), UK Power Networks hosted its **'Innovation Week' via Social Media** (P.0034); the company used its Twitter account and Facebook page to share interesting facts and images about our projects. UK Power Networks posted an image of the Quadrature-booster asking the audience to guess what it is; this proved to be a popular generating 22 comments.

7.4 Learning and Dissemination activities in the next reporting period

In the first six-monthly report to Ofgem in June 2012, the project issued the FPP Knowledge Dissemination Roadmap, which is a plan to inform stakeholders what knowledge the project would share, how it would be shared, with whom and at what stages. The FPP Knowledge Dissemination Roadmap is a live document and has been updated during the project to provide the project team with more detail of dissemination activities. The table below presents a view of the currently planned events for the first six months of 2014 in terms of learning dissemination:

Conferences and formal dissemination activities	Main Messages	Date
DistribuTech 2014 – Texas- P.0303 (abstracts accepted)	Managing IEC 61850 Traffic over a Radio Frequency Mesh for Active Network Management: Experience from the Flexible Plug and Play Field Trials in the UK – paper accepted. Presented by SGS on behalf of the project team.	January 2014
Flexible Plug and Play learning event – P.0287	The installation of the first 33kV Quadrature-booster	February 2014
Flexible Plug and Play technical tutorial – P.0352	The installation of the first 33kV Quadrature-booster	February 2014
Developments in Power System Protection 2014 (DPSP). Abstracts accepted for oral and poster sessions.	The Protection of a Quadrature-booster Connected on the Distribution Network – paper submitted (P.0354) - Oral An Investigation into Alternatives to Directional Overcurrent Protection on Grid Transformers to Improve the Network Capacity to Accommodate Reverse Power Flow – paper submitted (P.0355) - Poster	April 2014
CIRED 2014	In progress	June 2014
Internal directorate road shows - P.0356	This includes road shows in our southern region as the FPP connection offer will be integrated into our business by Q2 2015.	2014
University of Cambridge: Paper 3 : Distributed Generation: *Opportunities for Distribution Network Operators*	To evaluate the opportunities and challenges for DNOs when connecting DG within the distribution network. To quantify the most relevant benefits of facilitating earlier and greater quantities of DG related to the DG incentives, losses reduction and network reinforcement deferral with a focus on the FPP trial from UK Power Networks.	March 2014
University of Cambridge: Paper 4: Evaluation of procurement options for distributed generation resources by electric utilities	To evaluate the different mechanisms for the procurement of distributed generation resources by electric utilities and to identify the best practice. To explore potential initiatives from DNOs (apart from those based on national policies) that allow them to lead specific procurement process with a focus on small size distributed generation projects	March 2014

Finally, the project team has completed an extensive exercise to review the expected learning outcomes that were first listed in the Use Cases in the final bid document that was sent to Ofgem in August 2011. Firstly all expected learning outcomes were reviewed to confirm whether they had been met and also disseminated. For those learning outcomes that were outstanding the project team has used this reporting period to ensure the technical trials have been designed to meet those learning outcomes. In parallel to this exercise, the project team has also ensured all the communications products that are yet to be started are used to disseminate the new knowledge, thus ensuring as that the project delivers in-line with its plans.

7.5 Flexible Plug and Play knowledge library

For more detailed information on any aspects of the project, there are multiple reports and papers available to read, as well as the ability to watch our first two learning event on our project website: www.flexibleplugandplay.co.uk

Please note that this is not an exhaustive list of documents and if you are unable to find what you are looking for, please do not hesitate to contact us at innovation@ukpowernetworks.co.uk.

Topic	Title	Type	Date
Stakeholder Engagement	Stakeholder Engagement learning report (SDRC 9.8)	Learning report	September 2012
Commercial Arrangements	Principles of Access learning report (SDRC 9.2)	Learning report	December 2012
Commercial Arrangements	Experience of the use of smarter connection arrangements for distributed wind generation facilities (University of Cambridge)	Learning report	December 2012
Commercial Arrangements	Smart commercial arrangements for non-firm connections	Learning event available to watch online	March 2013
Commercial Arrangements	CIRED 2013: Commercial Arrangements for an Active Network Management	Technical paper	June 2013
Commercial Arrangements	12th Wind Integration Workshop: Active Network Management for integrating renewable energy to the distribution network: a commercial perspective	Technical paper	August 2013
Commercial Arrangements	Finding the optimal approach for allocating and realising distribution system capacity: Deciding between interruptible connections and firm DG connections (University of Cambridge)	Academic paper	October 2013
Communications Platform	Communication Platform learning report (SDRC 9.3)	Learning report	March 2013

Topic	Title	Type	Date
Communications Platform	CIRED 2013: Modern communications infrastructure to enable flexible management of network constraints and increased levels of distributed generation	Technical paper	June 2013
Communications Platform	The deployment of an Internet Protocol-based Communications Platform	Learning event available to watch online	June 2013
Quadrature-booster	TechCon Asia 2013 - Pacific: The Design, Manufacture and Operation of a 33kV Quadrature Booster	Technical paper	April 2013
Quadrature-booster	CIRED 2013: Quadrature-booster trial at 33kV	Technical paper	June 2013
Quadrature-booster	Quadrature-booster learning report (SDRC 9.8)	Learning report	August 2013
Quadrature-booster	TechCon 13 Euro: The Design and Deployment of a Quadrature Booster on UK Power Networks' 33kV Distribution Network	Technical paper	November 2013
Systems integration	CIRED 2013: An open and scalable active network management solution for a faster and cheaper distributed generation connection	Technical paper	June 2013
Systems Integration	A demonstration of the technical characteristics of the Flexible Plug and Play solution	Learning report	September 2013

8. Intellectual Property Rights (IPR)

During the current reporting period the following IPR (foreground or relevant foreground) has been generated (June 2013 – December 2013):

Workstream	IPR description	IPR Owner
DA	P.0311.Quadrature-booster Trial Design	UK Power Networks
DA	P.0312.Active Network Management & Generator Control Trial Design	UK Power Networks
DA	P.0313.Dynamic Line Rating Trial Design	UK Power Networks
DA	P.0314.Communications Platform Trial Design	UK Power Networks
DA	P.0315.Modern Protection Relay Trial Design	UK Power Networks
DA	P.0316.Active Voltage Control Trial Design	UK Power Networks
DA	P.0317.System Integration Trial Design	UK Power Networks
WS2	P.0102.Factory acceptance test for the Quadrature-booster control system	Fundamentals
WS2	P.0150.Dynamic Line Rating Design Deployment Brief	UK Power Networks

Workstream	IPR description	IPR Owner
WS2	P.0218 – Quadrature-booster control system scheme design drawings	Fundamentals
WS2	P.0219.Reverse power flow control drawings	Alstom
WS2	P.0220.Dynamic Line Rating control drawings	Alstom
WS2	P.0251.Factory acceptance test for Quadrature-booster	Wilson Transformer
WS2	P.0252.Modern Protection Relays a Solution for Reverse Power Flows Design Deployment Brief v1	UK Power Networks
WS2	P.0263.Modern Protection Relay Functional Design Specification	Alstom
WS2	P.0264.Quadrature-booster control system production specification (February 2013)	Fundamentals
WS2	P.0270.Dynamic Line Rating Factory acceptance test results	Alstom
WS2	P.0271.Dynamic Line Rating Protection programmable scheme logic and settings files	Alstom
WS2	P.0272.Protection programmable scheme logic and settings files	UK Power Networks
WS2	P.0275.Quadrature-booster engineering operating standard	UK Power Networks
WS2	P.0276.Quadrature-booster control system engineering operating standard	UK Power Networks
WS2	P.0279.Protection programmable scheme logic and settings files	Alstom / UK Power Networks
WS2	P.0268.FPP.SDRC9.8 Deployment of Quad-Booster	UK Power Networks
WS3	P.0361.Comparative curtailment analysis of LIFO vs Pro-Rata	Smarter Grid Solutions / UK Power Networks
WS4	P.0130.Active Network Management Acceptance Test Specification and Results	Smarter Grid Solutions / UK Power Networks
WS6	P.0362.Strategic Investment Model Build Phase Update	Imperial College London / UK Power Networks
WS7	P.0004.TechCon 2013 – full paper/presentation – Quadrature-booster	UK Power Networks
WS7	P.0072.12th International Workshop on Large-Scale Integration of Wind Power into Power Systems (paper/presentation)	UK Power Networks
WS7	P.0302.Smart Grid Mission to Canada – full paper/presentation	UK Power Networks
WS8	P.0142. Flexible Plug and Play Test Specification	Smarter Grid Solutions / UK Power Networks
WS8	WS08.P.0363 SDRC 9.4 - A demonstration of the technical characteristics of the Flexible Plug and Play solution	UK Power Networks

9. Risk management

The FPP project has established a risk management process, as described in detail in the FPP Project Handbook. Please see Appendix 1 for an extract of the risk management process. It allows for the communication and escalation of key risks and issues within the project, and defines where decisions will be made and how these will be communicated back to the workstream where the risk or issue has arisen. Risks are reviewed weekly at workstream level and fortnightly at project level by the Project Board. Key project risks are then escalated to the Project Steering Committee for review and approval of the mitigation on a six week cycle basis.

Ref#	W/S	Risk & Impact Description	BID Mitigation	Mitigation (update)	Status
BID R0001	WS1	The Communications platform may not meet the smart applications' performance requirements leading to system incompatibilities and unsatisfactory trial results	The Communications platform should be subject to performance testing using smart devices or simulators under various operating conditions. Communications requirements to be defined at design stage and suitable Communications technology chosen for the purpose of the trials. UK Power Networks to agree Service Level Agreements for Communications platform.	As part of the acceptance tests performed for the communications platform, IEC 61850 communication trials were included both in the lab and in the field using IEC 61850 traffic simulators. The test demonstrated that the communication solution deployed in the trial area was and is capable of acting as a leaver for simulated IEC 6150 traffic.	

Ref#	W/S	Risk & Impact Description	BID Mitigation	Mitigation (update)	Status
BID R0002	WS1	Failure to secure suitable mounting positions/space for the communications equipment due to limited space in UK Power Networks-owned premises or assets e.g. poles – leading to lengthy negotiations with property owners resulting in programme delays	Optimise design and minimise mounting positions/space required. Investigate alternative options for mounting such as a third party provider. Carry out detailed site surveys early in the project.	Suitable mounting locations for the communications equipment, relays, have been identified at UK Power Networks Low Voltage (LV) distribution pole infrastructure. All installs at LV distribution poles were completed.	Closed
BID R0003	WS1	Silver Spring Networks may have to use an unlicensed spectrum if they are unable to get a trial licence on time leading to possible adverse perception from other project stakeholders	Establish whether trial licenses would be available by Q1 2012.	Silver Spring Networks was awarded an Ofcom development licence on 19 December 2012 for the duration of the project.	Closed

Ref#	W/S	Risk & Impact Description	BID Mitigation	Mitigation (update)	Status
BID R0004	WS3	Insufficient levels of Renewable Generation (RG) connecting – Generators may not want to participate (if for example the project interferes with their normal operations) during the FPP project timescales leading to failure to fully trial the FPP in the planned timescales	Engage with generators as early as possible to understand the risks and issues likely to impact their (generators) normal operations in order to actively manage/mitigate them	FPP has successfully engaged with 18 developers that have now been offered connections. Five customers have now accepted their FPP connection offers we are working towards connecting their projects within timeframe of the FPP project. One of these projects is seeking connection in January 2014 providing an early start to the actual trials. In addition, the FPP project continuously monitors the connections pipeline and will be issuing additional offers to interested DG customers.	

Ref#	W/S	Risk & Impact Description	BID Mitigation	Mitigation (update)	Status
BID R0005	DA	Different vendor protocols/ characteristics could potentially compromise the interoperability trials which may cause delays during system integration and trials	Ensure that ALL communications application is based on international standards, and all devices and systems are tested and certified to these standards Ensure that ALL devices are subject to testing in pre-production environment	Interoperability tests have been successfully completed and all certification achieved.	
BID R0006	PM	Project Partner(s) withdrawing their participation in the FPP project at a late stage leading to lengthy programme delays to institute their replacement(s) and in the worst case the collapse of the FPP	Issue principles of collaboration and request official Letters of Intent from Partners to reduce probability of partners withdrawing from the project – Reduce dependency on specific partners – this is a vendor agnostic project	All contracts with Partners have now been completed with clear technical and commercial scope. Relevant exit clauses have been incorporated to ensure project continuity in the event of an early withdrawal of one of the parties.	Closed

Ref#	W/S	Risk & Impact Description	BID Mitigation	Mitigation (update)	Status
BID R0007	DA	If actual MWh or hours of DG operation diverge (adversely) significantly from results within smart grid application feasibility assessment then this may lead to possible complaints from generators.	Ensure that DG developers are made aware in advance that the curtailment assessment results are based on estimates and that the actual levels of curtailment are likely to change year on year. Data used in studies should be as accurate as possible and assessment methods agreed by all stakeholders as being suitable. Develop suitable commercial and legal framework for making such connections offers.	Technical Mitigation unchanged – data used in studies should be as accurate as possible and assumptions used fully transparent. In addition, the project is working closely with the DG customers to support them through their due diligence process by providing additional information/analysis and clarifications as required. This will ensure better understanding of the mechanics of the curtailment and increased confidence in the curtailment analysis presented.	

Ref#	W/S	Risk & Impact Description	BID Mitigation	Mitigation (update)	Status
BID R0008	PM	Delays in resourcing and negotiation/drafting of delivery contracts could result in delays in project delivery.	The resourcing process/production of job descriptions and contract drafting to start pre-contract award. UK Power Networks to partly resource project. Contracting resource has been allowed for key roles.	The team is now fully established, most resources are permanent UK Power Networks employees, but where key skills are not available internally, interim consultants have been engaged. The resourcing situation is being monitored and action will be taken if necessary.	
BID R0009	WS03	Local Opposition to Wind Energy development contributing to negative publicity for UK Power Networks within the project area	UK Power Networks will proactively engage local stakeholders and promote the work the project is doing (looking at alternative to reinforcement and new lines/cables)	There has been no local opposition to date and therefore no further action is required.	
BID R0010	WS8	System integration issues occurring due to inadequate testing in technical workstreams (WS) leading to delays	Ensure that the deliverables from each workstream are appropriately tested prior to system integration activities and allow sufficient time to develop test specifications and to conduct the testing	High-level test plan and detailed pre-production environment specification currently being developed. The relevant activities are being incorporated into the detailed project plan. Extensive lab and field testing will be carried out to ensure no issues in commissioning.	Closed

10. Other

There is no additional information to report.

11. Consistency with the full submission

The work currently being undertaken within the project is consistent with the bid submission as amended by change request approved by Ofgem on 15 August 2013.

12. Accuracy assurance statement

The project implemented a project governance structure, as outlined in the project handbook that effectively and efficiently manages the project and all its products. All information produced and held by the project is reviewed and updated when required to ensure quality and accuracy. This report has gone through an internal project review and a further review within UK Power Networks to ensure the accuracy of information.

We hereby confirm that this report represents a true, complete and accurate statement on the progress of the Flexible Plug and Play Low Carbon Networks project in its third reporting six monthly period and an accurate view of our understanding of the activities for the next reporting period.

Signed Ben Wilson

Date 18/12/13

Ben Wilson
Director of Strategy & Regulation and CFO
UK Power Networks

13. Appendix

Appendix 1 – Risk Management

To support the FPP Risk Management process each risk is given a RAG Status to provide visual representation and understanding of the risks current status. The RAG status is determined upon the probability of the risk occurring and the consequences if the risk eventuates. Please see below for the Probability and Consequence Table Calculator:

Probability and Consequence Table Calculator:

	1	2	3	4	5
Probability	Rare	Unlikely	Possible	Likely	Almost certain
Consequence	Minimal	Minor	Moderate	Major	Catastrophic

Probability
1. Rare – May occur in exceptional circumstances - 0-10%
2. Unlikely – Uncommon but has been known to occur - 10-20%
3. possible – Could occur 20-75%
4. Likely – May occur 75%-90%
5. Almost certain – Expected to occur with a likelihood 90-100%

Consequence
1. Minimal
2. Minor
3. Moderate
4. Major
5. Catastrophic

Once a rating has been determined for the probability and consequences the RAG status (high, medium and low) is calculated by multiplying the probability against the consequences, e.g. taking a probability of 4, which is classified as likely, and multiplying this against a consequence of 2, which is classified as a Moderate, would give you and overall risk rating of 8, which would be risk rated as a RAG status of GREEN (Low)

Probability						
	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
		Consequence				