Flexible Plug and Play

FPP Briefing Document – Issued with the FPP Connection Offer November 2013

UTILITY INDUSTRY ACHIEVEMENT AWARDS 2012

UTILITY OF THE YEAR

UK Power Networks
Delivering your energy

Contents

Acronyms

Term	Definition
ANM	Active Network Management
DG	Distributed Generation
FPP	Flexible Plug and Play
GPS	Global Positioning System
IP	Internet Protocol
LCNF	Low Carbon Networks Fund
MP	Measurement Point
RF	Radio Frequency
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
SGS	Smarter Grid Solutions
WAN	Wide Area Network

1. Introduction

Purpose and Objective

Since 1 March 2013 UK Power Networks has started to offer connection alternatives within the Flexible Plug and Play (FPP) trial area.

The FPP connection offer ("Interruptible Connection Offer") describes the works required to connect the specific generation project to the closest viable point of connection and outlines the estimated cost for that alternative. It also references the Connection Agreement to which these interruptible connections will be subject to.

This document has been written to complement the corresponding connection offer of each customer, to provide participating distributed generation (DG) developers detailed information on the Flexible Plug and Play project and outline the technical characteristics of the proposed connection. Finally, the briefing document describes the commercial terms to which all projects under the same Active Network Management (ANM) scheme will be subject to.

In addition to this briefing document, generators will also receive from UK Power Networks an assessment report describing the estimated annual curtailment levels for their generation plants, a connection agreement template.

More specifically:

- Section 2 describes the Flexible Plug and Play project and gives a general overview of the technical and commercial problems to be addressed
- Section 3 provides additional detail on the technical solutions proposed by FPP
- Section 4 describes the commercial implications of ANM, outlines the Capacity Quota concept, and enlists the rules by which developers will connect their projects.
- Section 5 describes the process for curtailment forecasting
- Finally, section 6 sets out the next steps for developers.

2. Flexible Plug and Play

UK Power Networks is trialling innovative solutions to provide connections to distributed generators in a cheaper and faster manner to avoid the need for extensive reinforcement investment which can be both costly and lengthy in terms of time.

One of these initiatives, led by UK Power Networks with £6.7 million of funding from Ofgem's Low Carbon Networks Fund (LCNF), is the Flexible Plug and Play project. In summary, the company is looking to trial a number of "smart" technologies to be able to provide connections to distributed generation projects in a constrained part of its network where, under UK Power Networks' normal operating conditions, no capacity would otherwise be available. By combining a real-time understanding of the nature and extent of the constraints on its network with the ability to manage the output of generation in any constrained area, UK Power Networks aims to be able to connect distributed generation to its network in a more timely and cost effective manner in return for a connection which may be curtailed from time to time in accordance with the principles explained in this document.

2.1 The trial area

All projects considered for the FPP connection alternative are located within the section of UK Power Networks' Eastern Power Network (EPN) between Peterborough, March and Wisbech, the trial area that has been chosen for an initial roll out of this new approach to connections. This document provides a description of the technical devices to be implemented as well as the terms that will underpin the connection agreement of the projects connected.

2.2 The projects

Throughout 2012, UK Power Networks identified several generation projects within the FPP trial area that had received connection offers that were too expensive to make their projects viable. The FPP team then conducted technical analysis of each connection request and UK Power Networks provided the customers with an alternative cheaper interruptible connection. Part of the analysis carried forward and presented in this report resulted in the identification of a 33.5MW quota of interruptible capacity connecting into March Grid. Since March 2013, the FPP team has engaged with more projects in the area that are eligible for an FPP connection.

2.3 Description of constraints and proposed solutions

There are two constrained locations that have been identified within the FPP trial area. The first is at the Bury-Peterborough Central 33kV circuit. The second, and relevant to this document, is located at the March Grid substation.

2.3.1 March Grid

The existing infrastructure at March Grid consists of 2x45MVA 132/33kV transformers and an interconnected 33kV network supplying small 33/11kV primary substations. The main constraint on March Grid is the exhausted reverse power capacity, which is limited by the maximum settings (75% of transformer nameplate rating) applied to the existing Directional Overcurrent Protection (DOC) – a legacy protection methodology.

At 75% settings the DOC protection on the 33kV side of the transformer feeders are now operating with increasing settings to accommodate the reverse power flows resulting from the local embedded generation. A simplified diagram is shown below.

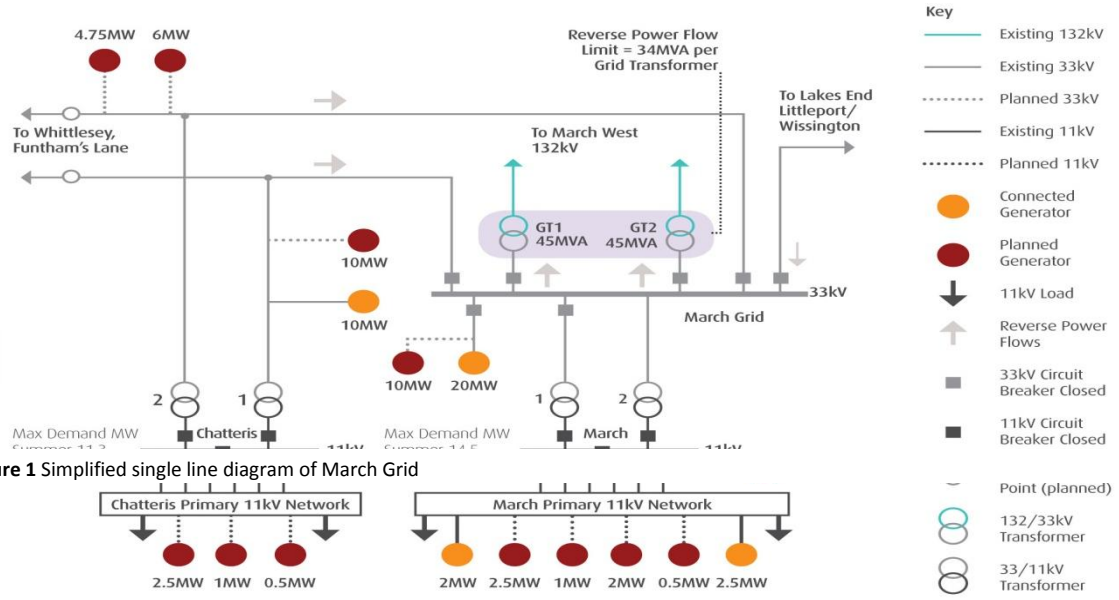

Figure 1 Simplified single line diagram of March Grid

2.3.2 Proposed solution for March Grid

The FPP project proposes to offer the customers their closest point of connection (feeding into March Grid) and implement an Active Network Management scheme to control those FPP generators. The ANM scheme will ensure that no more than 34MVA (or 45MVA once the DOC is resolved) are exported through the transformers at any given time. In reality, a 10% operating margin will be applied to the limits as a safety margin.

The active management of the generators will result in lost output for the generators as estimated by the curtailment estimates which are further described in Section 5 of this document.

2.3.3 Export limits

UK Power Networks is currently developing technical solutions in order to increase the reverse power capacity on site to 100% of the rating of the transformer. The solutions will be implemented by the end of 2013 and as such 100% reverse power rating (45MVA in N-1 conditions) has been assumed to be the operating limit for the curtailment analysis carried out.

3. Additional detail on technical solutions

3.1 Active Network Management

An active network management (ANM) scheme will be deployed to manage the two constrained areas on the distribution network in a co-ordinated manner. The ANM application, which is designed, supplied and commissioned by Smart Grid Solutions (SGS), will monitor system parameters in real time and autonomously control the output of generators and other devices to maintain the network within the limits set by those constraints. The ANM scheme will actively manage the network under the FPP project by monitoring thermal, voltage and power flow constraints at specific measurement points.

The FPP solution is designed as an autonomous system to actively manage the additional participating DG to the network without interfering with the operation of existing UK Power Networks' SCADA systems. The active management will hence enable smart utilisation of existing assets by opening up additional headroom for DG connections which would otherwise be restricted.

The ANM solution is also designed to cater for various abnormal network conditions such as communications outage and equipment failure where the relevant ANM component changes its operation mode or takes an appropriate action. In line with the design of the whole FPP solution, ANM central controller (device) also employs "dual-redundancy" principles with its system and hardware duplication to ensure maximum availability.

Smarter Grid Solutions have extensive experience in deploying active network management schemes. The technology implemented for the FPP project is based on the same platform used in the Orkney Smart Grid project. In Orkney, the SGS ANM solution has been in operation successfully since 2009 actively managing nine generators.

3.1.1 Fail Safe mode

In the event of any failure or loss of communications, the ANM scheme takes 'fail safe' action to ensure a safe and reliable operation of the network. For example, if the communications with a Measurement Point (MP) is

lost, all the generators affected by that constraint location are curtailed to a safe level. Similarly, if the communications with a generator is lost, that generator is locally controlled to a safe operating position.

3.1.2 Thresholds

For the purpose of network management, each generator's installation is considered a DG unit. ANM utilises intelligent algorithms to make smart decisions as and when the measurement parameters breach pre-defined thresholds. ***sgs power flow*** is the real time algorithm delivering real power active management. It gathers information from the power distribution network and issues set points to DG units on that network according to the following principles:

- Power output from DG units is curtailed to ensure thermal ratings are not exceeded
- Constraints are managed by issuing set points to curtail the output of the DG units or by tripping the DG unit circuit breaker
- DG units are curtailed and "released" according to the pre-agreed Principles of Access mode (see Section 4 for further detail)
- Subject to the above conditions, power output from DG units is maximised at all times.

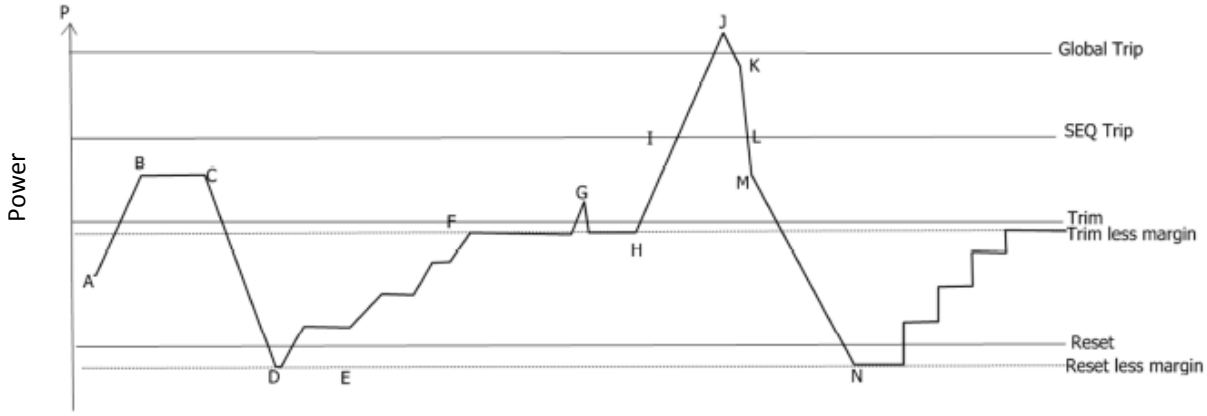

Figure 2 Power variation at a measurement point over time

To understand how ANM operates, the diagram on Figure 2 illustrates the power varying at a measurement point (MP) at a constrained location over time, and various associated scenarios as per the description below:

- From A-B-C the network power increases above the Trim margin and stays there for long enough for the MP to enter the Trim state. Power is then controlled down to Reset less Margin at point D.
- From D-F the MP is in the Releasing state and the levels of curtailment are decreased so as to ensure that the power is increased in controlled steps back to the Trim Less Margin value.
- At point G, the power spikes above the Trim threshold, but returns below the Trim threshold quickly enough not to trigger a trim state.
- At point H the power starts rising rapidly.
- At point I the Sequential (SEQ) trip threshold is breached and the observation deadline for SEQ trip is set.
- At point J, the power spikes above Global trip, but does not stay there long enough to cause a Global Trip state.
- At point K, the SEQ trip deadline, started at point I, expires causing a Sequential Trip. Upon tripping the first generator, the power drops rapidly to point L at which point the Trim observation time starts.
- At point M the Trim Observation time expires causing a Trim down to point N, and subsequent release back to Trim Less Margin.

3.1.3 Interfacing ANM to DG

For each DG customer UK Power Networks will install and commission local ANM equipment within the interface substation and connect with the DG control system. The ANM solution will include devices in addition to the standard electrical and SCADA equipment (i.e. Remote Terminal Unit (RTU), switchgear, GPS aerial, etc.) which is covered in the business as usual connection process.

For the Flexible Plug and Play project, the cost of the ANM equipment is covered by the funding from Ofgem's Low Carbon Network fund. This equipment includes:

- Cabinet with local ANM controller
- Radio Frequency (RF) mesh communications equipment inside the cabinet
- An externally or internally mounted aerial for the RF mesh equipment cabled to the ANM cabinet
- Cabling and connection of ANM to UK Power Networks' equipment

A detailed technical specification document will be issued separately detailing the requirements for interfacing the ANM equipment to the DG control system. The FPP project team will work with its project partners to assist each developer in designing and interfacing with the ANM.

3.2 Communications Platform

An end-to-end Internet Protocol (IP) communications infrastructure solution is provided by the project for the purpose of the ANM. This will include a core multi-service platform from *Cable & Wireless Worldwide* which will connect the ANM at UK Power Networks' control centre in Ipswich to two hub substations at March and Peterborough Central substations. These two hub sites will then connect to all FPP substations using a Radio Frequency mesh wireless network.

Amongst other, this communication platform will have the following benefits:

- ✓ The two hub sites will provide dual redundancy architecture so that all the substations remain connected in the case of one hub site failure.
- ✓ RF mesh network provides multiple available routes at any time due to its meshed architecture
- ✓ The RF mesh network has a dynamic and "self-healing" capability. As new devices come online and other devices go offline, the network adjusts, and routes converge on new destinations.

The IP communications infrastructure will enable the wide range of smart devices to be integrated onto the distribution network and demonstrate interoperability. Additionally, it will facilitate the data exchange and control capability of ANM to implement the technical and commercial solutions in real time to manage networks constraints.

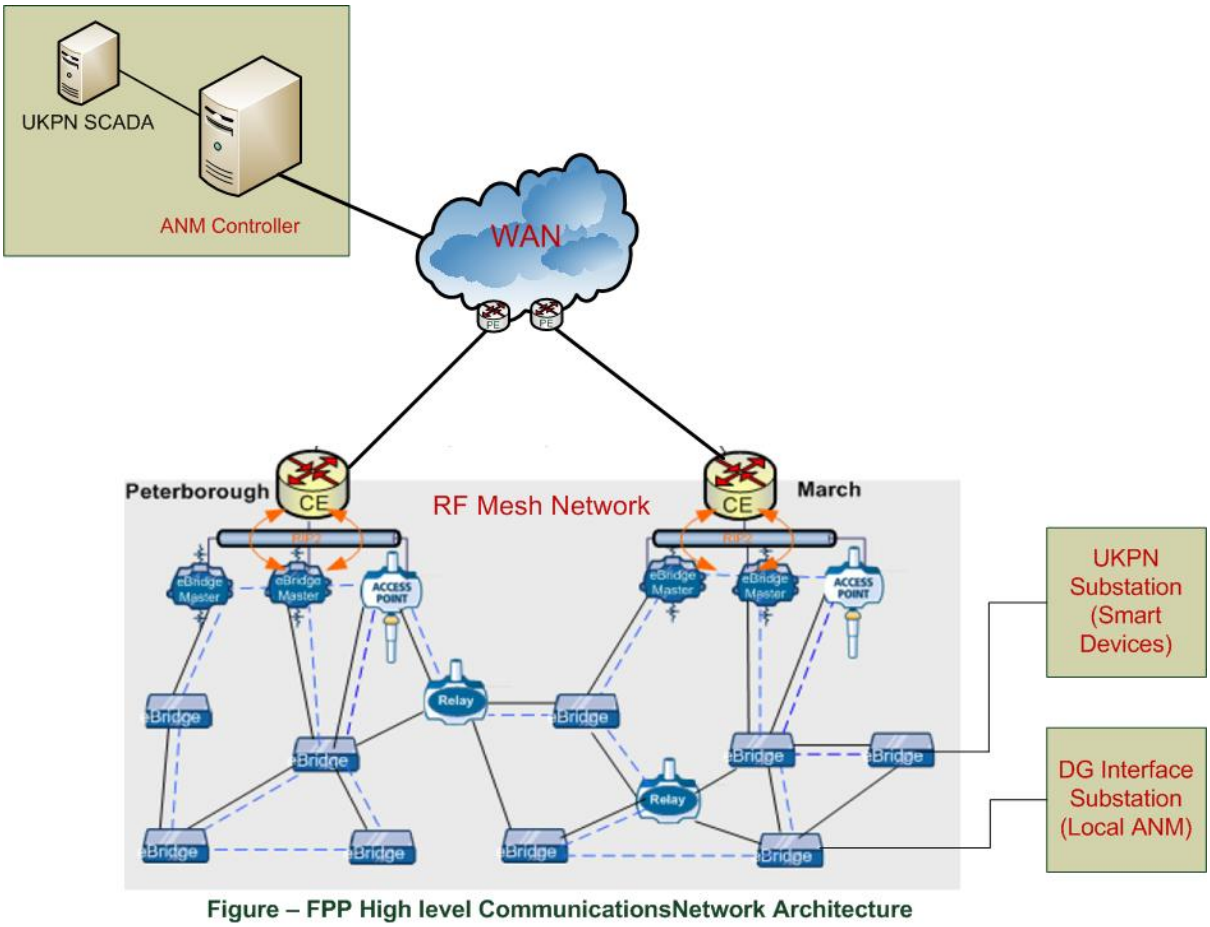

Figure – FPP High level CommunicationsNetwork Architecture

Figure 3 IP Communications Network Architecture

Figure 3 shows a high level diagram of the FPP architecture with an ANM controller connected to UK Power Networks and DG interface substations via Wide Area Network (WAN) and RF mesh network. The RF mesh equipment will require an aerial installation which can be either internal or external depending on the signal coverage inside the interface substation.

4. Commercial Implications

All developers will be receiving an upfront capex saving on their connection cost compared to their business as usual offer because the connection points will be closer to their generation stations. However, by accepting an offer by which they will have their generation curtailed, a fundamental element to the interruptible connection agreement is the order in which all generators will be subject to this curtailment. This means that for several FPP generators connected under the same constraint, the rules by which the network operator will decide to curtail their output to prevent the power flows from reaching the limits must be clear. These rules are known as the “Principles of Access”.

4.1 Principles of Access

After conducting thorough analysis on the rules of curtailment, UK Power Networks has decided to curtail all generators under the same constraint in March Grid in a pro-rata scheme[1] up to a capacity limit of 33.5MW. Pro-rata curtailment resolves constraints output based upon each generator's proportional contribution. As such, curtailment is shared equally amongst all generators. Once the quota is full, curtailment is applied in a Last In First Out order. Curtailment is controlled by the Active Network Management system and is programmed to respond in line with the rules defined by UK Power Networks (i.e. pro-rata curtailment).

4.2 Capacity Quota

To provide certainty to developers that curtailment levels will not reach unsustainable levels, UK Power Networks will guarantee not to connect more than a certain amount of megawatts at a given point and share curtailment equally amongst those generators.

The amount of megawatts defined as the Capacity Quota or Capacity Limit, has been calculated on the basis of the cost of reinforcement. This approach is based on the idea that by sharing the curtailment, as more generation connects, the levels of curtailment increase for each generator, and therefore the cost of curtailment (i.e. their revenue loss) increases. Meanwhile, if all generators were to share proportionally the cost of reinforcement, the more generation connects, the less expensive reinforcement would become. It would therefore reach a point where generators would economically prefer to pay for reinforcement than sustain curtailment costs. This dynamic is described in the Figure 4.

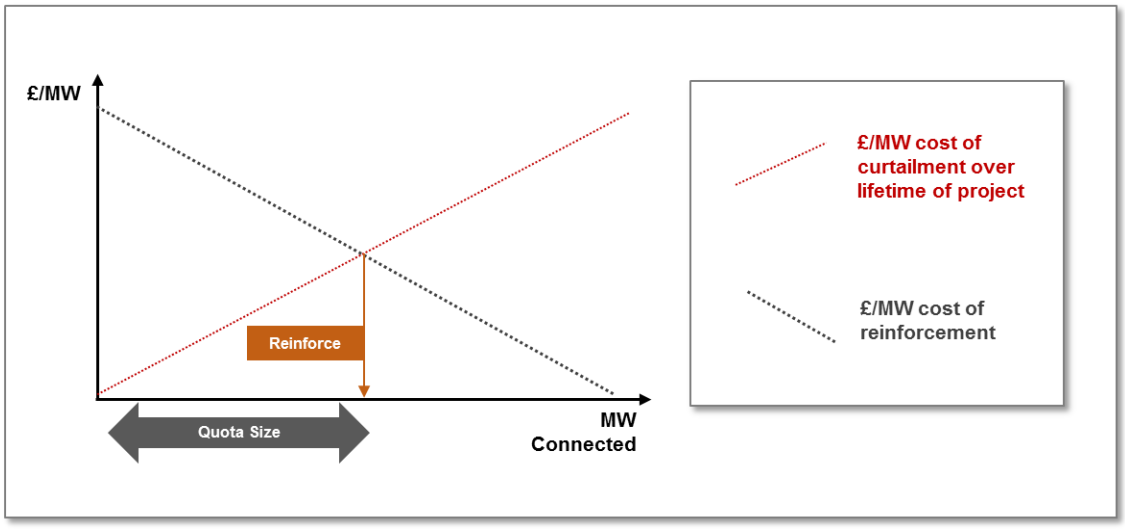

Figure 4 Capacity Quota concept

[1] Please see the *"Principles of Access Report - Final Report on smart commercial arrangement for generators connecting under the Flexible Plug and Play Project"*, UK Power Networks and Baringa Partners, December 2012 >>

Therefore, the quota has been set at the level where the cost of curtailment is equal or exceeds the cost of reinforcement. Please see the *"Flexible Plug and Play: Capacity quota calculation for March Grid"* paper for the description of the methodology used to calculate the March Grid quota.

Figure 5 shows the results for the March Grid constraint where UK Power Networks will set the Capacity Quota at 33.5MW.

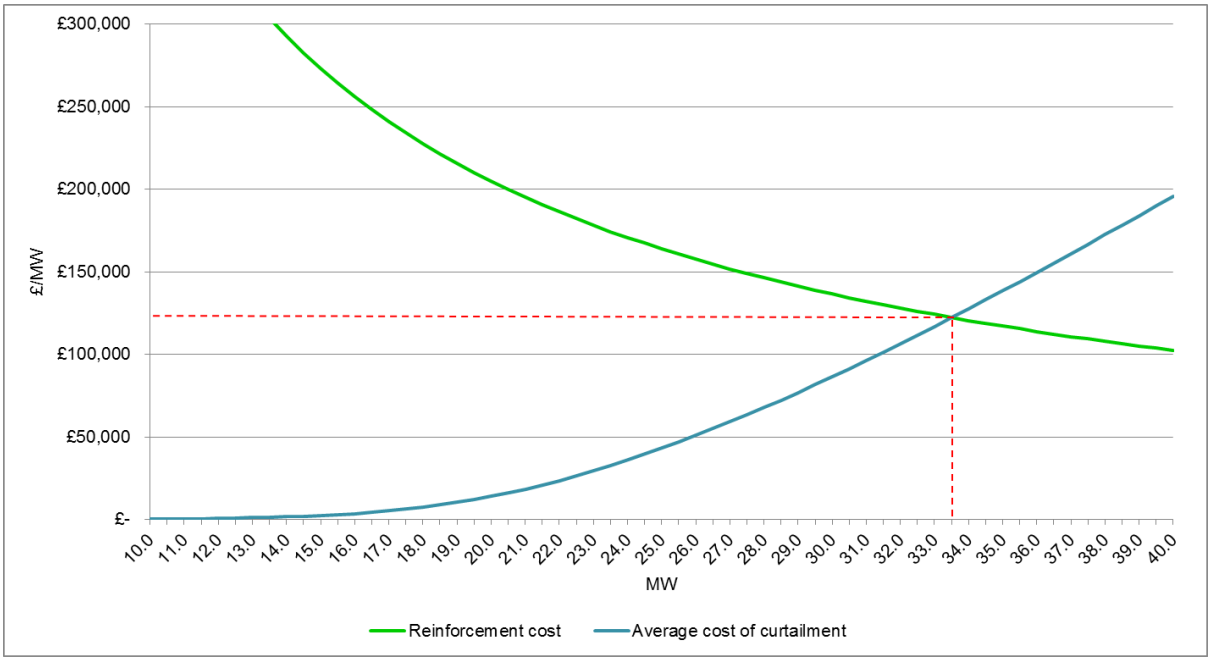

Figure 5 March Grid Capacity Quota calculation

4.3 Terms for the Connection Agreement

The rules under which generators at March Grid will connect are:

1. Generators that are already connected will not be subject to the Active Network Management
2. Until such time that March Grid is reinforced, all future generation that connects within the constrained area will be subject to an interruptible connection through Active Network Management control (ANM Generators).
3. Curtailment of generation output that is required to avoid a breach of the operational limits on the relevant circuit will be shared equally (i.e. pro rata) across all ANM Generators contributing to that constraint.
4. UK Power Networks will limit the total capacity of generation connected within the constrained area to a pre-agreed cap (Capacity Limit).
5. UK Power Networks will inform ANM Generators when the Capacity Limit has been met.
6. Anyone who connects after the Capacity Limit has been filled will be subject to 100% curtailment before any ANM Generator curtailment. This means that UK Power Networks will apply a Last In First Out principles of Access once the Capacity Limit has been reached.

Please note that reference to "interruptible" connections mean connection terms in which the generators are subject to curtailment of their export in specific conditions. "Firm" connections are connections in which all generation output is guaranteed to be accepted into the network under normal operating conditions.

4.4 Quota Status

As your connection offer has been issued, UK Power Networks may have offered the capacity to fill the quota, but may not have final decisions from the prior customers. This means that your curtailment estimates will reflect your position in the Quota Register regarding previously issued connection offers.

5. Curtailment forecasting

Specific curtailment forecasting has been conducted to provide developers with an idea of the levels of curtailment envisioned in the moment the projects connect, as well as the worst case scenario, i.e. when the quota is reached.

5.1 Assumptions

For the purpose of creating certainty around the levels of generation that customers will have throughout the year, UK Power Networks will use power flow modelling capabilities of Smarter Grid Solutions (SGS). SGS has significant experience in this area having been instrumental in building confidence in the curtailment forecasting provided to generators that have invested in interruptible connections offered by Scottish and Southern Energy Power Distribution on its Orkney smart grid project.

The input assumptions used in the forecast analysis relate to the core drivers of curtailment which are:

- Demand profile of customers on the local network behind the thermal constraint on the relevant circuit;
- Capacity factor and export profiles of both firm generators and those connected to the ANM scheme;
- Level of micro-generation export that will not be integrated to the FPP project (by virtue of the fact that they are too small to be cost effectively considered within the ANM scheme) and will therefore not be controllable within the ANM network;
- Network configuration and operating conditions; and
- Capacity limit of the relevant circuit and its relationship with wind speed and other climatic effects.

Please see the *"Flexible Plug and Play: Curtailment Assessment Methodology"* report that outlines the curtailment forecast methodology used by SGS, explains the assumptions selected and provides the individual curtailment estimates for the projects. Finally, the table below synthesises the specific assumptions used for the March Grid curtailment reports.

ASSUMPTIONS	MARCH GRID	SOURCE
a) Network Configuration	Whittlesey and Funtham's Lane transfer to Peterborough Central (NC1)	UK Power Networks' Planning department - this is the planned standard running arrangement from summer 2013 onwards
b) Demand growth	Assume zero demand growth	
c) Micro-generation growth	Based UK Power Networks' forecast in EPN area	Element Energy
d) Capacity factor of generators connected	30% - wind 100% - always on	Feedback from participating generation projects via the Request for Information form
e) Contribution of each generator to the constraint	Constraint Sensitivity Factor	As derived by SGS
f) Number of constraints	1 for March Grid	Network studies carried out by UK Power Networks
g) Generation mix	33MW wind and 0.5 always on	Baringa study report "Principles of Access", Dec 2012
h) Principles of Access	Pro-Rata – Reinforcement Quota	Baringa study report "Principles of Access", Dec 2012
i) Limits	45 MVA	Transformer capacity (N-1) and proposed protection improvement projects currently progressed by UK Power Networks
j) Operating Margins	10%	Previous experience of SGS in Orkney Smart Grid project

6. Next Steps

Upon receiving their connection offer letter, each developer must evaluate the FPP alternative based on the information provided. Throughout the following months UK Power Networks will work closely with developers to address any concern or question regarding the information provided to help them make an informed decision before the expiration date of their FPP offer.

The Flexible Plug and Play project has been programmed and will be financed by the LCNF until December 2014.