Active Network Management for integrating renewable energy to the distribution network

A Commercial Perspective

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Abstract

The 'Flexible Plug and Play Low Carbon Networks' (FPP) project aims to facilitate faster and cheaper connections of renewable generation onto the distribution network, by using innovative technical and commercial solutions. Within this project UK Power Networks will address the commercial implications of installing an Active Network Management scheme to connect generators to its distribution network. This paper describes the commercial implications of interruptible connections for the FPP project. Outlining the need to define clear rules for controlling generators' output, the importance of providing certainty to the customers to be able to finance their projects, and the relevance of conducting further assessment of where risk is allocated. The project has successfully issued interruptible connections that are attractive for customers and will be implementing the connection agreements for at least two wind farm projects in the beginning of 2014.

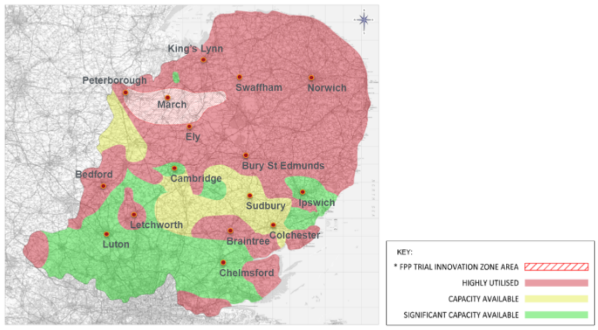
Keywords: Active Network Management, Distribution Network Operator, Interruptible Connections, Distributed Generation

I. Background

Climate change and energy security concerns have encouraged the UK government to find means to facilitate the development of renewable energy generation for diversifying the country's electricity supply. However, with increasing energy generation as well as increasing electricity demand, the Distribution Network Operators (DNOs) face the challenges of optimising network use, avoiding investment on reinforcement ahead of need, while providing connection services to any customer who requires them.

The Flexible Plug and Play (FPP) is an innovation project, funded by Ofgem's Low Carbon Network Fund, which is addressing this concern by implementing smart grid technologies. The project aims to enable cheaper and faster integration of renewable generation to distribution networks by maximising the existing network and actively managing constraints. This will be achieved through the integration of smart devices such as dynamic line rating, a Quadrature-booster transformer, transformer tap changer control relays, modern protection relays, and smart applications such as Active Network Management (ANM).

Figure 1. Eastern Power Networks – Flexible Plug and Play trial area



II. Problem and Solution

A. Constrained Networks

Figure 1 outlines the areas of the eastern network that are highly utilized in red. Specifically in the FPP trial are there have been increased connection requests since 2010. There are several drivers behind the continuous increase in connection requests. First, the government has provided sufficient incentives such as the Feed In Tariff and Renewable Obligations to encourage renewable energy generation development. Second, environment awareness, self energy supply and energy efficiency initiatives are motivating customers to have their own local sources of energy. Third, there are specific geographical areas that have high natural resources such as wind and sun and therefore suitable for power generation. These conditions are exposing DNOs to reach network limits as developers seek more and more generation connections for their projects.

The FPP trial area, shown in Figure 1, that covers a 700sqkm area located in the East of England, UK has favourable characteristics for wind and solar generation; however, due to the existing network infrastructure as of August 2013, more than 144MW of actual generation already connected and over 200MW of projects at planning stage, the distribution network is experiencing reverse power flow, thermal and voltage constraints. Therefore, when new generation developers seek for a connection in this specific part of the network, they are usually offered a point of connection either further away or at a higher voltage level. This results in very expensive connection cost which most times make these projects unviable.

B. Active Network Management and Commercial Constraints

Active Network Management (ANM) involves a range of software, automation and controls that monitor the grid in real time to ensure it remains within its operating limits. By actively monitoring the network, the system can identify any latent capacity in the existing grid. Once limits are exceeded the ANM control system sends a signal to the generators to reduce their output.

The commercial implications of providing a connection that is subject to being curtailed (i.e. limiting the energy that generators input to the network) implies financial uncertainty to projects that depend on a return of investment driven on renewable, and hence intermittent, sources. However, by offering customers an interruptible connection controlled by ANM, the DNO can use its existing assets and connect them to a constrained part of the network and therefore saving customers up to 90% on their upfront capex connection cost.

III. Commercial Analysis - Alternatives for Commercial Solutions for Interruptible Connections

The Flexible Plug and Play project has engaged with suitable and willing customers to take part in the trial. These represent generation projects ranging from a small 0.5MW wind turbine to large 10MW projects that have now been presented with cheaper alternative connection offers under an ANM scheme. Specifically, UK Power Networks has identified wind, solar and anaerobic digestor developments within the trial area.

Three issues arise with the interruptible nature of these smart connections. The first is to determine the order in which generators should be curtailed in the scenario that there is more than one generator connected behind the constraint. The second is to provide certainty to these generators by accurately estimating the expected curtailment throughout the lifetime of their project. Finally, there is a challenge on how to identify who is most suitable to take the financial risk of that uncertainty, i.e. the network owner or operator, the generator or the consumer, given that all of these operate under different regulatory bases.

March Grid Case Study

For the purpose of exemplifying the issues addressed in this paper, UK Power Networks has simulated the March Grid Network, a constrained section within the FPP trial area, where several developers are seeking to connect their projects. The March Grid substation has 45MVA transformers that will determine the amount of power flow allowed back into the system. This is an example of a reverse power flow constraint. ANM will ensure that no more than 45MVA is exported through the transformers at any given time. This same principle applies for similar conditions for networks that present thermal and voltage constraints.

Table 1 outlines the details of the projects considered as well as the costs savings from the Business as Usual (i.e. firm) and the FPP (i.e. interruptible) connection offers.

TABLE I. Projects Seeking Connections Under FPP

	Flexible Plug and Play potential customers					
Gen	***MW***	***Tech***	***BAU***[a]	***FPP***	***Savings***	***Status***
A	5	Wind	£1.2m	£650k	45.2%	Expired
B	0.5	Wind	£1.9m	£235k	87.6%	Expired
C	10	Wind	£4.8m	£590k	87.8%	Accepted
D	7.2	Wind	£3.5m	£881k	74.9%	Accepted
E	1.5	Wind	£1.9m	£157k	91.9%	Valid
F	1	Wind	£2m	£385	81.2%	Expired
G	0.5	CHP	£1.9m	£350k	81.6%	Valid
H	0.5	CHP	£2.5m	£117k	95.0%	Valid
I	0.5	Wind	£0.8m	£157k	81.0%	Valid

a. BAU refers to Business as Usual – firm connection offer

A. Principles of Access

A central component in any commercial connection proposal is to provide a clear and predictable set of rules by which generators will be curtailed in the event that a constraint occurs, i.e. the principles that establish the access rights to the network.

For integrating the FPP proposal for the March Grid generators, UK Power Networks, in collaboration with University of Cambridge [1], considered two main rules of curtailment: Last In First Out (LIFO), based on a first come first serve principle, where any binding network constraint is resolved by curtailing first the generator who connected last; and Pro-rata curtailment, which resolves constraints based upon each generator's proportional contribution to the restriction.

Curtailment analysis proved that for the specific March Grid constraint, LIFO may not be technically efficient, as it may not connect as many MW as the network could sustain; however, it provide certainty to the first developers because they are insulated against greater curtailment caused by the connection of later generation. On the other hand, the Pro-rata approach actually allows for more generation to connect by sharing curtailment equally amongst all generators that are exporting onto the network in the moment of the constraint [2].

With the purpose of optimising the network use, UK Power Networks has implemented Pro-rata curtailment for the FPP trial.

B. Providing Certainty – Curtailment Estimates

Generators will always prefer to have a firm connection. However, each generation project connecting under FPP should theoretically be able to accept a level of curtailment before the project fails to meet its internal investment hurdle rate. This is on the basis that each generator will receive a saving on its upfront connection charge versus connecting firm.

Capacity Quota

The key challenge with Pro-rata curtailment is the need to determine a limit of the amount of generation the network operator will allow to connect behind a specific constraint to avoid intolerable levels of curtailment [3]. To implement this principle, UK Power Networks has decided to adopt a Capacity Quota mechanism.

This approach is based on defining a limit of capacity to connect by calculating the cost of curtailment to the generator (i.e. lost revenue as a result of having their output constrained), and identifying where this cost would equal or exceed the cost of reinforcing the network (i.e. the cost of conducting the works for all generation to connect on a firm basis). This concept is described in Figure 2.

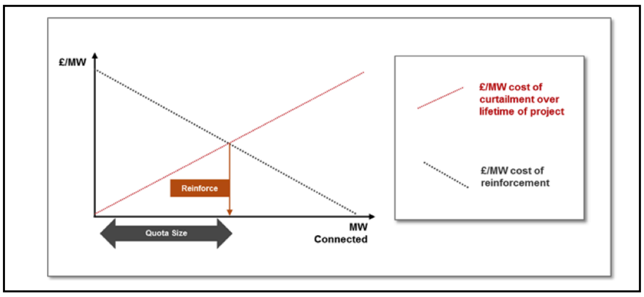


Figure 2. Quota set by reference to reinforcement costs

Calculating the quota

The first step is to calculate the cost of curtailment per MW, based on the Net Present Value (NPV) of the lost revenues from the aggregate curtailment throughout the lifetime of the generation projects. For estimating curtailment, the generation mix is an important assumption. Specifically for March Grid, if we connect 50% solar and 50% wind the likelihood of getting curtailed is less for these complementary generation profiles, than if 100% of wind energy was connected where generation would be highly correlated.

Dividing the cost of reinforcement the by the amount of MW released with those specific reinforcement works, the cost per MW of reinforcement is estimated. The Capacity Quota is then set with the intersection of these two values, i.e. the point at which developers would theoretically rather pay their share of the reinforcement and have firm connections than to sustain the estimated curtailment cost. For the March Grid example, UK Power Networks was able to offer 33.5MW of interruptible capacity [4].

Modelling Curtailment

UK Power Networks provides certainty to its customers, within the interruptible connection offers, by committing of not connecting more capacity than the established limit. However, the most important figure for them to understand is how much curtailment will be once that limit is reached, i.e. when the full interruptible capacity has been used. By modelling the technical characteristics of the grid, using a robust set of assumption and simulating curtailment under the specified principles of access, UK Power Network uses power flow analysis so that generators can have visibility on the likely levels of curtailment through time with a reasonable degree of certainty.

These assumptions include network design and historical generation data to estimate how future generation and load connections will behave. Also generators must understand the values given to capacity factor for wind and solar farms, expected demand growth, and the uptake in micro-generation, such as small local solar panels that determine the worst case level of curtailment for each new generator in the Flexible Plug and Play trial area.

C. Risk Allocation

The premise of the analysis conducted for the FPP project has been that there will be no compensation for curtailment to generators under any circumstance. Therefore, the need to communicate this clearly to customers and allow them to understand that the implication of ANM sits solely at their own risk is critical for the success of the project.

Given the current regulatory framework for DNOs, generation customers are faced with full connection costs. This is outlined in the charging methodology and the definition of the minimum scheme [5], which indicates that the incremental reinforcement works that are sole used assets are charged to the single generator requesting the connection. One of the key advantages of an ANM scheme is that it defers extensive reinforcement and it avoids taking the stranding risk associated to network investment ahead of need. However, when evaluating the FPP or interruptible connection, both the upfront (cheaper) cost for the alternative as well as the future costs for the enduring firm connection should be considered.

With all curtailment risk left with the generators, the key consideration for them to make their investment decision will be the level of confidence they can place in the curtailment forecasts. Any design feature of the commercial and technical arrangements that introduces greater uncertainty will make it more difficult for generators to “bank” their connection agreement.

Collaboration on network reinforcement

By applying a coordinated approach, generators can connect in a constrained area of the network without triggering the reinforcement immediately and instead accept a level of curtailment of their output. Therefore, if over time enough generators have connected under FPP there could come a point where sufficient capacity has connected such that the shared cost of the modular reinforcement action becomes an attractive alternative for generators. For the March Grid example, assuming that all Generators on Table 1 were already connected, the moment a supposed Generator J requested the remaining capacity of the Capacity Quota, they would then, theoretically, all be interested in sharing the cost of reinforcement to convert their connections to firm.

This approach relies upon the generators themselves choosing to initiate reinforcement instead of accepting curtailment. For this to happen, it is key that curtailment is applied in a Pro-rata manner so that the cost of curtailment is allocated symmetrically amongst generators. This way, when trading off the incremental cost of reinforcement against the reduction in curtailment experienced, generators would be in the same, or at least a relatively similar position, for assessing the trade-off. This would not be the case for LIFO where developers would be experiencing different levels of curtailment.

The key benefit of this approach is that instead of reinforcing first and either requiring the first generator (or the consumer, if socialised) to bear the stranded investment risk, generation is allowed to come forward in advance of the reinforcement decision while the quota is sized on the cost of a common ultimate objective – namely a fully firm connection.

IV. Challenges and Next steps

As of August 2013, UK Power Networks has made nine specific interruptible offers to real generation customers of which two have been accepted. This proves that a) the offers have been suitable and commercially attractive to the generators' requirements, and b) that the proposed connection terms are compliant with the current regulatory framework for DNOs in Britain. However, for customers under the proposed actively managed terms of the connection, interruptibility of their output becomes yet another variable to be considered when financing their projects.

Although trying to implement a "reinforcement quota approach" would allow a more sophisticated appraisal of the need for strategic investment, there are key financial concerns for generators as to the certainty of levels of curtailment and the need to make a deferred connection payment at an unknown date. The question then arises as to how reinforcement is treated in the commercial arrangements once the quota is full. Broadly speaking, there are two options feasible within the regulatory framework:

a) Mandatory Reinforcement – Include a hard-wired reinforcement cost into the connection contract. Once the quota had been filled, each generator would be obliged to fund the reinforcement at that pre-agreed price.

b) Voluntary Reinforcement - At the point of reaching the trigger, generators would be offered the option to reinforce. If they accept and decide to fund reinforcement, they would then have a firm connection. If they do not accept they would remain non-firm and subject to on-going potential curtailment.

For the purpose of the FPP project a voluntary approach has been implemented, and it will be for the future to tell if customers will be willing to "buy firm" once the quota is full. However, this does not mean that the mandatory approach could be as attractive for both DNO and customers. One potential problem is that the reinforcement scheme which the quota is based upon might not be the optimal technical solution in 10 or more years when the quota is full and the network conditions may have potentially shifted.

V. Conclusions

UK Power Networks seeks to understand what conditions will enable DNOs to utilise smart grid solutions, minimise curtailment of generation output and, in general, optimise the network, in order to facilitate the integration of renewable energies such as wind. The novelty of smart grid technologies and contractual agreements will facilitate management and operation of the network in real-time and has now proven to provide attractive connection alternatives for DG customers.

Based on the cost benefit analysis conducted by University of Cambridge of the FPP connection offer, it appears that smaller wind generation projects are more likely to receive higher benefits (i.e. higher Net Present Value (NPV)/MW) than larger generation projects, but all present positive NPV that will most likely influence them to accept such connection offers [6]. Having the first projects connected will provide a precedent to the acceptance of interruptibility and create confidence on the technology for both customers as well as for their financing institutions.

By effectively proposing interruptible connection agreements to customers, UK Power Networks has incorporated key learnings that will be critical for embedding interruptible connections as a business as usual practice:

- To be able to comply within the regulatory framework, it's important to keep the connection offers within the national terms of connection
- For successfully embedding this practice into the business, it is key to comply with current practices such as regulatory compliance dates such as time to issue connections offers, providing customer the certainty that these are within the current framework.
- Finding a balance between conservative assumptions for curtailment to be realistic but not too conservative for finance to be more expensive than required is also important for satisfying both generation project developers as well as their banks.
- Customers are incentivised to have a faster connection due to the uncertainty of tariffs and compensation schemes that government re-assesses periodically. Therefore, if connecting under interruptible terms guarantees that they can secure a specific tariff, FPP becomes an attractive alternative.

Going forward UK Power Networks will continue to offer interruptible connections in the trial area. The next steps of the project will look to understand how to incorporate this practice into the rest of the network.

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