FLEXIBLE PLUG AND PLAY LOW CARBON NETWORKS: COMMERCIAL SOLUTIONS FOR ACTIVE NETWORK MANAGEMENT

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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 their distribution network. This paper reviews the rules under which generators can have their output controlled and curtailed and outlines four commercial alternatives to provide certainty to developers on their generation investment. It proposes a Reinforcement Guarantee approach as an attractive option for Distribution Network Operators (DNOs) to tackle network investments in a strategic manner. This is done through the utilization of smart technologies that bring forward generation within the existing infrastructure avoiding high stranded investment risk.

INTRODUCTION

The FPP project, funded by the Low Carbon Network Fund, is trialing various smart solutions to enable distributed generation (DG) to connect onto the network located in a 700km^2 area between Peterborough and Cambridge in the east of England which currently experiences voltage, thermal and power flow constraints. This paper will provide an overview of the commercial alternatives for offering connections to projects in this area.

Specifically, there are three key issues that must be considered when defining commercial terms for these smart connections. The first is to address the interruptible nature of the connections and define the order in which generators should be curtailed when there is more than one project contributing to the same constraint. The second is to provide certainty of the estimated levels of curtailment, and the third is to identify who is most suitable to take the financial risk of the uncertainty (i.e. the network operator, the generator or the consumer).

The Problem

Renewable energy projects seeking connections in this constrained part of the network have received expensive connection offers which make their projects unviable. The high connection costs of these projects are due to the extensive reinforcement works required to mitigate the specific network constraints regarding each connection. Although these expensive connections represent an unrestricted (i.e. firm) solution, developers are not in a position to assume these costs.

The Solution

By installing Active Network Management (ANM) and smart devices in the constrained part of the network, UK Power Networks will optimise the use of the current network infrastructure. This is achieved by managing generation in real time and curtailing the generator’s output at certain periods of time. ANM provides a practical, faster and more cost effective in terms of upfront capital connection cost alternative to connecting DG. However, the commercial consequences of providing a connection that is subject to being constrained (i.e. non-firm connection) implies financial uncertainty for projects that depend on a return on investment driven on intermittent sources of energy. This work has focused on developing a solution that can be implemented as part of the FPP project and within the existing regulatory regime.

March Grid Case Study

For the purpose of exemplifying the issues addressed in this paper, UK Power Networks has conducted simulation of the March Grid Network, a constrained section within the FPP trial area, where several developers are seeking to connect their wind energy projects. There are at least seven developers, with installed capacity ranging from 0.5MW to 16.4MW, which are seeking to connect within that area.

Principles of Access

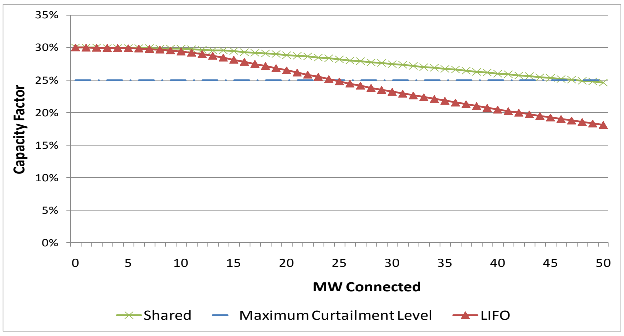
In order to give some certainty to generators as to the level of curtailment they will experience under the actively managed connection, a central component in any commercial proposal will be to provide a clear and predictable set of rules by which generators will be curtailed in the event that a constraint occurs (i.e. principles of access). By modelling the technical characteristics of the grid, using a robust set of assumptions and simulating curtailment under these specified principles of access, generators can then forecast the likely levels of curtailment through time with a reasonable degree of certainty.
There are three main rules of curtailment that have been assessed:
1. Last In First Out (LIFO) curtailment is based on a first come first serve principle. Any binding network constraint is resolved by curtailing first the generator who connected last. Although this alternative may not be technically efficient, as it may not connect as many MW as the network could sustain, it does provide certainty to the first developers because they are insulated against greater curtailment caused by the connection of later generation.
2. Pro-Rata curtailment resolves constraints based on each generator's proportional contribution to the restriction. As such, when the limits of the network are reached, curtailment is shared equally amongst all generators that are exporting onto the network in the moment of the constraint.
3. Market based approach considers paying compensation for exceeding a defined level of curtailment. This option is most attractive for developers since it provides certainty of their maximum revenue loss.

A study conducted by University of Cambridge, as part of the FPP project, looks at lessons learned abroad of how renewable generation is connected and actively managed in other countries under different regulatory frameworks. This research includes four case studies, including the Orkney project with ANM technology implemented by Scottish and Southern Energy and the Connect and Manage scheme implemented in the transmission sector in the UK. It also looks at the particular case of Ireland, and the ambitious renewable energy program for California in the USA [1]. These cases reflect implementation of the three principles of access mentioned above. However, due to the current regulatory framework and for the needs of the FPP project, UK Power networks has decided not to consider the possibility of DNOs underwriting curtailment risk implemented by some of these case studies. Only LIFO and Pro-Rata have been assessed from both a commercial and technical perspective.

Assessment between LIFO and Pro-Rata

As mentioned above, given the upfront savings in their connection cost, each generation project connecting under FPP should be able to accept a level of curtailment before the project fails to meet its internal investment hurdle rate (i.e. "acceptable" curtailment).
It can be argued that LIFO is potentially inefficient as it leaves a portion of this "acceptable" curtailment unutilized, leading to a reduction in the overall amount of generation that can connect in any constrained zone. The last generators, for example, would never be inclined to connect due to the high levels of curtailment expected. Pro-Rata, on the other hand, could potentially use the network to its full capacity while curtailing generators under that "acceptable" level of curtailment.
To understand the technical implications of these two principles of access, curtailment scenarios were compared by modeling both schemes, under the same assumptions, for the March Grid case study. Assuming a maximum curtailment level of a 3% drop in annual capacity factor (i.e. assuming capacity factor of 30%, curtailment would result in a curtailed capacity factor of 27%), sharing curtailment across all wind generators pro-rata theoretically allows the connection of around 83% more generation in a constrained zone than if generators were curtailed based on LIFO. Figure 1 outlines the forecast results.

Figure 1 Curtailed capacity factors under LIFO vs. Pro-Rata for March Grid



Although Pro-Rata might be optimal from a network efficiency point of view, its key problem is determining a limit to the amount of generation the network operator allows connecting without reaching unsustainable levels of curtailment.

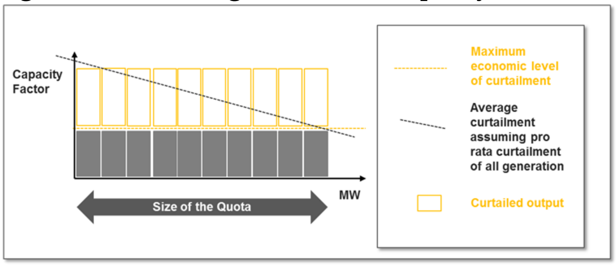
Commercial Packages

To explore how Pro-Rata curtailment could be implemented, UK Power Networks has defined four commercial packages:

1. Time Vintaging: This option considers grouping generators into "vintages" by reference to the period of time in which they applied for connection. For example, the DNO would set six month time gates and curtailment would be applied pro-rata to generators *within* the same vintage. In resolving any constraint, generators in the *second to last* vintage would only be curtailed in the event that the output of all the generators in the *last* vintage had been curtailed to zero (and so on), applying LIFO *between* vintages. This approach however does not resolve the uncertainty of how much generation could connect within a time period, and avoid intolerable levels of curtailment.

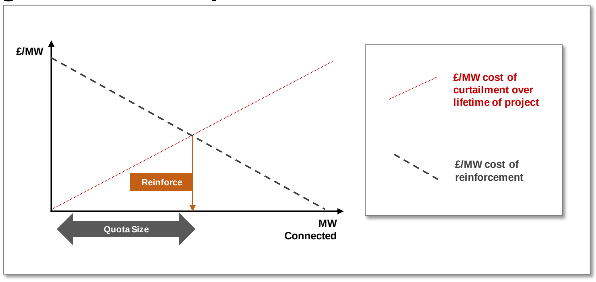
2. Capacity Quota: This alternative proposes to calculate the maximum level of capacity that can viably connect in any given constrained zone upfront by defining a "tolerable level of curtailment". To achieve this, the DNO must model how shared curtailment increases as more generators connect. By fixing the limit on capacity at a point which returns tolerable levels of curtailment for all generators, a quota based approach looks to provide some certainty to them. Figure 2 describes this approach. However, in reality, there is considerable variation in the sensitivity of different generators to curtailment which are driven by assumptions on technology type, capacity factor, capex and savings on their FPP connection. Given the variance in appetite for curtailment amongst generation types and the sensitivity of the results to changes in the assumptions, picking the "right" level of tolerable curtailment requires the DNO to make a value judgment that, given its position, might not be feasible for it to make without extensive bilateral dialogue with its potential generator clients.

Figure 2 Determining the size of a Capacity Quota



3. Reinforcement Quota: This approach is based on the reinforcement cost, i.e. the cost of conducting the reinforcement works for all generation to connect on a firm basis. This option is a variant on the capacity quota approach. However, instead of defining the quota by reference to a maximum curtailment level, it looks to define the quota by reference to the level of capacity connected in a constrained zone at which the cost to each generator in terms of lost revenue as a result of curtailment (i.e. "curtailment cost") equals or exceeds the cost of reinforcing the network (i.e. the cost of "buying firm"). In deciding whether to connect under this proposal, each developer would have to get comfortable that their project can withstand the curtailment triggered by generation connecting up to the level of the quota before reinforcement is triggered. Figure 3 describes this alternative.

Figure 3 Quota set by reference to reinforcement costs

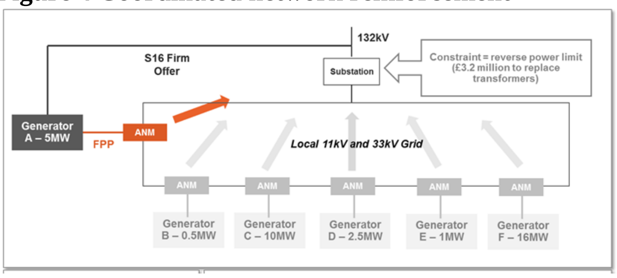


4. Capacity auction. There may not always be an affordable reinforcement alternative before curtailment levels are too high, in that case a capacity auction could be used. A capacity auction proposes that the DNO advertise the availability of network capacity and recruit generators that might potentially be interested in connecting in that particular constrained zone. Each generator would then be asked to bid the annual level of curtailment that it would be prepared to accept over the lifetime of its project. The level of demand for connection at different levels of curtailment could then be matched against the maximum capacity quota that returned that level of annual curtailment.

Collaboration on network reinforcement

One of the key advantages of an ANM scheme is that it allows connecting generation projects throughout a period of time without having to charge the first generator for the reinforcement works, and it avoids taking the stranding risk associated to network investment ahead of need. As such, when applying the charging methodology and the definition of the minimum scheme [2], there is invariably a cheaper incremental solution involving extended sole use assets to connect that single generator to another unconstrained part of the network.

Figure 4 Coordinated network reinforcement



By applying the Reinforcement Guarantee approach, generators can connect in a constrained zone of the network without triggering the reinforcement and instead accepting a level of curtailment of their output. Then, if over time, enough of them have connected under FPP there could come a point where sufficient capacity has connected such that the shared cost of the modular reinforcement action is a viable proposition for generators. For the March Grid example, assuming that Generators A, B, C, D, and E were already connected, the moment Generator F requested a connection, they would all then be interested in sharing the cost of reinforcement. This is described in Figure 4.

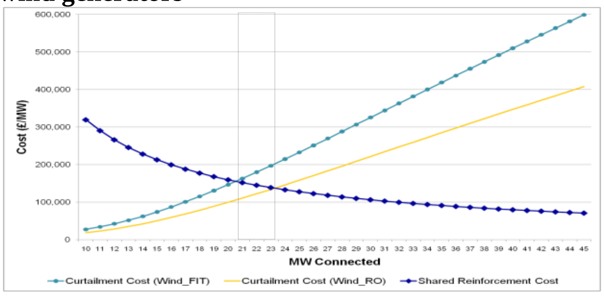
Calculating the quota

To implement the Reinforcement Guarantee approach, the DNO will need to simulate the levels of curtailment for the estimated generation mix in that part of the network. For example, for the March Grid case study, the area in Cambridgeshire in which the trial zone is located is ideally suited for onshore wind generation due its topography. This explains why 100% of distributed generators already connected in that area are wind farms. Therefore, this study has assumed all wind generation.

Once the curtailment estimates are clear, the DNO will calculate the Net Present Value of the lost revenues from the aggregate curtailment throughout the lifetime of the generation projects. This will define the cost of curtailment per MW. The amount of revenue loss will depend on the subsidy regime under which each wind generator is governed. As such, it is important to assess how the trade-off between lost revenue and shared reinforcement cost varies across wind generators funded under the two principal support schemes – the Renewable Obligation (RO) mechanism and the small scale Feed-In-Tariff (FIT).

In the same way, analysis will be done to determine the cost per MW of reinforcement. With the intersection of these two values, the “reinforcement trigger” will identify the point at which developers would rather pay their share of the reinforcement and have a firm connection than sustain the estimated curtailment cost. Figure 6 exemplifies how for the March Grid example, between 21 and 23 MW of capacity would present levels of curtailment that would be reasonable for generators before they would prefer to pay their share of reinforcement.

Figure 5 Curtailment / reinforcement trade-off for wind generators



With all curtailment risk left with the generator, the key consideration for making an 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.

Conclusions and next steps

The Reinforcement Guarantee model 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. 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:

a) Mandatory Reinforcement – Include a hard-wired reinforcement cost into the connection contract. Once the quota is 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.

The FPP project will further explore the Reinforcement Guarantee option with the interested generation developers in the area and it intends to trial its application for offering non-firm generation connections.

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[2] UKPN, 2012, “Statement of methodology and charges for connection to the electricity distribution systems of Eastern Power Networks PLC, London Power Networks PLC & South Eastern Power Networks PLC”

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