DISTRIBUTED GENERATION: OPPORTUNITIES FOR DISTRIBUTION NETWORK OPERATORS, GENERATORS AND WIDER SOCIETY

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ABSTRACT

This paper analyses and quantifies the opportunities that different parties such as the DNOs, generators and society may have when connecting more Distributed Generation (DG) within the distribution grid. The quantification of benefits is presented across three scenarios which analyse firm and non-firm connections under different assumptions of installed capacity, generation mix and curtailment level. Results suggest that DG owners benefit the most and wider society the least. Thus, a smart connection incentive is proposed in order to get a better distribution of the benefits for connecting more DG.

INTRODUCTION

DG introduces new challenges to Distributed Network Operators (DNOs) but also opportunities that reflect the economic benefits arising from more active networks. These challenges and opportunities are not only technical. Regulation and innovative commercial arrangements have an important role to play in allowing the DNOs to capture an appropriate share of these benefits.

The aim of this paper is to evaluate the opportunities and challenges facing the different parties when connecting more DG within a distribution network. This study will quantify the most relevant benefits of facilitating earlier and greater quantities of DG by examining the difference between smart connection arrangements and conventional connection arrangements in the face of network constraints. The study is focused on a constrained area of the March Grid (East of England) operated by UK Power Networks. This area has been selected by the DNO because of increasing DG to be the trial area of the Flexible Plug and Play project that is being implemented by UK Power Networks. Benefits are represented by DG incentives and profits for connecting DG units (including embedded benefits). The paper also introduces a smart connection incentive in order to encourage quicker and cheaper connections and to have a better balance in the distribution of benefits.

QUANTIFICATION OF BENEFITS

This section quantifies the benefits that DNOs may be entitled to for connecting more DG in their respective networks. In addition, benefits to wider society and to generators are also estimated. The analysis is performed based on the cost benefit analysis (CBA) methodology discussed in the report "Finding the optimal approach for allocating and releasing distribution system capacity: Deciding between interruptible connections and firm DG connections " produced by the Energy Policy Research Group in the context of the Flexible Plug and Play Project (Anaya and Pollitt, 2013). Under this project, UK Power Networks, the largest DNO in the UK, is looking at different options for connecting more DG. Developers are seeking connections at constrained parts of the network that operate within the trial area in the East of England (March Grid). The constrained area is driven by the excessive reverse power that flows on the existing 45 MVA transformers (132/33kV). Only interruptible connections are now possible in this area without any major reinforcement works.

Three scenarios have been evaluated in this study. The diversity of scenarios: (1) illustrates and assesses different connection options in case of restricted capacity (constrained area); (2) provides insights about the possible solutions (deciding between smart interruptible connections or full connection subject to reinforcement) and the costs of selecting one or other (via the net present value of each solution); and (3) contributes to a better explanation of the different connection situations that generators face in the real world.

We have assumed a fixed demand across the project lifetime (set at 20 years), a maximum curtailment level for each type of technology (modelled by Smarter Grid Solutions, a project partner), different sizes of installed capacity and a combination of types of renewable generation technologies, see Table 1.

Table 1: Summary of Scenarios

Scenario	Installed capacity (MW)	Generation mix (% installed capacity) wind	solar PV	AD CHP
Scenario 1	14.5	100%		
Scenario 2	27.627	52.5%	43.9%	3.6%
Scenario 3	33.5	60.8%	36.2%	3.0%

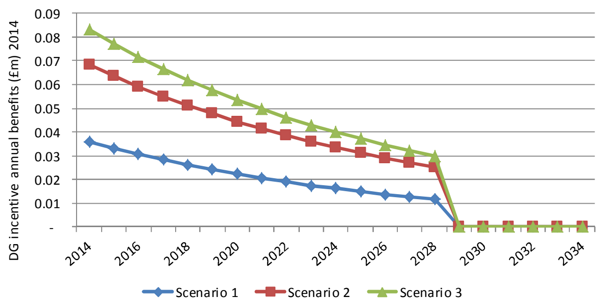
Benefits to DNOs, generators and wider society are estimated in the following sections for each scenario. All figures are expressed in 2014 prices and technology specific discount rates (pre-tax real) have been used for NPV estimations in agreement with the latest generation costs report published by DECC (2013). It has been assumed a project lifetime of 20 years (period 2014-2034) regardless of the type of generation plant. The assumptions, formulas and references are shown (Anaya and Pollitt, 2013)

DNOs' Benefits

DG incentives and our proposed smart connection incentive represent the DNOs benefits. The DG incentives were introduced in the previous price control review (DPCR4, which ran from 2005-2010). In addition, this study proposes the introduction of a smart connection incentive that would encourage the expansion of DG connections using smart solutions. This incentive would need to be paid by the generators to the DNO.

DG incentives represent a kind of cost-recovery mechanism that contributes to the reduction of uncertainty regarding the volumes of DG connections. Accordingly to OFGEM, the DG incentives help to reduce the risks to DNOs and their customers of bad forecasts of volumes and costs which would have otherwise been part of allowed revenues set ex ante with the rest of the price control. The incentives apply to all generators, on all voltages. In agreement with Harrison *et al.* (2007) and Siano *et al.* (2009), it was assumed that the total benefits arising from the DG incentives are represented by those related to the annual operation and maintenance (O&M) allowance valued at £1/kW and the annual DG capacity allowance also valued at £1/kW in the current price control (DPCR5: 2010-2015). DNOs currently benefit from both incentives regardless of the existence of use of system capex. The incentives are valid for 15 years after the date of connection (for this study is 2014) and need to be inflation adjusted. Total benefits have been calculated for each scenario. Figure 1 depicts the annual benefits.

Figure 1: DG Incentives Benefits over time



It is noteworthy that under the context of RIIO-ED1, OFGEM agreed to remove this scheme. This means that DNOs will only benefit from this scheme until 31st March 2015. Following OFGEM (2013), one of the main reasons of the removal was the perceived complexity of the scheme was a barrier to the connection of DG. In addition, OFGEM believes that DG incentives are no longer required given the package of measures sets in RIIO-ED1 (OFGEM, 2012a).

In terms of the smart connection incentive, this recreates the benefits from the losses incentive (removed in 2012).This was removed due to data volatility which affects the degree of certainty in the estimation of losses (OFGEM, 2012b). Even though general losses incentives have been removed, OFGEM is committed to continue with the incentives for losses reduction in the upcoming price control period 2015-2023 (RIIO-ED1). Around £32m in losses incentive is expected to be awarded in three tranches over the eight years; up to £8m in year 2, up to £10m in year four and up to £14m in year six (OFGEM, 2013).

Thus, we would need to quantify first the benefits from losses reduction (MWh) in order to estimate the smart connection incentive. Different studies have evaluated the impact that DG has on electric losses. Most of them have made specific assumptions regarding DG penetration, load factor, generation mix, voltage limits, network load, among others. Similarly, different techniques have been applied such as those based on computational algorithms (Mendez *et al.,* 2006; Siano *et al.* 2009).

For our estimations we are going to use a different approach based on the losses associated with the different voltage levels that DG can connect. The contribution (in percentage terms) of the total distribution losses per voltage level is taken into consideration for estimating the reduction of electric losses due to the connection of DG units at 11 kV and 33 kV. We are assuming that DG will contribute to system losses reduction and that there is a low chance that the injection of power exceeds the local demand. Following OFGEM (2003), the share of losses across different voltage levels is around 19% (132kV), 14% (33kV), 34% (11 kV) and 34% (LV, including meters). Thus, if a generator is connected at 33 kV, electric losses savings would be around 19% of the average distribution losses. If this is connected at 11kV, savings would be in the order of 33% (19% + 14%). We have assumed that the initial target loss level is equal to the average distribution losses (period 2005/06-2009/10) estimated at 4.89% for UKPN Eastern Power Networks (EPN).

Losses have been calculated on an annual basis for each generator at their respective voltage level. For example, Wind 1 (Scenario 1) generates around 1,310 MWh per year, the target annual losses would be 64.05 MWh (1,310*4.89%), thus losses reduction are of the order of 21.13 MWh (64.05*33% @ 11 kV). The same procedure is applied to the rest of generators with non-firm and firm connections across the three scenarios. Table 2 shows the list of generators for each scenario and their respective installed capacity and associated voltage connection level.

Table 2: Summary of DG connections for each scenario

DG Owner	Cap. (MW)	S1	S2	S3	Voltage 33kV	Voltage 11kV
Wind 1	0.5	x	x	x		x
Wind 2	1	x	x	x		x
Wind 3	1.5	x	x	x		x
Wind 4	0.5	x	x	x		x
Wind 5	10	x	x	x	x	
Wind 6	0.5	x	x	x		x
Wind 7	0.5	x	x	x		x
Solar PV1	4		x	x	x	
Solar PV2	6.9		x	x	x	
Solar PV3	1.2		x	x		x
AD CHP 1	0.5		x	x		x
AD CHP 2	0.5		x	x		x
Wind 8	5.8			x	x	
Total (MW)		14.5	27.6	33.5		

In order to calculate the monetary savings of losses reduction, we have valued losses at £48.42/MWh (2012/13 prices). This is in agreement with the value assumed by OFGEM in the CBA modelling for RIIO-ED1. This value remains the same (real values) for the project lifetime.

Thus the smart connection incentive would take the following values: £15,850/MW (Scenario 1), £12,360/MW (Scenario 2) and £12,395/MW (Scenario 3), with an average value of £13,535/MW. These figures are calculated dividing the NPV of the losses savings over the project lifetime by the installed capacity (related to each scenario). In order to look at how reasonable this incentive is, we have compared this figure with the savings (applicable to generators) due to deferral of investment based on the year when the network upgrade is made (t+1,…., t+20). UK Power Networks have estimated a gross upgrade cost of £4.1m (2012 prices) which mainly reflects those costs associated with the replacement of specific transformers that will allow the increase of the system capacity related to the March Grid constrained area up to 90 MW. The network constraint is located on the two 132/33 kV transformers at the March Grid substation. These costs should be incurred by the generators because they have not been budgeted and are not part of the DNO's allowed revenues. Thus, we find it convenient to use the value of £4.1m as a reference for computing the benefits due to network deferral but applicable to generators. The expected investment can be postponed for the generator for months or years, thus the estimation of benefits are related to the value of this investment over time.

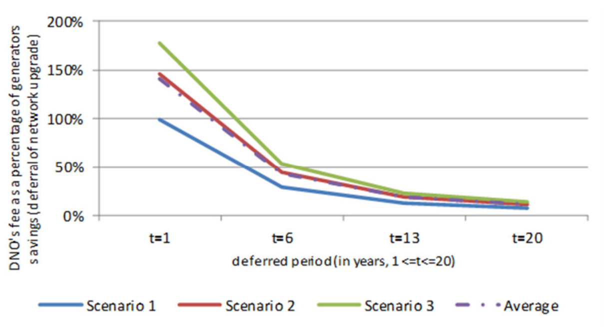
Benefits from network deferral are estimated by the difference between the gross value of the network investment at present time and the gross present value of the deferred investment at specific year.

$$Benefits\ (t_i) = NI * \left(1 - \frac{1}{e^{\delta * t_i}}\right) \qquad \text{Eq. (1)}$$

Where NI is the total network investment (£4.1m), δ is the annual interest rate (5.7%), t_i represents the time of investment deferral (in years) from i=1 to 20. It has been assumed that the project lifetime is 20 years.

Taking into consideration the different network deferral scenarios suggested in this study, the smart connection incentive may represent between 8% (Scenario 1, t+20) and 178% (Scenario 3, t+1) of total savings due to network investment deferral. The lowest rate corresponds to investment deferral of 20 years while the highest rate relates to an investment deferral of only 1 year. Figure 2 illustrates this dynamic.

Figure 2: Smart connection incentive as percentage of total savings for network investment deferral



Generators' Benefits

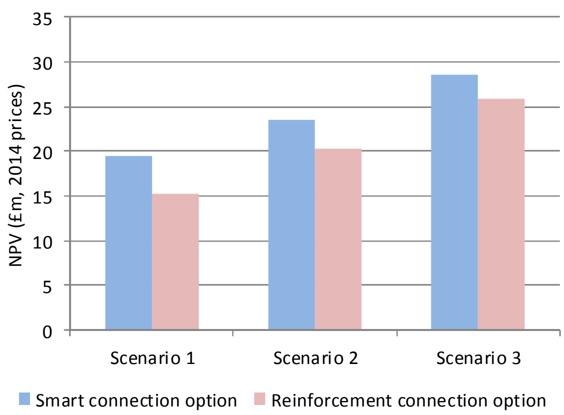
The generators' benefits are represented by the profits that generators get from connecting DG units (revenues minus costs). These include (1) the energy revenues, (2) the generator share of embedded benefits – which refer to those costs that generators may save when they are directly connected to the distribution network instead of the transmission network, (3) energy savings (for solar PV) – which refer to those savings that owners of solar PV generators enjoy when the produced electricity is used for own consumption on site; less the suggested smart connection incentive. Revenues are composed of the sale of electricity in the wholesale market and of the subsidies and incentives (e.g. FIT, RO, LEC) received by renewable generators. Costs involve generation and connection costs. Generation costs refer to operating and capital expenses associated with electricity generation which vary depending on the kind of technology. Connection costs include those associated with smart or non-firm connections (FPP connection costs) and those associated with the network upgrade when a firm connection is preferred (reinforcement costs). The array of generators for each scenario is the current list of generators (updated to December 2014) that are planning to connect to the constrained area of March Grid before April 2015. Three connection scenarios are evaluated: only wind with partial quota (14.5 MW), mix of generation with partial quota (27.627 MW) and mix of generation with full quota (33.5 MW). The annual curtailment limit varies across the three scenarios, being Scenario 3 the one with the highest level of curtailment limits, see Table 3.

Table 3: Array of generators for each scenario

DG Owner	Annual curtailment (MWh)			FPP connection costs
	S1	S2	S3	(£m)
Wind 1	1	21	24	0.06
Wind 2	2	43	48	0.13
Wind 3	3	64	73	0.19
Wind 4	1	21	24	0.06
Wind 5	22	428	484	1.29
Wind 6	1	21	24	0.06
Wind 7	1	21	24	0.06
Solar PV1		84	90	0.52
Solar PV2		146	156	0.89
Solar PV3		25	27	0.15
AD CHP 1		19	22	0.06
AD CHP 2		19	22	0.06
Wind 8			284	0.76

Results from the CBA suggest that across the three scenarios, the smart connection option is the one preferred by all generators regardless their size and type of technology. This fact can be explained by the low rates of annual curtailment that generators are subject to, especially in Scenario 1 when less than 50% of total interruptible capacity quota has been allocated to wind generators only. Figure 3 depicts these results (including embedded benefits).

Figure 3: CBA Results – Electricity Generation Costs

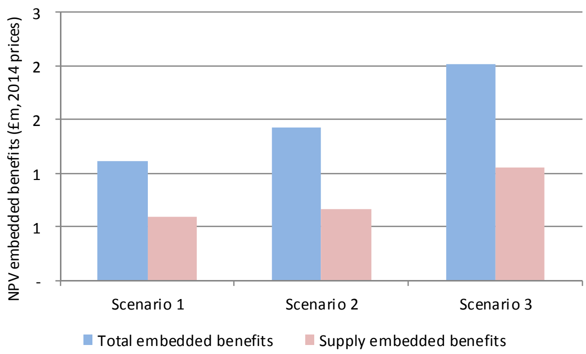


We also observe that the results are very sensitive to the discount rate used in the analysis. A 10% discount rate would produce an important decrease in the net benefits; however the most affected would be the solar PV generators with negative NPV value (Scenario 2 and 3 with or without embedded benefits).

Wider Societal Benefits

These are composed of the suppliers' embedded benefits. Benefits from the reduction of carbon emissions (due to decrease in energy losses) have not been considered because the electricity prices (which are taken into consideration for the estimation of revenues) already include in their estimation the price of carbon. Thus, its inclusion may distort the estimation of benefits due to the potential double counting of savings due to the reduction of carbon emissions originated by the decrease in energy losses. In agreement with Baring-UK Power Networks (2013), embedded benefits are related to the benefits associated with the supplier avoidance of balancing system charges, supplier transmission loss reduction and distribution line losses. Figure 4 illustrates the NPV of the supply embedded benefits for the smart connection option. We observe that the supply embedded benefits represent on average around 51% of the total embedded benefits (composed of generation and supply embedded benefits).

Figure 4: NPV of total and supply embedded benefits



SUMMARY AND DISCUSSION OF BENEFITS

The summary of benefits, including the allocation of these across the different parties are shown in Table 4.

The figures refer only to the non-firm connection option because this is the only one that relates to a smart connection (under the firm connection option, generators export 100% of their electricity and there is no need to manage the generation output actively). It is observed that DNOs and wider societal benefit the least and generators the most. Electricity generation net benefits are the ones that contribute importantly to the total generators' benefits.

Table 4: Total benefits for smart connections

Parties	Type of benefit (£m)	Unit	S1	S2	S3
DG owners	Non-firm connections (going smarter)	£m	19.00	22.73	27.68
	Embedded benefits (generators)	£m	0.52	0.76	0.97
	(-) Smart connection incentive	£m	-0.23	-0.34	-0.42
DNO	DG incentives	£m	0.38	0.77	0.92
	Smart connection incentive	£m	0.23	0.34	0.42
Wider society	Embedded benefits (suppliers)	£m	0.60	0.67	1.05
	(-) DG incentives	£m	-0.38	-0.77	-0.92
Total benefits		£m	**20.11**	**24.16**	**29.70**
		£/MW	1.39	0.87	0.89

Among the main factors that contribute to this are the different subsidy schemes that generators are entitled such as FIT and ROC. In relation to DNO's benefits, DG incentives represent around 67% of the total benefits allocated to the DNO; if the smart connection incentive also is taken into account. Under the current price control review (DPCR5) and the forthcoming one (RIIO-ED1), apart from DG incentives that related to the MW connected; there are not specific initiatives that promote and encourage DNOs to connect more DG units within their networks (OFGEM, 2013).

In contrast with other metrics which are usually incentivised/penalised (i.e. Incentive on Connection Engagement - ICE, Guaranteed Standards of Performance - GSOP), there is not any metrics related to the connection of more MW and incentive payments. The increase in DG connections, especially those that would require network reinforcement, may affect negatively customers if these costs need to be socialised. The network upgrade will benefit not only the DNO but also the DG owners, however customers will always pay for this. Customers don't benefit if performance is rewarded generously by them. Thus, we think that it is important to identify the way to distribute more efficiently the benefits for connecting more DG. One option could be to implement a kind of smart connection incentive as proposed in this study. The size of this incentive is in agreement with the losses incentives (already removed) that DNOs would have received. Our estimations suggest that the smart connection incentive only represents a small proportion of the benefits associated with the deferral of network reinforcement. This would be around 11% for Scenario 1 with an investment deferral of 20 years. We also note that the estimation of benefits are also very sensitive to the discount rate and that the solar PV generators are those that would suffer the most with negative NPV if a discount rate of 10% is taken into account instead of the 6.2% assumed in this study based on DECC (2013). From Table 4, we also observe that wider society is actually worse off in Scenario 2 and 3 because of the DG incentive payments. This makes a stronger case for charging DG a smart connection fee rather than having an incentive payment paid by DNO customers.

CONCLUSIONS

The case study evaluated in this paper refers to the Flexible Plug and Play trial that is being implemented by UK Power Network in the March Grid constrained area. Different kinds of benefits have been identified and allocated across the parties. Electricity generation benefits are those with the highest proportion over total benefits. This means that generators are those that benefit the most when the smart connection option is the one selected. Our results suggest the introduction of the smart connection incentive, paid by the generators to the DNO, may help to allocate more efficiently the distribution of the benefits from connecting more DG units.

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