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Going smarter in the connection of distributed generation

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ABSTRACT

This study explores and quantifies the benefits of connecting more distributed generation (DG) with and without the use of smart connections in Great Britain. We examine the impacts on different parties (Distribution Network Operators, wider society and generators). As illustration we use a specific case study. Alternative connection scenarios are proposed (with partial and full interruptible capacity quota under a mix of generation with different technology-specific curtailment levels) for integrating DG units in a constrained area of the East of England covered by the Flexible Plug and Play project. The smart (interruptible) connection option is the preferred option across all the scenarios (higher NPV/MW). The analysis of the distribution of benefits between the different parties suggests that generators capture most of the benefits while DNOs and wider society capture much less benefit. A *smart connection incentive*, which recreates the benefits to DNOs from an earlier losses incentive, is proposed. By contrast with other societally desirable metrics which are usually incentivised or penalised, there is currently no direct connection between more DG MWs connected and DNO incentive payments. Our proposed *smart connection incentive*, by charging DG for smarter connection may help to distribute more efficiently the benefits for connecting more DG.

1. Introduction

The growth of Distributed Generation (DG) is being influenced by renewable energy targets and related regulation. Diverse incentive and subsidy schemes that benefit renewable generators have been applied in many countries. Electric utilities (which own distribution networks) play an important role by operating and facilitating the connection of more DG units. However, the operation of DG units might be subject to unbundling rules. For instance in the EU, Distribution System Operators (DSOs) are prevented from owning and operating generating units.

The expansion of DG brings benefits to different parties such as DG developers/owners, network utilities and society, but there are also challenges. On the one hand, the incorporation of DG into distribution networks produces important effects on the traditional operation of Distribution Network Operators (DNOs). Existing distribution networks are designed to be passive and to transport electricity from transmission grid off-take points to end customers with minimal levels of control, monitoring and supervision; and were not designed to accommodate generation at lower voltages. On the other hand, DG may have a positive effect across the different parties, not only in terms of technical issues (losses reduction,[1] security of supply, provision of ancillary services) but also in terms of other benefits arising from the use of active networks via innovative (smarter) commercial arrangements.

The paper has two major aims. The first one relates to the evaluation and estimation of the most relevant benefits from facilitating earlier and greater quantities of DG by examining different connection scenarios (with and without smart solutions) applicable to the GB energy market context. A cost-benefit analysis (CBA) methodology is proposed and conducted. The CBA refers to a specific case study (the Flexible Plug and Play project implemented by UK Power Networks). The paper estimates the allocation of these benefits across the different parties (DNOs, generators and wider society[2]). We want to know how each of the parties benefit and to what extent. The second one involves a regulatory proposal that would put in place a better incentive to lead the system agents (i.e. DNOs) to facilitate the right investment. Based on the distribution of these benefits, the authors propose an innovative way that may help to get a more efficient allocation of them: the introduction of a *smart connection incentive*. This incentive would encourage cheaper and quicker DG connections and would contribute to a more efficient use of the distribution grid

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[1] Based on the British context, this study assumes that power losses are lower when integrating more DG (Passey et al., 2011; Eurelectric, 2013). For high penetration levels of DG the results can be opposite (Quezada et al., 2006; González-Longatt, 2007; NREL, 2016). However, in contrast with the previous work, Cohen and Callaway (2015) find that losses decrease when increasing PV penetration.

[2] In this study, wider society is represented by energy suppliers (or demand customers).

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Table 1
Literature review – Economics of DG.

Author (s)	Scope of the paper and findings
DEA (2007)	Evaluates the different benefits of DG by discussing specific case studies applied in the United States of America. It notes the benefits to electric utilities with a focus on electric system planning and operations (peak load reduction, ancillary services provision and improvements in quality of supply). However, the study states that the economics of DG is determined by its very site-specific characteristics which means that the majority of benefits are easily captured by customer-owned DG and are greater than those for the utility owned-DG. For instance, through the implementation of demand side response programs incentives are given to customers-owned DG for reducing the electricity consumption during peak periods in addition to other sources of revenue.
Harrison et al. (2007)	Explore the trade-offs related to the connection of DG in the UK context. They quantify the benefits for DNOs and generators taking into account the DG incentives, losses incentives and network deferral benefits (estimated at £250/kW). Using a multi-objective optimal power flow, they find that the optimal DG capacity to be connected at different locations and the associated benefits vary between the DNO and generators/developers when benefits from network deferral are not included. If these are included, the optimal capacity and associated benefits between the DNOs and generators/developers are quite similar.
Siano et al. (2009)	Assess the influence of DG ownership on the economics of DG. Similar to the above study, the optimal capacity allocation and the respective revenues were determined. Two scenarios are explored: DNO owning DG and unbundled DNO. They find that the prohibition of DG ownership limits the DG capacity (and associated revenues) that the DNO may connect (without exceeding the maximum technically capacity). They suggest that the ownership option may be allowed under specific operational restrictions (i.e. peak load) in order to limit the revenues for the sale of electricity. Different ways to deal with the lack of incentives for the DNO (due to the ownership limitation) are also proposed, by implementing cost reflective charging or tendering (for bidding capacity).
Abou El-Ela et al. (2010)	Estimate the maximum optimal benefits of DG using a multi-objective optimisation technique in order to optimise more than one objective function simultaneously (composite benefits). The objective functions are represented by improvements in the voltage profile, increases in spinning reserve, power flow reduction in critical lines and line-loss reduction. Specific weights are also used for each function. The authors suggest that siting (bus) and sizing of DG affect importantly the amount of the objective functions. Results from the composite benefits indicate that DG has the largest influence on power loss reduction followed by spinning reserve.
Zangiabadi et al. (2011)	Explore the economics of customer-owned DG developers using a Monte Carlo based method. Three different scenarios are assessed, based on the load required per type of customers (residential, industrial/commercial) and a sensitivity analysis is also conducted with different electric price scenarios. An award policy is also proposed which represents the extra payment (above the market electricity price) that a utility would pay to customer-owned DG. This amount is higher during peak level. Results show important benefits for customer-owned DG developers and utilities when a suitable power purchase agreement policy is implemented. Customer benefits are highest when there is production of electricity at times of peak load and the utility captures the deferment benefit during peak load operation, potentially reducing losses.
Ben Amor et al. (2012)	Evaluate the economic value of renewable DG (with a focus on solar PV and micro-wind for different capacities) in the province of Quebec (Canada) under different climate conditions. The economic value is estimated by the difference between the life cycle cost and the hourly market price in four jurisdictions adjacent to Quebec. The evaluation also includes the environmental benefits related to carbon tax levels and avoided greenhouse gas (GHG) emissions. They find that DG has no net economic benefits (with or without the internalisation of environmental benefits) excluding the case of 30 kW micro-wind. This fact is mainly explained by the high DG acquisition costs which makes this market unprofitable in the Northeastern American region.
Pruitt et al. (2013)	Evaluate the economic viability of combined heat and power DG by comparing the costs and savings (including emission savings) of supplying the power and heating demand to commercial building owners (with and without DG). Eight scenarios are proposed varying the building type (hotel, office), energy market (California, Wisconsin), and technological system design and dispatch. The authors find that energy savings are driven by the high electricity to gas price ratio and market price net metering, and by the use of technologies with greater electric and thermal efficiencies (e.g. in California). In terms of emission savings, those markets with a higher rate of carbon emissions (in relation to those from the combustion of natural gas) tend to have higher savings (e.g. in Wisconsin). The authors find that it is difficult to achieve positive energy savings and positive emissions savings at the same time. This is mainly explained by the high costs of low-emitting fuel sources (e.g. gas, nuclear) and the low costs of high-emitting fuel sources (e.g. coal).

infrastructure by reducing unnecessary network reinforcement works (usually borne by end customers). Even though there is a large literature on DG, there is still a gap in the evaluation of the economics of DG that involves not only DG owners/developers/technologies, but also the electric utilities (i.e. DNOs in the UK or DSOs – distribution system operators - in the rest of Europe) and wider society, taking into consideration the specific regulatory context and market arrangements that these are subject to. A brief review of studies that involve economics and benefits of DG suggests that these are concentrated on the benefits for DNOs (including operational improvements, i.e. power losses reduction, ancillary services), DG developers/owners (where benefits are mainly driven by the sale of electricity and at customer level by avoiding wholesale electricity purchase) and benefits related to specific DG technologies (e.g. wind, solar PV, CHP). A summary of some of them is reported in Table 1.

From Table 1 we note that the majority of studies are focused on the benefits for a specific party and this means that an integrated approach is not presented. This is in agreement with Allan et al. (2015) which find that even though there is an extensive DG literature, there are few studies that relate to the pure economics of an individual or group of DG and even less that look at the system-wide impacts of DG. This is explained by the heterogeneous nature of DG which increases the complexity of this kind of evaluation.

This paper represents an extension of the findings presented in Anaya and Pollitt (2015a) where only the benefits for distributed generators were estimated. This study explores the distribution of benefits across the different parties taking into account the regulatory context (such as specific incentives provided to DNOs and DG owners in the GB energy market). The study is focused on a constrained area of the East of England (known as the March Grid) operated by UK Power Networks (the largest DNO in the UK). This area has been selected (due to increasing DG) by the DNO to be the trial area of the Flexible Plug and Play (FPP) project, implemented by UK Power Networks. Even though this study is focused on the UK energy market, the method can be easily applied in a different regulatory environment. For instance in the USA, there are different programmes that promote the expansion of DG.[3] Thus, the type of benefits to be included in the CBA in the USA context (or other) may differ from the one applied in this study.

The paper is organised as follows. Section two discusses the different dimensions of going smarter: smarter technical solutions, smarter commercial arrangements and smarter regulation. Section three describes the methodology for quantifying the benefits of going smarter and shows the results applicable to our case study (relating to the Flexible Plug and Play trial). Section four lays out the conclusions of this study.

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[3] There is a mix of federal, state and local regulatory frameworks. Among these are Federal Tax Benefits (FTB), Renewable Energy Certificate (REC) and Solar Renewable Energy Certificate (SREC), production and cost-based incentives, tax credits (in addition to the FTB), net metering, others (NREL, 2015).