ANCILLARY SERVICE PROVISION FROM DISTRIBUTED GENERATION

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INTRODUCTION

The overall aim of the study was to investigate the potential for creating ancillary service markets at the distribution level in Great Britain (GB). This included a review of ancillary services market design options, an exploration of the opportunities for distributed generation to provide these services and an investigation of corresponding commercial frameworks. A value-based approach was adopted for each ancillary service in order to assess the financial materiality to generators.

OBJECTIVES AND SCOPE

The specific objectives of this study were to:

- Investigate any existing arrangements for distribution level ancillary services markets worldwide;
- review the high level options for the design of ancillary service markets;
- examine the prospects and opportunities for the different forms of Distributed Generation (DG);
- investigate the commercial frameworks and technical procedures that might be required;
- explore the infrastructure requirements; and
- assess the impact on different market participants.

The scope of this study was to:

- Consider the opportunities for DG to contribute to existing Transmission System Operator (TSO) ancillary services [1]; and,
- investigate the potential for DG to contribute to new Distribution System Operator (DSO) services that could develop in the short to medium term.

The study investigated the potential for distribution level ancillary services to be provided by generators, in-line with the anticipated increase in electricity generation from distributed resources.

Whilst renewable electricity generation connected to distribution networks represents a key component of UK Government energy policy and targets, this study has sought to evaluate the distribution ancillary service market opportunities applicable to both renewable and non-renewable forms of distributed generation.

A pre-requisite for the detailed development of operational and commercial models was that any new services should be financially material to the distributed generator whilst remaining economically and operationally attractive to network operators. Consequently, value based approaches were adopted for each ancillary service in order that the attractiveness of distributed and renewable generation projects might be improved.

The ancillary services for which potential arrangements have been explored are:

- TSO Frequency Response;
- TSO Regulating and Standing Reserve;
- TSO Reactive Power;
- DSO Security of Supply contributions;
- DSO Quality of Supply Services; and
- DSO Voltage and Power Flow Management Services.

It should be recognised that in the GB context, distribution and supply activities have been segregated such that DSOs are solely responsible for distribution network operation and development, whereas suppliers are responsible for energy sales to customers. It should also be noted that DSOs do not normally engage in any electricity generation activities.

TSO Frequency Response

Frequency Response services are required by the TSO to maintain the system frequency within statutory tolerances. Frequency control is achieved through the real-time matching of supply to demand. Distribution connected Combined Cycle Gas Turbine (CCGT) plant already provide this service to TSOs.

A key feature of TSO frequency response provision is the requirement for generators to be part-loaded. It is unlikely that TSO frequency response services will be provided regularly by renewable generation, as the opportunity cost of operating part-loaded will be relatively high. This is because the compensation for part-loading would not only need to recover the cost of reduced energy revenues but also the costs associated with the loss of Renewables Obligation Certificate (ROC) revenue [2]. It is therefore unlikely that renewable

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1 An incentive arrangement requiring suppliers to procure a proportion of their electricity requirements from renewable sources
generation will be able to compete effectively in frequency response markets.

Although mandatory frequency response capabilities may become a technical requirement for large distribution connected wind farms, thereby ‘resolving’ any infrastructure constraints, the extent to which the TSO will utilise such capabilities is likely to be very limited.

The value of TSO Frequency Response is estimated to vary between £0.40/kW per annum for wind generation and £2.50/kW per annum for CCGT technology (excluding holding costs).

**TSO Regulating and Standing Reserve**

Reserve energy is required to provide rapid access to generation, to accommodate errors in demand forecasting, to provide contingency arrangements for generation failures and to restore frequency response capabilities.

The key differences between frequency response and reserve services relate to delivery timescales. Typically, reserve services are manually initiated and involve longer lead times. A consequence of simplified service initiation procedures is a reduction in the sophistication of control requirements, thus making reserve more attractive to smaller providers.

It is unlikely that synchronised reserve will be provided by renewable generation, as the compensation for part-load operation would also need to recover the loss of ROC revenue. Non-renewable distributed generation already provides standing reserve services to the TSO at a value of approximately £7/kW per annum. Increased DG participation could be facilitated by expanded aggregation services.

**TSO Reactive Power**

TSO reactive power can be sourced from distributed generators, especially those connected at 132 kV, for transmission system voltage regulation. Reactive power sourced at lower distribution voltages will reduce the reactive power required from transmission-connected generation (at peak loads).

DG connected at lower voltage levels can make a significant impact on the amount of reactive power exchanged between TSO and DSO systems. A simple generic model was developed to illustrate DSO reactive power import reductions at different levels of DG penetration. The value of DG derived reductions in DSO reactive imports was estimated to be approximately £1.20/kW per annum. The impact of DG on TSO reactive power market will be driven by many different variables. More work would be required to determine the impact of DG on DSO reactive requirements.

The impact of reactive power management on the transport capabilities of distribution circuits was also investigated. DG connected close to loads could extend the transport capabilities of existing circuits. The value of this service would be limited by the low cost of power factor compensation equipment. It is unlikely that this would represent significant income for DG. High DG availabilities would be needed for DSOs to consider such services.

**DSO Security of Supply Contributions**

The proposed GB Engineering Recommendation P2/6 [3][4] could broaden opportunities for DSOs to consider contributions to network security from DG. However, as DSO networks should currently comply with ER P2/5, the requirement for security contributions from DG may be limited in the short-term. In the medium to long term, load growth and asset replacements could increase opportunities for DG to provide network support services.

The value of security provided by non-intermittent DG can be related to the avoided or deferred costs of network reinforcement. DG can also substitute for network automation facilities. This is particularly relevant when considering security contribution of intermittent generation such as wind.

A number of examples were used to illustrate the potential value of network security services. For non-intermittent generators, values in the range of £1/kW to £12/kW per annum were derived, depending upon the complexity of the network solution avoided. It is anticipated that most reinforcements would be at the lower end of this range.

As a result of regulatory incentives to improve Quality of Supply [5], in terms of Customer Interruptions (CI) and Customer Minutes Lost (CML), DSOs have made considerable investments in 11kV and 0.4kV networks. A result of this investment is that distribution networks in GB are generally “over compliant” with planning and security standards. For the foreseeable future, the scope for DG to provide security services at these voltages could be limited.

**DSO Quality of Supply Services**

In future, there could be opportunities for DG to improve supply quality to customers connected at 0.4 and 11 kV, given the overall contribution of these voltage levels to regulatory Quality of Supply statistics.

In order for DG to improve service quality on such networks, the generation must also be connected at 0.4 or 11 kV, thus restricting opportunities to relatively small generators. A key requirement for DG, to reduce the impact of service outages, is an islanded operating capability.

Analysis suggests that the annual benefit of islanding operation was approximately £1.40/kW/annum and £19/kW/annum [6] for residential and commercial customers respectively. Due to the complexity of islanding, it is unlikely that DG will be able to significantly reduce CIs and CMLs in the short or medium term.
DSO Voltage and Power Flow Management services

Our analysis revealed that voltage control and flow management problems are essentially network planning related issues as they relate to supply restoration times following network failures (GB Engineering Recommendations P2/5 or P2/6).

The relatively low availability of DG (compared to distribution network components), combined with the UK’s deterministic voltage standards, means that opportunities may be limited for DG to provide voltage support or overload reduction. Generally, non-intermittent DG would be suitable for such applications. Inverter connected renewable generation, such as Doubly Fed Induction Generators (DFIG) or Photovoltaics (PV), represent an exception, as reactive power is generally independent of active power output.

Opportunities to provide voltage and power flow management services will improve with increased penetrations of DG due to the higher collective availability. The value of these services was estimated to be the order £1.50/kWh/annum.

Ancillary Service Capabilities of Different Generation Technologies

The ancillary service capabilities of renewable and non-renewable technologies are summarised in Table 1 and Table 2.

Table 1 – Summary of renewable technology capabilities

<table>
<thead>
<tr>
<th>Ancillary Service</th>
<th>DG Technology Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Wind non-DFIG</td>
</tr>
<tr>
<td></td>
<td>DFIG*</td>
</tr>
<tr>
<td></td>
<td>Biomass</td>
</tr>
<tr>
<td></td>
<td>Land Fill</td>
</tr>
<tr>
<td></td>
<td>Solar PV</td>
</tr>
<tr>
<td></td>
<td>Hydro</td>
</tr>
<tr>
<td>Frequency</td>
<td>&lt; 50 MW</td>
</tr>
<tr>
<td></td>
<td>&gt;50 MW</td>
</tr>
<tr>
<td></td>
<td>1–100MW</td>
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<tr>
<td></td>
<td>1 – 10MW</td>
</tr>
<tr>
<td></td>
<td>&lt;100 kW</td>
</tr>
<tr>
<td></td>
<td>&gt;1MW</td>
</tr>
<tr>
<td>Reserve</td>
<td>HF only</td>
</tr>
<tr>
<td>Reactive</td>
<td>Possible</td>
</tr>
<tr>
<td>Network Support</td>
<td>Future island?</td>
</tr>
<tr>
<td>Black Start</td>
<td>Possible</td>
</tr>
</tbody>
</table>

* Wind Farms <50 MW may employ DFIG machines in future

Table 2 – Summary of non-renewable technology capabilities

<table>
<thead>
<tr>
<th>Ancillary Service</th>
<th>DG Technology Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>CCGT</td>
</tr>
<tr>
<td></td>
<td>Large CHP</td>
</tr>
<tr>
<td></td>
<td>Micro CHP</td>
</tr>
<tr>
<td></td>
<td>Diesel &amp; OCGT (Standby)</td>
</tr>
<tr>
<td>Frequency</td>
<td>&gt;100 MW</td>
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<tr>
<td></td>
<td>1–100MW</td>
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<tr>
<td></td>
<td>1 – 5 kW</td>
</tr>
<tr>
<td></td>
<td>&lt; 50 MW</td>
</tr>
<tr>
<td>Reserve</td>
<td>Limited</td>
</tr>
<tr>
<td>Reactive</td>
<td>Possible</td>
</tr>
<tr>
<td>Network Support</td>
<td>Future island?</td>
</tr>
<tr>
<td>Black Start</td>
<td>Possible</td>
</tr>
</tbody>
</table>

Whilst all of the above services were explored in detail, only TSO Frequency Response, TSO Regulating and Standing reserve and DSO Security of Supply contributions represent realistic opportunities for distributed generators in the short or medium term.

Combined Cycle Gas Turbines (CCGT) and DFIG wind farms were the most promising technologies for the provision of TSO Frequency Response services whereas CCGT, diesel standby generators and perhaps even microCHP were best placed to provide reserve services.

It was found that, to varying degrees, DSO Security of Supply services could be provided by most existing distributed generation technologies.

As the majority of existing DG has been installed for electricity supply purposes, very few generators are equipped with the infrastructure necessary to provide ancillary services. Such infrastructure includes governors, automatic voltage regulators, resynchronisation facilities, appropriate protection, monitoring and communication facilities.

Commercial, Technical and Policy Implications

The most appropriate commercial arrangements for response and reserve services appear to be market-based mechanisms. Ideally the current arrangements employed by the GB TSO could be extended. Expanding the existing aggregation arrangements, utilising lower cost infrastructure, would facilitate increased participation from smaller generators.

The most appropriate commercial arrangements for DSO Security of Supply services appear to be bilateral contracts due to the localised and site-specific nature of network security requirements.

Opportunities for DG to provide ancillary services will undoubtedly increase as DG penetrations and availabilities increase.

The analysis undertaken suggests that the value of the most feasible ancillary services will be low relative to energy income. Consequently, such services will represent incremental revenue opportunities for DG. In general, it would not be possible to develop DG investment proposals solely on the basis of ancillary service income.

Niche opportunities will emerge for DG to provide ancillary services, usually in circumstances where constraints restrict network development, e.g. environmental, planning and terrain related constraints.

In an era with significantly increased levels of DG operating on active distribution networks, the opportunities for DG to provide ancillary services may increase. However, on active networks there is an increased likelihood that due to distribution network constraints, the DSO may not permit certain modes of operation. Consequently there could be
increased delivery uncertainty regarding the provision of TSO ancillary services from distributed generators connected to active networks.

In circumstances where a distributed generator receives conflicting instructions regarding the provision of different ancillary services, local services should take precedence over national services.

Higher penetrations of DG will increase DSO options regarding network operation and development decisions, which could (in certain situations) lead to lower overall costs.

Increased penetration of DG could also enhance competition in TSO markets for frequency response and reserve. This could be particularly relevant should the demand for these services increase with intermittent generation.

In Britain, the output from distributed generation is largely purchased by suppliers and settled through supplier demand accounts as part of the British Electricity Transmission and Trading Arrangements (BETTA). Consequently, suppliers must ensure they are aware of generator operating regimes and also whether generator operation is likely to be influenced by ancillary service provision. Supplier concerns will relate to wholesale energy imbalance exposures and the fulfilment of ROC targets. Suppliers will require notification of ancillary service provision, in order to suitably revise their demand forecasts. Ancillary service instructions requiring a rapid response will inevitably impact upon supplier imbalance exposures and therefore potentially reduce the value of the energy supplied.

A new regulatory initiative in the British electricity market is the introduction of Registered Power Zones (RPZs) [7], which are intended to encourage DSOs to develop and demonstrate new, more cost effective ways of connecting and operating generation. RPZs could provide an initial platform for the development of appropriate ancillary services. In order for new technical solutions to become widely accepted, an appropriate contractual framework will need to be established, and RPZs could be used to develop such arrangements.

It is important to stress that provision of ancillary services from DG should not jeopardise or degrade security of supply and may even contribute to its enhancement in future.

It should be recognised that the provision of ancillary services from DG should not impact negatively upon DG contributions towards climate change targets.

In addition, the provision of ancillary services from distributed generation could, in niche situations, avoid any negative impact of network investment in environmentally sensitive areas.

Although this work explored ancillary services opportunities for DG in the short to medium term, long-term approaches also need to be investigated given the fundamental changes to the structure of power systems that may emerge in future.

**Recommendations**

The extent of opportunities on DSO networks will largely relate to load growth and asset replacement profiles. Whilst it has not been possible to quantify the relative magnitudes of these opportunities within this project, such information will be critical to evaluating service materiality under alternative future development scenarios and should be explored further.

In order that a consistent and transparent set of arrangements can emerge to facilitate increased network security contributions from DG, it will be necessary to establish principles (and potentially standardise commercial arrangements) for procurement processes and valuation methodologies. Indeed, a standardised 'model-form' contract suitable for localisation by individual DSOs could prove beneficial.

A major concern of DSOs regarding the reliance on distributed generators to provide network support services will relate to non-delivery risk exposures. Such exposures could be financial, regulatory or legal in nature. Consequently, the issues associated with service non-delivery require further exploration.

Whist the current aggregation arrangements have been successful in encouraging non-BM participants into the market for standing reserve, the associated infrastructure costs could deter wider participation. In order to extend aggregation opportunities further, new low-cost communication and monitoring arrangements should be evaluated.

A potential problem for DSOs relates to the current UK regulatory framework in terms of capital expenditure (CAPEX) and operational expenditure (OPEX) funding distinctions. At present, network security is procured through CAPEX, which does not currently accommodate generation contributions. The current arrangements for OPEX are not ideal as DSOs could be financially penalised for funding ancillary services through this route. More work will be required to establish a suitable funding mechanism for network security and support.

**REFERENCES**


