# THE VALUE OF DISTRIBUTED GENERATION FOR MITIGATING NETWORK RISK

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## *ABSTRACT*

*This paper addresses the issue of the extent to which Distributed Generation (DG) can mitigate the risk of customer disconnection in the event of outages on the distribution network. A methodology has been developed which takes into account not only the type of DG but also its operating profile, location on the network, and connection contract. This methodology is illustrated by a case study involving four different types of DG at a location in the north of England, where there is the possibility of using DG to defer expensive capital investment by at least 10 years.*

## INTRODUCTION

In any country, network security is a matter of public concern, and may be subject to regulation. In the UK, the distribution network design standard P2 specifies the level minimum of security required as a function of group demand, in terms of maximum restoration times allowed for groups of customer demand. For example, in a network where the peak demand is 150 MW, following a single outage (n-1), the standard requires that at least 130 MW of this demand should be restored immediately, with the remaining demand of up to 20 MW restored within 3 hours. In the event of a second outage (n-2), defined in P2 as occurring while there is a planned first outage on the network, the requirement is that at least 50 MW should be restored within 3 hours, while the remaining demand of up to 100 MW should be restored within the time taken to restore the planned first outage [1].

The design of networks throughout the UK reflects this standard. So, for example, at extra high voltages (EHV), which in the UK includes 33, 66 and 132 kV, there will usually be built-in circuit duplication, either by doubling up a radial connection, or by incorporating the load point into a ring, or even a more complicated mesh configuration. Such duplication reduces the level of network risk.

Another possible source of network risk reduction is the presence of embedded or distributed generation (DG) within the network. For example, a 10 MW generator fuelled by landfill gas could in theory increase the security of supply to nearby customers potentially by the same amount as an additional 10 MW transformer with connections to the national grid. The latest version of the P2 standard, P2/6 published in 2006, included for the first time, guidelines about the capacity credit that can be ascribed for various types of DG. In this standard a detailed set of tables evaluates the potential security contribution from DG as a percentage of the maximum capacity of each generator, the precise percentage is a function of the, availability, number of independent units, and intermittency of each DG unit on a site [1].

While these guidelines are helpful, the real value to the distribution network operator (DNO), and to the customer, of such distributed generation depends not only on the type of generation, but also upon a number of other factors, including the network configuration into which the generator is connected, the connection contract and the actual pattern of generation variability throughout the year. In this paper, a methodology has been developed to include these factors, and this methodology is illustrated by a case study based on an actual part of the UK network where the level of network risk is higher than typical.

### Research Background

Distribution networks in the UK and in other developed countries tend to be around 40-50 years old, and designed for uni-directional power flows. The increase over the past 10-20 years of small-scale generators, connecting into the distribution network at a wide range of voltages and locations, can affect some of the assumptions underpinning this type of architecture including those related to power flows, voltage control and the provision of network security [2].

The advantages of DG to network reliability have been researched, although to a lesser extent than the potential problems, and associated solutions, of incorporating DG. Following the publication of version 6 of the P2 design standard in 2006, a review was commissioned by the national regulator OFGEM and published in 2007 [3]. This review found no actual evidence at that time of DNOs invoking the provisions of P2/6 to secure demand groups using DG. It also points out that the regulatory framework at the time did not incentivize DNOs to make payments to generators for network security contributions. This is in contrast to the Dutch electricity market, where such payments are occasionally made. However, the review noted that the inclusion of DG capacity credit in P2/6 had the potential to affect the design of and investment in future networks, as a result of increasing the amount of DG which can be used to contribute towards network security.

Looking ahead, national and international targets for the low carbon economy have led to a number of forecasts of load growth and increased renewable generation, including DG, that can be anticipated over the period 2010-2030 [4, 5, 6]. This anticipated load growth is due mainly to the take up of two technologies which can replace oil and gas consumption, namely electric vehicles and heat pumps. The forecasts cover a wide range, typically averaging 1% per year, but in some cases and locations averaging 2.5% per year over the 20 year period. The higher figure is taken as indicative in this paper.

Such load growth would first affect those parts of the network which are already operating at close to their capacity. The case study which is presented in this paper is based on one such industrial and residential location in the north of England. [7]

## METHODOLOGY

The design standard P2/6 includes a number of tables to enable the capacity credit that can be ascribed to a given DG installation to be calculated. In addition there are further supporting documents that form an integral part of P2/6 that can be applied where the assumptions implicit in this standard are thought to be overly conservative or otherwise inappropriate. This paper, however, focuses on the DG security contribution included in the main P2 standard document. The methodology described in this paper and illustrated by a case study, expands on the factors that a network design engineer should consider when assessing the security contribution from generators. The methodology has five distinct steps, which are illustrated with reference to the case study.

### 1. Identify likely network risk scenarios

Under what circumstances might the security contribution from DG mitigate the risk of supply interruption? In the case study, there was concern that one supply point (SP) substation, equipped with two 132/33 kV transformers, might not have sufficient short term capacity to maintain customer supplies at times of peak load when there was a single unplanned outage until demand could be transferred to one of two adjacent SPs which are also equipped with two 132/33kV transformers. This risk would increase (affecting times of less than peak load) in future years given the expected load growth. In these circumstances, the availability of connected DG could make up for the shortfall of transformer capacity following the loss of a circuit.

### 2. Identify relevant generation on the network

Some generators may be located in the wrong place on the network to be able to mitigate the risks identified. Others may be too small to make any significant contribution. Inspection of the network diagrams and additional DNO information will enable these generators to be eliminated from consideration. In the case study, four DG sites, with capacities ranging from 7 MW to 42 MW, remained to be considered.

### 3. Identify how each DG site operates

The operational objectives and constraints of the site are relevant here, together with historic generator operational / export data where this exists, to show how the site actually operates from day to day. For a planned DG site which is not yet operational, these values and quantities would need to be estimated. In the case study, operational data was available for each site, and objectives and constraints could be derived from this data and from generation company publicity. If necessary, the company could be contacted directly. For example, one of the generators in the case study was a municipal waste incinerator, staffed to operate continuously, and generating a steady 10 MW except for occasional shutdowns (planned or unplanned). By contrast, another generator was a single gas turbine unit, operating with a small number of staff, operated on a far less consistent basis, probably in response to the fluctuating ratio of unit prices for gas and electricity.

### 4. Investigate the connection of each DG site

The precise network topology connecting each site may be relevant. For example, a remote wind farm may be connected to the at-risk SP by overhead lines whose rating is insufficient to transmit the full wind farm capacity (perhaps because the wind farm is normally connected to a different SP). Then, even at times when the wind farm is generating at its maximum capacity, that power may not all be available to mitigate network risk as required.

### 5. Evaluate the allowable capacity credit

Once the likely network risk scenarios, method of generation operation and connection constraints have been identified for each site, it should be possible to determine the useful contribution that each site can be reasonably relied upon to make at any time, typically times of peak demand, but also under other circumstances such as during a planned outage during a time of lower demand. This is illustrated by taking a more detailed look at the case study, and comparing the results obtained by this methodology with those specified by the main body of the standard 2/6.

## CASE STUDY IN DETAIL

The four DG sites identified as possibly relevant to mitigating network risk at the three SPs under consideration will now be examined in turn.

### A. Merchant Combined Cycle Gas Turbine

This single CCGT generator is rated at 42 MW, and operated by a small team of 9 people [8]. The capacity credit indicated in P2/6 for a single CCGT generator is 63% of its capacity, or 26.4 MW [1].

Inspection of the export profile indicates that operation the generator appears to be related to movements of energy prices i.e. there are periods of inactivity (i.e. no generation) and extended periods where the generator exports at its full capacity of around 40 MVA [9]. For short periods, probably during start-up, this generator (which is connected directly to the 33 kV busbars at the SP) becomes a net consumer, of up to 4 MVA.

The precise nature of the connection contract between the generator and the DNO is relevant here. If the contract is for a non-interruptible supply, then perhaps the occasional demand for up to 4 MVA could occur at a peak demand time, and should perhaps be allowed for as a negative capacity credit. Also, since the generator seems to operate depending on the energy market, it may be optimistic in practice to add the full 26.4 MW indicated in P2/6 to the SP firm capacity, since there is a limited degree of certainty that it would be available if and when it was required.

If, on the other hand, the contract specified that the full generation capacity of 42 MW would be made available on demand, for example within a period of at most 3 hours, then arguably that full capacity should be regarded as available to mitigate network risk. This would increase the firm capacity at the SP sufficiently to be capable of meeting 2.5% load growth until at least 2020. This facility could be particularly useful during periods of extended planned maintenance on a single 132 kV circuit to the SP. Conversely, there might be need to manage carefully the short-term load required by the generator if it needed to import power during start-up during what was already an unplanned (n-1) event. This could be achieved by running up the generator before the normal network demand increased above a pre established threshold.

The difference between these two possible contracts indicates the value of the second contract to the DNO. The availability of this CCGT generator on standby may enable the DNO to defer costly 132 kV reinforcement projects by 10 years, or even longer at growth rates below 2.5%. The annualised value of such deferment, plus the reduction in expected penalty costs for any loss of customer supply, could be calculated to give the value to the DNO of such a contract.

### B. Municipal Waste Incinerator

This waste-to-energy plant is located in a city centre [10]. It includes a single generator, operated 24 hours per day by a staff of 29 people. Generator capacity is 10 MW, and it is connected via a single transformer to a 33 kV circuit feeding a different SP from generator A.

The capacity credit indicated in P2/6 for a single unit waste-to-energy generator is 58%, giving an increase of 5.8 MW at the SP [1]. However, load profile data suggests that this generator operates more or less continuously, and in practice could probably be relied upon in an (n-1) situation to provide a full 10.0 MVA at peak times, without requiring a special contract to do so. When the generator is not operational, the maximum site load imported from the 33 kV network is in the region of 2 MVA.

### C. Large Industrial Site

The processes on this large chemical industrial site require both steam and electricity, and since around 1997 there have been three on-site generators to supply this, with a total electrical capacity of 16.1 MW [11]. They are connected to the DNO network at 33 kV via two circuits. P2/6 capacity credit for 3 CHP generators is assessed at 73% of capacity, or 11.8 MW [1]. In theory, this value could be added to the 5.8 MW allowed at generator B, which is connected to the same SP.

In practice, generation site C cannot be relied upon to provide a security contribution in the same way as for that at site B. The generators at this site are designed and sized to supply the industrial load and typically supply on-site energy rather than export to the DNO system. Industrial customers with generating capacity tend to be significant consumers of electricity, and their generating capacity is primarily, if not only, for their own benefit.

In practical terms, it seems reasonable to assume that, in an (n-1) situation at the SP, whether planned or unplanned, generator B would supply 10 MVA into the network, but site C would be self-contained, neither supplying nor demanding energy.

### D. Remote Wind Farm

Far more remote from its SP than the three generating sites so far discussed is a small wind farm. It is supplied via a dedicated 11 kV feeder to a primary substation, then two 33 kV circuits to the SP. The wind farm was commissioned in 1993 and consists of 13 turbines arranged in two rows, each turbine rated at 500 kW, giving a maximum possible output of 6.5 MW [12].

The capacity credit indicated in P2/6 depends on the persistence of this wind farm, and has a maximum value of 28% [1]. Using this figure gives a credit of 1.82 MW. This figure is too small to make a significant difference to security of supply at the SP. It is possible that in the future this 17 year old wind farm could be upgraded with larger turbines, however in practice this might be constrained by the physical limitations on site.

Examination of historical load profiles at this wind farm shows that the generation follows the typical, relatively unpredictable pattern for wind farms [11]. Hence, in practice, this wind farm makes no reliable contribution to network security at the SP and should therefore not be included in such calculations.

## CONCLUSIONS

The standard P2/6, together with the supporting documentation, provides guidance on a capacity credit allowance for DG which takes into account the location, availability, number of independent units, and intermittency of each DG site [1]. The methodology presented in this paper adds to those factors others including the network configuration into which the generator is connected, the connection contract, and the actual pattern of generation variability throughout the year.

This methodology is applied to a particular case study in the north of England, where relevant DG includes a merchant CCGT, a municipal waste incinerator, a large industrial site and a remote wind farm. The P2/6 credits allowed for these four generators are 63%, 58%, 73% and 28% of capacity respectively. The methodology develops revised figures so that the last three become 100%, 0% and 0% respectively. The first figure, which represents the largest generator could be either decreased to below zero, or increased to 100%, depending on the nature of its connection contract. In the latter case, the benefit to the DNO could be to defer expensive network reinforcement which would otherwise be required to comply with the design standard by at least 10 years.

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