ON-LINE ASSESSMENT FOR DISTRIBUTED GENERATION CONNECTIONS

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ABSTRACT
The proliferation of distributed generation (DG) brings with it many challenges, not least how to design DG grid connections in a cost effective manner. This paper describes further research and development work being carried out in the United Kingdom (UK) to address this issue. It is based on an innovative new Smartgrid software system designed to automate the initial assessment process for determining potential options for connecting new distributed generation plants to an electricity distribution system.

INTRODUCTION
Senergy Econnect and Imass have developed a powerful on-line grid connection assessment tool (www.gridconnection.co.uk), which links geographical and electrical network information into an integrated database and processes this data automatically to produce a report covering the technical and cost implications of connecting DG to the electrical grid. This tool is now available for Great Britain and supports the assessment of projects from 2MW (Mega Watts) to 100MW and is currently being applied by a range of clients seeking to generate rapid connection evaluations. The main benefit of the service is to facilitate the evaluation of the integration of renewable energy plants into the distribution network and to avoid wasteful investigation of potential renewable energy sites which are too difficult or too costly to connect to the distribution network.

The original partners have been joined by Durham University and recently embarked on pioneering research to investigate the development of additional functionality for this on-line tool, including estimation tools for connections below 5MW and for connections to transmission network. This is described further in the remainder of this paper.

CONNECTION STUDIES BELOW 5MW
The current version of the grid connection website (www.gridconnection.co.uk) is supported by an electrical and a costing database which enable its automated assessment tool to produce a report presenting a range of connection options to the 33kV to 132kV network in England and Wales and 33kV network in Scotland. The information underlying the electrical database is derived from data published by the Distribution Network Operators (DNO) in the form of their Long Term Development Statement (LTDS).

For generation plant of a capacity typically 5MW and under, more cost effective connection may be achieved by considering the lower voltage levels of the distribution network (20kV, 11kV and 6.6kV networks), denoted “the 11kV network” in the rest of this paper. Information about these parts of the distribution network is very scant in the LTDS and detailed information is not available in the public domain.

This means that when considering connections of generation plants to the 11kV network, a specific request must be made to the DNO for network data. Such data can take many weeks to be supplied and also the DNO is likely to make a charge for it. Once the data is obtained, specialist electrical engineering expertise is required to interpret the data and produce a range of connection options and costs. This may be carried out by the DNO or an independent specialist.

The budget for development of generation in the sub 5MW range is lower than for higher capacity schemes, and full network studies at the earlier stage of development may be too expensive. This tends to lead the developer to investigate the grid connection aspect of the development at a later stage in the site prospection and development process. The cost of grid connection for these smaller schemes can often take a higher proportion of the overall...
costs than for larger schemes, and can make the difference between a site being financially viable or not. It is important that for these smaller capacity schemes, some indication of grid connection feasibility is obtained as early as possible in the process at an affordable cost.

This has lead to the idea of developing an early 11kV generation connection assessment tool which could be offered at a comparatively low cost on the grid connection website.

**Methodology**

As there is limited amount of information available in the public domain about the electrical and geographical configuration of the 11kV network in Great Britain, a fully accurate assessment of connection options is not possible without full 11kV data. However some indication of connection costs and technical feasibility can be derived from using estimation tools and statistical methodologies. Whilst not providing exact answers, such methods can still be of value in helping a small generation plant developer take a view on the financial viability of the site(s) being considered.

The work carried out to date as part of this research has involved defining these estimation and statistical methods and developing a prototype tool which codifies these methods. The research has then focused its efforts on identifying the critical pieces of information, which should they be made available in the public domain, would make a significant improvement to the accuracy and usefulness of the estimation methods.

Eight test cases have been selected using real 11kV network data from the EDF Energy Eastern and Southern areas. A full model of the electrical network in these areas has been created and studies of voltage rise and thermal constraints have been carried out at Durham University to establish a baseline for the research. The results obtained provide the actual capacity of the network to accept new generation plants, and the methods used are very similar to those that a DNO would employ when preparing a connection offer for a prospective generation plant customer.

The test cases have been selected using three primary criteria to provide a range of possible connection types:

- Whether the generation connection point is close or far from the primary (e.g. 33kV/11kV) substation
- Whether the area where the generation site is located is mostly rural or urban
- Whether there is already some generation connected to the same part of the 11kV network

The prototype tool was run for each of the eight test cases and the results compared to the results from the full model. In addition, costs based on estimated and actual geographic location of the 11kV network were also computed and included as part of the results.

A sensitivity analysis was carried out varying the parameters of electrical rating and geographical distances. These parameters were selected based on the team’s knowledge of electrical power systems. On one side, full data was used for the base line, on the other only data available in the public domain was used. Then a range of scenarios were run to include additional information not currently available in the public domain in order to assess its impact on the value of the results. This is illustrated in Figure 1.

![Figure 1: Parameters used for the sensitivity analysis](image-url)

**Results**

The results of the sensitivity analysis are presented in a graphical format for easy interpretation, with results for technical assessments and cost assessments shown separately. The primary aim was to plot the relative position of the estimation methods and the actual results, with the view to establish if the estimation methods provide a conservative (safe) answer. The second aim was to establish the usefulness of the results when being applied to actual generation connection situations.

The results of the technical assessment are shown in Figure 2 and Figure 3. Figure 2 illustrates the results when the weakest rating information is used. The results are expressed as a MW (Mega Watt) capacity of the network to
accept the connection of new generation plants. Actual results, obtained from the full electrical model, are shown in dark blue. Estimated results, obtained from the prototype tool, are shown in yellow.

The results of the cost assessment are shown in Figure 4. The results are shown for connections by underground cable in a soft dig condition (verge of a road) and include basic road traffic management. The results are expressed as a cost in £0,000, and include the new cable, the new substation, the connection into the existing network and the new generator assets excluding the generator itself. Actual results, obtained using actual geographical location of the 11kV network, are shown in dark blue. Estimated results, obtained using an estimation of the geographical location of the 11kV network, are shown in yellow.

The results clearly show that the estimation for the cost is sometimes above and sometimes below the actual cost, which means that the estimation method needs a more accurate estimation of the distance in order to produce conservative (safe) results.

**Conclusions**

The overall conclusions from the sensitivity analysis carried out to date indicate that more accurate geographic information and some indication of weakest thermal rating improve the results significantly. The next step is to trial practical means to obtain these two pieces of information.

The geographic information could be derived from the geographical location for the secondary (11kV/LV) substations, which is a lot less onerous than attempting to obtain the full geographic information for the 11kV network.

An indication of weakest thermal rating for the whole of the 11kV network may or may not be practical to obtain depending on how much work would be involved for a
DNO to supply such information. An alternative method may be to characterise sections of 11kV networks into representative categories and use this characterisation to supplement the estimation methods from public data.

Further investigation in these areas will be carried out and the prototype tool re-run to obtain new results. The results of the research will then be used to inform the practicality of providing an on-line service on the grid connection website.

ASSESSMENTS ABOVE 100MW
The current version of the grid connection website enables users to assess the options for connections of generation plants in the range 2MW to 100MW. Those plants with capacity higher than 100MW are more likely to connect to the transmission network, which comprises the 275kV to 400kV networks in England and Wales, and the 132kV to 400kV network in Scotland. Information about the transmission network is available in the public domain in the form of published “seven year statements”, which include the whole of Great Britain.

The distribution network in Scotland only extends as far as the 33kV network, which means that there is a lower limit for assessments of generation connections in Scotland. Extending the data in Scotland to include the 132kV (transmission) network data would extend the range in Scotland up to 100MW, in line with England and Wales.

There is significant activity in the development of larger wind farms, particularly offshore, to meet the renewable energy targets set out by the government. Such larger schemes would connect to the transmission network.

Given the range of reasons above, the task of investigating options for providing transmission data and automated assessments on the grid connection website has been initiated. So far, only preliminary research has been carried out and this paper presents the outline of the research methodology.

Methodology
Transmission data is divided in two separate sets, namely geographic data and electrical data, in a similar fashion to the distribution data already being supplied on the grid connection website.

The electrical data is provided for the current and for the subsequent six years (thus the name “seven year statement”). The data includes details of planned changes to the network assets, together with generation and load connections. In this respect, the transmission data differs from the distribution network data, which is published for the current year and has very sparse and only general indication of planned changes for the following few years.

Assessments of connections to the transmission network come under the regulatory framework of the GB SQSS (Great Britain Security and Quality of Supply Standards). There are some differences with the Distribution Code for distribution networks and the largest impact is on the method for costing the connection and establishing the best time to connect, including estimating what the queue for generation connection to the transmission network may be in future years. The basic underlying technical assessments are not fundamentally different from the distribution network connection assessments, but more complex additional assessments are required, including coping with the fact that the network is interconnected and the requirements for network stability.

Benefits and conclusions
From the user’s point of view, the benefits from having a fully integrated set of transmission network data, combining electrical and geographical information are numerous:

- Access to electronic data which can then be easily loaded into power system analysis tools for specific connection assessments
- Easy access to integrated data showing a clear picture of the future state of the network, generation and load connections
- Ability to build scenarios for assessments, based on the user’s view of the future developments of the network and connection of other generation plants

The next step in this research will be to draw up the detailed technical requirements for the transmission data and for tools to produce the benefits listed above.

FUTURE WORK
In addition to the work described in this paper, the research team will also investigate methods to evaluate the benefits of emerging active network management and techniques used to reduce the cost and increase the annual energy yield of a particular DG connection. The work will start with a listing of all smart grid technologies currently at or near to commercial stage and quantify how they operate. Methods for estimation tool will then be assessed and where practical requirements for assessment tools will be drawn up.

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