Maximising Distributed Generation Capacity in Deregulated Markets

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Connecting Distributed Generation

Renewable energy resources are generally located in remote areas and tend to connect to the distribution network as distributed generation (DG). DG fundamentally alters the operation of distribution networks giving rise to the range of well-known impacts given in Figure 1.

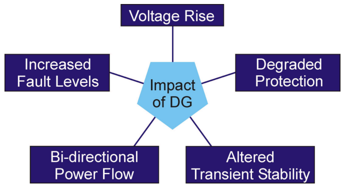

Figure 1: DG Impacts

Distribution Network Operators (DNOs) examine the impacts from individual DG schemes following an application to connect. To preserve quality of supply during normal operation, the appraisal is normally performed under worst-case conditions. Typically, this is with maximum DG output at minimum load, creating the largest reverse power flow and consequently voltage rise – the major constraint on DG capacity in rural areas.

Impact Mitigation

Adverse impacts can be mitigated but methods are project and impact specific. Voltage rise can be eased by network/generator operational changes or through circuit reinforcement (Figure 2). These measures allow DG connection but they can lead to lost DG revenue or significant capital costs. Project economics may be affected as current deep charging compels developers to finance capital expenditure. Alternative shallow charging options allow DNOs to fund network upgrades and collect use-of-system charges. While this lowers developer's up-front costs, the DNO must justify the investment.

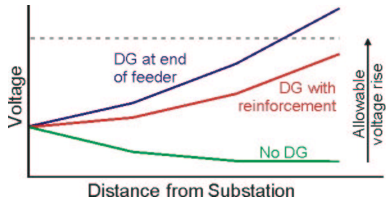

Figure 2: Mitigating voltage rise with circuit reinforcement

In addition to the economic impact of mitigation measures, current DG connection policy could limit renewable penetration. Network access guarantees granted to projects mean that subsequent connections must not impact adversely. Hence, an early and quite minor connection can preclude larger developments, i.e. cause network *sterilisation*.

Capacity Evaluation

Solutions to these issues will include DNOs issuing guidance regarding the existence of spare connection capacity. To do this, DNOs need to ascertain the capacity of new DG that may be connected to their distribution networks within physical constraints. Although such studies have been carried out for the transmission network in Scotland, studies at distribution-level are relatively more intense and time consuming given the greater number of possible connection points and the added influence of voltage constraints.

A variety of techniques have been used for distribution system optimisations. Here, Optimal Power Flow (OPF) is applied to maximise capacity across selected individual or multiple locations, identifying available network capacity. As DG operates at fixed power factor, standard OPF active power optimisations that assume voltage control are not suitable. The alternative was to use the common model of DG as a negative load. The use of a load shedding optimisation to maximise negative load enables the delivery of maximum capacity. This has been termed *reverse load-ability*.

The technique has been implemented within the OPF component of PSS/E together with a specially-written piece of Windows™ software (known as the Simulation Manager) to interface to PSS/E and control the process of data preparation, optimisation and results extraction and analysis (Figure 3). This has allowed complex analyses to be conducted with relative ease.

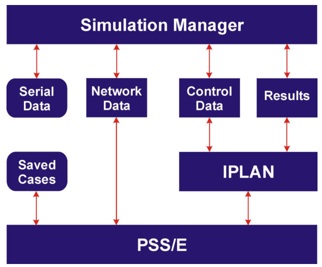

Figure 3: PSS/E – Simulation Manager interface

Case Study System

The system used in this work is part of the UK transmission and distribution network. The region has extensive potential for wind and mini-hydro along with 300 MW of existing centrally-dispatched generation. Figure 4 illustrates a sub-section of the network from 132 kV down to the 11 kV substations. The relatively abundant renewable resources in this region are indicated at their potential points of connection.

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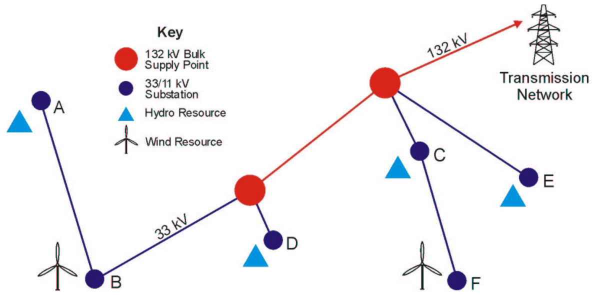

Figure 4: Case study network

Maximising Renewable Capacity

Figure 5 shows the available capacity at several combinations of locations (DG at 0.9 lagging power factor). 3.5 MW of capacity is found to be available at Location A. Locations A and B together allow a capacity of almost 15 MW although only 870 kW is allocated at A. Without network reinforcement connection of the full 3.5 MW of mini-hydro capacity at A would sterilise that section of the network and preclude development of the larger wind resource at B. Restricting capacity at A to 870 kW, however, allows 14 MW of DG at B. The other combinations repeat this pattern. Essentially, overall increases in DG capacity can be achieved by limiting capacity at individual (less suitable) sites.

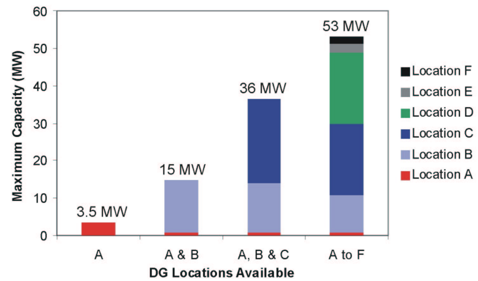

Figure 5: Network capacity available with combinations of location

Benefits

This approach offers DNOs a rapid, adaptable and objective means of evaluating network capacity available for DG connections using commonly available tools (OPF). Its use would help limit the need for expensive mitigation and lower network sterilisation risk thus enhancing renewable penetration.

Acknowledgements

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