System Security & Plant Margin with Intermittent Renewable Generation

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Executive Summary

Regulators have a difficult task of creating a framework that secures future electricity supplies at a level that meets the needs of a spectrum of end users. In liberalised markets this is becoming more difficult due to increasing uncertainty, partly because of the priority given to renewable energy sources, which deters investors in conventional generation. The renewable energy displaces conventional generation output reducing their utilisation to levels that may not be financially viable. This has prompted some government agencies to consider the deployment of capacity markets to encourage new entry by providing a stable income. This involves fixing a level of security on behalf of consumers and determining the level of capacity required to realise this in practice. A complication with renewable generation is fixing the capacity contribution that can be expected from intermittent sources like wind. There is also a need to estimate the potential capacity contribution from increased levels of international interconnection and demand side regulation. This note discusses some of the issues facing regulatory and government agencies in creating a commercial environment that encourages the development of levels of security that match consumer expectations and budgets. It discusses:

- The normal approach to estimating system security and the apropriate target plant margin of capacity over expected peak demand;
- An approach to estimating the optimal level of security based on the value of lost load to consumers compared to the costs of securing more generationcapacity;
- Reviewing an approach to securing future capacity through an auction process;
- An approach to taking account of the intermittency of renewable generation sources based on probability functions;
- Determining the level of capacity support that may be available through interconnectors with adjacent utilities;
- Accommodating the impacvt of increased demand side market participation through the application of smart meter technology.

Security Analysis

The target level of security is usually expressed as the number of hours/year of potential shortfall in generation to meet demand. A typical figure is 8 hrs/year and generally relates to the probability of super-grid connected generation being unable to meet the total super-grid demand. A key factor influencing the security is the prevailing plant margin being the percentage of excess generation capacity over that required to meet peak demand. A typical value would be around 20% to take account of loss of generation availability, worse than average weather and demand forecast error. Figure 1 has been constructed based on a probabilistic model of a system of the size of GB with an annual demand of 325TWh and a tranche of 500MW conventional generators with an assumed overall availability of 0.85. The demand is represented by a function that determines the probability of the demand being at different levels and the generation by the probability of a number of units being unavailable. The figure shows the hours of shortfall reducing to around 8 hours/year with a 20% plant margin with the equivalent loss of load probability (LOLP) shown on the secondary axis. The graph also shows the associated probable value of un-served energy in GWhrs/year that increases exponentially with lower plant margins. The availability represents that due to planned and forced outages to also take account of the potential for shortfalls to occur during the maintenance programme when cold periods occur before generation is returned to service. The overall generation availability is used to determine the probability of a number of units being out of service for different periods of the year. With the same scenario if the annual availability were to be improved to 0.9 then the same security standard would be realised using 137 units of 500MW or 4500 MWs less capacity. This is equivalent to the percentage improvement in availability of around 5.9% expressed as a percentage of the total installed capacity.

The loss of load in this analysis relates to that resulting from generation shortfall. There is also a potential loss due to network disturbances that may be higher at the distribution level but affecting fewer consumers and an overall consistent approach is needed. It is pointless having high generation capacity margins when more demand is likely to be lost due to network failures.

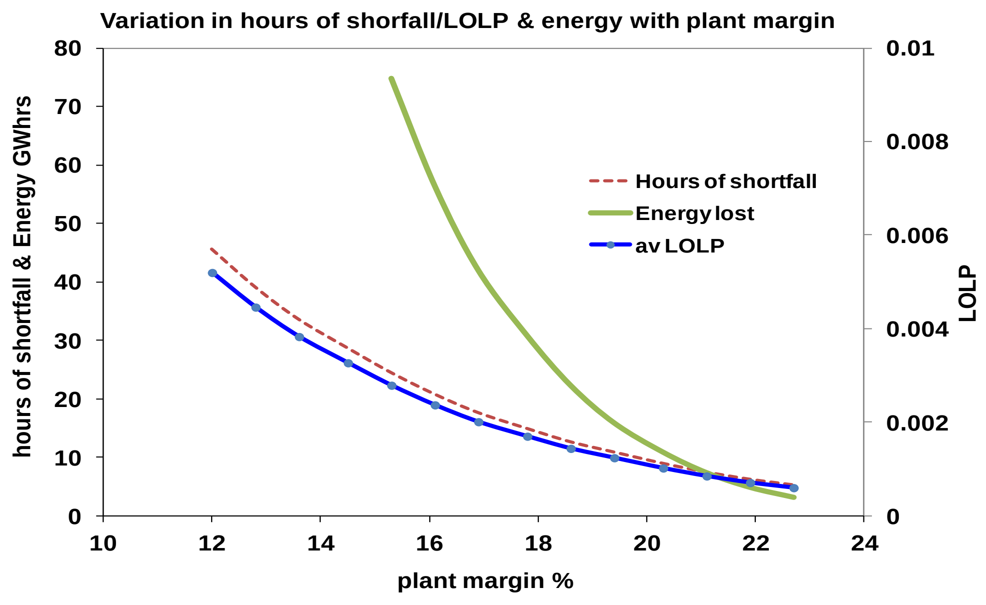

Figure 1 – LOLP and plant margin

Economic Analysis

In determining the target generation capacity and margin, consideration needs to be given to the impact on consumers. This is represented by attributing a value to the lost load (VLL). This is usually expressed as a cost/kWh with average values around €10/kWh (£8.5/kWh). This is dependent on the customer and type of load with values ranging from around €5-15/kWh. Given the potential cost to consumers of un-served energy and the annual cost of providing new capacity, the optimum can be established. This occurs when the costs of an increment of new capacity equates to the reduction in un-served energy priced at VLL.

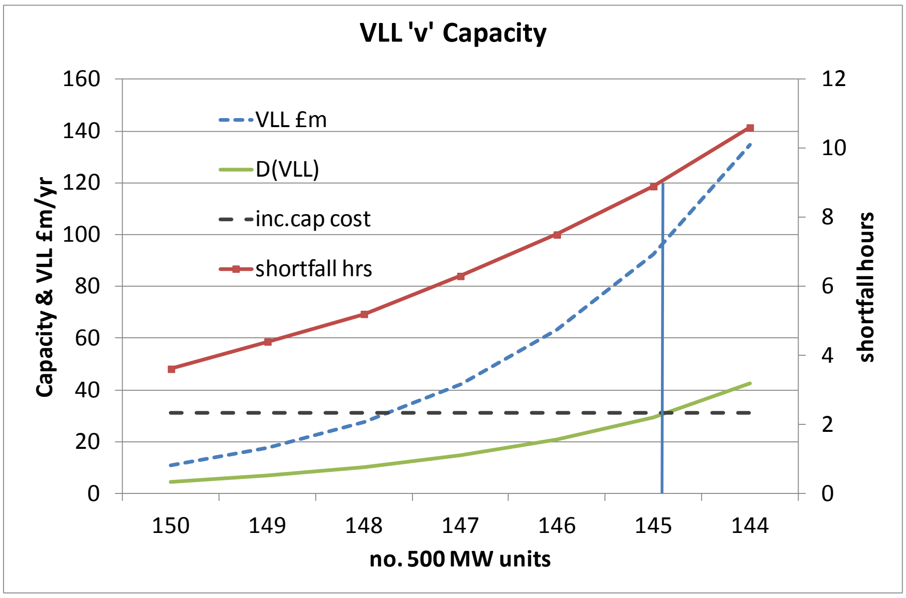

Figure 2 – Optimal Capacity

The results of a typical analysis, based on the same scenario, are shown in figure 2 and include the incremental value of lost consumer demand (shown as the solid line) and the incremental cost of new capacity (as a horizontal solid line). In this example the two lines intersect at around 9 hrs of shortfall per year as read form the secondary axis. With a 145 units the VLL/yr is £92.4m reducing to £63.1m with 146 units with the saving matching the annual fixed cost of the new unit. The limitation of this general approach is that it is difficult to distinguish between the security needs of a small business reliant on supplies for its communication and computing infrastructure and the retired pensioner living in fuel poverty and having to switch off appliances to avoid costs. Also, the analysis is based on specific contracted new capacity rather than a general capacity payment to all generators.

It is generally assumed by economists that payments for capacity will be offset by a commensurate reduction in wholesale energy prices. In practice the developing requirements to balance wind intermittency are most economically met by open cycle gas turbines. This is because they have low capital costs and are flexible but their running costs maybe 50% higher than combined-cycle gas turbines due to their lower efficiency. In the absence of alternative balancing options, like hydro, OCGTs are likely to often set a high marginal price. Bid monitoring to check the bid legitimacy compared to expected actual running costs is used in some market implementations but would not help in this situation.

Capacity Procurement

Mechanisms need to be established to secure capacity provision. Capacity auctions may be used to foster competition in the capacity market and they may be operated on a descending clock format. Pricing is often based around typical OCGT costs, less their expected revenue, with a maximum level set by new entrants and existing generators taking a minimum value. It is necessary to establish what happens to unsuccessful bidders. A lead time of a few years is necessary to take account of the time taken to establish consent and construct a station. It is also desirable to facilitate demand side participation, but different lead times may be appropriate reflecting the nature of their business. A system of penalties is considered necessary to ensure high levels of delivery in the event for both the demand and generation side.

There is the option for the SO to contract for specific capacity additions to meet security requirements rather than introduce an overall system capacity market. This has the advantage of minimising the additional cost and containing the influence on the wholesale market. This is a particularly relevant approach where the requirement is to balance intermittent generation like wind. It is analogous to the SO contracting for support through interconnectors.

The Impact of Intermittent Sources

The addition to the plant mix of a significant proportion of intermittent sources of generation like wind requires an analysis of their expected contribution to meeting peak demands. This can be analysed in a number of ways.

- A simple approach is to simulate an annual dispatch of generation both with and without the wind generation subtracted from demand. This will show the generation that is not used when the wind energy is included compared to that without wind for a specific set of data for annual demand and wind generation;
- A more rigorous approach is to establish a probability function for wind output for comparison with the probability of conventional generation being available and the demand being at a defined level.

To fully account for the variations in wind in relation to demand it is preferable to use actual data that takes account of diversity. Figure 3 shows the statistical analysis of some typical aggregated actual wind data compared to an equivalent Weibull function as used to derive the wind output of individual generators. It shows some similarity at higher levels of output but deviates at lower output levels. An actual probability function for wind has been derived and used together with generation and demand probability to determine the capacity contribution of wind.

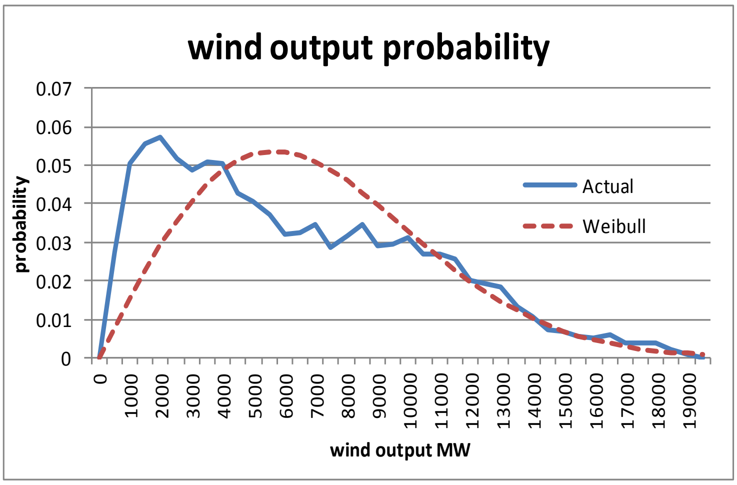

Figure 3 – Aggregated Wind Probability

The process involves:

- establishing the conventional generation capacity meeting the defined security criteria;
- reduce conventional capacity but include wind generation and establish that capacity meeting the same security criteria;
- hence determine effective capacity contibution of wind as the difference between the conventional capacity with no wind and that with wind.

The simplistic dispatch approach results in capacity credits for wind of around 10% of installed capacity but this does not allow for any probability of shortfall. The more rigorous probabilistic approach results in contributions of up to 16% in this example. The actual estimate depends on a number of assumptions such as average wind load factors and the availability attributed to conventional generation.

Interconnection

With increasing levels of international interconnection, there is a tendency in plant margin analysis to attribute capacity contributions based on interconnection ratings. There is a risk in this process of double accounting capacity with adjacent utilities both assuming they can get support from their neighbour. Across Europe countries could be experiencing similar adverse weather patterns with coincident high demand levels with little spare capacity to provide support. Some support may be expected where one of the utilities is enjoying high levels of availability but they may not be prepared to reduce their margins. There is also the requirement to have interconnector transmission capacity available that may have already been reserved for trading. Arrangements can be put in place to provide support with contracts that recognise the cost of maintaining capacity available. Support can only be guaranteed when firm capacity contracts are in place and these are frequently used to maintain secure margins as an alternative to building more capacity locally.

Demand side Regulation

The advent of smart meters offers the option to exercise a level of control over end user demand that could be used to shift demand from high to lower periods. It is expected that the option should be available to enable end-user participation in a capacity market. It is more difficult to monitor and confirm delivery when a load reduction is invoked and predict the reduction that may be realised when other factors such as adverse weather may cause demand that is not controlled to be increased. There may also be effective substitution of the controlled demand by other appliances.

There is likely to be some inherent reluctance to allowing external control of in-house programmes of activity that are based on wider considerations, and there will be a need to establish tariff incentives. Schemes are in place around the world generally based on energy use that is less sensitive to short term interruption like air conditioning and heating systems. Schemes implemented in the USA include tariff incentives to encourage participation and have proved cost effective compared to other options. In the UK one option that could be available providing flexibility, is managing the charging of electric vehicles as their use expands. Demand side regulation can make a contribution to balancing intermittency locally but is not likely to prove a panacea for overall system balancing with large tranches of wind generation and other intermittent sources.

The increasing cost of energy is affecting the economics of embedded generation. Local CHP schemes can realise high levels of efficiency where the waste heat can be utilised. They can also avoid the high costs associated with transmission and distribution network losses where the demand is local. Local small scale wind farms are being built that can be connected at the distribution level and it may prove attractive to use demand side regulation to support balancing their intermittency.

The developments taking place on the distribution networks moves them from being largely passive networks to more active controlled networks. This requires a more interactive interface between the distribution and transmission System Operators to manage the overall system security. It also introduces complication in the process of predicting future demand for generation capacity planning. The traditional forecasting approach used by the transmission system operator was based on historic demand profiles as recorded at the bulk supply points to the distribution systems but these records are now being distorted by control action at the distribution level affecting the demand and output of embedded generation.

Conclusion

There is a fundamental limitation in fully liberalised markets in using short term energy markets to guide the development of the optimum level of generation capacity to meet future security requirements. The simplistic economic approach is that market price rises will encourage new capacity. But, there are increasing levels of government intervention in the market in the form of subsidies, capacity payments and contracting for nuclear generation aimed at meeting wider environmental and security objectives. Understandably, these have the effect of undermining the market and general investor confidence leading to potential capacity shortfalls in future years. The expansion of intermittent energy sources, embedded generation, demand side regulation and interconnection as discussed in this paper further add to the complication. There are also questions to be addressed related to the interaction of intermittent sources with less flexible generation like nuclear and CHP that affect the plant mix. At times of light load, wind output may need to be curtailed to accommodate inflexible generation and maintain sufficient conventional generation reserve in service for the System Operator to maintain secure system operation.

There is an urgent need for the development of an overall indicative energy plan that analyses and quantifies all the issues and enables investors to analyse their options and assess their risks. There are examples from other countries of medium term energy plans providing a background to investment analysis. In the current situation, the subject area is too complex to assume that all will be resolved by market mechanisms and it is too open to influence from lobby groups with particular vested interests. The mixture of generation development also has significant implications to the future requirements of the transmission and distribution systems. The overall costs may run into 100s of billion pounds and a mechanism is needed to encourage development that is close to the optimum to maintain business competitiveness.

There are a number of areas of research that are necessary to support future regulatory policy related to setting security standards:

- Establishing the capacity contribution to system security that can be expected from renewable sources;
- Facilitating demand side particpation in energy and capacity markets through the application of smart meter instalations;
- Determining the levels of security that should apply at the transmission and distribution levels consistent with consumer needs and overall system security;
- Ensuring access to the networks and markets by new local embedded generation sources and energy storage systems.
- Restructuring the regulatory price review processes to accommodate the changes in system infrastructure and facilitate innovation;
- Determine a regulatory regime appropriate to the applicationof smart meter technology to ensure consumers receive a share of any benefits.

As distribution networks become more active with embedded renewable generation, CHP schemes and domestic heat pumps, solar energy systems and electric vehicles, modelling capability will need to be developed to establish the collective impact on demand levels and profiles. The regulatory agencies will play an expanding role in building a framework to meet the changing environment whilst protecting consumer interests.

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