Oxera

Agenda

Advancing economics in business

Margin for error? Security of supply in electricity

Electricity supply security relies on sufficient and timely investment in generation and network infrastructure. Market liberalisation is placing the responsibility for ensuring security firmly on the private sector, but how can we be sure that markets are investing appropriately? A benchmark is needed against which to monitor market performance

In theory, the optimal level of supply security can be calculated at the point where the cost of providing additional security (ie, the incremental investment undertaken) equals the benefit of that additional security in terms of the value of the avoided interruption costs. In reality, considerable emphasis is placed on proxy measures of system security, such as the plant margin[1]—ie, the percentage of installed generation capacity above peak electricity demand.

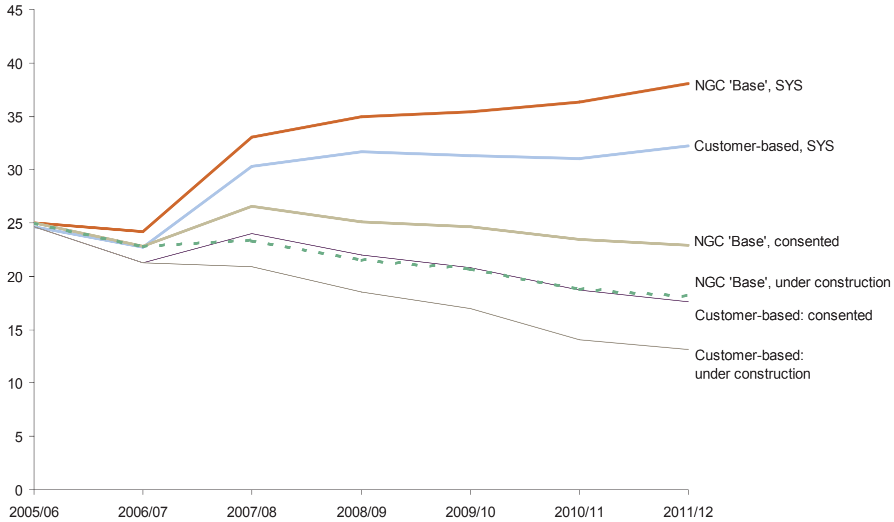
While the plant margin is a simple, transparent measure of generation adequacy, it is an imperfect representation of the security of supply inherent in a system. Security depends on the reliability of the different sources of generation and the correlation of the output of those sources with demand variations—the plant margin does not provide information on these factors.

In an environment where the generation mix and the input fuel supply sources are stable, the proxy may have some validity. However, where fundamental changes are occurring in the energy system, the relationship between the plant margin and security of supply will itself change. The UK is effectively at a point where the simple plant margin is beginning to lose its relevance:

– existing generating capacity is ageing, thereby increasing the risk of operational failure;
– diversity in generation sources is expected to decline as gas accounts for an increasing proportion of capacity over time;
– as the UK Continental Shelf (UKCS) declines, the UK will become increasingly dependent on imported gas, potentially adding to delivery risk;
– there will be a growing contribution from intermittent renewable generation sources—particularly wind power.

Therefore, even this winter, relatively high reported GB margins of 22%[2] have not alleviated concerns over the possibility of interruptions. With National Grid publishing projections of future plant margins out to 2012 that range from 13% to 38%,[3] depending on the assumptions of plant retirement, new build and demand growth (see Figure 1), it is important to consider how the relationship between plant margins and security may change.

Figure 1 Generation plant margin forecasts (%)



Source: National Grid (2005), 'Seven Year Statement', May.

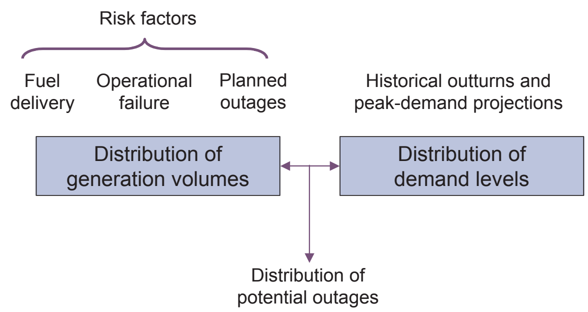
This article presents an initial investigation into the sensitivity of this relationship to different generation mixes, illustrating how relatively secure electricity supply does not automatically follow from a high plant margin.

The security metric

The first question to be answered is 'what is security of supply?' For the purposes of this analysis, electricity supply security is defined as the expected level of electricity demand that is unserved over a specified period.[4] The focus is on generation adequacy; therefore, interruptions due to network failures are not considered, since the capital programmes and performance of networks are subject to a detailed regulatory incentive framework.[5] These network failures will nevertheless be very important for consumers.

Oxera has developed a simulation model that allows the expected level of energy unserved through shortfalls in generation capacity to be estimated under a range of market scenarios. This security metric is derived from the joint consideration of two distribution functions over a pre-specified period (a period of one quarter is used here, but longer or shorter time periods could be applied): one for the outturn level of demand, the other for the outturn level of available generation volumes (as illustrated in Figure 2).

Figure 2 Deriving energy unserved



Source: Oxera.

Measures of plant reliability

Whereas the shape of the demand distribution is based on historical outturns, the generation distribution is constructed from a stylised model of the generation sector on a plant-by-plant basis, with each plant (or plant type) subject to differing risks of failure (or unavailability of capacity) as a result of:

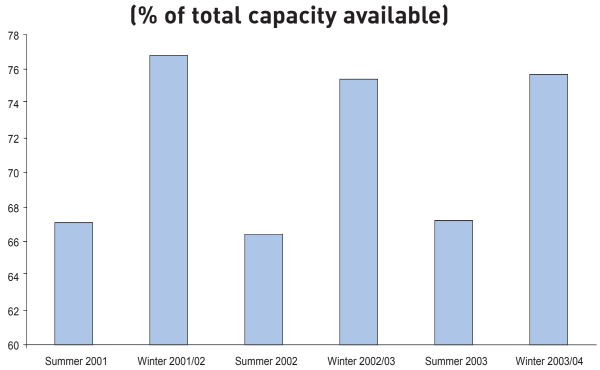
– planned outages for maintenance; or
– operational failure; or
– input fuel interruptions.

Planned maintenance programmes are largely predictable and of known duration (the majority of maintenance downtime has traditionally been during the summer months when demand is lower), thus imposing a seasonal pattern on the technically available generation capacity. This pattern is observable in Figure 3, where availability is significantly higher in the winter periods.

However, outturn availability is also a function of the commercial requirement for the plant at that time. Thus, it does not correctly reflect the pattern of unplanned outages for technical or fuel reasons and therefore may underestimate the ability of generation capacity to respond to plant failures or demand spikes. The probability of unplanned outages for different generation types has therefore been taken from data presented in a study undertaken by UMIST in 1999, which reviewed the actual forced outage rates for different generation types over a variety of time periods.[6]

More detailed work on input fuel risks was undertaken using simulation models. For wind, Oxera used analysis based on a 20-year data series from the Met Office to determine the effective capacity provision of wind generation over the course of a year. For gas supply, Oxera constructed scenarios of the potential levels of gas supply outages on the basis of simulations of the reliability of the present delivery infrastructure, potential sources of supply and levels of gas demand.

Figure 3 Outturn availability patterns (% of total capacity available)



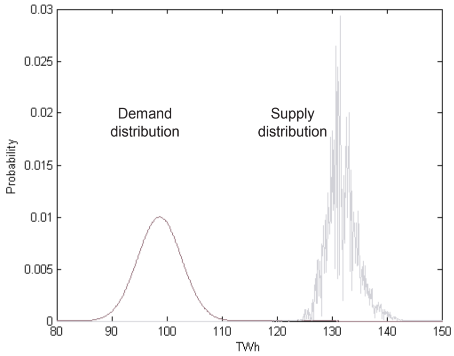
Source: National Grid Transco (2004), 'Trends in Unforeseen Outages on Generating Plant', February.

Calculating the level of security

Comparison of the coincidence of these distributions allows the expected energy unserved to be calculated as well as specific probabilities for individual 'events', or failures of varying sizes. To illustrate, the approach has been applied to the conditions prevailing in the first quarter of 2005, producing the distribution functions shown in Figure 4, where the left-hand curve is the demand distribution and the right-hand curve the supply distribution.

As can be seen, there is no significant overlap, and hence a zero expected level of energy unserved as a result of generation shortages, something which may be

Figure 4 Demand and supply distributions, Q1 2005



Source: Oxera modelling.

anticipated given the high plant margin at the time (24.3% in 2004/05). However, as the plant margin and fuel mix are varied, the results change.

Table 1 shows how the expected energy unserved changes when the Q1 2005 demand and generation mix is maintained, but total generation capacity is adjusted to produce lower plant margins.[7]

Table 1 Impact of capacity margin on outage probabilities

Q1 2005 plant margin (adjusted, %)	Expected energy unserved (MWh)	Probability of an outage of 10GWh	Probability of an outage of 100GWh
23.5 (base)	0	<0.0001	<0.0001
22.50	0	<0.0001	<0.0001
15	0.15	<0.0001	<0.0001
12.5	2.12	<0.0001	<0.0001
10	25.00	<0.0001	<0.0001
7.5	248.73	<0.0001	<0.0001
5	2009.80	0.002	0.001

Source: Oxera.

As the table shows, when the plant margin declines, the expected level of energy unserved increases (although in this scenario the actual volume lost would be less than 0.003% of total demand), as does the probability of larger outages. This is because, with the decline in plant margin, the system becomes less able to absorb the stochastic shocks that affect it. Nevertheless, not until the margin falls to around 10% are expected levels of energy unserved in the order of MWh; even at a margin of 5%, there is only a 0.02% probability of outages, roughly equivalent to the present level of distribution losses (around 13GWh per annum). The fact that much lower margins appear to be relatively secure may explain the current lack of concern in the market regarding the absence of activity on new build. Moreover, it supports the relatively low capacity margin figure of 12.5% incorporated in the Standard Market Design of the US Federal Energy Regulatory Commission (FERC).

Security and generation mix

While the different forms of generation face the same types of risk, the severity of the risk varies significantly between them. For example, coal and nuclear face input fuel risk, but the probability of having insufficient supplies is estimated to be several orders of magnitude lower than the risk of very low (or very high) wind speeds, which adversely affect wind farm generation. Therefore, it is informative to consider how the physical security parameters vary when the generation mix is substantially different for a given level of generating capacity.

Table 2 illustrates the comparison between the level of security using the 2005 plant mix and a revised plant mix based on a likely outturn for the future plant mix around 2015 (shown in Table 3). This is important as it incorporates a large contribution from the two generation types with the greatest associated fuel risks: wind and gas.

The differences in the outcomes are stark. Under the alternative generation mix, the expected outage at a 13.3% plant margin is around 12 times higher than that at an 8.3% margin under the current generation mix. Furthermore, there is a 1% chance that there will be outages at least as large as the present total network-related interruptions in the UK.[8]

The reason for this contrast in the security position is that the types of security risk to which the system is exposed affect a higher proportion of the total generation mix, so there is less effective insurance capacity to respond when these events occur.[9] It is an illustration that a simple plant margin indicator can provide a misleading reflection of the level of security inherent in an electricity system.

Table 2 Impact of generation diversity on expected outages

Plant margin (%)	Expected energy unserved (MWh) 2005 mix	2015 mix
20.8	0	12.54
15.8	0.15	899.35
13.3	2.12	3133.90
10.8	25.00	15,020.00
8.3	248.73	92,596.00

Source: Oxera.

Table 3 Generation mix assumptions

Generation type	Proportion of capacity (%) 2005	2015
Gas	36	52
Nuclear	16	4
Coal	35	18
Wind	1	13
Interconnectors	3	2
Oil	5	0
Other	4	9

Source: Oxera.

Conclusions

The physical security analysis presented in this article has illustrated that:

– the existing electricity system would appear to be relatively robust to problems of generation shortages, even at much lower levels of plant margin;
– as the plant margin falls, the system becomes more vulnerable to outages;
– the level of security at a given plant margin is sensitive to the underlying generation mix, thereby suggesting that a simple plant margin indicator is inadequate as a measure of the level of security and that some means of integrating the diversity and plant margin measures would be a useful additional metric.

The fact that not only are the plant margin and mix changing over time, but that there may also be changes in the reliability of plant (through ageing, technological advances, new supporting infrastructure, etc) suggests that it is unlikely that a single plant margin figure will suffice. Nevertheless, even with a mix more dependent on intermittent sources of generation and imported gas supplies, the average volume of energy lost is only 0.1% of total expected demand. The main issue is whether the relatively small risk of a major interruption implied by these figures is one that the markets and policy-makers are willing to bear.

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[1] Also referred to as the reserve margin or the capacity margin.
[2] Department of Trade and Industry (DTI) (2005), 'Secretary of State's First Report to Parliament on Security of Gas and Electricity Supply in Great Britain', July.
[3] National Grid (2005), 'Seven Year Statement', May.
[4] This is consistent with assumptions of 'risk-neutral' consumers, but results may differ if risk aversion is considered.
[5] The fact remains, however, that, over the past 20 years, there have been no interruptions due to lack of generation capacity in the UK, and further investment in network resilience and performance would provide significant benefits in terms of improved security.
[6] Rios, M., Bell, K., Kirschen, D. and Allan, R. (1999), 'Computation of the Value of Security of Supply: Final Report', October. While it is acknowledged that observed forced outage rates may vary according to the age of plant and the actual maintenance programme, the UMIST report estimates have been applied uniformly across each generation type.
[7] The plant margins presented are with respect to a de-rated wind capacity.
[8] This result has been derived assuming the same risk of input fuel outages for gas stations. In reality, two effects may alter the relevant input fuel risk if such a generation mix were to emerge. First, for a given gas infrastructure, greater demand from gas-fired stations on the system may increase the risk of fuel shortages. Second, during the period over which the plant mix altered, additional gas infrastructure may be built, which could reduce input fuel risks depending on the source of delivered gas using the additional infrastructure.
[9] To illustrate, the 13.3% absolute plant margin corresponds to a 12.5% effective plant margin when wind generation is down-rated in the 2005 mix. However, when the 2015 mix is used (which has substantially higher wind generation), the effective margin is around 3%.

If you have any questions regarding the issues raised in this article, please contact the editor, Derek Holt: tel +44 (0) 1865 253 000 or email d.holt@oxera.com

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