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RESPONSE TO NATIONAL GRID CONSULTATION:

OPERATING THE ELECTRICITY TRANSMISSION NETWORKS IN 2020

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ABOUT THE RENEWABLE ENERGY FOUNDATION

The Renewable Energy Foundation is a registered research and education charity encouraging the development of renewable energy and energy conservation whilst emphasizing that such development must be governed by the fundamental principles of sustainability. REF is supported by private donation and has no political affiliation or corporate membership. In pursuit of its principal goals, REF highlights the need for an overall energy policy that is balanced, ecologically sensitive, and effective.

ABOUT THE AUTHORS

Mr Paul-Frederik Bach

Paul-Frederik Bach has more than 40 years' experience in power system planning. He worked with grid and generation planning at ELSAM, the coordinating office for west Danish power stations, until 1997. As planning director at Eltra, Transmission System Operator in West Denmark, he was in charge of West Denmark's affiliation to the Nordic spot market for electricity, Nord Pool, in 1999. Until retirement in 2005, his main responsibility was the integration of large amounts of wind power into the power grid in Denmark. He is still active as a consultant with an interest in safe and efficient integration of wind power, particularly the prevention of disturbances by advanced system control measures.

Dr John Constable

John Constable is the Director of Policy and Research for the Renewable Energy Foundation, an independent charity that provides data and information about renewable energy technologies. Dr Constable read English at Magdalene College, Cambridge, taking his PhD there in 1993. He subsequently taught at both Kyoto University, Japan, and at Cambridge, where in 2005 he was a Senior Research Fellow of Magdalene College. He is the co-discoverer, with the Japanese particle physicist and economist, Hideaki Aoyama, of the mathematical distinction between verse and prose in English. He has been working in energy policy since 2004, and he is currently responsible for co-ordinating the Foundation's large circle of practical and academic engineers, and for the direction of policy.

Dr Lee Moroney

Lee Moroney is the Director of Planning for the Renewable Energy Foundation. She has a PhD in Chemistry from University College Cardiff. After gaining her PhD, she worked as a research scientist on synchrotron radiation studies of solids in the United Kingdom and the United States. In the 1980s she started a computer consultancy specialising in bespoke mathematical and database software for stock broking. She has 30 years of experience in data analysis and information mining from large datasets of varying quality in both scientific and financial disciplines.

INTRODUCTION

i. This response text has been co-authored by Mr Paul-Frederick Bach, who is the principal author, and two directors of Renewable Energy Foundation (REF).

ii. REF asked Mr Bach for his views on this consultation as we believe them to be of unique value to National Grid, and indeed to anyone interested in the current policy direction of the United Kingdom.

iii. We would take this opportunity of drawing National Grid's attention to recent work conducted for REF by Mr Bach on the relationship between wind power flows and spot prices in Germany and Denmark.[1] One of the principal findings of Mr Bach's study is that the widely held assumption that Denmark had integrated a quantity of wind equivalent to 20% of its total electrical energy consumption (MWhs) was misleading. In fact, the Danish and German markets have become closely synchronised, largely because of wind, and it is more realistic to say that Denmark and Germany combined, in conjunction with the balancing resources of Norwegian hydro, have integrated about 7% of MWhs from wind power.

iv. Thus, the United Kingdom is much closer to the frontier of knowledge in this field than has been hitherto appreciated, and due to the effectively islanded nature of the UK grid, faces much more complex and sensitive problems relating to wind power integration. If very large wind capacities of 30 GWs and upwards are built, as currently envisaged by the UK government, this will confront the electricity sector with unprecedented technical difficulties, solutions to which do not yet exist, and costs which are in many cases uncertain.

v. We recognise that from National Grid's perspective these costs can be to some degree passed through to the consumer. However, it would be helpful if National Grid were to make it plain to Government that the magnitude and future uncertainty of these costs is a grave cause for concern, particularly in current economic circumstances, and that government should moderate the pace of development in the non-dispatchable renewable sector such as wind power so that integration solutions can be developed in tandem with deployment, and costs kept within reasonable bounds. A diversified portfolio of renewable technologies, particularly dispatchable solutions, would significantly ease the problems described in the consultation document.

vi. In this context it is worth recalling that NG has prominently stated that there is no technical obstacle to the government's targets, only economic costs, for example in a recent

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[1] For summary and overview see: http://www.ref.org.uk/PublicationDetails/53.

submission to the Enterprise and Culture Committee of the Scottish Government in 2004: "We believe that, if there is a limit to the amount of wind that can be accommodated, that limit is likely to be determined by economic/market considerations."[2]

vii. We think it would be helpful to the general public if NG were to clarify the position by indicating what is known to all analysts, namely that the "technical"/"economic" distinction is a false dichotomy. While it is true that there is no fundamental physical law barring the introduction of high levels of wind, it is a matter of fact that technical difficulties and uncertainties manifest themselves as increasing and increasingly uncertain *costs*. It is conceivable that at a certain point, as yet unknown, the difficulties become so intractable and the costs of progressing further with solutions so high, that there is a practical barrier.

viii. That is to say, at lower levels of wind penetration (<5 GW), as at present, the difficulties are moderate and the solutions known and readily obtained. The costs at this level are real, but moderate.

ix. As higher levels of wind (>5GW) are introduced the degree to which the solutions are fully understood and can be confidently predicted begins to decrease.

x. At high levels (>10 GW) the solutions are conceivable but cannot be accurately costed, except to say that the cost is likely to be high.

xi. At extremely high levels (>20 GW) the solutions are only vaguely conceivable, and the costs consequently very high, since the development of the solution must be included in the overall cost.

xii. In what follows we attempt to explore this range of uncertainties with specific answers to the consultation questions.

xiii. Overall, we congratulate National Grid on the clear description of the broad range of issues and difficulties associated with implementing the renewable energy strategy. The present power system operation is based on many years' experience of the stochastic elements of the power system, particularly the availability of large conventional power plants, and the short-term, forecast of total system load in the following few hours (with 4 hours as an important limit). NG's operating reserve requirements are based on this experience. Wind power will add a new and different stochastic element that will almost certainly require new methods and procedures.

xiv. However, the methods and solutions presented by NG in the consultation appear to be based on the architecture of the present power system and the contemporary electricity

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[2] http://www.scottish.parliament.uk/business/committees/enterprise/inquiries/rei/ec04-reis-ngt.htm

market arrangements. This may be justified up to a 24% share of wind energy contemplated by NG, but then again it may not.

xv. Bearing this uncertainty in mind, it would be prudent to improve monitoring of demand side balancing resources by ensuring that improved regional grid control concepts are implemented by the Distribution Network operators (DNOs). For example, the DNOs should provide aggregated data on embedded generation for NG and the general public. If this data is made available promptly, and at an adequate quality level, there should be sufficient time available for development and implementation of new system structures before 2020.

xvi. NG seem to consider their operating reserve mainly in terms of upward regulation; that is to say the need for more generation to meet demand. Danish experience, however, shows clearly that operating reserves must be provided for both upward and downward regulation. We hear anecdotal evidence that upward frequency excursions due to wind power are already a feature in some areas of the UK system, and are not surprised. More transparency in regard to this matter would assist all parties.

xvii. Improved market arrangements also deserve discussion, particularly in the light of the recent Ofgem papers on market power and liquidity in the wholesale market.[3] The perspectives will be discussed further below.

3 Ofgem, Addressing Market Power Concerns in the Electricity Wholesale Sector - Initial Policy Proposals (30 March 2009). Ofgem, Liquidity in the GB wholesale energy markets (8 June 2009).

Answers to Consultation Questions

Q 1: How do National Grid's observations align with your experience or modelling of wind generation?

1.1: It is our experience that historic modelling of wind generation output has been over-simplistic and failed to account explicitly for wind shear effects. For example, paragraph 5.7 of the consultation, whilst correct, ought to say *'A typical wind turbine will generate electricity when* ***wind speeds at hub height are*** *around 4m/s…' etc.* Crucially, it is the hub height wind speed which is the important metric for determining wind turbine energy yield, and obtaining accurate hub height wind speeds is not easy.

1.2: Wind shear is the variation in wind speed (and direction) with altitude. Because of the ready availability of Met Office wind speed data at 10m height, this low altitude data is often used to predict wind farm output. It is our experience that this can lead to significant errors in prediction because variation in wind shear is difficult to take into account.

1.3: It is not possible to extrapolate from wind speeds measured at 10m height to derive hub height wind speeds. The wind shear varies throughout the day and also varies with meteorological conditions and time of year. If, however, wind speeds over a range of heights are measured, then it is possible to derive a reasonable approximation of hub height wind speed using the power law; i.e.

$$V_1/V_2 = (h_1/h_2)^m \qquad \ldots 1$$

where

V_1 = wind speed (m/s) at height of h_1 metres above ground level

V_2 = wind speed (m/s) at height of h_2 metres above ground level

m = wind shear exponent

1.4: The wind shear exponent varies with time of day and meteorological conditions. If long term wind speed data at two or more heights are obtained, then the wind shear exponent may be derived for each measurement interval and from this, the contemporaneous wind speed at hub height derived, and in turn, a reasonable estimate of the wind turbine power output for that time interval derived.

1.5: REF has recently obtained a number of sets of anemometry data for different sites predominantly in the south east of the UK. These datasets include wind speeds at two or more heights, every 10 minutes for periods ranging from several weeks to several years. We have carried out a limited analysis of these datasets and this work is ongoing.

1.6: We are aware that wind farm developers have in the past predicted wind speeds assuming a wind shear does not vary with time of day or meteorological conditions. It has been routinely assumed that the difference in wind speed with height is fixed and solely determined by the terrain.

1.7: Figures 1 and 2, following, compare quarterly load factors for one of our sets of data derived (1) erroneously assuming a fixed shear between 10m and hub height and (2) correctly taking variable shear into account. These show that failing to take variable shear into account would lead one to assume that wind energy output peaks in the middle of the day, whereas the correct derivation shows such effect is negligible in the autumn, winter and spring quarters, with only the summer quarter showing a small rise in the day. It should be noted that these figures represents a single year's high anemometry data for a single site in Norfolk, but it is interesting to note the similarity in profile between Figure 2 and the graphs on page 18 of REF's Spot Price Study which show the average daily wind power profiles for West Denmark 2008. We believe it is similar to Figure 3 in the NG Consultation document.

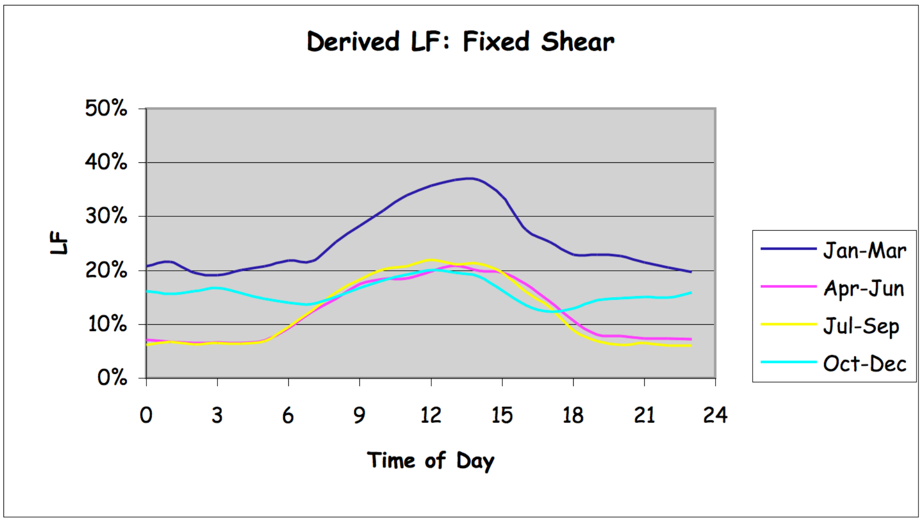

Figure 1: Annual load factor by time of day and quarters of the year derived by ***incorrectly*** *assuming a fixed wind shear factor between 10m wind speed measurements and turbine hub height.*

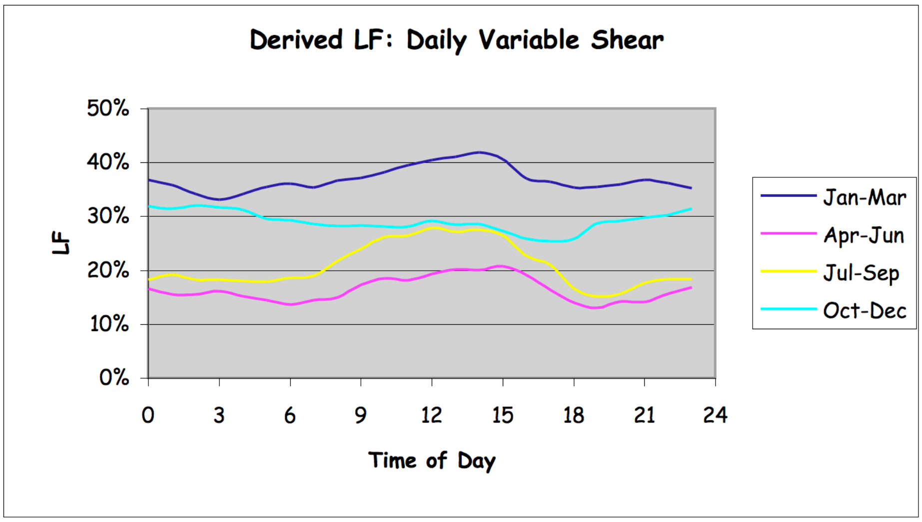

Figure 2. Annual load factor by time of day and quarters of the year derived ***correctly****, accounting for the daily varying wind shear factor with height.*

1.8: Figure 3 is a further demonstration of the problems of neglecting variable wind shear in the calculation of load factors. This shows the same dataset converted to load factors using both variable and fixed shear, and comparing these load factors with actual load factors derived from the Renewables Obligation Certificates issued by Ofgem for actual wind farms in the region. This shows that the variable shear calculation provides a very much more convincing match to real load factor profiles.

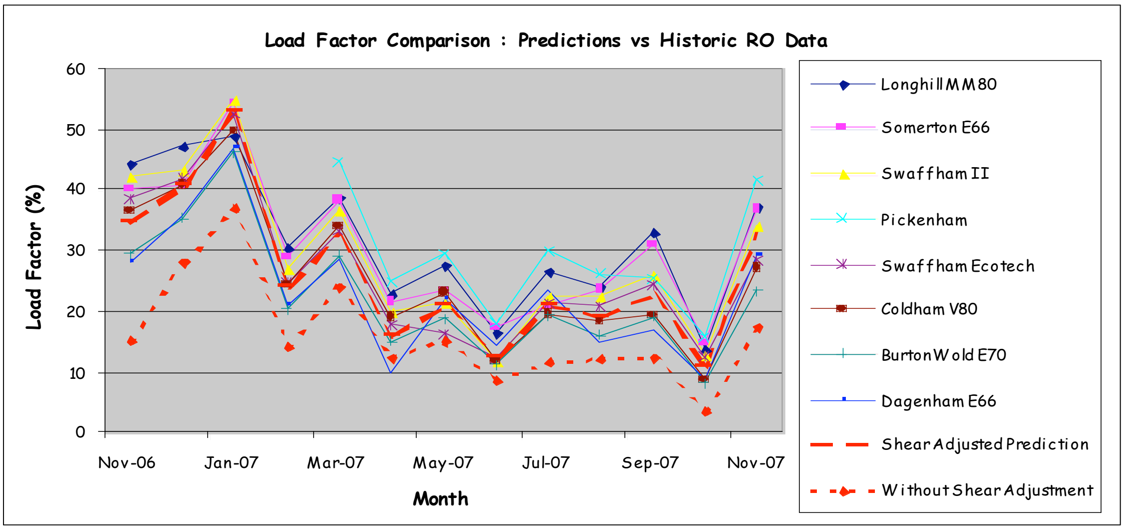

Figure 3. Comparison of actual load factors determined from Ofgem ROC data with derived load factors using a fixed shear factor to derive hub height wind speeds and variable shear factor from high anemometry data at two heights.

1.9: From our preliminary analysis, it appears that one third of the total wind energy is generated between the night hours of 23:00 to 07:00, which if repeated across the country, could have significant implications for balancing at times of low demand and high wind power penetration.

Q 2: Are we correct in assuming that wind generation is controllable enough to assist in operating the networks?

2.1: Yes, up to a point, but as mentioned elsewhere in the Consultation paper this question not only has technical but also economical and environmental dimensions. Curtailing wind power for balancing purposes would be wasteful, unacceptable to the public who are subsidising wind power, and have economic implications for the generators concerned; new overall solutions may be required.

Q 3: Should National Grid assume that Supercritical Coal generators will provide some flexibility in operation which will assist in operating the networks?

3.1: Danish experience confirms the potential flexibility of the supercritical coal power plants. However there are other matters to consider (as in Q2), and it should be noted the intermittent operation is not popular amongst Danish operators. Effects on O&M costs and reliability will need to be considered further.

Q 4: Should we assume that nuclear generators will continue to concentrate on base-load operation?

4.1: No comment available.

Q 5: Is it likely that Carbon Capture plant will impose material restrictions on the operation of electricity generating plant?

5.1: There is no practical experience available.

Q 6: Are there other aspects of tidal or marine technologies that we should consider further at this stage?

6.1: We believe that tidal technologies are under-supported in the Government's policy and that significant benefits would accrue from a more diversified renewable energy mix. Reducing the proportion of wind power in favour of tidal power would, we believe, reduce costs necessary to accommodate the variability of wind. It would be useful for NG to emphasise the economic and technical advantages of the more predictable technologies, as compared with wind.

Q 7: Are there other restrictions we should consider in developing a view on gas fired generator flexibility?

7.1: The Consultation paper refers to "almost two decades of success in making use of the services offered by CCGT operators in operating the transmission networks" (para 5.41)'. The question is how a CCGT plant will behave under conditions of intermittent operation. CCGT plants are known to have low efficiency in part load operation, and may have increased O&M costs and reduced availability. Perhaps it is possible to obtain flexibility by operating a large number of CCGT plants in on/off mode.

7.2: An alternative could be to have a number of gas fired supercritical plants without gas turbines. A 400 MW gas fired unit in Denmark was designed for a significant number of hours of part load operation. It has 48% efficiency at full load, 47% at 60% load, 45% at 40% load and 38% at 20% load.

7.3: The Danish EcoGrid.dk project was intended to find solutions for a 50% share of wind energy, but unfortunately it did not succeed in presenting a type of flexible power plant capable of fitting into the future power system.[4] This future flexible power plant was supposed to meet technical, economical, environmental requirements, as well as the demands of security of supply demands. The necessary trade-off deserves attention and public discussion. So far no solution has been found to meet all demands.

Q 8: What is your view of future electricity demand growth and how would you quantify any uncertainty around this?

8.1: As noted in REF submissions to Government we do not believe that energy efficiency measures will result in reduced demand in any sector; indeed against a background of a growing population and a return to growth it is rational to expect significant growth in all sectors, and particularly in electricity consumption.

8.2: Furthermore, and although this may seem paradoxical to the general public, efficient utilisation of a large share of wind energy will require additional electrical demand.

8.3: It must be a flexible type of demand depending on the availability of cheap electricity. It could be for charging batteries or for the heating of water for district heating systems. Such demands must be forecast separately from the rest of the system in order that uncertainties in this new type of demand will be responsive to the supply of electricity. They cannot be treated in the same way as normal demand.

8.4: There may well be different categories of flexible demand, and indeed a merit order. For example, when there is no other alternative but waste, it might be justifiable to use electricity to heat water, otherwise an application of low merit since it uses high grade energy to do low grade work.

8.5: On the other hand, heat pumps have a higher merit ranking, since they return more heat than could be obtained from the electrical input on its own, and could probably be operated with more expensive electricity.

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4 EcoGrid.dk, Phase 1 Summary Report, Steps towards a Danish Power System with 50% Wind Energy (2009). Funded by Energinet.dk, and available from their website: http://www.energinet.dk/NR/rdonlyres/3CD91ABB-2024-48E3-A0BB-AECC0ACDD725/0/Phase1SummaryReport.pdf.

Q 9: Are there other developments which will change the way that electricity will be consumed in 2020 that we should consider?

9.1: NG's principal concern should be that the high share of wind power will distort the profile of the residual load beyond recognition. This is relatively well understood.

9.2: In addition, the rapid development of sophisticated electronic communication is already altering working and leisure activities. The impact of this on electricity demand is not easy to predict.

9.3: Moreover, the ways in which these changes may combine can only be guessed at, and create considerable uncertainties for NG.

9.4: There is clearly a potential for novel demand patterns to contribute to a dynamic match between supply and demand, but this should not be taken for granted.

Q 10: Do you share our view that distribution companies, suppliers, aggregators and ourselves will all value and compete for demand side services?

10.1: Yes. Furthermore, if there are no rules regulating the trade with demand side services there could be an unproductive competition between DNOs, suppliers, producers, aggregators and the TSO. Such competition will probably not be open and transparent to end users. This outcome should be avoided.

10.2: Ofgem recently pointed out that the GB wholesale electricity sector is vulnerable to undue exploitation of market power,[5] and we note in addition that the vertically integrated power companies will be able to consolidate their market positions if they can acquire control of essential parts of the demand side resources.

10.3: Efficient demand side services will depend on local communication and information systems. These should be organized by the DNOs, and nationwide, open, and transparent market arrangements for demand side services should be established. Customers should be able to sell their services to anybody within the framework of a common market system.

Q 11: Are our assumptions around the number of electric vehicles in 2020 reasonable?

11.1: No better estimates available.

Q 12: Is it valid to assume that electric vehicle charging will be co-ordinated via a smart grid or something similar and will react to price signals?

12.1: There will need to be an intelligent local infrastructure for the supply of electric cars, for at least two reasons:

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5 Ofgem, Addressing Market Power Concerns in the Electricity Wholesale Sector - Initial Policy Proposals (30 March 2009).

- Wind power will distort the residual demand curve. Figure 5 in the NG paper is misleading because it cannot reflect future periods with surplus and shortage. Time of day tariffs will give irrelevant signals, as already indicated by NG in 5.71.
- There is a significant risk of local overload due to the simultaneous charging of electric cars.

12.2: Each device must be able to optimize the charging process on behalf of the car owner, and a market arrangement for local households must provide relevant dynamic price information for the computer in the charging device. Such systems do not appear spontaneously, indeed they can only result from a deliberately planned implementation process. It is important that this process aims at serving the customers' interests rather than influencing the customers to serve the interests of the major participants in the operation of the electricity industry. However, it is those major participants who must plan the implementation process. There is clearly a role here for a body such as Ofgem to represent the interests of consumers.

Q 13: Do you foresee a greater or lesser role from embedded and distributed generation than we have assumed?

13.1: Increased use of combined heat and power (CHP) could improve the efficiency of the energy system in the UK significantly. In the short term, micro CHP may be the most effective solution because very little infrastructure for district heating has been established, but most micro CHP will rely on the availability of suitably priced gas supplies.

13.2: Only a political decision to encourage CHP can bring about the economic incentives, and the planning necessary for a long-term development of pipework.

Q 14: Is our anticipated improvement in wind forecasting performance at 4 hours ahead achievable?

14.1: It would be a cautious strategy not to anticipate any significant improvement.

14.2: The outcome of a forecast is an expected value. There are periods with stable weather conditions and low forecast uncertainty and other less stable periods with high forecast uncertainty. Therefore an estimated confidence interval can be useful information in planning for operating reserves.

14.3: Wind power forecasts more than 4 hours ahead also deserve attention and development effort, not least because the operational planning for the thermal units requires more than 4 hour's warning.

Q 15: Do you have any views on our projected Short Term Operating Reserve requirement under 'Gone Green'?

15.1: Appendix A, Derivation of Reserve Levels, is a formal definition of Short Term Operating Reserve Requirement (STORR). The following figure can be helpful in understanding the elements of STORR:

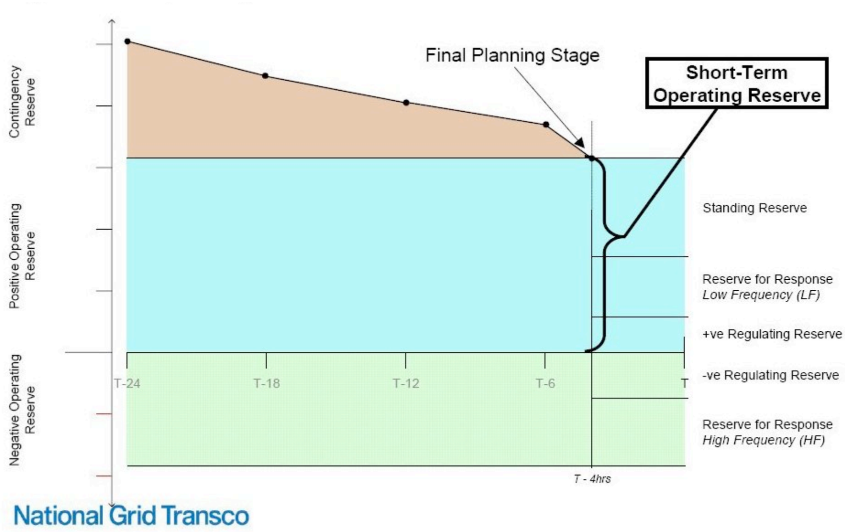

Figure 4: NGT Operation Reserves[6]

15.2: In case of sudden changes of the power balance, the *Reserve for Response* must be ready for immediate reaction to high or low frequencies. The typical reason will be the loss of a large generator or a feeder line.

15.3: *Regulating reserves* are used for equalizing of slow deviations (forecast errors). Balancing services are discussed in section 8 (Q34 to Q44). Reserve for Response and Regulating Reserve are two-way reserves.

15.4: When reserve capacity is activated it must be replaced by contingency reserves as rapidly as possible in order to maintain ongoing system balance and security.

15.5: STORR is based on the experience that sudden operational crises usually require immediate *additional* generation, for example as the result of the loss of a large generator. However, a large loss of load is relatively unlikely since the load centres are connected to a meshed network.

15.6: Danish experience shows that wind power causes significant changes to the stochastic properties of the conventional power system.

15.7: For example, the need for fast generation reduction (or load increase) will be a frequent occurrence. Consequently, two-way operating reserves will be required. Sections 6.70 to 6.72

6 Andrew Ryan: *NGT's Role in Securing Reserve*, National Grid Transco, UK Transmission (presentation).

include comments on 'negative reserve'. In our view NG would be well-advised to consider a more symmetric presentation of operating reserves, with as much emphasis on downward as upward regulation.

15.8: The Danish system operator, Energinet.dk, depends on operating reserves in both directions. The current magnitudes are shown table 5.3 in the Energinet *System Plan 2006*.[7]

Q 16: Do you have any views on our projected volumes, prices and costs for STORR under 'Gone Green'?

16.1: There are so many uncertainties around the Gone Green scenario that it is difficult to form firm views.

Q 17: Is National Grid's current view that 'low wind' events across Great Britain need to be considered when evaluating electricity operating margins reasonable?

17.1: The considerations in 6.28 to 6.37 are strongly related to peak times for the traditional load. However, we emphasise that Danish experience shows that wind power can disturb the regularity of system operation with resulting power shortages *at any time*.

17.2: Our recently published study on *The Effects of Wind Power on Spot Prices* elaborates on wind power output for one control area in Germany and two control areas in Denmark for the years 2006, 2007 and 2008.[8] The three control areas cover a geographical area that is about 1,150 km from north to south, but only about 400 km from west to east. The results are probably not entirely representative for Great Britain, but they may have indicative value and assist in the design of suitable models and research projects.

17.3: The three areas had together a wind power maximum at 10,267 MW (1 hour average) in 2008 and a minimum at 29 MW (1 hour average). Several long calms have been observed, for instance two consecutive weeks in December 2007 causing very high spot market prices in Germany and Denmark.[9]

17.4: Similar analyses for Great Britain would require convenient public access to recorded time series for generation, exchanges and market prices. They would be extremely valuable, and we urge NG to commit resources to this examination.

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[7] Energinet, System Plan 2006 (http://www.energinet.dk/NR/rdonlyres/0E6D80FC-91CB-462F-AC4E-2701C2A2A30E/0/Systemplan2006GBS.pdf).

[8] Paul-Frederik Bach, *The Effects of Wind Power on Spot Prices* (Renewable Energy Foundation: London 2009).

[9] *The Effects of Wind Power on Spot Prices*, Fig. 25.

Q 18: Are our generator availability assumptions reasonable for application to analysis of future operating margins?

18.1: It is unclear why *availability* figures are used for the calculation of operating margins. Based on normal definitions it seems more reasonable to use *reliability* figures.

18.2: The 60% availability of hydro in table 6 probably reflects the energy availability and not the ability of a hydro plant to respond to a short-term demand for power.

18.3: The 100% availability of interconnections is unrealistic by any definition. *The Effects of Wind Power on Spot Prices* publishes the reliability record for five interconnections over three years. See section 3.4 in each of the annual statistical surveys (appendix 3, 4 and 5).

18.4: None of the five interconnections had 100% availability in any of the three years.

18.5: We note that the availability of interconnections appears to be overestimated by average figures since some system operators only define a reduced capacity when there is a demand for exchange.

Q 19: We would welcome comments from market participants on how they expect to manage periods of low wind generation output and whether this is an important consideration for them.

19.1: No comment.

Q 20: Are we correct to highlight the importance of wider European issues in electricity operating margin analysis?

20.1: Figure 13 provides a powerful illustration of a major dilemma in British electricity supply. There are rules within the UCTE defining reserve obligations for each country, and the future rules after the establishment of ENTSO-E will probably also include reserve capacity obligations for each member. Interconnections can be very useful during emergencies, but if full import is assumed in the reserve calculations then corresponding agreements must be made with relevant parties in other countries. This is touched on by NG in 6.66.

20.2: NG calls (in 6.65) for *more innovative solutions* to bridge any operating margin gap. This is a core problem for all power systems planning for a large share of wind energy.

Q 21: Are there further technical solutions for maintaining operating margins which we have not mentioned here?

21.1: Demand side resources, such as frequency responsive devices, could be considered, and we note that the recent consultation from DECC, *Delivering secure low carbon electricity*, places much emphasis on this matter. There are, however, concerns about the scale on which such measures can realistically be expected to apply.

Q 22: Do you think National Grid's view of future operating margins is useful and do you have views on how this should be presented?

22.1: The presentation by NG in 6.46 to 6.68 is interesting and useful.

Q 23: Are our assumptions regarding the level of electricity demand during the minimum demand periods reasonable?

23.1: Overflow problems will be most frequent during traditional minimum load periods. NG knows (6.71) that flexible demand and embedded generation may cause increased uncertainty in demand forecasting. Furthermore, the evidence we have presented in response to **Q1** concerning higher than once-expected wind energy production during the night hours of 23:00 to 07:00 is relevant here. We suspect that wind energy will need to be curtailed during low demand times for lower levels of wind power penetration that has hitherto been anticipated.

23.2: One reaction to the uncertainty in demand forecasting would be to accept the uncertainty and assume a considerable contribution from new price responsive demands, with customers reducing or increasing load in reaction to price signals. Of course, market structures would have to be designed to ensure that such demands were called into being.

Q 24: Are our generation availability assumptions for minimum demand periods reasonable?

24.1: It is unclear how the availability figures can be used for the calculation of minimum thermal generation. There must be other constraints, particularly in order to maintain system stability.

Q 25: Is our central assumption regarding wind generation bid prices related to ROCs reasonable?

25.1: Wind farm profitability as measured by the internal rate of return (IRR) is very sensitive to load factor. SSE has recently observed that at current ROC and electricity prices a 10% increase in generation can add 1% to IRR.[10] Bearing this in mind it is clear that if wind generators are to engage in the balancing mechanism they must determine their prices in relation to lost RO income.

Q 26: Is it reasonable to assume that minimum demand periods will be managed using Interconnectors and Wind Generation in preference to the curtailment of Nuclear Generation?

26.1: This curious question, following 6.77 to 6.86, reflects the results in table 9.

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[10] Scottish and Southern Energy, *Investor presentation* (July 2009), slide 23. Available from: http://investorcentre.scottish-southern.co.uk/pdf/Investor_Presentation_010709.pdf

26.2: A certain quantity of large synchronous generation must be connected to the grid with appropriate geographical dispersion at any time in order to provide the necessary inertia and short circuit capacity for safe operation.

26.3: According to table 9, NG considers 4.1 GW nuclear plus 2.4 GW of CHP and CCGT to be sufficient in 2020/21. This is doubtful, and further work on this matter may be required.

26.4: A reasonable balance must depend on technical, economical, environmental and security criteria. If the final choice is between two poor solutions then other longer term solutions must have been ignored.

26.5: The energy policy will be a failure unless a very high utilisation of clean energy sources can be achieved, but for technical reasons such as those noted above it will be a long term challenge to minimise wastage of clean energy.

Q 27: Do you agree with National Grid's view of increased balancing activity in the future due to variation in market length?

27.1: It is possible that that the increase in NIV could be reduced if the alternative balancing measures which we have suggested elsewhere prove to be effective. In particular, we believe that it might be helpful if renewable generators were motivated to minimise their impact on the balancing system. We note the positive outcome from the Bonneville Power Administration's introduction of Persistence Scheduling.[11]

Q 28: Do you agree with National Grid's view that ramping effects will impact on operation of the networks?

28.1: Yes. According to Danish observations, ramping up will increase considerably for a few hours a year, while ramping down will show smaller increases for a higher number of hours.

28.2: We note this may have an impact on the O&M costs of the ramping generators, and their reliability.

28.3: Other impacts of ramping deserve to be investigated, such as the impact of fluctuations in gas demand from CCGT on the gas grid.

Q 29: Do you believe that a new approach is required in the development of System Operator to generation or demand control point interfaces for 2020?

29.1: The power system architecture should be carefully reconsidered in the light of the new problems facing those responsible for the safe and economical operation of the system.

[11] http://www.bpa.gov/corporate/WindPower/index.cfm

29.2: Amongst the most important elements should be new responsibilities for the Distribution Network Operators (DNOs), and a system-wide information system serving customers, producers, traders and market operators.

29.3: National Grid and the DNOs should organize and operate the communication system, but some independent oversight may be required to ensure that the interests of consumers and other participants are respected.

Q 30: Are there any specific factors which suggest that adequate flexibility will not be available to National Grid for use in operating the networks in 2020?

30.1: There will probably be adequate flexibility available to NG in 2020 *if curtailment of wind power and load shedding are conducted on a significant scale*. However, this may have economic implications for the wind generators if they are not compensated for being constrained off, and for consumers if they are.

30.2: The overall impact of regular load shedding on a large population and its economy may not be acceptable.

30.3: Similarly, the economic impact of regularly curtailing and compensating wind output significant and must be considered.

Q 31: The combined challenge of:

a) ensuring the networks are operated safely and securely against a background of generation variability; whilst

b) getting more from existing infrastructure;

suggests to us that control, communication and information systems have a greater part to play in controlling flows across the transmission networks.

Are there alternative approaches which should be considered?

31.1: So far nobody has demonstrated a perfect power system architecture for a mixture of embedded, uncontrollable and highly variable generation.

31.2: Some alternative models have been suggested, but these are still largely speculative. A vast development and test process will be required in order to collect, experience and extract the best solutions. NG would serve the public interest if it made it clear to politicians that these solutions cannot be simply taken off the shelf or pulled out of a hat in short order and to suit arbitrarily imposed targets, for renewables for example.

31.3: Time and patient engineering are required, and dream-scenario results cannot be guaranteed.

Q 32: What criteria should National Grid use in developing any requirements for information regarding embedded generators? Are there other ways of obtaining this information?

32.1: 7.58 to 7.66 is a very good description of a gradual loss of control due to an increasing share of embedded generation. NG will need aggregated information of power balances, available reserves, and other local matters of general relevance to the power system.

32.2: We feel that more information about existing embedded wind generation in the system is vital to get a clearer picture of variability, and to address this, we would recommend that NG requires developers supply the SCADA data collected by wind farm site operators be provided to NG or to a DNO (who could aggregate and pass on to NG) as a pre-condition to obtaining a grid connection.

32.3: The DNOs may face increasing voltage and congestion problems due to less predictive demand side behaviour.

32.4: A common information framework should be developed for the regional grids for implementation and operation by the DNOs.

Q 33: Are there additional options that National Grid should consider to maintain a Black Start capability?

33.1: NG seems to have a reasonable black start policy.

33.2: It is essential that each black start facility is as simple as possible for the simple reason that experience has shown that complex schemes often fail when they are activated under stress, for example during the blackout in East Denmark in 2003.

33.3: Black start at distribution level has been considered in Denmark, but the protection systems were not able to deal with this option.

Q 34: Are we correct in assuming that new interconnectors will be able to meet some of our Balancing Services requirement?

34.1: It is important to recognise that interconnectors are transport devices giving access to international markets where balancing services can be obtained. However, the interconnector is not itself a balancing service and the presence of the interconnector does not guarantee the provision of the balancing service.

34.2: Wind power will be expanded in several European countries, and the supply of balancing services will be a growing business area. Indeed, there will not only be competition to supply such services, but at certain times there will competition between purchasers for scarce services.

34.3: Norway has excellent balancing resources, but in most other European countries they will probably be in short supply. Therefore the international market price of balancing services may be high. It should be noted that domestic balancing services will have a competitive advantage because foreign services must carry transfer charges, directly or indirectly.

34.4: It should also be observed that interconnectors cannot be available for all purposes at the same time. If an interconnector capacity is reserved for balancing it cannot be available for the market.

Q 35: What is your view on the potential of electric vehicles to provide balancing and other energy services?

35.1: Demand side resources can provide essential contributions to the system balance if the necessary infrastructure is available (see Q12). It will require political determination to develop such infrastructure and to activate the resources. The cost to the economy considered as a consumer must be considered.

Q 36: How much of the electricity demand in Great Britain do you think could be regarded as discretionary or deferrable and hence available for use as a Balancing Service or other energy service?

36.1: Section 8.30 mentions "the instantaneous power demand which might be manipulated". This remark seems to reflect a view of customers as an object to be manipulated to serve the interests of the system. This is politically questionable, and may be regarded as unacceptable.

36.2: A different model is to regard the customer as autonomous, with automatic devices dynamically optimizing their operation in accordance with the preferences of the customer and the current conditions.

Q 37: What specific actions should National Grid take to facilitate Balancing Services from demand-side providers while maintaining the required quality and volume of service?

37.1: As already mentioned in Q29 and Q31 this will require coordination with the DNOs on a coherent system architecture including advanced two-way communication with the end customers. The development process will probably also require political support.

Q 38: Are there further aspects of storage or other storage technologies we should consider when looking forward to 2020?

38.1: The potential for storage appears to us to be focused on the regulation of power quality in the short term (as at the Tomamae plant in Japan). That is, it is hard to see that storage could economically provide inter-seasonal smoothing of wind energy output, for example.

38.2: A key issue will be ensuring that the costs of any storage-related services are borne equitably; simple socialisation of cost may not be a just solution.

Q 39: What are the prospects for the provision of Balancing Services from new OCGTs or other 'Back-Up' generation?

39.1: The use of OCGTs for balancing is sub-optimal solution since they must run permanently at part load in order to be ready for regulation in both directions. See Q7. Rapid firing up from cold is possible, but has various O&M, reliability, and cost implications.

Q 40: Is our mapping of technology to Balancing Services reasonable?

40.1: Smart Metering is a tool supporting Dynamic Demand. It cannot produce balancing services.

40.2: Interconnectors are transport facilities. They cannot produce balancing services. Perhaps the heading should have been Foreign Services.

40.3: OCGTs are less suited as two-way reserve. We would suggest that Table 14 should record the answer "No" for the "Frequency Response" and "Energy Balancing" boxes

Q 41: Is a statement of National Grid's view of its long term Balancing Services requirement useful to industry stakeholders?

41.3: Perhaps, but there is so much uncertainty about the accuracy of NG's view, that this use is perhaps more intellectual than commercial.

Q 42: What period should a long term Balancing Services Requirement statement cover?

42.1: A long-term statement on the future framework for NG's provision of balancing services will be useful for potential suppliers of balancing services. 5 to 10 years ahead seems to be reasonable considering the investments required and the construction time.

Q 43: What changes to the current reserve products would better encourage the provision of reserve services?

43.1: Paragraphs 8.52 to 8.54 present important and difficult questions. Ancillary services are typically traded in a market with only one purchaser. Perhaps a new generation of flexible generation units can supply both the wholesale market and the balancing market.

Q 44: What actions would ensure that procurement of reserve services does not impact adversely on the efficient operation of the wholesale energy markets?

44.1: This is a serious concern in most countries. The market arrangements should encourage producers to install sufficient capacity for both purposes. However, there is no evidence that the proper market model has been demonstrated anywhere.

44.2: Again, we urge NG to make it clear to politicians that patient engineering is required in these extremely novel and difficult areas.

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